S/1. Sabir, M., 1963. Geology of Banda Atai Khan, Bodla, Hazara. M.Sc. Thesis, Punjab University, Lahore, 30p.

Key words: Geology, structure, Hazara.

S/2. Sabir, M.A. & Rehman, S.S., 2000. Hydrological characteristics of Indus Kohistan. Abstracts, Third South Asia Geological Congress, Lahore, p.144.

Key words: Hydrology, Indus Kohistan.

S/3. Sabir, M.A., Rizvi, S.I., Mehmood, T. & Sarwar, A., 1985. Ground water conditions in bajaur Agency, N.W.F.P. M.Sc. thesis, department of Geology, University of Peshawar.

This study describes the effects of ground water due to pumping out water from 110 tube wells in Bajaur agency, installed by F.A.T.A.D.C. In this study special emphasis was given to record the decline and to ascertain the rate of decline of ground water level due to pumping. Individual tube wells performance in terms of specific capacity test and the properties of the aquifer were also studied.
The study area comprises major portion of Bajaur agency. The area in the west is connected to Mohmand agency, and in the east is connected to Dir .The total survey area measures 788 sq miles. This area is in the form of plains. The top layer of the plains in which these tube wells are installed, is mostly of clay alternated by gravels, boulders, clay and sand. The area is basically igneous and metamorphic in nature.
The main source of irrigation is ground water and only a few farmers resort to barani cultivation. In addition to tube wells, dug wells are also present in this area but used for domestic purposes only. In Bajaur area water is available at various depths ranging from 50 feet to 200 feets which is fit for drinking and irrigation purposes.
Key words: Hydrology, groundwater, Bajaur Agency.

S/4. Sadin, M., 1976. Geology of the northern part of Khyber Agency. M.Sc. Thesis, Peshawar University, 25p.

Key words: Geology, Khyber Agency.

S/5. Sadin, M. & Shah, H., 1989. Geological map of Thana quadrangle, Topographic Sheet No. 43 B/2. GSP.

The Thana area in Malakand Agency and Swat is occupied by metamorphosed pelitic and calcareous rocks with intrusions of granitic rocks. The various lithologies are marked on the detailed geological map
Key words: Geological map, Thana, Malakand.

S/6. Saeed, A.S., Alam, M. & Khan, M.W., 1985. Groundwater conditions of Rustam area Mardan, N.W.F.P. M.Sc. Thesis, University of Peshawar, 71p.

Wapda has recently started work on ground water investigation in Rustam area. The main objective of the present work in Rustam is to:

1. Increase agriculture production, through improvement of water supply, drainage and through soil reclamation.
2. To improve the economic and financial condition of the farmers.
3. To stimulate economic activity in the area.
4. To provide subsoil drainage, by tube wells, where feasible and by open drains, where tube wells are not feasible.
5. To provide water to present unagricultural areas, if available after supply to the present commanded area.
6. To improve the subsurface water supply to those areas where cultivation is done by rain fall.

The project area is irrigated by persian wells, but most parts of this area in the north of Rustam is cultivated by rain fall.
It has been established from lithologic logs of the test wells drilled in this area, that the subsurface geology of this area includes moderate water-bearing sand and gravels with a considerable thickness of clay over certain area of Rustam unit. The aquifer is generally overlain by clay, silt and clayey shale ranging in thickness from few feet to several feet. The aquifer is not confined in the area, because the water level is very low in test wells. Generally water table ranges in the area from 30-40 feet. Due to low water bearing zones and deep water table there is no water logged area in Rustam valley.
Agriculture production of the area has declined due to non-availability of water for irrigation throughout the year. Mostly the people of this area cultivate their land farms with the help of rain water supply. The analysis of the surrounded wells water and soil sample show that the area has an excellent quality for agriculture. The water contain about 108 ppm of dissolved solids. Majority of the water sample contain less than 540 ppm of dissolved solids. Average contents of solid range from 102-280 ppm
Soil texture is moderately coarse to fine and medium to fine with good porosity and high capillarity. The rate of infiltration is very good. The soil is generally calcareous pedocals and reclaimable with water leaching and is highly productive. The soil of Rustam area is generally nonsalinized, because there is no water logging. Due to fertility of the soil, the production can increase with development of water subsurface resources. Rustam area has pure water of bicarbonate type and permeability is good also. Generally the aquifer of the area is low and has deep water table, so salinity is not seen everywhere.
Key words: Groundwater, Rustam, Mardan.

S/7. Saeed, G. & Karim T., 1989. Magnetite deposits of Sherwan area, Abbottabad district, NWFP, Pakistan. Geological Survey of Pakistan, Information Release 438.

Key words: Mineral deposits, magnetite, Abbottabad.

S/8. Saeed, Q.M., 1982-84. Micropaleontology and stratigraphy of the Jhalar Area-the Kala Chitta Range, Attock District. M.Sc. Thesis, Punjab University, Lahore, 91p.

A geological map of the Jhalar area -the Kala Chitta Range, on a scale of 1" to 0.789 mile or 1:50,000 and covering an area of 16.43 square miles has been prepared to discuss the stratigraphy and micropaleontology of the area. An attempt has been made to discuss the importance of foraminiferal content of these rock units, for determining the depositional pattern and age. The geological sequence of the Kala Chitta Range with a view to recognize the continuity or unique aspects of the lithostratigraphic units in the adjoining area. The various geological events that occur in the area and their geological implications have also been discussed. In the Kala Chitta Range there are some eighteen lithostratigraphic units but the area under discussion comprises ten lithostratigraphic units mostly of marine environments and with non-marine units.
Key words: Micropaleontology, stratigraphy, Kalachitta Range, Attock.

S/9. Safdar, M., 1983-85. Geology and tectonics of Burawai Area, Upper Kaghan valley, District Mansehra, Pakistan. M.Sc. Thesis, Punjab University, Lahore, 125p.

Nearly 114 sq. km. in the vicinity of Burawai, upper Kaghan valley has been geologically mapped, at the first time. This thesis presents first time accounts of geomorphology, lithostratigraphy, petrography and economic geology of the area. The area constitutes rocks representing old Indo-Pak basement rocks, comprising pelites, calc-pelites and marbles have been metamorphosed to kyanite and sillimanite grades. These are intruded by para-autochthonous sheet granites also metamorphosed. Major structure comprises an open synform possibly part of a larger structural basin. The western part comprises the nose of a larger antiform. Marble, biotite mica and kyanite are important mineral deposits which deem further exploration and evaluation. This thesis also includes petrogenesis of the rock units as well as numerous sketches sections and photographs, illustrating the geology of the area.
Key words: Tectonics, structure, Burawai, Kaghan, Mansehra.

S/10. Safdar, M. & Hasan, R., 1964. A study of barite deposits of Hazara. Pakistan Journal of Scientific and Industrial Research 17, 111-117.

Key words: Barite, Hazara.

S/11. Sahibzada, M.Z., 1973. Geomorphological analysis of Peshawar region. Journal of the University of Peshawar 15.

Key words: Geomorphology, geography, Peshawar.

S/12. Sahibzada, Z.A. & Khan, M.Z., 1984. Petrology of a part of Ambela granitic complex, Buner-Swat. M.Sc. M.Sc. Thesis, University of Peshawar, 58p.

This is a cursory study of a part of the Ambela granitic complex. Petrographic information accompanies geological map. Major element chemistry of selected samples is also presented.
Key words: Petrography, geochemistry, Ambela, Buner.

S/13. Sahni, M.R., 1939. Mesozoic brachiopoda of the Bannu District. Geological Survey of India, Memoir, Palaeontologica Indica (New Series) 27(1), 23p.

Key words: Palaeontology, Mesozoic, brachiopods, Bannu, India.

S/14. Sahni, M.R. & Sastri, V.V., 1957. A monograph of the orbitolines found in the Indian continent (Chitral, Gilgit and Kashmir), Tibet and Burma, with observation on the age of associated volcanic series. Geological Survey of India Memoirs, Palaeontologica Indica (New Series) 33(3), 44p.

Key words: Chronology, tectonics, Indian Continent.

S/15. Said, M., 1972. Land-use and land resources of Dera Ismail Khan District. Board of Economic Inquiry, NWFP, University of Peshawar, Publication 84, 160p.

This detailed document deals with various aspects of land, its resources and its use. The chapter on Physical and Human aspect gives information on physiography, surface water, groundwater and landforms. The latter have been divided into active flood plain, meander flood plain, rolling sand plain, hilly sandy plain, alluvial fans and piedmont plain. There is a brief mention of sandstone, shale, conglomerate and limestone (covering 11.1% of the District) of the hilly areas.
Key words: Land-use, land resources, D I Khan, NWFP.

S/16. Said, M., 1975. The Quaternary chronology of the Bar Daman area, Peshawar Valley. Abstracts, 3rd All Pakistan Geographical Conference, Islamabad, p.7.

Key words: Chronology, Quaternary sediments, Peshawar.

S/17. Said, M., 1975. Some observation on the development of alluvial fans in the Khattak foot hills. Abstracts, 3rd All Pakistan Geographical Conference, Islamabad, . p.4.

Key words: Alluvial Fan, Khattak foot hills.

S/18. Said, M., 1985. The effects of Tarbela Dam on the sediments load of the Indus River as recorded at the Attock Bridge. Presidential Address, Engineering Section, 23rd Annual Conference of Scientific Society of Pakistan, Lahore.

Key words: Tarbela Dam, sediments load, Indus River, Attock Bridge.

S/19. Said, M., 1991. Natural hazards of the Hunza Valley. Pakistan Journal of Geography 1, 45-52.

For more information, see Said (1992b).
Key words: Hazards, landslides, Hunza.

S/20. Said, M., 1991. Natural hazards in the Northern Areas of Pakistan. Culture Area Karakorum, Newsletter 1, 7-8.

Key words: Hazards, landslides, Pakistan.

S/21. Said, M., 1992a. Natural hazards of the Hunza valley. Culture Area Karakorum, Newsletter 2, 9-10.

For more information, see Said (1992b).
Key words: Hazards, landslides, Pakistan.

S/22. Said, M., 1992b. Natural hazards of the Hunza Valley. Proceedings, National Seminar on Progress of Geography in Pakistan, University of Peshawar, 75-83.

This is a report of a study conducted in 1991 between Danyor and Hindi. It describes geological hazards such as earthquakes, with mention of some of the major earthquake since 1871. Geomorphological hazards have been commented upon (mass-movement, rock falls, rock slide, debris slide, and mud flows), together with the accounts of floods in the Hunza River and tributary streams, glacial hazards, eolial hazards (sandstone), biotic hazards and climatic hazards.
Key words: Hazards, landslides, Hunza.

S/23. Said, M., 1995. Natural hazards of Hunza and Astor valleys. In: Stellrecht, I. (ed.), Pak-German Workshop on Problems of Comparative High Mountains Research with Regard to the Karakorum, Tubingen, October 12-14, 1992. Culture Area Karakorum, Occasional Papers 2, 33-43.

Key words: Hazards, landslides, Astor Valley, Pakistan

S/24. Said, M., 1998. Natural hazards of Shigar valley, Northern Areas, Pakistan. In: Stellrecht, I. (ed.), Karakorum-Hindukush-Himalaya: Dynamics of Change. Culture Area Karakorum, Scientific Studies 4. Rudiger Koppe, Koln.

Key words: Natural hazards, Shigar Valley, Tectonics.

S/25. Said, M. & Majid, M., 1977. The Pleistocene history of the terrestrial deposits of Bar Daman area, Peshawar valley. Journal of Science and Technology, Peshawar University 1, 39-47.

The detailed mapping of the Bar Daman area, has revealed the presence of a variety of surface deposits, ranging from siltstone to gravel, sand and loess. It appears that during the second Himalayan glaciation, this area was covered by a fresh water lake, in which siltstone, mainly older loess, reworked by torrents was deposited. This lake was drained away during the following warm phase, and in places, sand was laid on the top of the siltstone by aggrading streams, the early phase of the third Himalayan glaciation is recorded by fac gravels. A fossil soil reflects warm and wet conditions, perhaps an interstadial. The last phase of the third glaciation is chracterised by cold and dry conditions as is shown by the thick deposits of loess. The last glaciation is recorded by the formation of fans, while Holocene is marked by large scale changes in the drainage of this area.
Key words: Pleistocene, terrestrial deposits, Bar Daman, Peshawar.

S/26. Saif, S.I., 1970. Chromite occurrences in Utmankhel area of Mohmand Agency, NWFP, Pakistan. Geological Bulletin, University of Peshawar 5, 134-135.

The Utmankhel area lies adjacent to Charsadda Tehsil of Peshawar district and its boundary starts about seven miles north of Tangi. In the area under investigation the Peshawar plain skirts the hills where the elevation culminates from 1550 to 5520 feet. The ultramafic outcrops form a linear belt from two to five miles wide and extend for over 25 miles. The important localities in the Utmankhel area from where the chromite has been reported are in the vicinity of Babu, Bucha, Prang Ghar, Daghai and Balola villages. The mineralization is sporadic and lenticular.
Key words: Chromite, geochemistry, Utmankhel, Mohmand Agency.

S/27. Saif, S.I., 1971. A geological traverse through Mohmand Agency and Bajaur, NWFP West Pakistan. Geological Bulletin, University of Peshawar 6, 74-81.

Traverses in Mohmand Agency and Bajaur reveal that the area is underlain by a variety of metamorphic and igneous rocks. Slates, phyllites, schists, amphibolites and interbedded crystalline limestone cover extensive part of the area. Granite, microgranite and diorites are the igneous rocks found in addition to a thick ultramafic body, which is closely associated with the carbonate horizon.
Extensive marble reserves of various grades and shades have been encountered. The carbonate horizon mostly yields pure white, greenish and brownish marble, as well as several varieties of limestone. Big economical blocks of marbles can be extracted. This part of the metasedimentary terrain may be the northern termination of a large fold having connection with the Mullangori structure.
Key words: Metamorphic, igneous, granite, diorite, marble, Mohmand agency.

S/28. Saifullah, 1997. Heavy and trace metal abundance related to pollution in Peshawar city, N.W.F.P., Pakistan. M.Phil. Thesis, University of Peshawar.

Key words: Heavy metals, trace metals, health hazards, pollution, Peshawar.

S/29. Saleem, M., 1969. Geophysical investigations of Upper Swat. M.Sc. Thesis, Punjab University, Lahore.

Key words: Geophysics, seismicity, Swat.

S/30. Saleem, M., 1983-85. Electrical Resistivity for groundwater potentials in Shekhan, Landai Bala and Shahabkhal Area, District Peshawar. M.Sc. Thesis, Punjab University, Lahore, 31p.

Electrical resistivity survey in Shekhan, Landai Bala and Shahabkhel area was carried out in collaboration with Hydrology Directorate WAPDA Peshawar. The main purpose of the survey was to determine hydrogeological features like depth to bed rock, nature and thickness of aquifers and the quality of groundwater to select suitable sites for tubewell installation in the project area.

According to the resistivity survey and drilling data the entire area is underlain by low resistive clay. The overlying alluvium is composed of alternating layers of gravels and clays. Groundwater appears to be quite fresh in the entire area and seems to be under artesian pressure at many places. The water depth varies from 50 to 70 meters in the area under investigation.
In the project area, thirty one probes were carried out. After interpreting the data, the V.E.S. No. 6, 7, 8, 10, 16, 19 and 22 have been selected for the test drilling, however other probe sites also indicate presence of aquifers in the area but of varying thickness. The entire area appears to be favorable for tubewell installation, however the yielding of water depends upon the nature of aquifers may vary from half cusec to one and half cusec in the project area.
Key words: Resistivity, groundwater, drilling, aquifers, Peshawar.

S/31. Saleem, Z.A., 1963a. Gravity and magnetic studies in Swat State of Pakistan. Abstracts, 15th All Pakistan Science Conference, Lahore, p. F9-10.

Key words: Gravity, magnetic study, Swat.

S/32. Saleem, Z.A., 1963b. A geophysical study of the Swat Granite and associated rocks. M.Sc. Thesis, Punjab University, Lahore.

Key words: Geophysics, geography, granites, Swat.

S/33. Saleemi, A.A., 1978. Modal investigations of some granitic complexes of the northwest Himalayas, Pakistan. Geological Bulletin, Punjab University 15, 32-38.

Modal analyses are given of 21 rocks from northwards extension of the Hazara granitic complex in the Battal-Batgram area, and 11 rocks from the Nanga Parbat granitic massif, along with their brief descriptions. The data were plotted in the Streckeissen's triangular diagram for quartzofeldspathic plutonic rocks and discussed. The results are compared with those from the previously investigated Hazara granitic complex and the Lower Swat granitic complex. The conclusions are generalized with reference to theories of origin complexes of the northwest Himalayas.
Key words: Petrography, granitic complex, Hazara, Nanga Parbat.

S/34. Saleemi, A.A., 1997. Industrial application of illite-smectite rich clays from Karak, northwestern Pakistan. Abstracts, 3rd Pakistan Geological Congress, University of Peshawar, p.55.

For additional information, consult the following.
Key words: Illite-smectite, clays, Industrial uses, Karak.

S/35. Saleemi, A.A. & Ahmed, Z., 2000a. Mineral and chemical composition of Karak mudstone, Kohat Plateau, Pakistan: Implications for smectite-illization and provenance. Sedimentary Geology 130, 229-247.

The Karak mudstone interbedded in an Eocene evaporite sequence, is dominated by R-1 ordered illite-smectite with a 20 to 30% expandable component. Minor phases include kaolinite, chlorite, illite/muscovite, plagioclase, potash feldspar, quartz, dolomite and pyrite. The present illite-smectite was probably originally smectite or highly expandable illite-smectite which underwent conversion to illite-smectite with a low expandable component in a comparatively low-temperature (ca. 100°C) closed-system sedimentary basinal diagenetic environment at a depth of ca. 5 km. Al^{3+} and K^{+} necessary for the conversion reaction were provided through the breakdown of potash feldspar. Burial under a 5 km thick pile of sediments produced some of the observed structures. Whole-rock chemistry presented here suggests that the mudstone formed by severe weathering of acidic source rocks. The influx of freshwater probably flushed out Ba, Rb, Ca and Mn from the restricted basin.

Key words: Mudstone, illite-smectite, clays, sedimentary deposit, Karak.

S/36. Saleemi, A.A. & Ahmed, Z., 2000b. Acid activation and bleaching capacity of illite-smectite rich clays from Karak area, North West Pakistan. Late Abstracts, Third South Asia Geological Congress, Lahore, p.1.

Key words: Acid treatment, bleaching, illite-smectite, clays, Karak.

S/37. Saleemi, B.A., 1974. Geology of Kotegram and Akhagram quadrangle, District Dir, NWFP., West Pakistan. Geological Survey of Pakistan, Information Release 80.

Key words: Geology, lithology, Kotegram, Dir.

S/38. Salim, A., Sulaiman, E. & Ullah, M., 1988. General geology of a part of Karak District, N.W.F.P., Pakistan. M.Sc. Thesis, University of Peshawar, 40p.

The present work describes the general geology of a part 6f Karak district (Bahaderkhel and Latumber) on scale of 1:12,500. Various lithological units present in it include, from bottom to top, Bahaderkhel Salt, Jatta Gypsum, Kuldana Formation, Kohat Formation, Kamlial Formation, Chinji Formation and Nagri Formation. The strata of the study area are moderately to highly folded and faulted under the effect of Himalayan orogeny. The folds and faults are classified on the basis of size as regional, local and minor. The folds are generally gentle to open. Major faults strike SW-NE. The map view expression of both normal and reverse slip faults have been observed by the presence of graben faults and tear faults respectively. The tear faults can be easily observed by omission and repetition of stratigraphic sequences. Tear faults are the result of unability of translating a huge regional block as a single unit. The salt tectonic of varying intensities result in the squeezed out diapiric, plug like and domal exposure of Bahaderkhel Salt in the core of the Behaderkhel anticline. The outcrop pattern very closely shows that all younger formations are sharply wrapping around the Salt and gypsum core. The economic deposits of the area include Rock salt, Gypsum and limestone. The typical favourable structural setting makes the whole region a promising target for the exploration of oil & gas.
Key words: Geology, geomorphology, stratigraphy, Karak.

S/39. Sameeni, S.J., 1994. Microfaunal studies of Lower Margalla Hill Limestone of Bandi area, Hazara, Pakistan. Pakistan Journal of Geology 2 & 3, 45-52.

This paper deals with the micropalaeontological studies of Lower Eocene Margala Hill Limestone from Bandi area Hazara. Fifteen species of age diagnostic larger foraminifera are recorded including three typical Paleocene species of the genus Ranikothalia are reported for the first time from Margala Hill Limestone and association of the genus Ranikothalia along with typical Eocene species confirms its presence in the Lower Eocene (YPRESIAN) deposits of Pakistan.
Key words: Palaeontology, biodiversity, Margalla Hill Limestone, Bandi, Hazara.

S/40. Sameeni, S.J. & Mirza, K., 2000. Planktonic foraminifera from the Upper Cretaceous Kawagarh Formation of Jabri area, Hazara, Northern Pakistan. Abstracts, Third South Asia Geological Congress, Lahore, 161-162.

Key words: Foraminifera, Cretaceous, Kawagarh Formation, Jabri area, Hazara.

S/41. Samiullah, Sharafatullah & Nasrullah, 1986. Geology and structure of Karak Quadrangle, Kohat. M.Sc. Thesis, University of Peshawar, 62p.

The present work describes the geology and structures of a part of Karak bounded by latitudes 33° 8' 0"to 38° 11' 27" N and longitude 70° 56' 53" to 71° 1' 37" E of Karak quadrangle. The map was enlarged from 1:50,000 survey of Pakistan toposheet scale. The area is moderate to highly folded and a few faults of considerable extent and significant movement have been observed. The folds are open, plunging with their axes trending EW. In the area, a central anticline is bordered by the two adjacent synclines one on each side.

The Stratigraphy of the area is as follows;

Pliocene	Siwalik Group	Nagri Formation
		Chinji Formation
Miocene	Rawalpindi Group	Kamlial Formation
Eocene		Kohat Formation
		Kuldana Formation
		Jatta Gypsum
		Bahadur khel salt

The rocks of the above two ages (Pliocene and Miocene) are considered to be fluvial in nature and are thought to be composed of the Himalayan Molasse, while the rocks of the Eocene age are thought to be most probably the deposits of evaporite basin.

The rocks have been moderately to highly folded and faulted, and shows two distinct phases of deformation, in harmony with the earlier phases of Himalayan orogeny. The first phase of deformation give rise to the three major F1 folds while the second phase of deformation give rise to the secondary intraformational folds. The faults occurring in the area are mainly two sets. One set comprises of only one fault which is thrust fault. The second set is composed of four diapiric, gravity faults. Both the two sets of faults appear to be associated with the second phase of deformation and are the youngest. The investigated areas has great geological importance partly because of the fact that the younger little deformed rock assemblages here are suited for petroleum exploration. Besides, the presence of abundant economic minerals like rock salt, gypsum and limestone, also make it economically viable area.

Key words: Geology, structure, Karak quadrangle, Kohat.

S/42. Sano, S., 1993. Origin of chromite ore deposit: A review. View of petrologic approach on origin of chromite ore deposit in Pakistan ophiolites. Proceedings of Geoscience Colloquium, Geoscience Lab, Geological Survey of Pakistan, Islamabad 5, 97-112.

Describes relationship of ophiolite type and chromite ore deposits, and their origin. Gives a brief account of the Malakand occurrence and notes their similarity with the island arc deposits.

Key words: Ophiolite, chromite, Malakand, Island arc.

S/43. Sano, S., Khan, S.R., Nakagawa, M. & Ohta, E., 1994. Chromite ore deposits in dunite of the Malakand Ultramafic body, Pakistan. Abstract Geological Society of Japan, Annual Meeting, Sapparo, Japan.

Key words: Chromite, dunite, ultramafic, Malakand.

S/44. Sano, S., Nakajima, T. & Khan, S.R., 1996. Geology and isotope geochemistry of the Jijal complex, Kohistan, northern Pakistan. In: Kausar, A.B. & Yajima, J. (Eds.), Geology, Geochemistry, Economic Geology and Rock Magnetism of the Kohistan Arc. Proceedings of Geoscience Colloquium, Geoscience Lab, Geological Survey of Pakistan, Islamabad 15, 127-135.

The Jijal ultramafic-mafic complex in northern Pakistan is a small body of a few tens of square kilometers, but has drawn big attention as to be a root zone of the so- called "Kohistan paleo-island arc" (e.g., Jan and Howie, 1981; Bard, 1983), or, a possible fossil of the uppermost mantle to lower crust in the surface-exposed crust- mantle cross section. This short report presents a geological overview of the Jijal complex based on our field survey along the

Karakoram Highway in 1992 and the following petrographical work, as well as the newly obtained Sr-Nd isotopic data on the Jijal complex and their petrogenetic implications.
Key words: Geology, geochemistry, Jijal Complex, Kohistan.

S/45. Sarhad Development Authority, 1977. Feasibility study of the Target Area-1 (Kakul) of the Hazara Phosphate Project. P.D.N.C.B. Consultant Limited, London, Volume 1.

Key words: Phosphate, Abbottabad, Hazara.

S/46. Sarhad Development Authority, 1977. Feasibility study of the Target Area-2 (Lagarband) of the Hazara Phosphate Project. P.D.N.C.B. Consultant Limited, London, Volume 1.

Key words: Phosphate, exploration, Abbottabad, Hazara.

S/47. Sarhad Development Authority, 1977. Overall evaluation of the designated Hazara phosphate area. P.D.N.C.B. Consultant Limited, London, Volume 1.

Key words: Economic geology, phosphate, exploration, mining, Abbottabad, Hazara.

S/48. Sarhad Development Authority, 1978. Technical proposal for the exploration and mining planning of the Lagarband area of the Hazara Phosphate Project. P.D.N.C.B. Consultant Limited, London, Volume 1.

Key words: Economic geology, exploration, mining, phosphate, Abbottabad, Hazara.

S/49. Sarhad Development Authority, 1978. Commercial proposal for the exploration and mining planning of the Lagarband area of the Hazara Phosphate Project. P.D.N.C.B. Consultant Limited, London, Volume 2.

Key words: Exploration, mining, phosphate, Abbottabad, Hazara.

S/50. Sarkar, S.S., 1964. On the rates of evolution of some mammals from India and Pakistan. International Geological Congress, New Delhi 22(8), 282-292.

Key words: Evolution, habitat, mammals, siwaliks, India, Pakistan.

S/51. Sartenaer, P., 1965. Rhynchonelloidea de Shogram et Kuragh (Chitral), Italian Expedition to Karakorum and Hindu Kush. Brill. Leiden, Scien. Rep., 1(4), 55–56.

This paper describes Devonian Rhynchonelloidea from Shogran and Kuragh in Chitral.
Key words: Devonian, Rhynchonelloidea, Chitral.

S/52. Sarwar, A., 1997. Litho and stream sediment geochemical investigations for base metals and precious metals in Timargara, Maidan and Jandul Area, District Dir, Northern Pakistan. M.Phil. Thesis, University of Peshawar, 164p.

The area of study (about 900 sq. km.) is a part of the Kohistan island arc in the northern part of Pakistan. The Kohistan island arc, which is a part of Kohistan-Ladakh island arc, represent a cross section through an intra-oceanic island arc sequence which develop as a result of the northward subduction of Neotethyan oceanic lithosphere during late Jurassic and Cretaceous time. It is bounded by the Main Mantle Thrust (MMT) in the south and Main Karakoram Thrust (MKT) or Shayok suture in the north in the Pakistani terrane.

The area of study is located immediately north of the MMT in Dir district. It has a complex geology and is mainly composed of amphibolites, metadiorites and metagabbronorites, metagranodiorites, metagranites and metavolcanics with subordinate amount of hornblendites, ultramafites and tonalites. The area has been investigated for preliminary geology, however, no detail geochemical investigation has been carried out for precious and base metals mineralization. This study has main emphasis on the rocks and stream sediments (both pan concentrates and -80 mesh fine fraction) geochemical survey for gold and base metals in order to delineate areas likely to contain mineralization and be worthy of follow-up work.

The area has been divided into 56 drainage cells ranging from 2-50 km2 with an average density of about one site per 15 km2. From each cell a pan concentrate and -80 mesh fine traction were collected for geochemical analyses of Au, Ag, Cu, Zn, Pb, Co, Ni, and Cr, by atomic absorption. The visible gold as piece, speck and color was identified in the pan concentrates at the site. The floats were also examined for alteration and other geological phenomenon at each site. The pan concentrates are dominantly composed of magnetite whereas zircon, quartz, pyroxene, garnet, hornblende, feldspar, tourmaline, chromite and rock fragments occur as minor constituents.

The geochemical data for rock samples, pan-concentrates and fine fractions of stream sediments have been displayed and evaluated by considering various geostatistical methods.

Geochemical maps have also been prepared on the basis of single and multi-elements consideration in order to pin point areas of most interest. These studies show that panconcentrates have higher concentration of all the elements as compared to that of fine fraction. These elements are silicate bounded rather than sulfide bound in stream sediments. The higher concentration of Cu, Pb, Zn, Ni, Cr, Co and Ag could be related to the bed rock rather than to specific mineralization in the area. The anomalous gold, however, could not be directly related to the bed rock but it could possibly be related to the existence of gold-bearing mineralization in the north and north-eastern part of Samarbagh area, the detail geochemical survey is, therefore, recommended for follow-up in the region.

Key words: Stream sediment, geochemistry, precious metals, Timargara, Dir.

S/53. Sarwar, G. & DeJong, K.A., 1979. Arcs, Oroclines, Syntaxes - the curvatures of Mountain Belts in Pakistan. In: Farah, A. & DeJong, K.A. (Eds.), Geodynamics of Pakistan. Geological Survey of Pakistan, Quetta, 341-350.

The bent mountain belts of Pakistan are discussed in terms of the convergence of the Indo-Pakistan subcontinent with the Eurasian blocks to the west and north of it. The triangular northwest part of the Indo-Pakistan block was compressed simultaneously from the west, east and north, the latter compression being the most severe. Deformation occurred along the margins and crustal material was expelled, mainly to the south. The Pamir Himalaya Arc, the Nanga Parbat-Haramosh massif, the Hazara-Kashmir Syntaxis, the Bannu-Potwar thrust sheet, the Salt Range Composite Orocline, and the Sulaiman Arc are explained as a result of this north-south compression. The Quetta Syntaxis is seen to result from obstruction of the southward moving sedimentary cover of the Sulaiman Arc by the thick wedge of Neogene sediments in the Sibi trough. Finally, based on geological evidence, it is suggested that a large block (the Khuzdar-Karachi Block), behaving as an independent tectonic unit, is being rotated counter-clockwise at the western margin of the Indo-Pakistan plate. The Khuzdar Knot and the Karachi Arc form the southern and northern parts of the Khuzdar-Karachi Block respectively.

Key words: Orogeny, syntaxes, mountain belts, Pakistan.

S/54. Sarwar, M., 1971. A Javanese Rhinoceros recorded from the upper Siwalik of Azad Kashmir, Pakistan. Geological Bulletin, University of Peshawar 6, 49-53.

A mammalian fragmentary collection comprising a right upper third premolar, a fragment of the occipital region and a thoracic vertebra, made from the Pinjor Zone of the Upper Siwaliks of Azad Kashmir, Pakistan, is here referred as Rhinoceros Kendengindicus *Dubois*. This species was discovered by Dubois in 1908 from Java but was hitherto unrecorded from the Siwalik Hills.

Key words: Vertebrate palaeontology, Rhinoceros, Pinjor zone, siwaliks, Azad Kashmir.

S/55. Sarwar, M., 1972. Taxonomy and distribution of the Siwalik Proboscidea. Department of Zoology Bulletin, Punjab University, New Series, 10, 1-172.

Key words: Vertebrate palaeontology, taxonomy, proboscidea, siwalik.

S/56. Sarwar, M., 1978a. A record of the genus Mammuthus Burnett from the Pinjor Formations of the Pakistan Siwaliks. Punjab University, Geological Bulletin, 15, 78-80.

Key words: Vertebrate palaeontology, Mammuthus Bumett, Pinjor Formation, siwaliks.

S/57. Sarwar, M., 1978b. On the stegodont ancestry of the elephant. Punjab University, Geological Bulletin, 15, 62-68.

Stegodont ancestry of the family Elephantidae has been suggested, Genus Antelephas descended from Stegoton and in turn gave rise to the genus Elephas. Elephas planifrons has been regarded as ancestor of the later elephants and the mammoths.
Key words: Vertebrate palaeontology, elephant, stegodont.

S/58. Sarwar, M., 1980a. A new mammoth from the upper Siwaliks of Pakistan. Journal of Science Research, University of Punjab, 9 (1-2), 43-48.

Key words: Vertebrate palaeontology, mammoth, siwaliks.

S/59. Sarwar, M., 1980b. Dental morphology and distribution of Tetralophodon punjabienis progressus, Sarwar. Pakistan Journal of Zoology, 12 (2), 199-204.

Key words: Vertebrate palaeontology, morphology, tetralophodon.

S/60. Sarwar, M., 1981a. A new Elephant from the upper Siwaliks of Pabbi hills, Panjab, Pakistan. Geological Bulletin, University of Punjab 16, 131-137.

Elephas corrugatus, new species, from Pinjor Zone of the Upper Siwaliks exhibits a combination of primitive and advance dental characters. In a comparison with the known Asiatic elephants, it has proved to be a specialized form. It was a short-lived abortive offshoot of the species, Elephas planifions.
Key words: Vertebrate palaeontology, elephant, siwaliks, Pabbi hills, Punjab.

S/61. Sarwar, M., 1981b. Evolution of the molar ridge-plates in elephants. Punjab University, Geological Bulletin, 16, 138-140.

Elephas corrugatus, a new species, from Pinjar Zone of the upper Siwaliks exhibits a combination of primitive and advance dental characters. In a comparison with the known Asiatic elephants, it has proved to be a specialized form. It was a short lived abortive offshoot of the species, Elephas plantifrons.
Key words: Vertebrate palaeontology, elephants, siwaliks.

S/62. Sarwar, M., 1987a. Milk molar morphology in Stegodon dhokawanensis Sarwar, Punjab University, Geological Bulletin, 22, 92-94.

A left maxillary portion bearing a deciduous fourth premolar (P.U.P.C.* 66/3) of some stegodont skull is described from Pabbi Hills of district Gujrat, Punjab. On the basis of dental features, it has been referred to the species,

Stregodon dhokawanensis described by Sarwar in 1977. Thus, P.U.P.C 66/3 provide information about the morphology of the milk dentition in the species Stegodon dhokawanensis.
Key words: Vertebrate palaeontology, morphology, Pabbi Hills, Gujrat, Punjab.

S/63. Sarwar, M., 1987b. The presence of a Chinese stegodont proboscidean in the Siwaliks of Azad Kashmir, Pakistan. Punjab University, Geological bulletin, 22, 72-75.

A stegodont fourth upper premolar is described from the Dhokpathanian of Bhimbhar district Mirpur, Azad Kashmir, Pakistan. The tooth being primitive in structure of its ridge-crests and the crown heights has been compared with the primitive stegodonts. A detailed study has indicated that it is conspecific with the Chinese species, Stegodon sinensis Owen. This is the first Stegodont species common to Chinese Tertiary and the Siwaliks. The discovery of Chinese species from the Siwaliks means that the proboscides migration was possible across Himalayas during Lower/ Middle Pliocene.
Key words: Vertebrate palaeontology, proboscidean, Pliocene, siwaliks, Azad Kashmir, Himalaya.

S/64. Sarwar, M., Aftab, F. & Akhtar, M., 1988. The first bunolistriodont suid from the Siwaliks. Acta Mineralogica Pakistanica, 4, 87-89.

Key words: Vertebrate palaeontology, bunolistriodont, siwaliks.

S/65. Sarwar, M. & Akhtar, M., 1987. A New Sivatherine Giraff from Pabbi hills of Potwar Pakistan. Kashmir Journal of Geology 5, 95-100pp.

A large-sized giraffid upper second molar has been described. A thorough investigation has revealed that it may be included in the gems Bramatherium but as a new species, Bramatherium geraadsi.
Key words: Palaeontology, giraff, Pabbi hills, Potwar.

S/66. Sarwar, M. & Akhtar, M., 1989. A case of extreme forward inclination in the molar plates of the Genus Anancus Aymard. Kashmir Journal of Geology 6 & 7, 183-184.

A molar fragment of the genus Anancus is described. It shows an extreme forward inclination of the molar ridge-plates.
Key words: Vertebrate palaeontology, molar plates, Anancus aymard, siwaliks.

S/67. Sarwar, M. & Akhtar, M., 1991a. A new anthracotheriid genus from Vasnal, Punjab, Pakistan. Kashmir Journal of Geology, 8 & 9, 157-160.

Key words: Vertebrate palaeontology, Anthracotheriid, Vasnal, Punjab.

S/68. Sarwar, M. & Akhtar, M., 1991b. First Description of the Lower Molar in the Clawed Horse Macrotherium Salinum Cooper (Perissodactyla: Mammalia). Kashmir Journal of Geology 8 & 9, 161-164.

A posterior chalicothere mandibular fragment bearing the partially erupted last molar is described. A comparison with the known Siwalik forms has indicated that it belongs to the species Macrotherium Salinum Cooper. It is the first description of the lower last molar in the said species.
Key words: Vertebrate palaeontology, mammal, Perissodactyla, siwaliks.

S/69. Sarwar, M., Akhtar, M., Ahmad, Z. & Rahim, S.A., 1989. A transitional gomphotheriid from Dhokpathan type locality. Kashmir Journal of Geology 6 & 7, 153-156.

A right lower last molar from Dhokpattan type locality is described. It shows Tetralophodon/ Stegotetrabelodon characteristics of the crown.
Key words: Vertebrate paleontology, Gomphotheriid, Azad Kashmir.

S/70. Sarwar, M., Bakr, A. & Akhtar, M., 1986. A new genus of the family Hyaenidae gray from the upper Siwalik beds of the Punjab. Geological Bulletin, University of Punjab 21, 87-94.

Two fragments of an anterior half a hyaenid skull from Neogene Upper Siwaliks of district Attock, Pakistan are described here as a new genus, Romeria. The conclusion is based on the overall morphology of check teeth, location of the first molar and the size of the third incisor.
Key words: Vertebrate palaeontology, Hyaenidae, siwaliks, Punjab.

S/71. Sarwar, M. & Nafees, G., 1984. Evolution of the Siwalik Bunodont and Bunolophodont Proboscidea. Kashmir Journal of Geology 2, 109-115.

A comparative study of the bunodont and bunolophodont Siwalik mastodonts indicates that Hemimastodon crepusuli (Pilgrim, 1908) was related to Palaeoomastodon (Phiomia) and was a member of the relict probosidean fauna that continued on surviving in the Sub-Continent. Genera Synconophus and Stegolophodon, which are the product of local evolution, have been regarded as descendant of the genus Gomphotherium.
Key words: Vertebrate palaeontology, evolution, Bunolophodont, Proboscidea, Siwaliks.

S/72. Sarwar, M., Rahim, A., Nasreen, S. & Roohi, G., 1987. A New Bunodont Suid from Siwaliks of Pakistan. Kashmir Journal of Geology 5, 87-on ward.

Three mandibular rami bearing two crowned and bunodont artiodactyle teeth and an isolated bunodont tooth have been recovered from various localities of Middle and Upper Siwaliks of Punjab, Pakistan. This new material is described as Dicoryphochoerus mirkhalensis sp. n. It was fairly gigantic suid and was probably the culminating species of the genus.
Key words: Vertebrate palaeontology, bunodont, siwaliks.

S/73. Sarwar, M., Rahim, S.A., Munir, S. & Nazir, F., 1986. A new Lamellibranch from the upper Siwaliks of Pabbi hills, Punjab, Pakistan. Geological Bulletin, University of Punjab 21, 50-54.

An internal cast of a unionid has been described from the Pinjorian of Pabbi Hills of district Gujrat. A careful examination has revealed that it is a new species of the genus Trapezoideus Simpson. This new species, Trapezoideus sardhokensis as it is named, was a large trapezoid, extremely compressed laterally and with extremely compressed umbones.
Key words: Vertebrate palaeontology, Lamellibranch, siwaliks, Pabbi hills, Gujrat.

S/74. Sattar, A., 1985-87. Mineralogical/geochemical studies of rocks, soils and water, Khanaspur Dewal Area. M.Sc. Thesis, Punjab University, Lahore, 103p.

This report gives an account of Mineralogical and geochemical studies carried out in Khanspur and Dewal area. The prescribed area lies to the north of Murree, in extreme east of Abbottabad and southwest of Muzaffarabad. Except an area of about 6 sq. km. which belongs to District Rawalpindi, the area lies in Abbottabad District, N.W.F.P. It is a mountainous region with fairly high relief. Geological mapping of approximately 56 sq. km. on lithostrategraphic basis, at the scale 1:10,000 was carried out. The stratigraphic succession ranges from Datta Formation (Jurassic) to Murree Formation (Miocene).The lithology is mainly limestone, shales and sandstone. Extensive sampling of rocks, soils and water was carried out and these samples were studied in laboratory and data regarding these studies are given in this report. A brief systematic description of various rock units in hand specimen and thin

section is included. A brief description of chemical staining techniques applied to the limestones and that of performed limestone analysis is also given. A chapter regarding the detai1 geochemica1 studies of soils of the project area is also included. This chapter gives an account of all the parameters necessary for soil study and according to these parameters, the soils of the area are categorized as non-sodic, non-saline. Geochemistry of two main streams of the area has also been studied in detail and the data regarding the chemical analysis of the water are reported and interpreted by various graphica1 techniques. According to these data, the minera1 components and other parameters lie within the safe limits, established for water to be used for domestic and agriculture purposes. Chemical characteristics of waters of various springs of the area, originated in different rock units have also been studied and interpreted in detail. Spring waters are also fit for irrigation and drinking purposes. Finally, there is a general discussion about the waters of the area and the effect of various encountered rock units on the chemistry of water passing through them.
Key words: Minerology, geochemistry, Khanaspur.

S/75. Sattar, A., Chaudhry, M.N. & Mateen, A., 2001. Petrology of amphibolites from higher Himalayan crystalline unite, upper Kaghan valley, NW Himalaya, Pakistan. Abstracts, 4th Pakistan Geological Congress, Islamabad, 9-10.

The Higher Himalayan Crystalline unit in the Upper Kaghan Valley is composed of a lower basement and an upper cover. The lower basement is composed predominantly of granitoids, migmatites, micaceous quartzites and pelite schists. Marbles, calc-pelite gneisses, graphitic schists, quartzites and amphibolites are subordinate lithologies. The cover to this basement is composed of amphibolite sheets intercalated with marbles grading upward to a sequence of calc-pelite gneisses and marbles which are in turn overlain by pelite schists and micaceous quartzites sequence.
The amphibolites in the Upper Kaghan Valley occur either as feeder dykes in the basement or more commonly as extensive sheets in the basal portion of the cover where these are inter-bedded with marbles and calc-pelites. These metabasic rocks are predominantly garnet amphibolites composed of amphibole, calcic plagioclase, and almandine. Quartz, sphene and magnetite occur as accessories. At places due to retrogression some epidote and chlorite may also be found. Around Besal these rocks have been subjected to eclogite facies metamorphism and are comprised essentially of almandine±omphacite. Quartz, rutile and kyanite occur as accessories. Coesite may occur at places.
Major and trace element geochemical data were plotted on variation and discrimination diagrams and spidergrams with normalization to known basaltic compositions. This data strongly suggest a within plate extensional regime for these metabasic rocks. To be more precise, these are tholeiitic flood basalts with minor sub alkaline to alkaline trend. The geology of the area also supports this conclusion since the emplacement of these bodies is entirely within continental crust and there are no ultramafic and felsic bodies genetically associated with them. Furthermore they occur as concordant sheet like bodies indicating a flood basalt type origin.
Key words: Petrology, amphibolites, Kaghan, Himalaya.

S/76. Satti, M.Z., 1991-92. Geological mapping of Nauseri-Yadgar Area and evaluation of geotechnical properties of rock aggregates of the area. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 123p.

The dolomite, limestone and sandstone concrete aggregates have been investigated from Yadgar to Nauseri Area. The evaluation of mechanical properties effect the quality of the aggregates presently being used in civil engineering projects. Mineralogically alkali-aggregate reactive minerals involve silica particularly chert, chalcedony, chlorite and clay minerals. The alkali carbonate reactions involve argillacious dolomite, dolomitic limestone and agrillites. Concrete deterioration due to alkali silica reaction have been investigated from nearly all major geographical regions of Azad Kashmir. In Yadgar dolomite chert is found. Chert is common in gravels, derived from various limestone formations. These chert seem to show a low level of alkali expensivity, but when this is combined with other forms attack on concrete. It may contribute to durability failures. Siliceous limestone, some of which contain chalcedony are known from Batmang area and some example appear to be a major fracturing concrete deterioration. Agrillites associated with alkali expansive reaction in concrete have been described particularly from Margala Hill Limestone. The test result reveals the use of concrete aggregates from the area after treatments.
Key words: Geotechnical, limestone, aggregate, Azad Kashmir.

S/77. SavoiaAosta, Aimoni Duca di Spoleto, 1930. Spedizione nel Caracorum. Boll. R. Soc. Geogr. Ital.,ser.VI, 7, 3-20.

Key words: Karakoram Expedition.

S/78. Savia Luigi Amedeo Duca Degli Abruzzi, 1910a. Viaggio di esplorazione nel monti del Caracorum. Riv. Club. Alpino Ital., 29 suppl. Fasc.1.

Key words: Italian Expedition, exploration, Karakoram.

S/79. Savia Luigi Amedeo Duca Degli Abruzzi, 1910b. Explorazione ai Monti del Caracorum. Boll. R. Soc. Geogr. Ital.ser. IV, 47, 435-469.

Key words: Italian Expedition, exploration, Karakoram.

S/80. Sawada, Y., Kausar, A.B., Kubo, K., Takahasi, Y. & Takahasi, Y., 1996. Sedimentary structures in the Chilas igneous complex of the Kohistan arc, northern Pakistan. In: Kausar, A.B. & Yajima, J. (Eds.), Geology, Geochemistry, Economic Geology and Rock Magnetism of the Kohistan Arc. Proceedings of Geoscience Colloquium, Geoscience Lab, Geological Survey of Pakistan, Islamabad 15, 173-181.

The Kohistan island arc is exposed in the western Himalaya of northern Pakistan, where it is bounded by the Main Karakoram Thrust (MKT) to the north and the Main Mantle Thrust (MMT) to the south (Fig. 1) The Kohistan arc consists of a series of east-west trending Cretaceous to Miocene sedimentary, volcanic, plutonic and metamorphic rocks. It is widely interpreted as an island arc sequence which developed above the northward subducting Tethyan oceanic plate. Based on Rb-Sr and K-Ar Ages of syn-collisional leucogranites intruded into the Rakaposhi volcanics (Petterson & Windley, 1985;1990; Treloar et al., 1989), the collision between the Asian continent and Kohistan arc probably took place between 102 to 75Ma. Following this, the main collision of amalgamated Asian continent-Kohistan arc with the Indian continent commenced at about 50Ma (e.g. Patriat & Achach, 1984) during which the Kohistan block obducted onto the Indian continent. South of MKT lie the slates, turbidites, volcaniclastic sediments and limestones of the Albian to Aptian "Yasin Group" (Pudsey, 1986) which may have been deposited within and intra-arc basin. The Yasin Group overlies the submarine to subaerial basic to intermediate arc-type tholeiitic volcanics intercalated with limestones of the "Rakaposhi (Chalt) volcanics". The Rakaposhi volcanics and metasediments were intruded by tonalite and diorite during the late Cretaceous to Miocene. These plutons form a vast complex of intrusions in the northern part of the Kohistan arc, termed the Kohistan batholiths by Petterson & Windley (1985)

Key words: Sedimentary structures, Chilas complex, Kohistan arc.

S/81. Sawada, Y., Kubo, K., Kausar, A.B. & Takahashi, Y., 1993. Primary magma of the Chilas complex in the Kohistan arc, northern Pakistan. Proceedings of Geoscience Colloquium, Geoscience Lab, Geological Survey of Pakistan, Islamabad 7, 97-119.

A description of the Chilas in the Kohistan island arc is given together with preliminary trace- and RE elements geochemistry.

Key words: Magma, geochemistry, Chilas complex, Kohistan arc, Northern Pakistan.

S/82. Sayab, M., 1997. Geology of Nanga Parbat Syntaxis along the Astor valley transect, N. Pakistan. M.Sc. Thesis, Department of Geology, University of Peshawar, 130p.

The Nanga Parbat-Haramosh syntaxis represents the youngest phase of thermal, tectonic and metamorphic activity in the Himalaya. The massif is an active crustal scale antiformal structure comprising Indian plate basement gneisses and cover sequence. The Nangaparbat rocks in the Indus gorge section have previously been divided into grey Iskere gneiss and pink Shengus gneiss. During recent mapping along the Astor valley transect, south of Indus valley, several new lithological units have been identified. These include 1) Mushkin grey gneiss 2) Harchu pink gneiss and 3) Rattu formation. The Mushkin gneiss is a medium-grained, locally porphyroclastic gneiss of grey colour probably representing the basement complex.
Harchu pink gneiss is clearly derived from a sedimentary protolith (as suggested by the preserved relicts of quartzite and calc-silicate components. In addition, certain lithologies of the unit also contains preserved sedimentry cyclic sequence. The Rattu formation comprises meta-pellites, marbles, calc-silicates pods and lenses and is considered to represent a metamorphosed cover sequence. Structural cross-section form north-west to south-east reveals that the Nanga Parbat sequence consists of two crustal-scale antiformal structures with a tight faulted synform in between. It is noticeble that the Mushkin grey gneiss exhumes with repect to the cover sequence at the margins. Field and petrographic data shows that Rattu formation and Harchu pink gneiss reaches upto kyanite and sillimanite metamorphic grades, whereas the Mushkin grey gneiss lack these minerals. The Mushkin grey gneiss exhibits a great variety of migmatitic (metatexis) structures, indicate that the Mushkin grey gneiss has experienced more severe metamorphic conditions than any other rock unit in the Astor section. Our Preliminary studies indicate possibilities of correlation between Mushkin and Harchu gneisses from the Astor valley with the Iskere and Shengus gneisses from the Indus valley, respectively.
Key words: Structure, petrology, Nanga Parbat Syntaxis, Astor, Himalaya.

S/83. Sayab, M., Butt, K.A., Khan, M.A. & Rafiq, M., 2001. Parallel, sub-parallel drainage pattern in the Surghar-Shinghar Range control by Neo-tectonic extension fractures associated with Main Frontal Thrust. Abstracts, 4th Pakistan Geological Congress, Islamabad, 73-74.

The Surghar-Shinghar Range at the eastern margin of the Bannu basin is a N-S oriented àntiform in the hanging wall of the Surghar Thrust. The range is bisected by a set of N-S compressional fractures parallel to the axis of the anticline. Orthogonal to this set of fractures is an E-W oriented set of extensional fractures. The age of the Surghar anticline and associated structures is constrained by the sediments involved in the deformation. The Siwalik sediments in the Surghar-Shinghar Range are not older than 7-8 Ma. The involvement of these sediments together with the recent alluvium in the deformation suggests role of neo-tectonics in the origin of Surghar-Shinghar Range. Based on the stress and strain analyses, we suggest that compressional and extensional fractures in the rocks of the Siwalik Group are the product of the compressional tectonics associated with the Surghar Thrust (Main Frontal Thrust) at the eastern margin of the range.
A study of geomorphology of the Surghar- Shinghar Range using field observations, aided by Landsat TM and SPOT satellite images, suggests predominance of a parallel, sub parallel drainage pattern across the range. A parallelism between the drainage pattern of the range and the E-W extensional fractures suggests role of structural control on the geomorphology. The EW extensional fractures are dilated by seasonal drainage, forming steep gorges, especially in the Siwalik sediments. The Siwalik sediments mostly consist of friable to moderately hard sandstone interbedded with varying proportions of shale horizons. The extensional fractures in these lithologies facilitate drainage along these lines, thereby controlling the geomorphic processes.
Key words: Neo-tectonics, drainage, Main Frontal Thrust, Surghar-Shighar Range, Trans-Indus Salt Range.

S/84. Sayab, M., Khan, M.A., Butt, K.A. & Pervaiz, K., 1999. Analyses of joints and associated neo-tectonic deformation band shear zones in the Siwalik Group of southern Surghar-Shinghar Range, Trans-Indus Ranges, Pakistan. Geological Bulletin, University of Peshawar 32, 25-39.

This study presents field observations on joints and deformation band shear zones (DBSZs) at the southern flank of the Sarkai-Mochi Mar (SMM) anticline, which is the southern most structure of the Surghar-Shinghar Range. The eastern flank of the anticline is eroded to form steep scarps, exposing the high angle trace of the Surghar Thrust (the Dara Tang fault). Two joint sets NS/NNE and EW/WNW are observed at the southern flank of the SMM-anticline, where the strike of the strata is about east west. These joints are restricted to the hard sandstone bands of the Dhok Pathan and Nagri formations. Field observations show that NS/NNE oriented joints are compressional and E W M oriented joints are extensional in geometry. The orthogonal relationship of compressional and extensional joints yields rectangular blocks ('15x6cm) in the hard sandstone bands. Minor folds with fold axes and axial planes parallel to the compressional joints (NS/NNE) are not uncommon.

The area also contains two sets of strike-slip DBSZs that cut across the sedimentary strata at high angles. The NS steeply oriented DBSZs are strongly banded foliated), with mesoscopic dextral sense of movement. These DBSZs are common and well developed on the south-eastern part of the SMM-anticline. The second set with ~501'- 6 0 0 ~ orientation comprising incipient tabular DBSZs with sinistral movement, cut across the fabric of the NS oriented DBSZs. The two DBSZs form a conjugate geometry.

The frequency of these DBSZs is high close to the trace of the Dara Tang fault. Since, the Dhok Pathan Formation is the youngest lithological unit in the area ('O.8Ma), the presence of both the joints and DBSZs in the upper levels of the formation suggests on- going neo-tectonics in this region. Based on field evidences, three deformational phases have been suggested for the formation of joints and shear zones. The compressional and extensional joints with a component of folding are formed simultaneously in the first deformation phase. This is followed by the second deformation phase in the form of NS oriented banded shear zones. The third deformational phase is characterized by the oriented tabular shear zones, which sinisterly cut the NS oriented banded shear zones at an angle of about 500-600. The dynamics of the SMM anticline in the context of regional tectonics suggest that the structure experienced compression from west to east during the fold formation. The southern flank of the SMM anticline, where the strike of the beds is east west, is recognized as the plunging hinge area of the fold. Thus, the east-west oriented beds experienced east-west compression and north-south extension in the form of joints and minor folds. We assume that the origin of both compressional and extensional joints in the Mochi Mar and pan of the Qabul Khel areas may be related with the folding of SMM anticline. As the north-south oriented Dara Tang fault (Surghar Thrust) cuts across the sedimentary strata passing at the core of the SMM anticline the DBSZr in the area appear to be dynamically related with this fault.

Key words: Neo-tectonic, deformation, siwalik group, Trans-Indus Salt Range.

S/85. Sayab, M., Khan, M.A. & Jan, M.Q., 1997. Geology of the Nanga Parbat syntaxis along the Astor valley transect, Northern Pakistan. Geological Bulletin, University of Peshawar 30, 285-296.

The Nanga Parbat-Haramosh syntaxis represents the youngest phase of thermal, tectonic and metamorphic activity in the Himalaya. The syntaxis is an active crustal-scale antiformal structure comprising Indian plate basement gneisses and cover sequence. The Nanga Parbat rocks in the Indus gorge section have previously been divided into grey Iskere gneiss and pink Shengus gneiss. Along the Astor valley transect, south of Indus valley, several new lithological units have been identified. These include 1) Muskhin grey gneiss 2) Harchu pink gneiss and 3) Rattu formation. The Mushkin gneiss is medium-grained, locally-porphyroclastic gneiss of grey colour probably representing the basement complex. Harchu pink gneiss is clearly derived from a sedimentary protolith (as suggested by the preserved relicts of quartzite, calc-silicate components and preserved sedimentry structures). The Rattu formation comprises meta-pellites, marbles, calc-silicates pods and lenses and is considered to represent a metamorphosed cover sequence. Structural cross-section from north-west to south-east reveals that the Nanga Parbat sequence consists of two crustal-scale antiformal structures with a tight faulted synform in between. It is noticeble that the Mushkin grey gneiss exhumes with respect to the cover sequence at the margins. Field and petrographic data show that the Rattu formation and Harchu pink gneiss reaches upto kyanite and sillimanite metamorphic grades, whereas the Mushkin grey gneiss lacks these minerals. The Mushkin grey gneiss exhibits a great variety of migmatite structures, indicating that the Mushkin grey gneiss has experienced more severe metamorphic conditions than any other rock unit in the Astor section. Our preliminary studies indicate possibilities of correlation between Mushkin and Harchu gneisses from the Astor valley with the Iskere and Shengus gneisses from the Indus valley, respectively.

Key words: Tectonics, petrology, Nanga Parbat Syntaxis, Himalaya.

S/86. Sayab, M., Khan, M.A., Khattak, M.U.K. & Jan, M.Q., 1997. Geology of the Nanga Parbat syntaxis along the Astor valley transect. Abstracts, 3rd Pakistan Geological Congress, University of Peshawar, p.56.

Key words: Structure, Nanga Parbat Syntaxis, Astor, Himalaya.

S/87. Sayab, M., Khan, M.A. & Rafiq, M., 1999. Rotated and displaced clay balls as kinematic indicators along shear zones in sandstones of the Siwalik group of Surghar-Shinghar Range, Trans-Indus Ranges, Pakistan. Geological Bulletin, University of Peshawar 32, 89-104.

Neo-tectonic events in the Siwalik Group of Surghar-Shinghar Range are characterized by compressional, extensional and conjugate shear fractures. The compressional fractures are in the form of reverse faults mainly along clay ball scoured surfaces. The sense of shear in these fractures is interpreted from rotated and displaced clay ball geometry. Shearing along these weak planes provide kinematics of clay ball geometrical behavior and their mechanical strength characteristics under surface PIT conditions. Most of the displaced clay balls are moderately hard due to the presence of carbonates, while others constitute some fine carbonaceous material. Thus, the displacement in the clay balls is controlled by their hardness. Some displaced clay balls show nice geometrical arrangement of Riedel fracture sets accommodating strain during shearing. Despite near-surface conditions (i.e., incohesive-brittle) the clay balls, due to the inherited plastic character of clays, form structures resembling those in plastic regimes of deformation. These structures include asymmetric rotated clay balls with tail edges just like in porphyroclasts, while others are equally rotated forming oxidized boundaries within the sandstone matrix with no tail edges. The kinematics of both rotated and displaced clay balls show reverse sense of shear all along the compressional faults.
Key words: Shear zones, sandstone, siwalik, Trans-Indus Salt Range.

S/88. Sayab, M., Mazhar, F., Butt, K.A. & Khan, M.A., 2001. Structure of the Surghar Range at its southeastern flank with emphasis on Surghar Thrust. Abstracts, 4th Pakistan Geological Congress, Islamabad, 38-39.

Field observations are made on the southeastern flank of the Surghar Range. The east verging Surghar anticline is deeply eroded in this part of the range, exposing steep scarp of the Surghar Thrust, together with the older formations in its hanging wall. The thrust runs along the eastern margin of the Surghar anticline, bringing Punjab foreland alluvium in contact with upper Permian and Mesozoic rocks in the northern, and Neogene rocks in the southern parts of the fault trace. A number of thrust splays are recognized in the area to the south of Mitha Khattak village, where the thrust splits into several oblique-slip faults. These shear zones are typically brittle, generally cutting across the strata. These shear zones are lined with cataclasites and show distinct asymmetric kinematic indicators commonly found associated with reidel fractures.
Overall the N-S trending Surghar Range is divisible into two anticlines; Makarwal anticline in the north and Sarkai-Mochi Mar anticline in the south. These two are separated by an exceptional low topographic relief, which is defined by a syncline termed Gulapa-Darsola syncline in this study.
Key words: Structure, Surghar Thrust, Trans-Indus Salt Range.

S/89. Sayab, M., Qadir, A. & Khan, M.A., 2000. Structural styles, kinematics and shear zone geometries in sandstone of Pliocene Dhok Pathan Formation, Qubul Khel, Southern Surghar Range, Bannu Basin, Pakistan. Late Abstracts, Third South Asia Geological Congress, Lahore, 3-4.

Key words: Structure, sandstone, Pliocene, Dhok Pathan formation, siwaliks, Bannu basin.

S/90. Scally, F.A. de, 1989. The role of avalanche snow transport in seasonal snow melt, Himalaya Mountains, Pakistan. Ph.D. Thesis, University of Waterloo, Ontario.

Key words: Glaciers, avalanche, Himalaya.

S/91. Scally, F.A. de, & Gardner, J.S., 1990. Ablation of avalanched and undisturbed snow, Himalaya Mountains, Pakistan. Water Resources Research 26, 2757-2767.

Avalanche deposits represent a significant storage of winter snow on the south slope of the Himalaya Mountains, Pakistan, complicating the annual snowmelt cycle because of the differences in ablation of avalanche-transported snow and undisturbed snow. Measurements show very high rates of melting of both snow types, particularly of avalanche snow late in the melt season. The high rates are a function of the low latitude of the study area and the low elevation of the avalanche snow deposits, as well as heat release by condensation. Air temperature was closely Correlated with daily snowmelt and appears to hold promise as a predictor, however, data constraints prevent an energy balance analysis of this relationship. Gravimetric measurements show that condensation is important in the snow surface energy exchange and can represent a significant source of energy for snowmelt. Rainfall during warm conditions also makes a more significant contribution to snowmelt than shown in previous studies. The derived temperature-based melt factors or coefficients compare well with published figures from other mountain areas, but their confidence limits are sufficiently wide to produce significant errors in the prediction of basin snowmelt runoff.
Key words: Glaciers, snow ablation, Himalaya.

S/92. Scarascia, S., Colombi, B., Guerra, I. & Luongo, G., 1982. Preliminary report on seismic measurements along the profile Lawrencepur-Astor. Rend. Acc. Naz. Lincei.

Key words: Seismology, Lawrencepur-Astor.

S/93. Schärer, U., Copeland, P., Harrison, T.M. & Searle, M.P., 1990. Age, cooling history and origin of post-collisional leucogranites Karakoram Batholith, a multi-system isotope study. Journal of Geology 98, 233-251.

U-Pb dating on zircon and monazite from different varieties of leucogranites in the Karakoram Batholith reveals two distinct pulses of plutonism at 25.5 +0.3/-0.8 and 21.4 +0.3/-0.6 Ma. In both granites, these minerals contain inherited components, documenting the presence of Precambrian material in the magma source. A crustal origin of the granites, and long crustal residence times of the source rocks are confirmed by highly negative € Nd, strongly positive € ^{Sr}, and T^{Nd} DM in excess to 1 Ga. A biotite gneiss and a granitic dike from the Karakoram Metamorphic Complex south of the batholith yield very similar € Nd, € ^{Sr}, Sr, T^{Nd} DM. In a Pb evolution diagram, initial isotopic compositions for both the granites and the rocks from the metamorphic complex plot far above the reference field for MORB documenting very close affinity to the Eurasian (Tibetan) continental crust. The striking similarity of isotope signatures between leucogranites and the rocks in the metamorphic complex strengthen the view that granite source material lies in the metamorphic complex. $^{40}Ar/^{39}Ar$ step heating analyses from the leucogranites yield isochron ages of 6.4 ± 0.1 and 7.4 ± 0.2 Ma for biotite, 6.6 ± 0.1 and 6.4 ± 0.1 Ma for muscovite, and 4.6 ± 0.2 Ma for K-feldspar. The two rocks from the metamorphic complex define isochron ages of 10.6 ± 0.1 and 4.7 ± 0.1 Ma for biotite, 14.9 ± 0.3 Ma for muscovite, and 8.9 ± 0.4 and about 4 Ma for K-feldspar. All K-feldspars analyzed contain trapped non- atmospheric Ar components to various degrees. The radiometric ages show that the leucogranites cooled from 750-650^{0}C at 25-21 Ma to 250-350^{0}C at 6 Ma, i.e., their cooling through the Ar blocking temperature in mica and K-feldspar occurred 15 to 20 Ma after granite emplacement. This strongly suggests a major and rapid uplift in latest Miocene to Pliocene times. In contrast to the leucogranites, cooling of portions of the metamorphic complex reached mica-K-feldspar blocking temperatures about 5 to 10 Ma earlier, documenting earlier uplift in the Karakoram Metamorphic Complex than in the Karakoram Batholith.
Key words: Geochronology, cooling history, leucogranites, Karakoram Batholith.

S/94. Schlinger, C.M., Khan, M.J. & Wasilewski, P., 1989. Rock magnetism of the Kohistan island arc, Pakistan. Geological Bulletin, University of Peshawar 22, 83-101.

In Northern Pakistan a section of island arc crust is exposed in Kohistan, northwest Himalaya. To better understand how magnetism and magnetic mineralogy depend on metamorphism, crystalline rocks of the Kohistan island arc have studied, by means of field and laboratory investigations. The results are based on susceptibility and sampling traverses over 500 km in length, and rock magnetic and petrographic study of collected samples. Measurements and sampling concentrated on two profiles through Kohistan, one following the Swat River, the other following the Karakorum Highway. Of the lithologies sampled along these two profiles, the main sequence of interest consists of

rocks of the Kohistan island arc. With the exception of volumetrically minor serpentinized ultramafic rocks, the magnetic lithologies are pyroxene granulite, and gabbro-norite of the Chilas complex. Amphibolites, garnet granulites, metasupra-crustals and Kohistan arc diorites and granites are only weakly magnetized. The same is true Karakoram batholith granitoids. As far as prograde metamorphism of moderate to high-grade mafic rocks in the section is concerned, magnetic pyroxene granulites are strongly magnetized, relative to amphibolite facies equivalents and garnet granulites. Considering all lithologies, the calculated Koenigsberger's ratios are generally less than 2 (110 of 127 samples), commonly less than 1 (89 samples), and rarely in excess of 10 (3 samples), which indicates that the magnetization of these rocks is rarely dominated by remanence. The directions of natural remanent magnetization (NRM) are scattered, with a mean declination not far from zero, and a positive mean inclination. Petrographic and electron microprobe study of mineral assemblages and textures related to retrogressive metamorphism of pyroxene and garnet granulites shows that amphibolite facies overprinting along planar zones was an Fe-Ti oxide-consuming event. Lamellae of magnetite in magnetite-ilmenite intergrowths were replaced by silicates during retrogressive metamorphism of the pyroxene granulites. Regional-scale magnetic structure in this part of the crust is defined by magnetic contrasts between the Chilas complex and the surrounding Kamila amphibolites and Kohistan granites and diorites.
Key words: Magnetism, metamorphism, Kohistan Island Arc.

S/95. Schmetzer, K. & Bank, H., 1975. Geschliffene grossular-chlorit-epidot-hornfelse aus Pakistan. Zeits. Deutschen Gemmologischen Gesell 24, 245-247.

Material from Pakistan was found to have refractive index 1.730 and specific gravity 3.38-3.40. known as grossular, it consists of the minerals listed in the title.
Key words: Gemology.

S/96. Schneider, D.A., Edwards, M.A., Kidd, W.S.F., Khan, M.A., Seeber, L. & Zeitler P.K., 1999. Tectonics of Nanga Parbat, western Himalaya: Synkinematic plutonism within the doubly vergent shear zones of a crustal-scale pop-up structure. Geology 27, 999-1002.

Detailed mapping and geochrongologic investigations from the eastern, southern, and western Nanga Parbat-Haramosh massif reveal two thrust-displacement shear zones that have a spatial and temporal link with granite plutonism from ca.10 to 1 Ma. The shear zones define a crustal-scale antiformal pop-up structure, with dominant west-northwest-vergent and subordinate east-southeast-vergent thrusting. This substantially different than the surrounding area where the main exposed Himalayan structures are oriented parallel to the orogenic trend and are early to middle Miocene or older. Structures mapped throughout Nanga Parbat demonstrate that its rapid and young exhumation is not due to orogen-scale structural unroofing, and that sustained high erosion rates are required. The observed west-northwest-directed shortening is proposed to be a result of different arc-parallel motion accommodated at the syntaxial bend of the northwest Himalaya.
Key words: Tectonics, geochronology, synkinematic plutonism, Nanga Parbat.

S/97. Schneider, D.A., Edwards, M.A., Kidd, W.S.F. & Zeitler, P.K., 1999. Geochronologic summary and lithotectonic architecture of the Nanga Parbat-Haramosh Massif, NW Himalaya. Terra Nostra 99, Abstract Volume, 14th Himalaya-Karakoram-Tibet Workshop, Kloster Ettal, Germany, 137-138.

The Nanga Parbat-Haramosh massif (NPHM), most notable for its extremely young metamorphic and igneous ages, represents the most northerly exposure of Indian craton. Reworking of the Indian craton in the last 10 m.y. has been of a large enough scale to apparently fully overprint the Himalayan signature. Previously reported leucogranite crystallization ages for NPHM are markedly younger from those reported elsewhere in the Himalaya. Undeformed leucogranites within the massif show a southward younging of accessory mineral U- (Th)-Pb ages: a 10 Ma pluton in the north, to 5 Ma dikes along the Indus and Astor Valleys, and ~2 to 1 Ma dikes, stringers and larger plutons in the south near the main summit (Zeitler and Chamberlain, 1991; Zeitler et al., 1993; Schneider et al., 1997). To the SE and SW of the summit, leucogranites again increase in age: in the SE, a dike which cross cuts the Rupal shear yields monazite ages from 17-9 Ma as well as the Early Miocene Southern Chichi pluton (Schneider et al., this vol.):

to the SW, the much larger, and deformed, Jalhari granite yields monazite ages from 8-2 Ma, and in a separate sample 13 Ma. Thermochronologic results from basement micas are very young and indicate a similar southward-younging pattern, also with a marked age increase to the SE and SW, yielding typical Himalayan cooling ages in those areas.

In the central portions of the massif are found the highest-grade rocks and youngest ages. Zeitler et al. (1993) obtained a ~1 Ma zircon U-Pb age for the Tato pluton. Subsequently, for the Mazeno Pass pluton, the opposite (southern) side of the Nanga Parbat summit ridge from the Tato pluton, we (Schneider et al., 1997) obtained strikingly coincident zircon and monazite U-Th-Pb ages of 1.4 Ma. That the 1.4 Ma age is obtained on both zircons and monazites for a larger body of granite illustrates the degree of very young melting.

A number of the granites cross-cut large crustal scale shear zones, hence post-dating the displacement on, and constraining the timing of, the shear zones. Along the NW margin, a small, undeformed tourmaline-bearing granitic dike, which crosscuts the high strain fabric of the MMT yields an age of 7 Ma, requiring that deformation along the MMT ceased by at least that time. This is in agreement with the conclusions of Pêcher and Le Fort (in press) which suggest that ductile deformation ended around 7-6 Ma on the Nanga Parbat-Karakorum suture to the north. Deformation in the north was due to doming and the entire northern section of the massif behaved as a single crustal block (Pêcher and Le Fort, in press).

Along the Rupal shear zone, south of the Nanga Parbat summit, the 2-1 Ma Rupal dikes also provide key timing constraints on structures and fabrics of the Rupal valley; the oldest crystallization age gives the minimum age of deformation. In this case the oldest dike dated in this study gives an age of 2.3 Ma. Thus, cessation of ductile deformation had to occur before 2.3 Ma. Furthermore, dike emplacement was coeval with cooling where the dike ages are similar to the Ar/Ar biotite cooling ages in the valley. This suggests the dikes were emplaced into shallow crustal levels, the melt having possibly migrated along the Rupal shear and into fractures accompanying the general uplift and erosional unroofing. The ages and structural orientation of the Rupal dikes compare well with those of the dikes and stringers on the north side of the summit which give ages between 3 and I Ma (Zeitler et al., 1993). These were emplaced, and somewhat deformed, into the Raikot-Lichar shear zone. Furthermore, monazites from two deformed granites along the WNW margin of the massif (at Jalipur and Diamir) yield ages as young as 5-3 Ma. This implies that deformation in southern Nanga Parbat (south of Indus-Astor confluence) has ceased much more recently (4-3 Ma) than the north (Haramosh; 7 Ma), and the southern NPHM, like the north, may have behaved as a single crustal block, bounded to the south by the Rupal and Diamir shear zones.

Crystallization ages on the SE margin of the Rupal valley are significantly older. Both the geochronology of a thin leucogranite dike (mentioned above) which cross-cuts the fabric of the SE Rupal shear in Chichi valley and the thermochronology of the shear zone rocks constrain the age of that portion of the Rupal shear zone to having ceased by 10 Ma, if not older (Schneider et al., in press).

The basement lithology is fairly monotonous with ages from zircon cores showing a ubiquitous Early Proterozoic inheritance, typically clustering around 1870-1850 Ma. This, as noted by Whittington et al. (1998), is similar to the Early Proterozoic inheritance of the Lesser Himalayan sequence in the central part of the orogen and therefore differs from the High Himalayan Crystallines that are common to the NW Himalaya which NPHM has long been considered a part. The Early Proterozoic zircon inheritance exists in all of the massif's units: gneisses, schists, metasedimentary rocks and larger granite bodies (Zeitler et al., 1989; Zeitler and Chamberlain, 1991; Zeitler et al., 1993; Schneider et al., 1997; Schneider, unpub data). Only a few isolated granites do not contain inheritance: the smaller leucogranite dikes and, surprisingly, the larger Jutial pluton (Schneider et al., 1997). Markedly younger than the other units in the massif, Zeitler et al. (1989) report zircons from a sample of the Shengus gneiss, in NE Nanga Parbat, yielding a 500 Ma inheritance; this sample lies near the generally agreed upon ‘basement-cover’ contact. Our new results from granitic rocks at Manugush (Bunar Gah, SW Nanga Parbat) indicate a yet another unit, which yields a Cambro-Ordovician age. Zircons from the porphyroclastic garnet-muscovite, -kyanite gneiss with cm long feldspar laths yield concordant U-Pb ages of 480 Ma. A petrologically similar augen gneiss (termed ‘lath unit’) was described by Edwards (1998) on the SE side of Nanga Parbat (Astor Valley); Foster et al. (this vol.) have obtained
—500 Ma monazite ages from the cores of garnets within the lath unit. These samples also occupy the contact between the Nanga Parbat gneisses and the cover sequence. Based upon 1) the ‘basement-cover’ relationship across a large area, 2) the age, and 3) the similar petrologic nature between the W and E localities, we suggest that the Cambro-Ordovician lath unit was originally a largely continuous unit within the mass if, intruding into the ‘basement-cover’ contact. Edwards (1998) has suggested that the unit was intruded during, and subsequently underwent some of, the deformation associated with the main displacement of the MMT. The unit may be faulted and eroded away on the active western margin of the massif. Other sections of the NW Himalaya (Pakistan and India) and in Nepal also contain Cambro-Ordovician intrusions which, based on geochemical data, were generated by anatexis of continental crust (Miller and Frank, 1992).

In summary, the Nanga Parbat massif is mostly Early Proterozoic basement with interleaved deformed Cambro-Ordovician granites, reworked and exposed as recent as 2-3 Ma in the summit region. The overall structure, concentric metamorphic isograds and age pattern indicate the appearance of a young gneiss dome ‘popping-up’ on conjugate shear zones through Indian cover metasediments which have 20-30 Ma cooling ages.
Key words: Geochronology, lithotectonic, Nanga Parbat-Haramosh Massif, Proterozoic, NW Himalaya.

S/98. Schneider, D.A., Edwards, M., Kidd, W.S.F, Zeitler, P. & Coath, C.D., 1998. Magmatism and deformation within Nanga Parbat-Haramosh Massif, Pakistan Himalaya. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 176-178.

Background: A general association of young plutonism, deformation, and cooling within the Nanga Parbat-Haramosh massif (NPHM), Pakistan Himalaya, is clearly recognized (e.g., Zeitler and Chamberlain, Tectonics, 1991). Previously reported leucogranite crystallization ages for NPHM are markedly younger from those reported elsewhere in the Himalaya. Undeformed leucogranite dikes within the massif give U-(Th)-Pb zircon and monazite ages of <2 to 7 Ma (Zeitler and Chamberlain, Tectonics, 1991; Schneider et al., EOS, 1997) with the youngest ages found near the summit regions. Leucogranite dikes occurring near or within major shear zones are typically emplaced into tension gashes that are at a high angle to the principal shear zone orientation and with fracture geometries that are suggestive of subvertical opening. Larger intramassif plutons include 1) Tato, U-Pb zircon rim ages of ~1 Ma (Zeitler et al., Geology, 1993), 2) Mazeno Pass, U-Th-Pb zircon and monazite ages of ~1.4 Ma and 3) Jutial, U-Th-Pb zircon and monazite ages ~10 Ma (Schneider et al, EOS, 1997). The Tato and Jutial plutons lie on the NPHM western margin and have intruded into the active Raikot-Liachar fault system; the Mazeno Pass pluton has intruded along the northwestern tip of the Rupal-Chhichi shear zone (RCSZ). This shear zone is comprised of a large belt of NW dipping, porphyroclastic granitic orthogneiss with a ubiquitous non-coaxial fabric that is consistent with accommodation of southeast vergence of southern NPHM (Edwards et al., 12th HKT, 1997a). Notably, the RCSZ is coincident with a rapid increase in Ar/Ar biotite cooling ages to the southeast (Schneider et al., EOS, 1997). Another significant break in biotite cooling ages occurs across a broad ~N-S trending zone in southwest NPHM. Argon biotite cooling ages on the western side of this zone are 20-30 Ma, whereas on the eastern side (towards the summit) cooling ages are 6 Ma and younger (Schneider et al., EOS, 1997). We present here new geochronologic data from leucogranites within NPHM, which, together with new field observations (Edwards et al., this vol) and previous data (summarized above), can provide significant new constraints on the spatial and temporal association between plutonism and deformation within NPHM.
New data: Edwards et al. (this vol) report a large plutonic sequence (the Jalhari granite) that grades into granitic and porphyroclastic orthogneiss as a result of syn to post-deformational plutonism. This granite and gneiss belt is a ~5 km wide, ~30 km long N-S trending zone that marks the large cooling age discontinuity on the southwest corner of Nanga Parbat. Sense of shear is east side up, consistent with upward and westward displacement of NPHM. Ion microprobe Th-Pb monazite analyses of a deformed, biotite-rich portion of the Jalhari granite (near the village of Diamroi) yielded ages between ~3 and 9 Ma. These ages fall along a line which increases with increasing Th/U ratios. Backscatter/SEM images of the analyzed monazite grains indicate some that have a non-uniform texture, notably lacking clear core-rim zoning patterns. This chaotic textural pattern is too fine to allow analysis of any single composition within a grain, despite the very small beam size (~15-20 microns) of the ion microprobe. However, a few texturally homogeneous grains were analyzed; these yielded the youngest of our obtained ages (~3-4 Ma). Near Garal, 13 km south of the village of Diamroi, we sampled an undeformed medium grained granite, which is adjacent to, and possibly part of, the same Jalhari granite. Ion microprobe analyses of monazite grains yielded Th-Pb ages of 12 Ma. Th/U ratios of these monazites fall along the same trend as those of the Diamroi (deformed) granite. Our interpretation of the Jalhari granite is as follows:
an initial pulse(s) intruded and crystallized as young as ~12 Ma, 2) ongoing synkinematic magmatism (as represented by the patchy monazite grain textures indicative of multi-stage growth history) resulted in further pulses that juxtaposed deformed and undeformed portions of the granite, and 3) final crystallization was around 3.5 Ma. This 3.5 Ma lower age limit is consistent with our cooling ages on the southwestern side of the massif, inboard and east of the Jalhari granite belt.
In southern Nanga Parbat, we sampled a small (tens of cm) little-deformed granite dike which discordantly cuts orthogneiss of the Rupal-Chhichi shear zone in northern Chhichi Gah. Like the Jalhari granite, this granite dike also yielded a scatter of Th-Pb monazite ages, in this case between 9 and 17 Ma; these ages also fall along an increasing line with increasing Th/U ratios. BSE/SEM images of the monazites show a similar appearance to the monazites of

the Jalhari granite. Biotite cooling ages from the northern section of Chhichi Gah give ages of 9-10 Ma (Schneider, unpub data). As within SW NPHM, the cooling ages are concordant to the lower Th-Pb monazite age. We infer that most of the displacement along this ('outboard') portion of the RCSZ occurred prior to 9-10 Ma and, similar to the shear zone associated with the Jalhari granite, plutonism was focused within the shear zone.

Discussion

Our new results indicate a fundamental association between plutonism and the major NPHM shear zones. None of the numerous granites seen within NPMH are of large areal extent and we infer that there has not been a widespread melting event (c.f., High Himalaya leucogranites; e.g., Harrison et al., Geology, 1997) but numerous anatectic pulses over the last ~10 Ma (Butler et al., 1997). Magnetotelluric studies show that there is no significant partial melt zone directly beneath NPHM (Park and Mackie, GRL, 1997), consistent with anatexis that is restricted to small volumes and/or distinct episodes. The observed proximity of granites to shear zones suggests to us that these anatectic episodes may be related to deformation. We propose a conceptual model where crustal thickening and/or decompression melting promotes small amounts of melting and deformation enhanced melt extraction (e.g. Thompson & Connolly, Earth-Sci. Rev, 1995) allows melt migration to existing (or resulting) shear zones. This process

May be strain rate sensitive, whereby local anatexic episodes are a result of higher strain rates. With deformation enhanced melt migration, sufficient increase in melt percentages are rapidly attained, initiating melt migration that likely focusses within the shear zone (e.g Brown, Earth-Sci. Rev, 1994). These melt-filled shear zones are then sites of thermally weakened material that are the focus of further deformation, including when the material is cooling through the solidus. This creates a positive feedback situation whereby the presence of melt enhances deformation, and within the existing weak (shear) zone periods of granite emplacement continually reoccur.

Key words: Magmatism, deformation, tectonics, Nanga Parbat-Haramosh, Himalaya.

S/99. Schneider, D.A., Edwards, M.A., Kidd, W.S.F., Zeitler, P.K. & Coath, C.D., 1999. Early Miocene anatexis identified in the western syntaxis, Pakistan Himalaya. Earth and Planetary Science Letters 167, 121-129.

Evidence for typical Himalayan Early to Middle Miocene anatexis has remained elusive in the Nanga Parbat massif in the western Himalaya of Pakistan; previous work has identified only young plutonism (10-1 Ma). New U-(Th)-Pb data from the southern Chichi granite, a leucogranite in southern Nanga Parbat, reveal that crustal melting occurred during the Early Miocene. This largely undeformed, fine-grained pluton intrudes the Indian metasedimentary cover sequence adjacent to the Rupal shear, a major shear zone at Nanga Parbat. Th-Pb ion microprobe analysis of monazites from the Chichi granite yield ages between 22 Ma and 16 Ma, with majority of analysis lying at 19-18 Ma. U/Pb zircon analysis yields ages, which fall along a chord with lower intercept age of 19 Ma. The zircons also contain an ~1850 Ma inherited component. These data indicate that the Early Miocene anatexis that is ubiquitous in central portions of the Himalayan orogen, unreported anywhere in the NW Himalaya, also occurred in the western Himalayan syntaxis, and demonstrates that Nanga Parbat has a protracted melting history. A small granitic dike that cross-cuts the outer portion of the Rupal shear yields monazite ages between 22 Ma and 9 Ma, where the young ages correlate with high U concentrations. 40Ar-39Ar biotite ages from adjacent gneisses indicate cooling by 10 Ma, requiring significant displacement on this portion of the Rupal shear to be older than ~10 Ma and possibly as old as ~20 Ma.

Key words: Miocene, Nanga Parbat Massif, pluton, Himalayan Syntaxis.

S/100. Schneider, D.A., Edwards, M.A., Zeitler, P.K. & Coath, C.D., 1999. Mazeno Pass pluton and Jutial pluton, Pakistan Himalaya: age and implications for entrapment mechanisms of two granites in the Himalaya, Contributions to Mineralogy and Petrology 136, 273-284.

Zircon and monazite U-(Th)-Pb ion microprobe analysis were performed on the Mazeno Pass pluton and the Jutial pluton, two leucogranite bodies within the Nanga Parbat-Haramosh massif (NPHM), Pakistan Himalaya. Zircon rim ages and monazite ages indicate the Mazeno Pass pluton in southwest NPHM intruded at 1.40 ± 0.05 Ma; the Jutial pluton, to the north, similarly yields concordant zircon and monazite ages suggesting crystallization at 9.45 ± 0.06 Ma. The Jutial pluton was subsequently intruded by leucorgranite dikes at 5.3 Ma, as revealed by monazite ages. Concordancy of U-Pb and Th-Pb accessory mineral ages demonstrated the robustness of the technique on young rocks. Both plutons, some of the youngest in the Himalaya, have a general association with nearby shear zones that

we interpret to have played an integral role in granite evolution and emplacement setting ('deformation enhanced ascent'). Together with new field observations, these results provide an insight on the spatial and temporal relationship between plutonism and deformation relating to the development of the massif.

Key words: Mazeno Pass, Jutial pluton, Nanga Parbat, shear zones.

S/101. Schneider, D.A., Edwards, M.A., Zeitler, P.K. & Kidd, W.S.F., 1997. Ion microprobe U-Th-Pb and 39Ar/40Ar geochronology of Nanga Parbat-Haramosh Massif (part 1). Rupal Valley, southern Nanga Parbat, and Jutial granite, Haramosh area. Abstract volume, 12th Himalaya-Karakorum-Tibet International Workshop, Rome, Italy, 205-206.

The Nanga Parbat-Haramosh massif (NPHM), northern Pakistan-NW Himalaya syntaxial region-is a tectonic half window of partly re-worked, largely Proterozoic, Indian plate rocks that have been exhumed from beneath Mesozoic arc rocks of the Kohistan Ladakh Area. The metamorphic and thermal evolution of this anomalously hot, young massif has remained elusive.

Using UCLA’s National Jon Microprobe Facility, young U-(Th)-Pb ages on accessory minerals have been obtained. Single-grain, single-spot analyses were performed on zircons and monazites from basement rock and granites. Single-grain, total-fusion 39Ar/40Ar laser experiments were performed at Lehigh University to obtain cooling data of biotites in country rocks. We report here new geochronologic data, predominantly from southern NPHM, including the first in-Pb monazite age for a large leucogranite body, the Jutial granite.

We have conducted extensive sampling along the Rupal drainage through the southern flank of Nanga Parbat in conjunction with detailed structural mapping (Edwards and Kidd, this volume). In many cases, the tectonic role identified for mapped principal structures is further supported by results of geochronologic investigations.

The Mazeno Pass pluton (5400m) is a notably undeformed, tourmaline and biotite absent, fine-grained, muscovite granite which cross-cuts foliation of local biotite gneiss. U-Pb zircon analyses record a discordant age with an upper intercept of ~1860 Ma, representing the Precambrian protolith age, typical for the NPHM; this age is consistent with those of nearby gneisses and schists. The lower intercept is defined by a cluster of concordant zircon ages at ~1.4 Ma. Moreover, monazite from the same pluton also yielded a in-Pb age of ~4.4 Ma. Accordingly, we take 1.4 Ma as the intrusion age of the Mazeno Pass pluton.

In the central portion of Upper Rupal Valley (largely between Rupal and Shigiri villages), cm-in scale dykes invading granitic augen orthogneiss are found. These predominantly muscovite rich, tourmaline-bearing pegmatites are abundant throughout the massif and typically trend ~N-S, however, in central Upper Rupal they trend ~W-E and dip N, locally reflecting gneissic fabric (Edwards and Kidd, this volume). We sampled two Rupal dykes and obtained a monazite age of ~1.2 Ma from the first, and zircon and monazite ages of~2.2 Ma from the second. Such leucogranites within the massif have been suggested to be the result of decompression melting, allowing intrusion at shallow depths (Zeitler and Chamberlain, 1991).

A staurolite-kyanite-garnet schist sampled from Rupal valley, near the village of Tarshing gives U-Pb zircon ages clustering near or below concordia at ~l 860 Ma; furthermore, a few ages also fall along a discordia toward the origin with a lower intercept age of <5 Ma. Approximately 1-km south of Tarshing, up Chichi valley, both the biotite schist and the samples from the eastern edges of a ~SW trending, thick (kms), extensive belt of S-C fabric porphyroclastic granitic augen gneiss (the Rupal Shear Zone, see below) give a suite of total-fusion 39Ar/40Ar ages of >15 Ma. These differ sharply from the young (1.2 & 2.2 Ma) ages west and north of the Rupal shear zone, and indicate a marked contrast of exposed crustal depths, based upon the large displacements required by Rupal valley structures. An even larger age contrast is found in SW Nanga Parbat: A broad suite of total-fusion 39Ar/40Ar biotite ages mainly between 20 and 30 Ma are found for the area of Indian cover metapelites in Niat and Barai valleys (5-10 km W of Mazeno pass). Between Thia area and Mazeno / Toshe Gali, there is a steep ~NNE trending belt of faults that can be traced to both (1) the Tato shear in the Raikhot valley, and (2) the large thrust near the Indus at Raikhot/Liachar, where it locally forms the western margin of NPHM (the contact with Kohistan).

We propose that the Raikhot/Liachar southward continuation, and the Rupal shear zone, and other significant structures in the uppermost Rupal valley (Edwards and Kidd, this volume), have accommodated uplift of central Nanga Parbat on the W, S & E sides. We note that here on the Nanga Parbat southern flank, unlike the central and northern regions of NPHM, the shear zones that have accommodated “block uplift” are substantially inboard of the W & E margins (margins of India to Kohistan Ladakh Area). The area within these shear zones has enjoyed prolonged elevated temperatures sufficient to maintain open system behavior of Ar until a period coincident with plutonism and melting nearby. We regard peak metamorphism here to be contemporaneous with plutonism, and not to post-date it.

In the northwestern portion of the NPHM ("Haramosh area"), the Jutial granite is predominantly a two-mica, tourmaline granite, essentially undeformed. It intrudes and cross-cuts the surrounding quartzofeldspathic Nanga Parbat grey gneisses (termed "Jskere Gneiss", Madin et al., 1989). The approximate size of the body is difficult to determine, but our field observations suggest a diameter of at least 5 km. Observations by Butler and co-workers (1992), suggest at least two phases of intrusion can be distinguished. Two samples from the main body of the Jutial pluton were analysed: (1) a medium grained, tourmaline speckled granite and (2) a peginatitic version of the same rock. The appearance of this second, pegmatitic rock is similar (large muscovite books, tourmaline) to the very young leucogranite pegmatites of the southern portions of the massif. Both samples yielded concordant U-Pb zircon ages of 10±l Ma. A second igneous phase was also examined. This yielded am-Pb monazite age of 5.2±0.3 Ma. This phase lacks the amount of muscovite that the main body contains. Additionally in this phase, tourmaline is euhedral and roughly equal-granular (1-2 cm) and is distributed homogeneously throughout the rock. Previously reported biotite and muscovite 39Ar/40Ar cooling ages from the Jutial granite are ~5-6 Ma (George et al., 1995). It is noteworthy that our two new ages for Jutial occupy >50% of the time period occupied by the sudden and recent uplift of NPHM (i.e. since ~10 Ma). This suggests that the history of both plutonism and metamorphism is complex; that of a young, dynamically self-exposing area. The ~5Ma monazite age from Jutial granite is consistent with previous suggestions for young plutonism in both of the high massif areas (Zeitler and Chamberlain, 1991).

In addition to providing precise ages to identify thermal events and associated thermal and mechanical boundaries, our data has modified and refined the data array illustrated in Winslow et al. (1996). This now shows that within NPHM there has been differential exhumation and magmatism from north to south (younger in the south) reaching sufficiently large and well-localized displacements to involve major intra-massif shear zones, hitherto unreported for NPHM. This is a contribution from the Nanga Parbat Continental Dynamics Project

Key words: Microprobe, geochronology, Nanga Parbat, Jutial granite, Haramosh.

S/102. Schneider, D.A., Zeitler, P.K., Edwards, M. & Kidd, W.S.F, 1997. Geochronological constraints on the geometry and timing of anatexis and exhumation at Nanga Parbat: a progress report. Eos Transaction of American Geophysical Union 78, Spring Meeting Supplement 14, 111.

Key words: Geochronology, exhumation, Nanga Parbat, Geophysics.

S/103. Schneider, H.J., 1956. Bild and Bau des NW Karakoram. Photograph Forsch. 7, 80–91.

Key words: Orogeny, Karakoram.

S/104. Schneider, H.J., 1957. Tektonik und magmatismus im NW-Karakorum. Geologische Rundschau 46, 426-476.

The author described the geology of the North western Karakoram and showed that the rocks can be distinguished into laterally extending zones. The axial Karakoram batholith was considered to form a hetereogenous plutonic mass varying in composition from hornblend granodiorite to biotite granite with little or no hornblend. Such intrusions are considered to be synorogenic and of upper Cretaceous and early Tertiary age. Aplitic granite associated with the tectonic disruption of the region are post tectonic and post Oligocene.

Key words: Tectonics, magmatism, NW-Karakoram.

S/105. Schneider, H.J., 1959. Zur Diluvial Geschichte des NW-Karakorum. Mittelliungen Georgraphia Geselschaft München 44, 201-216.

Key words: Orogeny, Karakoram.

S/106. Schneider, H.J., 1960. Geosynklinale entwicklung und magmatisums an der wende Palaozoikum-Mesozoikum im NW-Himalaya und Karakorum. Geologische Rundschau 50, 334-352.

Key words: Magmatism, Paleozoic, Mesozoic, NW-Himalaya, Karakoram.

S/107. Schneider, W., 1976. Bodenschatz im nordwestlichen Pakistan. Aufschluss 27(4), 147-154.

Key words: Northern Pakistan.

S/108. Schomberg, Col. R.C.F., 1935. Some glaciers of upper Chitral. The Alpine Journal 47, 98-102.

On the 8th, 9th and 10th there was severe wind and snow at all points above Camp V. Angtsering added that during his last two days' sojourn above Camp IV the weather was good, but a great depth of snow covered everything but steep rocks.

The valley of the Yarkhun river, which during its course is known as the Mastuj, Chitral, or Kunar, is no more than a rocky trough with many lateral streams. It rises near Wakhan, in the grassy slopes of Baroghil, but it depends for its water supply on the great glaciers that are almost wholly confined to its left side: and it is this left side, with its moraines, fans, and deposits that demonstrate the great part that glaciers have played in the present condition of the Yarkhun valley in Northern Chitral. In summer this river is a swift, turgid, black flood, while it's affluents are equally unlovely.

Generally speaking, the rocky formation of the Hindu Raj and the Chitrali Hindu Kush do not lend themselves to glacier making, and in a region of great rock ranges and towering peaks, the glaciers are disappointing, for there is little chance of the snow accumulating on these perpendicular slopes, while the regular and heavy rainfall (to which I shall again refer) militates against any heavy deposits of ice and snow. The hanging glaciers are insignificant, the normal glaciers seem unusually small, and the visitor is disappointed in the somewhat non-Alpine appearance of the region. I certainly was. Perhaps I hoped for too much, but I am reluctant to think that the lack of glaciers in a country where one expects many can be wholly explained by the present era being one of glacial retreat.

At Warsum (Wassum), for instance, the fine glacier torrent flowed from a spectacularly insignificant ice and snow formation. It was only when we reached the Madod stream flowing into the left of the Yarkhun river, opposite the settlement of Shost, that I saw glaciers that would repay a visit. The stream in the early part of a July afternoon was a considerable torrent; we camped at Kand, a very small village high above the river, and some 21/2 miles from the Madod valley. Next day, with Daulat Shah of Hunza, who had a profound contempt for all Chitralis, and a local guide, we started for Madod.

We began badly. Our guide led us, although protesting and reluctant, up the side of a mountain from which he assured us we should see all: and as he was the owner of the valley, we felt he ought to know and so we gave in. My own idea was to skirt the right-hand of the valley and so ascend to the glacier, to which Daulat agreed. We followed instead the proprietor, obeying the rule of trusting the local expert. We toiled up and up to a height of 14,000 ft., and then poked our heads over and looked down on the Madod nala, to discover exactly what we expected that we were right and the expert was wrong.

We had to descend into the nala; tumbling down a steep hillside, no easy matter, but with Daulat as a guide (he had, of course, never seen the place before, but had the true Hillman's instinct) we reached the bottom of the right side of the Madod valley. The stream itself lay beyond, hidden between deep conglomerated cliffs. Above this, on the left, was some poor grazing and a little cultivation. We passed through the latter, then, climbing up the steep moraine, took an hour and a half to cross. A bitter wind blew out of a cloudless blue sky. Finally, in 51/2 hours we reached the top of the moraine and were rewarded with a fine view; then finding a sheltered place we were able to enjoy the spectacle in comfort.

The moraine was heaped up in the centre of the valley, but from its apex we found that it sloped away between ourselves and the glaciers in a deep trough. Although the whole valley was filled with the glacier, most of the ice, after casting up this moraine mountain (for so it was), turned aside and flowed to the left where it was piled up high on the grassy slope. It was a strange spectacle to see the ice-sheet climbing up the greensward.

On its right, the glacier had left in its wake a high knife-edge of detritus which deepened the effect of the trough. The glacier immediately below us that is, between the end of the valley and the moraine was covered with stone and rubbish, but there was no sign of any water although we expected to find a small tarn. Our attention was drawn to the head of the valley where, from a circle of abrupt and jutting peaks, fine glaciers flowed down from as many small colors, filling the bed of the valley with a clear broken mass of glittering ice. Between these flowing glaciers were hanging ones, the entire head of the valley being thus swathed in ice or snow. I estimated the length of this clear ice in the floor of the valley as 1200 yards long. Then it grew dirty as it sank lower, flowing between the old moraine and the left side of the valley. The actual snow deposits were limited to the head of the valley. On the right, facing S.E., there was not a vestige of snow and the roads were peculiarly arid and barren. On the left was a good deal of grass and a few traces of rapidly melting snow. The lower half of the valley as well as the fields referred to above contained willow and birch trees. There were no permanent inhabitants and the barley did not look very promising, but that was due as much to neglect as to the elevation, for we saw a horse calmly devouring the ripening crop and, although the guide drove it away, there was nothing to hinder it from returning. The next glacier visited was the Vedinkot and, on the way up the Yarkhun valley, we passed two or three others after leaving the Madod, but the river was impassable. Several of these glaciers were quite short, and wholly visible from the opposite or right bank. The Vedinkot or Chattiboi (a word which means 'lake-forming') flows N., and then turning N.W. reaches the left bank of the Yarkhun river flowing ab its base.

The snout of the glacier ends in perpendicular cliffs of clean white ice, with the river flowing below and lapping these ice-walls. All day and all night the crash of ice falling into the stream broke the silence: and when a large piece was detached there came a noise like thunder. The river, in consequence, was full of large blocks of ice, swirling and jostling together. A remarkable feature of the Vedinkot Glacier, which throughout its length completely filled the bed of its own valley, was that it was joined by the broad North Darkot valley with its own stream flowing in it, but the glacier of which was distant and had not advanced at all. In spite of this, on the left of this same valley, there were hanging glaciers and snow deposits of a considerable extent. The explanation of why this valley was not filled with a glacier like its fellow lies in the original shape of the Vedinkot valley. The steep icefall merged into an almost level sheet of ice, while the gradient suited the flow, continuance, and normal life of the glacier. The North Darkot, however, could not force its way down a longer and unsuitable course; the resistance and friction was greater than its momentum could overcome. The Pasu and Batura Glaciers in Hunza, the Western Aghias in the Tian Shan, and many other glaciers, which continue far down their valleys are largely indebted for their length to the gradient of the valley. Beginning with a steep icefall, but which gradually eases off, the flow of the glacier is moderated and the original momentum is diminished, while at the same time the ice stream can continue its course and preserve its identity far down into the valley.

The action of the sun is also limited to the actual surface of the glacier, of which the edges are protected by the sides of the valley. Again, the liquefaction of the steep icefall is neutralized by the gentler slope lower down. Besides the reasons given there is also, in the case of the South Darkot Glacier, a real failure in the ice of recent years. Some time ago there was a route over the Darkot Pass, down the glacier, to Vedinkot. Then for a number of years the North Darkot Glacier flows south from the Darkot Pass, and should not be confused with the glacier flowing direct into the upper Yarkhun from the same pass: this latter is the Chigar Glacier. It was closed in 1932 it was again passable, which indicates a decrease in the glacier: when crossing the Darkot Pass by the Chigar Glacier I could see that the South Darkot was easy enough. My Wakhi yak drivers, stating they would be at their homes in Vedinkot in a very short time when taking this route, disappeared contentedly down it. Near to Vedinkot was another glacier, the Pechutz or Hot Spring.

This small glacier was in a very large valley compared with its size, and suffers much from solar action on three sides, attacks from falling stones and lateral streams, and was quite a pathetic object, dwindled and shrunk in its too roomy bed. It was not wholly a case of a glacier having carved out a valley that it now fails to fill, for in this arid country a glacier is constantly exposed to outside influences which diminish it considerably. But so far as Vedinkot went, the great glacier more than compensated for the failure of its neighbours to fulfil their role and bring their ice to the river bank. It was a splendid spectacle, this long wall of ice towering over the roaring river. We heard that on one or two occasions spectators had been killed by splinters of the icewall falling across the river; we were very glad that it did not happen to us.

So far as dimensions go the principal feature of Northern Chitral is the great Chiantar Glacier, the true source of the Yarkhun river. This great glacier is, at a conservative estimate, some 20 miles long with an average width of 3-4 miles. Its bulk is most impressive, but is seen to the best advantage from 10 to 15 miles off. Otherwise, it can hardly be called a beautiful sight. Interesting, no doubt, but its flatness and regularity detract from the general effect. The surface of the glacier is singularly smooth, due to the very gentle gradient of the flow. Naturally the glacier is broken by friction near its rocky banks, but in 1933 crevasses were .few, while even mere superficial cracks were not numerous, and where I wandered on it, I could have driven over much in a light motor car. The Chiantar was a wonderfully clean glacier, the surface moraine being only abundant near the snout where there were quite a number of fast collapsing tables of immense size. I judged the glacier to be divided into three distinct parts. The head and snout were smooth and regular but, owing to a change in gradient, the centre was much broken by crevasses, yet,

even so, much less than could have been expected. A feature of the glacier was its consistency in width; from a point near its snout, or indeed from any neighbouring high ground, the whole glacier was visible, except for a small part at the head. I have tried to find the meaning of the word 'Chiantar,' which many glaciers bear. In Burishashki, the language of Hunza, Nagir and Yasin, the word means' spry, sprightly, smart,' but in rather a bad sense. What it means in Shina or in Khowar (Chitrali) I failed to discover. The glacier has one large but unnamed tributary, 6 miles long, flowing in on the left from the S., and which joins the main icestream, but preserving its own individuality, flows on the left side of the valley. Between it and the main glacier is a black band of moraine which is most conspicuous throughout its length. This tributary glacier joins the main one 5 miles from its termination in the Yarkhun river. As I have said, I found it easy to walk over the glacier; of this I did a great deal. I also crossed it with yaks about half a mile above its snout, and experienced little trouble except in getting on and off. I left slightly disappointed with the spectacular effect of this great ice river. The sides of the valley were monotonous and low, so was the smooth and tranquil sheet of ice; it was only by the effort of remembering its great bulk that I kept my interest alive. This vast ice river was, in fact, rather deadening.
The Chiantar Glacier appeared to me to be advancing very slowly. The Yarkhun river was quite unfordable anywhere, at any time, by day or night, though we watched it most carefully, since crossing the ice meant a considerable detour for all of us, and we were anxious to find a ford. All three glaciers, the Madod, Vedinkot, and Chiantar, were slowly advancing, but the_ other glaciers seen were small, generally static or retreating. From talking with the people it was evident that cloud-bursts are a feature of the country. I was shown tracts of territory near Wassum, for instance, where good arable land had been ruined by summer floods. In some places I saw settlements destroyed by the same cause, and the peasants attributed the damage to the heavy rain. In the Baroghil we heard alarming tales of the heavy and continuous downpours; we only escaped such a deluge by the happy accident of leaving the day before. This heavy rain must greatly affect the glaciers and especially retard vegetation; I think that this interference with the normal life of a glacier accounts: for the apparent vagaries of the ones in Chitral. I do not pretend to any elaborate study of the Chitrali glaciers; but it was clear that the smaller glaciers contrasted strangely with their neighbours, and I believe that they had suffered from the effects of a recent cloud-burst, having lost an unusual quantity of their ice, which they were in the less favourable position to replace. I have often watched a sudden storm on a glacier and even a comparatively light shower achieves a great deal. The warm rain corrodes the ice, stones are brought down with a clatter, and ice, rock and much else go rattling down, causing a marked change in even a small formation. It can hardly be argued that the Chitrali glaciers of the upper Yarkhun, whether of the Hindu Kush or Hindu Raj two names for one mountain group are different from others, and yet the ice deposits exhibit a strange inconstancy and waywardness. All I suggest is that the Chitrali glaciers n1ust be modified by these rain-storms which have so greatly altered the format ion of the valley itself.
Key words: Glaciers, Chitral, Alpine.

S/109. Schomberg, Col. R.C.F., 1938. Kafirs and glaciers: Tavels in Chitral. London, Hopkinson, Brighton. 287p, 24 plates.

The book describes exploring the mountains and villages of Chitral, including Tirich Mir.
Following a distinguished career in the British Army, Colonel Reginald Schomberg (1880-1958) became a writer, photographer and explorer travelling throughout Central Asia and the Himalayas between 1927 and 1947.
From the Himalayan Club Journal:
Kafiristan
One used to imagine a mysterious land inhabited by strange men and women, who used bows and arrows and spoke an unknown tongue. Colonel Alexander Gardner did visit the country in 1826, but then he had paid a call to almost every known portion of the earth, and unfortunately most of his records were lost. Mr. McNair, of the Indian Survey Department, carried out a most remarkable expedition in 1883, and Sir George Robertson’s visits to the country in the years 1889, 1890, and 1891 were described very fully in his book The Kafirs of the Hindu Kush. Since then little has been written of this out-of-the-way patch of Asia.
And now that untiring traveller Colonel Schomberg has given us a book which will gladden the hearts of all lovers of the Himalaya and Hindu Kush.
From the town of Chitral itself, Schomberg went first to the Bum- boret valley, where the Black Kafirs or Kalash live. From there his wanderings took a northerly line always bearing to the east. He visited nearly all the passes over the Hindu Kush, leading from Kafiristan and Chitral into Afghanistan and Wakhan, including the Dorah, the Nuqsan, the Kotgaz, and the Shan Jinali, all of which, with their heights and approaches, are usefully described. It is

interesting to note that the Kotgaz pass, which used to be a route into Badakshan, is now a confused mass of snow and ice and impassable to an ordinary pedestrian.
Schomberg considers that almost all the major glaciers of western Chitral are in retreat, and 'with black unseemly snouts, they look shabby, seedy, and decayed'.
It is when we come to the people themselves, however, that the true value of the book is shown, their superstitions, social customs, pastimes, festivals, and general mode of living being described in detail by a highly trained observer of central Asian tribes. A touch of humour throughout takes the edge off the dreadful laziness and shortcomings of the Chitrali — and makes the book intensely readable.
The Chitrali must be the most superstitious of all mortals. Their fairies are like ordinary men and women except that their heels are in front and their toes at the rear. Surely they must have a sister who inhabits the Khyber, for the Afridis used to tell me of an evil woman whose toes pointed aft, who compelled the lonely traveller to follow her by looking at him over her shoulder, and who then led him to a deserted graveyard to be devoured by goblins and demons!
The book is very fully illustrated with excellent photographs, including a beautiful picture of the peak of Tirich Mir; there is a clear good map, and also a very handy index for reference. An appendix at the end gives a complete historical sketch of Chitral. Altogether this is a remarkable book, which, being up to date, should be of very great use to any Political Officer or traveller in Chitral or Kafiristan.
Key words: Glaciers, Chitral.

S/110. Schouppe, A. von, 1965. Die Mittel - bis Oberdenonische Korallenfauna von Kuragh (Chitral). In: Italian Expeditions to the Karakorum (K2) and Hindu Kush, (A. Desio leader), Scientific Reports IV (1), Paleontology-Zoology-Botany, 14-53. Brill, Leiden.

Key words: Oberdinonische, fauna, Kuragh, Chitral.

S/111. Schouppe, M. & Fontan, D., 1993. Geological outline of Neelum Valley (Azad Kashmir, NE Pakistan). Abstract, Volume, 8th Himalaya-Karakoram-Tibet Workshop, Vienna, 77-78.

More than fourteen hundred square km area is being intensively mapped at the scale 1:50.000, between the Neelum River and the watershed separating the Neelum Valley from the Kaghan Valley. New ground is broken in the sense that it is the first time that a systematic regional mapping is undertaken in a zone, which is often forbidden to foreigners due to the political instability between the Indian and the Azad Kashmir. Geological data collected since 1991 greatly improve the understanding of the Higher Himalayan Crystalline (HHC) of Neelum Valley and relatively complete previous field observations made by other authors near the Hazara Kashmir Syntaxis.
Stratigraphy
In the HHC unit of Neelum we have distinguished a basement and a cover. The basement comprises a thick sedimentary sequence intruded by leucocratic garnet-bearing granitoids of pre-Himalayan age (presumably Early Paleozoic). The sedimentary rocks consist of a monotonous alternance of psammitic to pelitic schists with minor intercalations of impure marble. The contact between the granitoids and the schist is generally tectonized. Evidence of intrusive contacts are still observable:
spotted schisfs with andalusite relics and skarn in the Jagram-Kaiclpani area and magmatic contact in the Shardi-Surgun-Gumot area. Basaltic dykes cross-cut at low angle the regional banding of the basement. The cover has been divided into three units (from bottom to top):
unit A: a siliceous sequence made of impure quarzites associated with minor metaconglomerates, and a thick sequence of kyanite-bearing paragneisses.
unit B: an alternance of impure marble (frequently ruby-bearing), calcschist, and amphibolite.
unit C: a thick sequence mad. of graphite-bearing garnet micaschist. The contact between the basement and the cover is believed to be an old tactonized stratigraphic unconformity. The question remains open due to the lack of well accessible outcrops.
Metamorphism
The regional Himalayan metamorphism of the studied area has been shown to be of Barrovian type (Iron, biotite-chlorite zone to sillimanit zone) with an early eclogitic stage present only in the Shardi-Surgun-Gumot area. In the cover sequence of the Shardi.Surgun-Gumot, a typical kyanite-staurollte assemblage of high temperature amphibolitic facies, is wide-spread developed. Beside this assemblage, a few relics of previous prograde

metamorphism ore present. Some chlorite crystals, discordant on the schistosity, attest for a not intensive retrometamorphism in the green schist facies.
The sedimentary sequence of the basement, well developed in the Jagram-Kalaparil area, shows a metamorphic zonation consisting In a biotite-chlorite zone, a kyanite-staurolite zone and a sillimanite zone.
Rocks with biotite-chlorite assemblages were encountered near Kundaishahi. These assemblages may represent relics of a prograde phase of Barrovian metamorphism or a pro-Himalayan low-grade phase associated with the emplacement of the granitoids.
Kyanite-staurolite bearing assemblages are not common on the field. The typical assemblage consists in white mica, biotite, garnet, epidote and amphibole. Kyanite and staurolite, visible only in thin section, are associated with the spotted schists. They grow on old andalusite grains, already replaced by white mica and quartz. This suggests that the time of re-equilibration to the amphibolitic condition was relatively short.
Sillimanite appears in the sedimentary sequence with anatectic rooks (agmatites) as small needles or flak. It is associated with the first appearance of K-feldspar.
In the granitic rocks, the old magmatic white mica is partially or totally replaced by fibrous sillimanite. In the migmatitic gneisses, sillimanite coexists with kyanite and an incipient melting appears in small (dm) shear zones. In the Shordi-Surgun-Gumot area, basaltic dykes cross-cutting the migmatitic gneisses are characterized by, eclogitic assemblages (omphacite+garnet). These eclogitic assemblages are only preserved in the centre of the dykes. Sometimes, they are partly replaced by later discordant growth of hornblende and biotite arid along the border zone, by green schist assemblages. Eclogites in the same metamorphic setting, have been found also outside the mapped area. They appear In the Lillan Bastl area (Kaghan Valley) as strongly deformed pillow lavas and, in Kel area, as dykes cross-cutting migmatitic rocks. Eclogitic assemblages are not found in the Jogram-kalapani area where the basaltic dykes show an amphibolitic paragenessis with relics of the magmatic texture. The fact that eclogitic assemblages have been found in the Shardi-Surgun-Gumot area and that they are absent In the Jagram-Kalapani area, suggest a different metamorphic P-T-t path for both of them.
Structure
The basement- and the cover rocks of the Higher Himalaya Crystalline of Neelum Valley Illustrate the prevalent ductile nature of a complex Himalayan deformation. Four successive phases of folding have been distinguished on the field in both mapped areas (“Jagran-Kalapani” area and “Shardi-Surgun-Gumot” area).
An over spread penetrative schistosity (S1), derived from the preferred orientation of platy and acicular minerals lies subparallel to the banding. It is probably related to a large ductile shear at deep level, associated with isoclinal and intrafolial foldings (Fl). This first phase (Fl) developed an East oriented stretching lineation (L1) well expressed in some granites and amphibolites of the “Jagran-Kalapani” area. A second phase (F2) folded isoclinally the main schistosity and the banding. This phase brought off the transposition of the basement and cover sequence initiated by Fl. Later, a third phase of tight folding crenulated the main schistosity to develop a crenulation cleavage S3, 15º to 25º oblique to the banding. The geometry of all these structures is disturbed by the fourth folding phase, which produced open folds repeated with a wavelength of several kilometres. Their axial planes are subvertical and strike NE-SW. From place to place, the fold axes are sub-horizontal, gently plunging to the NE or to SW. This suggest further gentle deformations expressed in the rocks with a very large wavelength >20 km). We mention finally a set of small early deformations including kinking of the previous structural planes, different fracture sets and local sub-horizontal thrust planes, constantly characterized by a displacement of the roof to the SW.
Key words: Geology, stratigraphy, metamorphism, Azad Kashmir.

S/112. Schouppe, M., Fontan, D., Laduron, D. & Martinotti, G., 1995. Macro- and Mesoscopic Fold Interference Patterns in the Higher Himalayan Crystalline (HHC) and the Lesser Himalayan Crystalline (LHC) of the Kashmir Himalaya. Abstract Volume, 10th Himalaya-Karakoram-Tibet Workshop, (ETH Zurich) Switzerland.

Recent structural analysis at Neelum valley (figure 1) has drawn a detailed picture of the major Himalayan deformation phases which have affected the rocks of the Lesser - and Higher Himalayan Crystallines (LHC and HHC) of Azad Kashmir. At least four successive phases of deformation have been recognized in both the Precambrian basement and the Tethyan metasediments of the LHC and HHC. The Kalapani rock fragment, redrawn in figure 2, illustrates the phases of deformation Dl, D2a and D2b; the figure 3 illustrates the late phases D2, D3 and D4.
The earliest phase Dl of the Himalayan deformation is a penetrative ductile deformation which predates the peak of the Himalayan Barrowian metamorphism. It is characterized by intrafolial and isoclinal folds and by an axial plane

schistosity Si, best observed in some D2a fold hinge zones (figure 2). The foliation Si is defined by the orientation of the platy minerals. In the upper HHC of the Neelum valley, regional Di sheath-like folds induce a 1800 re-orientation of the Fl fold axis parallel to the N-S trend of the nappes tectonic transport.
lsoclinal folding also characterizes the early step (D2a) of the syn-metamorphic second phase of deformation (D2). Due to the focal re-orientation of the Fl axis, the Dl and D2a isoclinal folds show both coaxial (type 3) and not coaxial (type 2) fold interference patterns. The figure 2 illustrates an arrowhead fold interference pattern of type 2. The D2a phase of deformation has generated a fine penetrative S2a foliation and a mineralogical extensional lineation L2, particularly visible in some amphibolites and in some orthogneisses.
A second generation of structures (D2b) has been produced during the D2 phase of deformation. Open, close to tight D2b folds are related to the shearing stress responsible for the syn-metamorphic southwestward overthrusting of the HHC over the LHC along the MCT. Close to the MCT, the crenulation of the early structures has generated a S2b crenulation cleavage in the more pelitic rocks and a fracture cleavage in the more quartzitic rocks. As visible on the figure 2, D2a and D2b folds are coaxial, generating a wavy fold interference pattern (type 3).
The next phase of deformation D3 is only observable at the map scale. It consists in open flexural slip buckle folds with a more than 6,5 kilometers wavelength. The D3 fold axis trend NE-SW. The figure 3 is a synthetic map showing the macroscopic D2a and D3 folds exposed in the Neelum valley. In the lower half of the map, D2a and D3 folds are approximately perpendicular. They produce an intermediate interference pattern: arrow-head, dome and basin structures (type 1-2). On the other hand, the upper part of the map shows a considerably reduced obliquity between the Dl -D2 and D3 structural trends. In that case, the structures generate a near-coaxial type (2)-3 interference pattern.
A last D4 phase of deformation is mostly expressed by the doming of the earlier structures to build the Hazara Kashmir Syntaxis, of which the eastern flank crosses the Neelum valley along the MBT (lower left corner of the figure 3). In the Neelum valley, the distribution of the Precambrian basement outcrops is related to large domal structures elongated in the NNW-SSE direction, such as the domes alignment of Shikar and Ganja. Tethyan metasediments outcrop inside a large synform (“basin”) which trends NNW-SSE and goes through the village of Doarian. Since such large domes and basins do not occur each time D3 folds interfere with D2a folds, we believe that the D4 doming is the main factor of distribution of the basement/cover outcrops. The D4 doming has locally uplifted some previous D3-D2a domes and basins such as those of Shikar and Ganja.
Key words: Structure, deformation, ductile folds, shearing stress, Azad Kashmir.

S/113. Schrader, H.W., 1983. Contribution to the study of the distinction of natural and synthetic emeralds. Journal of Gemmology 18, 530-543.

Trace element contents of emeralds may be taken as a modern method to distinguish between natural and synthetic stones. It is also possible to differentiate between the localities of the natural emerald according to their chemical composition. The significant chemical characteristics of both natural and synthetic emeralds are discussed. The paper also shows that two emerald analyses from Pakistan have higher V, Sc, Ni, and lower Rb, Cr, and Mn than most other natural emeralds.
Key words: Gemology, synthetic and natural emeralds, Pakistan emeralds.

S/114. Schwan, W., 1980. Shortening structures in eastern and northwestern Himalayan rocks. Today and Tomorrow’s Printers and Publishers, New Dehli, 62p.

Key words: Shortening, structure, Himalaya.

S/115. Scott, C., 1992. Glacial sediment production by the steep valley glaciers of the Nanga Parbat massif, Pakistan Himalaya. Abstract Volume, 7th Himalaya-Karakoram Workshop, Department of Earth Sciences, Oxford University, England, 80.

Studies of sediments produced and transported by steep valley glacier systems in the Nanga Parbat massif, Pakistan Himalaya, raise questions -about the universal validity of present day theories of glacial sediment production, which have resulted from the study of European glaciers.

Whilst subglacial processes remain the dominant source of fine particle production, the supraglacial process of debris transport can also be seen to exhibit down-glacier fining of sediment. This view of non-passive transport of debris in the supraglacial zone is supported by Scanning Electron Microscopy of the fine sediment particles produced by these systems, which exhibit a clear down-glacier evolutionary sequence in particle morphology. Co-existing subglacial and supraglacial systems of particle comminution and fine sediment production are envisaged within the Himalayan glacier systems, where glaciers are typically high gradient with lengthy ablation/transport zones and of thick debris mantle cover. A comparison is made with a typical glacier system in the European Alps where tine sediment production is shown to be exclusive to the subglacial zone of traction. Reasons for the difference between these glacial systems are explored including glacial morphology, bedrock control of sediment input and the unique tectonic situation of the Nanga Parbat Massif within the Himalayan belt. The implications of this proposed Himalayan system for present day regional sediment output and for interpretations of Pleistocene valley glacier sediment systems are considered.

Key words: Glaciers, debris transport, sediments, Nanga Parbat.

S/116. Scott, C. & Derbyshire, E., 1990. Questions posed by a preliminary glacial landform-sedimentary map of the Nanga Parbat Himalaya. In Abstract volume, 5th Himalaya-Karakoram-Tibet Workshop, Milano, 53.

A preliminary map of the glacial landform-sediments associations on the flanks of Nanga Parbat in the Greater Himalaya is presented. It shows the form and distribution of moraines, glaciofluvial outwash, moraine fans, debris fans, talus slopes, protalus ramparts, hummocky moraines and a variety of terrane features.

The terraces are extremely large and are made up of diamictons in some cases over 100m thick. Terrace surface relief, however, rarely exceeds 10m; the small ridges and hummocks appearing to be retreatal end moraines. The present glaciers include several high-gradient ice streams which have advanced across some trunk valleys (such as the Rupal), constraining the trunk rivers and superimposing high lateral moraines (>100m) on the flat valley-floor sediments. Some moraines impound perched proglacial lakes. There is thus marked topographical discordance between the surface of the trunk valley ice-retreat outwash sediments and the late Holocene moraines. Extrapolation of Pleistocene glacial trimlines left by the trunk glaciers and smaller ice streams from the high gradient tributary valleys prevailed at that time. However, any frontal moraine systems in the trunk valleys sedimentary burial has occurred, fills may be several hundred meters thick. The thick terraces downstream, such as those at and below the Astor junction, contain little fluvial material: they may have been emplaced by glaciers and then dissected by the rivers. The map thus poses a number of questions including the mode of deposition of coarse diamictons, the origin of the terraces and their relationships to ice limits, and the relationship of the tributary valley deposits to the lithostratigraphy trunk valley fills.

Key words: Glacial landform, Nanga Parbat, Himalaya.

S/117. Scott, D. & Rouse, A., 1983. Karakoram-Alpine style. Mountain 93, 26-33.

Key words: Geomorphology, Karakoram.

S/118. Seall, R.R., 1989. A reconnaissance study of the fluid inclusion geochemistry of the emerald deposits of Pakistan and Afghanistan. In: Kazmi, A.H. & Snee, L.W. (ed.), Emeralds of Pakistan: Geology, Gemology and Genesis, 151-164. Van Nostrand Reinhold, New York.

This study documents the geochemical characteristics of the hydrothermal fluids responsible for emerald mineralization in Swat (Mingora Mine 1 and 2, Charbagh, and Barang) and a single sample from Panjsher in Afghanistan. It is concluded that 1) salinities ranged from essentially nil to approximately 20 wt% dissolved salts, 2) the inclusions contain up to 3 mole% of a CO_2-rich component, with up to 0.22 XCH4, 3) homogenization and decrepitation temperatures ranged from 150 to 349ºC, which is equivalent to entrapment temperatures of 250 to 449ºC at a confining pressure of 900 bars, and 4) boiling and fluid immiscibility were absent in all stages of hydrothermal activity recorded by these fluid inclusions.

The present data, especially those from the primary fluid inclusions suggest that mixing of a high temperature, high salinity fluid with a lower temperature, less saline fluid may have importance in mineral deposition. The only anomalous features of the fluid inclusions, observed in this reconnaissance study, are that the fluid inclusions from

Mine 2 are less saline than those from Mine 1, Charbagh and Barang, and that the fluid inclusions from Charbagh locally contain hematite daughters. All other fluid inclusion characteristics from the Swat district are indistinguishable from one mine to another. The sample from Panjsher is distinctly different from those of Swat. It contains numerous daughter minerals (including halite and sylvite) in inclusions oriented parallel to the c-axis.
Key words: Geochemistry, fluid inclusions, emerald deposits, Pakistan, Afghanistan.

S/119. Searle, M.P., 1989. Thermal model for the Baltoro-Muztagh Karakoram. Geological Bulletin, University of Peshawar 22, 1-9.

Following the Eocene (50 Ma.) collision of the Indian and Karakoram plates, crustal thickening and shortening in the Karakoram north of the Neo-Tethyan suture zones resulted in a widespread regional Barrovian metamorphism (M2) south of the Karakoram batholith. Pelitic lithologies are characterised by the assemblage: kyanite-staurolite-biotite-garnet-muscovite-plagioclase-quartz with sillimanite-muscovite and sillimanite-K-feldspar assemblages locally developed. Hornblende and diopside-bearing marbles and garnet-bearing amphibolites are also widespread. The age of this high pressure-high temperature metamorphism is constrained as post-50 Ma. (age of India-Asia collision) and pre-37 Ma. (age of cross-cutting, post-collisional granite plutons).
Intrusion of the 21 Ma. Baltoro batholith comprising compositions ranging from biotite monzogranite to two-mica leucogranite caused a high temperature-low pressure thermal aureole of contact metamorphism in the country rock. Andalusite-bearing hornfels along the northern contact of the batholith indicates maximum pressures of 3.5 kbars (350 MPa). A 750 increase in temperature in Kyanite sillimanite grade gneisses approaching the granite contact along the Baltoro glacier is modelled as the thermal upwarping of pre-36 Ma. Barrovian metamorphic isograds around the 21 Ma. contact aureole isotherms along the margins of the Baltoro batholith. Post-metamorphic folding of the early Barrovian metamorphic isograds is related to thrust culminations along the hanging-wall of the Main Karakoram Thrust - a reactivated breakback thrust along the older Shyok suture zone.
Key words: Thermal model, Baltoro-Muztagh, collision, Karakoram.

S/120. Searle, M.P., 1990. Baltoro-WildSide. Mountain 135, 26-31.

Key words: Baltoro, Karakoram.

S/121. Searle, M.P., 1991a. Geology and Tectonics of the Karakoram Mountains. John Wiley and Sons, New York, 358p.

This well produced book is a detailed compilation of the author's contribution as well as those of the earlier worker's contribution. It contains many figures, including geological maps, sketches, satellite imageries, field photographs, photomicrographs and tables. The book is divided into four parts: part 1, regional tectonic setting comprises Geological and Geophysical Constraints (Chapter1), Tectonics of Central Asia (Chapter 2), and Tectonics of the Himalaya (Chapter 3). Part 2, the greater Karakoram, comprises general statement, and Kohistan (Chapter 4), western Karakoram --Chitral-Yasin (Chapter 5), Hunza Karakoram (Chapter 6), Northern Karakoram Terrain (Chapter 7), Karakoram batholith --Baltoro, Biafo, Hushe areas (Chapter 8), Karakoram metamorphic complex (Chapter 9), and eastern Karakoram – Siachen-Nubra-Ladakh (Chapter 10). Part 3, Physical Geography consists of Quaternary and Present Glaciations (Chapter 11), and Geomorphology, Climate and Neo-tectonics (Chapter 12). Part 4, Orogenic processes comprises chapter 13 on Pre-Collision Crustal Evolution and Chapter 14 post –Collision Crustal Structure and Evolution. There are fifteen pages of references, and index and geological map of the Central Karakoram at 1:250,000 scale. The book also contains a summary of all the radiometric ages spanning Cretaceous-Tertiary that were available by 1991.
Key words: Geology, tectonics, Karakoram.

S/122. Searle, M.P., 1991b. A new geological map of the central Karakoram at 1/250,000 scale. Abstract Volume, 6th Himalaya-Karakoram-Tibet workshop, Grenoble, France, 75.

A new geological map of the central Karakoram based largely on the last five field seasons mapping is presented. The map covers the area from the Hunza Valley in the west to the Baltoro-Siachen glacier divide in the east, and from the Shimshal valley and Skamri glacier in the north to the Nanga Parbat massif and the Deosai plains in the south. The High Himalayan terrane of the Nanga Parbat-Haramosh massif forms part of the northwestern syntaxis of the Himalaya. The Kohistan terrane to the west and the Ladakh terrane to the east of the Nanga Parbat are continuous eastwards with the Trans-Himalayan batholith in southern Tibet. These terranes are bounded along the south by the Indus Suture Zone or Main Mantle Thrust and along the north by the Shyok suture zone or Main Karakoram Thrust.

The Karakoram terrane is continuous eastwards to the Lhasa Block in south Tibet, and is made up of three domains: the Karakoram metamorphic complex in the south, the Karakoram batholith and the northern Karakoram domain composed mainly of sedimentary rocks with structural culminations of high-grade gneisses along the K2-Braod Peak Range.

Key words: Geology, Hunza Valley, Baltoro-Siachen, Shimshal Valley, Ladakh, Karakoram.

S/123. Searle, M.P., 1993. Structure, Metamorphism and Cooling History of the Central Karakoram (North Pakistan). Abstract, Volume, 8th Himalaya-Karakoram-Tibet Workshop, Vienna, 50.

Prior to the Eocene (ca. 50 Ma) collision of the Indian and Asian plates, the southern margin of Asia in the Karakoram region was dominated by a series of Andean-type plutonic belts (Hushe gneiss, Muztagh Tower gneiss, K2 orthogneiss) and regional low-pressure andalusite, staurolite and garnet-grade metamorphism (Ml). Crustal shortening, thickening and regional metamorphism following collision occurred between 50-37 Ma and has been dated by a U-Pb zircon age from the Mango Gusar two-mica leucogranite which cross-cuts syn-metamorphic fabrics in the country rocks. Thermobarometry of kyanite and sillimanite-grade rocks indicates peak metamorphism (M2) at around 7000C and 8-9 kbars. Temperatures increase northwards along the Baltoro glacier transect towards the contact with the Baltoro granite where in situ partial melting begins in the sillimanite gneisses. Post-metamorphic folding of M2 isograds was associated with deep crustal gneiss domes and initiation of the Main Karakoram Thrust in the south. Post-M2 thermal relaxation followed from 37-25 Ma after which localized high heat concentrations at the base of the thickened crust caused widespread crustal melting and intrusion of the Baltoro granite at 25-2lMa. A high-temperature, low-pressure thermal aureole (M3) along the northern contact of the Baltoro monzogranite leucogranite is synchronous with the 21±0.5 Ma U-Pb zircon crystallization age of the granite. The Mitre contact aureole contains the assemblage: andalusite + cordierite +biotite+ muscovite + chlorite + plagioclase + quartz and indicates pressures less than 3.5 kbars. The increase of .T along the southern contact of the Baltoro granite is interpreted as the thermal upwarping of pre-37 Ma M2 isograds by 21 Ma M3 contact metamorphic isotherms. In the southern Karakoram pressures up to 10 kbars were attained by 37 Ma ago meaning that around 37-km of overburden has been eroded since the Eocene-Oligocene boundary giving a time-averaged exhumation rate of 0.95mm/year. The 21 Ma Baltoro granite crystallized at temperatures above 750oC and pressures above 10 kbars equating to depths of burial between 26-35 km. The exhumation or unroofing rate, which includes processes of uplift and erosion is between 1.2-1.6mm/year. Subduction of Indian continental crust and mantle lithosphere northwards beneath the Karakoram and Tarim Basin continental crust southwards beneath the KunLun and the northern Karakoram has created a lithospheric-scale pop-up structure with its axis of maximum uplift aligned along the Karakoram.

Key words: Structure, metamorphism, cooling history, Karakoram.

S/124. Searle, M.P., 1996a. Geological evidence against large-scale pre-Holocene offset along the Karakoram fault: Implications for the limited extrusion of Tibetan plateau. Tectonics, 15, 171–186.

Two end-member models proposed to accommodate the convergence between India and Asia north of the Himalaya are (1) homogeneous crustal thickening of the Tibetan plateau and (2) continental escape, or extrusion, of Tibet and southeast Asia, away from the indenting Indian plate. Foremost among the arguments supporting the latter would be large-scale (□1000-km) offsets and high present-day slip rates along the major strike-slip faults bounding the postulated extruding crust, notably the Altyn Tagh Fault along the northern margin of Tibet and the Karakoram Fault along the SW margin. Satellite photographic interpretation and field mapping in the Karakoram mountains in Pakistan, the Nubra-Siachen area of north Ladakh, and the Pamirs in Xinjiang show that although the Karakoram Fault is extremely active today, geological offsets along the right-lateral fault are probably less than 120 km. The 21±0.5 Ma Baltoro monzogranite-leucogranite batholith has been rotated clockwise about a vertical axis 35°–40°

into NW-SE alignment, parallel with the Karakoram Fault, east of the Siachen glacier, with a maximum offset of 90 km across the fault. The Bangong-Shyok suture zone similarly has a dextral offset of 85 km. The course of the Indus River, which was antecedent to the rise of the Ladakh, Karakoram, and Himalayan ranges, has been offset dextrally by 120 km south of Pangong Lake. If present-day slip rates (approximately 32 mm/yr) (Avouac and Tapponnier, 1993) are correct, only 4 Ma are required to obtain a 120-km offset. There is no geological evidence for any larger-scale pre-Holocene offsets, and it is suggested that the Karakoram Fault cannot have accommodated major eastward lateral motion of Tibetan crust. The fault has also exerted little or no influence on surface topographic uplift, cutting obliquely across the highest peaks of the Karakoram. Dextral motion along the central part of the Karakoram Fault has been transferred in the north to the Rangkul, Murghab, and Karasu transpressional faults in the central Pamir. North of Tashkurgan, the Karakoram Fault shows mainly normal motion around the Kongur and Mustagh Ata gneiss domes (metamorphic core complexes) and the extensional Muji graben. Minor dextral displacement has occurred along the Shiquanhe Fault, but this motion cannot be linked to the Jiale Fault of east Tibet. The southern end of the Karakoram Fault merges with the Indus (Yarlung) suture zone near Mount Kailas and does not cut across the Himalaya. The lack of large-scale geological offsets along the Karakoram Fault, together with its very recent initiation (?5 or 4 Ma), suggests that it is related to the Pliocene-Quaternary northward indentation of the Pamir, and not to any long-term extrusion of Tibetan crust following the Indian collision.
Key words: Geology, Holocene, Karakoram fault, India, Asia.

S/125. Searle, M.P., 1996b. Cooling history, erosion, exhumation and kinematics of the Himalaya-Karakoram-Tibet orogenic belt. In: Yin, A. & Harrison M. (Eds.), The Tectonic Evolution of Asia, Cambridge University Press, 110-137.

The cooling histories of metamorphic and magmatic rocks, as determined through the use of thermochronometers and radiogenic isotope systems, combined with thermobarometers, can provide useful constraints on our determinations of depths of burial and exhumation rates. This chapter reviews the reliable geochronologic data on segments across the Himalaya-Karakoram-southern Tibet orogenic belt, and cooling histories for each zone are inferred.
Southern Tibet and the Karakoram have been sub-aerial landmasses since the mid-Cretaceous and could have been topographically high, Andean-type continental margins prior to the collision of India at 60-50 Ma. Thick continental red-bed deposition, abundant calc-alkaline volcanism, and granite magmatism suggest a thickened crust along southern Asia as far back as about 150 Ma. The collision of India with the southern margin of Asia (Kohistan-Karakoram-Lhasa terranes) may have been diachronous, occurring earlier in northern Pakistan (ca. 60 Ma) than in Ladakh-southern Tibet (ca. 50 Ma). Following the collision, crustal thickening and the timing of peak metamorphism were diachronous both along the Himalaya (pre-40 Ma northern Pakistan; pre-31 Ma Zanskar; pre-20 Ma eastern Kashmir and western Garhwal; 11-4 Ma Nanga Parbat) and across the strike of the High Himalaya, propagating southward (in Zanskar, southwestward) with time. Thrusting along the base of the High Himalayan slab (Main Central Thrust, active 21-18 Ma) was synchronous with north south (in Zanskar, northeast southwest) extension along the top of the slab (South Tibetan Detachment zone). Kyanite and sillimanite gneisses in the footwall formed at pressures of 8-10 Kbar and depths of burial of 28-35-km, at 30-21 Ma, whereas anchimetamorphic sediments along the hanging wall have never been buried below about 5-6-km. Exhumation rates are far greater in the High Himalayan zone (1.4-2.1 mm/a) and southern Karakoram (1.2-1.6 mm/a) than along the zone of collision or along the northern Indian plate margin. The High Himalayan leucogranites span 24-9 Ma in the central Himalaya, and anatexis occurred at 21-19 Ma in Zanskar, approximately 30 m.y. after the collision.
The Karakoram underwent high-temperature high-pressure metamorphism during the Eocene (50-37 Ma) and widespread lower-crustal melting (Baltoro monzogranite-leucogranite batholith) and upper-mantle melting (lamprophyre dikes) during the early Miocene (25-21 Ma). Uplift of the rocks and erosion, resulting in exhumation of middle- and lower-crustal rocks during the Neogene, were controlled by major thrusts and normal faults, and to a lesser extent by the increasing intensity of the monsoon at 8-6 Ma. The cooling histories show that significant crustal thickening, widespread metamorphism, erosion, and exhumation (and, therefore, probably significant topographic elevation) occurred during the Eocene-Oligocene in the Karakoram and southern Tibet, and during the early Miocene along the central and eastern Himalaya, before the onset of the monsoon, before the major changes in climate and vegetation, and before the onset of east-west extension on the Tibet Plateau.
Key words: Cooling history, erosion, exhumation, kinematics, orogenic belt.

S/126. Searle, M.P., Crawford, M.B. & Rex, A.J., 1992. Field relations, geochemistry, origin and emplacement of the Baltoro granite, Central Karakoram. Transactions of the Royal Society of Edinburgh: Earth Sciences, 83, 519-538.

The Miocene Baltoro granite forms a massive plutonic unit within the Karakoram batholith, and is composed of comagmatic monzogranites and leucogranites with a mineralogy consisting of quartz-K-feldspar-plagioclase-biotite ± muscovite ± garnet, with accessory sphene, zircon, monazite and opaques. Geochemically the Baltoro granites are mildly peraluminous, and show a calc-alkaline trend on trace-element normalised diagrams with high LIL/HFS element ratios and negative Nb, P and Ti anomalies. REE are strongly fractionated with little or no Eu anomaly. Leucogranites are depleted in most elements compared to monzogranites with notable exceptions being Rb, K and the HREEs. Initial 87Sr/86Sr ratios are 0.7072-0.7128, considerably lower than High Himalayan leucogranites (0.74-0.79), and are indicative of a lower continental crust source. The probable petrogenesis of the Baltoro granite involves dehydration melting of a biotite-rich pelite to produce a voluminous, hot, water- undersaturated magma which could then separate from its source and intrude through an already thickened and still hot crust. Fractional crystallisation of the monzogranites produced the leucogranites and a pegmatite dyke swarm. A suite of lamprophyre dykes including amphibole- rich vogesites and biotite-rich minettes intrude the country rock, dominantly to the north, around the Baltoro granite. These calc-alkaline shoshonitic lamprophyres are volatile-rich mantle-derived melts intruded around the same time as the granite, indicating simultaneous melting of the mantle and lower crust beneath the Karakoram during the Miocene, approximately 30 Ma after the India-Asia collision which initially caused the crustal thickening. Intrusion of mantle melts provided heat to promote crustal melting and may have selectively contaminated the granite magma.
The Baltoro granite intrudes' sillimanite gneisses with melt pods along the southern margin indicating temperatures above 700 ^{0}C at the time of intrusion. Locally, internal fabrics and numerous aligned xenoliths along the southern margin in the Biafo glacier region indicate steep, southward-directed thrusting during emplacement. Along the northern contact, the Baltoro granite intrudes anchimetamorphic to greenschist facies metasedimentary rocks with an andalusite-bearing contact aureole. Northward-directed culmination collapse normal faulting during Miocene emplacement is inferred, in order to explain the P-T differences either side of the pluton. This also provided an extensional stress regime in the upper crust to accommodate the rising magma.
Key words: Geochemistry, Baltoro granite, Karakoram.

S/127. Searle, M.P., Crawford, M.B., Rex, A.J. & Rex, D.C., 1990. Origin and emplacement of the Baltoro granite, central Karakoram. In Abstract volume, 5th Himalaya-Karakoram-Tibet Workshop, Milano, 54.

The Miocene Baltoro granite forms a massive plutonic unit within the Karakoram batholith, and is composed of co-magmatic monzogranites and leucogranites with a mineralogy consisting of quartz-K-feldspar-plagioclase-biotite muscovite garnet, with accessory sphene, zircon, monazite and opaques. Geochemically the Baltoro granites are mildly peraluminous, and show an calc-alkaline trend on trace element normalized diagrams with high LIL/HFS element ratios and negative Nb, P and Ti anomalies. REE are strongly fractionated with little or no Eu anomaly. Leucogranites are depleted in most elements compared to monzogranites with notable exceptions being Rb, K and the HREEs. Initial 87Sr/86Sr, ratios are 0.7072-0.7128, considerably lower than High Himalayan leucogranites, but still indicative of a melting source in the lower continental crust.
The Baltoro granite was intruded at ca. 25-21 Ma from a lower crust-melting site into an already thickened and metamorphosed crust, approximately 30 Ma after the India-Asia collision. The Baltoro granite intrudes sillimanite gneisses with melt pods along the southern margin indicating temperatures at the times of intrusion of above 650oC. 40Ar/39Ar biotite ages of 7.9±0.2 Ma combined with previous U-Pb, Rb-Sr and K-Ar dating show that the Baltoro granites was intrude into already hot country rock and maintained high temperatures for ca. 7 Ma. this was followed by very rapid Pliocene-Pleistocene uplift-erosion and exhumation rates. Active crustal shortening and thickening occurred by syn-metamorphic deformation. Numerous aligned xenoliths along the southern margin indicate southward directed thrusting during emplacement. Along the northern contact the Baltoro granite intrudes metasedimentary rocks at maximum P-T conditions of greenschist facies, with an andalusite-bearing contact aureole. Northward-directed culmination collapse normal faulting during Miocene emplacement is inferred, in order to explain the P-T differences either side of the pluton.
Key words: Geochemistry, geochronology, Baltoro granite, tectonics, Karakoram.

S/128. Searle, M.P., Fraser, J.E., Hildebrand, P.R., Parrish, R.R. & Noble, S.R., 2000. Structural and Thermal Evolution of the South Asian Continental Margin along the Karakoram and Hindu Kush Ranges, North Pakistan. Abstract Volume, 15th Himalaya-Karakoram-Tibet Workshop, (Chengdu) China, 82-83.

Prior to the Collison and accretion of the Kohistan arc terrane during the late Cretaceous and the Indian plate after the early Eocene, the southern margin of Asia along the Hindu Kush, Karakoram and Lhasa block terranes was an active Andean-type continental margin. In south Tibet this margin was dominated by the calc-alkaline Ladakh-Gangdese granite batholith, associated andesitic volcanic rocks and continental red-beds. In contrast, the southern Karakoram exposes deep crustal metamorphic rocks and crustal melt leucogranites. New U-Pb age dating from the Hunza Valley and Baltoro Glacier region has revealed four spatially and temporally distinct metamorphic episodes. M1 sillimanite grade metamorphism in Hunza was a late Cretaceous event, probably caused by the accretion of the Kohistan arc to Asia. M2 was the major kyanite and sillimanite grade event during late Eocene-Oligocene crustal thickening and shortening, following India-Asia collision. Numerous melting events resulted in the formation of crustal melt granites throughout the last 50 Ma with multiple generations of dykes and very large scale crustal melting along the Baltoro monzogranite-leucogranite batholith during the late Oligocene-early Miocene. M3 metamorphism was a high- T, low- P contact thermal metamorphism around the Baltoro granite. In Hunza, younger staurolite grade metamorphism has been dated by U-Pb monazites at 16 Ma, with the Sumayar leucogranites intruded at 9.5 Ma crosscutting the metamorphic isograds. In the Baltoro region the youngest metamorphism, M4, is the sillimanite grade Dassu gneiss core complex dated by U-Pb on monazites as late Miocene-Pliocene (5.4±0.25) Ma with Precambrian protolith zircon cores (1855±11) Ma. Numerous gem-bearing pegmatite dykes cross-cut these rocks and are thought to have been intruded within the last 2~3 Ma. Structural mapping, combined with U-Pb geochronology shows that major metamorphic events can be both long-lasting (up to 20 Ma) and very restrictive, both in time and space.

The Hindu Kush range also has abundant sillimanite, kyanite and staurolite grade metamorphic rocks, but in contrast to the Karakoram, U-Pb dating shows that the most metamorphism was pre-collision of both Kohistan and India. U-Pb ages of monazite, xenotime and uraninite from gneisses, migmatites and leucogranites show that this high-T low-P metamorphism spanned the Jurassic-early Cretaceous and was probably related to magmatic heat from the Andean-type granites intruded along the margin. The only evidence of post-collisional crustal melting is the 24 Ma Gharam Chasma leucogranite with its associated dykes. The Hindu Kush is however one of the most seismically active continental zones known on Earth, with a narrow zone of earthquakes extending down to 300-km depth. The reflects the active subduction of lower Indian plate continental crust beneath the Hindu Kush-Pamir range today. The Hindu Kush, Karakoram and S. Tibet all represent the southern margin of the Asian plate, yet all have entirely different geology, structural, metamorphic and magmatic histories and seismic expression.

Key words: Structure, thermal evolution, collision, Kohistan arc, Karakoram, Hindukush.

S/129. Searle, M.P., Khan, M.A., Fraser, J.E., Gough, S.J. & Jan, M.Q., 1999. The tectonic evolution of the Kohistan-Karakoram collision belt along the Karakoram Highway transect, north Pakistan. Tectonics 18, 929-949.

The Kohistan arc terrane comprises an intra-oceanic island arc of Cretaceous age separating the Indian plate to the south from the Karakoram (Asian) plate to the north within the Indus suture zone of north Pakistan. The intra-oceanic arc volcanics (Chalt, Dras Group) were built on a foundation of dominantly mid-ocean ridge basalt (MORB)-related amphibolites of the Kamila Group. The subarc magma chamber is represented by multiple intrusions of a huge gabbro-norite complex (Chilas complex), which includes some ultramafic assemblages of residual mantle harzburgite and dunite, layered cumulates, and hornblendites cut by late stage dikes of hornblende + plagioclase pegmatites. The Chilas complex norites intrude the Gilgit metasediments of lower amphibolite and greenschist facies in northern Kohistan, which also form xenolithic roof pendants within the top of the Chilas complex. Along the southern margin of Kohistan, Jijal and Sapat complex ultramafics (dunites, harzburgites and websterites) form remnant suprasubduction zone ophiolitic mantle rocks along the hanging wall of the Main Mantle Thrust, the Cretaceous obduction plane along which Kohistan was emplaced onto Indian plate rocks. Garnet granulites of the Jijal complex, formed at 12–14 kbars, represent original magmatic lower crustal rocks subducted to

depths of at least 45 km and metamorphosed during high-pressure and high-temperature subduction of earlier arc-related rocks. Obduction of the Sapat ophiolite and Kohistan arc occurred between □75 and 55 Ma.
The closure of the Shyok suture zone separating Kohistan from the Karakoram plate must have occurred prior to 75 Ma, the age of the Jutal basic dikes which crosscut the closure-related fabrics, mainly late north directed backthrusting in the lower Hunza valley. Andean-type granitoid (gabbrodiorite-granodiorite-granite) emplacement along the Kohistan-Ladakh batholith ended at the time of India-Asia collision, □ 60–50 Myr ago. Postcollisional crustal thickening along the Karakoram led to multiple episodes of metamorphism from latest Cretaceous and throughout the Tertiary. Sillimanite grade metamorphism in Hunza was actually pre-India-Asia collision and may have resulted from the earlier Kohistan collision. Localized and sporadic crustal melting episodes across northern Kohistan (Indus confluence and Parri granite sheets) and the southern Karakoram (Hunza dikes and Sumayar and Mango Gusar leucogranites) occurred from 51 to 9 Ma and culminated in the huge Baltoro monzogranite-leucogranite intrusion 25–21 Myr ago. A vast network of leucogranitic and pegmatitite dikes containing gem quality aquamarine + muscovite ± tourmaline ± garnet ± biotite quartz are younger than 5 Ma and form the final phase of intrusion in the Haramosh area and parts of the southern Karakoram area.
Key words: Tectonics, collision, Kohistan arc, Shyok, Haramosh.

S/130. Searle, M.P., Khan, M.A., Jan, M.Q., DiPietro, J.A., Pogue, K.R., Pivnik, D.A., Sercombe, W.J., Izatt, C.N., Blisniuk, P.M., Treloar, P.J., Gaetani, M. & Zanchi, A., 1996. Geological Map of North Pakistan and adjacent areas of Northern Ladakh and Western Tibet (Western Himalaya, Salt Ranges, Kohistan, Karakoram, Hindu Kush), Scale: 1:650,000.

This is an updated compilation by Searle and Khan (eds.), based on the works of a number of people .
Key words: Geology, north Pakistan, Ladakh, Himalaya, Salt Range, Kohistan, Karakoram, Hindukush.

S/131. Searle, M.P. & Owen, L.A., 1999. The evolution of the Indus River in relation to topographic uplift, erosion, climate and geology of western Tibet, the Trans-Himalayan and high Himalayan Ranges. In: Meadows, A. & Meadows, P. (Eds.), The Indus River, Biodiversity, Resources, Humankind. Linnean Society of London, 210-230.

The Indus River is one of the major antecedent rivers of the Himalayas, its drainage course having been initiated prior to the uplift of High Himalayas. The source of the Indus is north of Mout Kailas (6,714 m) in the southern part of the Tibetan Plateau, and it collects drainage from the northern slopes of the Trans-Himalayan ranges. In the far western part of the Tibetan Plateau the course of the Indus River has been offset by about 120-km north-west along the active Karakoram Fault, a 700-km long dextral strike-slip fault which may have been active only for the last 4-5 Ma, with slip rates of 20-30 mm/year. South of the Pangong Lake the Indus rives cuts westward through the Ladakh granite batholith and then follows the trace of the Indus Suture Zone (the zone of late Collison between Indian and Asia) for about 200-km in Ladakh. The late Tertiary Indus molasses sediments in Ladakh show that this section of the Indus River was initiated possibly as long ago as the middle Eocene (45 Ma). The uplift of both the Ladakh range and the High Himalayan ranges post-dated the initiation of the Indus drainage course. The steepest gradient of the Indus River is in Baltistan (north Pakistan) where it cuts right through the middle of Nanga Parbat (8,125 m)-Haramosh (7,409 m) massif, the north-western most part of the High Himalayas, eroding a deep gorge and creating some of the largest single slopes on Earth. Radiometric dating from metamorphic rocks and crustal melt granites from Nanga Parbat shows that metamorphism and melting may have occurred as recently as 2.3-1.0 Ma ago. This indicates that uplift, erosion and exhumation rates are exceptionally high. Combining petrological, thermobaromateric and geochronological data, exhumation rates for Nanga Parbat are around 4.5-6 mm/year. Uplift of this region has influenced regional glaciations and dramatic climatic changes during late Tertiary and Quaternary times. The Indus Valley has been continuously modified by glacial and fluvial erosion, whilst earthquake-induced landslides have frequently caused damming and subsequent breaching of river, resulting in severe flooding, such as the great Indus flood of 1841. Erosional products are transported along the Indus River southwards to the plains of the Punjab and Sindh, and eventually into the Indus fan in the Arabian Sea.
Key words: Indus River, Karakoram fault, Nanga Parbat, glaciation, fluvial erosion, Indus fan.

S/132. Searle, M.P., Parrish, R.R., Tirrul, R. & Rex, D.C., 1990. Age of crystallization and cooling of the K2 gneiss in the Baltoro Karakoram. Journal of Geological Society, London, 147, 603-606.

The mountains of K2 (8611 m) and Broad Peak (8047 m) in the Baltoro Karakoram (northern Pakistan) are composed of plagioclase–hornblende and biotite–hornblende-K-feldspar orthogneisses and amphibolite–facies paragneisses, intruded by garnet–biotite–muscovite–tourmaline leucogranitic veins. A U-Pb zircon age of 115–120 Ma was obtained on an orthogneiss from the south face of K2. 40Ar-39Ar analysis on hornblende yields a plateau age of 90.6 ± 1.8 Ma, consistent with a mid-Cretaceous phase of magmatism, concomitant with early subduction-related components of the Karakoram batholith (Muztagh Tower unit, Hunza plutonic unit). We interpret the K2 gneiss as representing a culmination of mid-crustal rocks along a discontinuous but wide zone north of the Karakoram batholith.
Key words: Crystallization, K2 gneiss, Baltoro, Karakoram.

S/133. Searle, M.P., Rex, A.J., Parrish, R.R., Tirrul, R. & Rex, D.C., 1988. Geology, geochemistry and geochronology of the K2 gneiss, Baltoro Karakoram. Abstracts, 4th Himalayan-Karakoram-Tibet Workshop, Lausanne, Switzerland, p.12.

Please consult the preceding account for some part of the information.
Key words: Geology, geochemistry, geochronology, K2 gneiss, Baltoro, Karakoram.

S/134. Searle, M.P., Rex, A.J., Tirrul, R., Rex, D.C., Barnicoat, A. & Windley B.F., 1989. Metamorphic, magmatic and tectonic evolution of the Central Karakoram in the Biafo-Baltoro-Hushe regions of N. Pakistan. In: Malinconico, L.L. & Lillee, R.J. (Eds.), Tectonics of Western Himalayas. Geological Society of America, Special Paper 232, 47-74.

The central Karakoram can be divided into three main tectonic units from north to south: a northern Karakoram terrane, the Karakoram batholith, and the Karakoram metamorphic complex. In the Baltoro Glacier region the Karakoram magmatism includes intrusive suites that predate and postdate the India-Eurasia collision. The oldest subduction-related phases include Jurassic hornblendite to biotite monzogranite of the Hushe complex, and Cretaceous (ca. 82 to 75 Ma) hornblende-biotite metagranitoids of the Muztagh Tower unit, all of which were deformed during the India-Kohistan-Karakoram collision. Volumetrically dominant is a postcollisional granite, the Baltoro Plutonic Unit (BPU), which consists of biotite monzogranites to two-mica ± garnet leucogranites and pegmatite-aplites of mildly peraluminous affinity. The BPU represents the youngest magmatic phase of the composite Karakoram batholith with a U-Pb age of 21 ± 0.5 Ma and K-Ar mica cooling ages ranging from 11.7 to 5.25 Ma.
The Masherbrum migmatite complex (MMC), one of a series of such complexes along the southern margin of the batholith, immediately predates the BPU. Leucocratic dikes that cross-cut the MMC yield an Rb-Sr age of 14.1 ± 2.1 Ma and K-Ar ages of 17 to 10 Ma. The BPU is interpreted as a crustal melt ultimately derived from deep crustal levels and may not be related to leucogranite generation associated with the migmatite terrain to the south. Petrogenesis of the BPU is fundamentally different from that of the High Himalayan granites and may involve a degree of selective mantle contamination.
Four major metamorphic-deformation phases can be distinguished in the central Karakoram. The earliest, M1, is represented by low-pressure andalusite-staurolite–bearing assemblages that are spatially associated with igneous components of the Hushe complex of Jurassic age. The dominant thermal event was a widespread Barrovian-type metamorphism (M2), which was syntectonic to the main deformation and overprinted M1 assemblages. M2-related structures are cut by the 37.0 ± 0.8 Ma Mango Gusar two-mica granite pluton. M2 kyanite-garnet-plagioclase-quartz-muscovite-biotite-staurolite assemblages indicate minimum pressure temperature (P-T) conditions of 550°C and 5.5 kbar (550 MPa).
Thermal effects related to intrusion of the BPU constitute M3. Along its northern margin at Mitre Peak, the assemblage andalusite-cordierite-chlorite-biotite-muscovite-quartz-plagioclase indicates a *maximum* pressure of 3.75 kbar (375 MPa, ≃ 12.5-km depth). Along its southern margin at Paiyu, the presence of granitic melt pods with sillimanite, muscovite, plagioclase, and quartz indicates a minimum pressure of ca. 3.5 kbar (350 MPa) and a

temperature 75° higher than local M2 assemblages. The replacement of kyanite by sillimanite and the appearance of granitic melt pods approaching the BPU along the Baltoro Glacier transect, may be an M3 overprinting of M2. M4 (<5 Ma) is a syntectonic retrogressive metamorphism along the hanging wall of the Main Karakoram Thrust—a breakback thrust responsible for the recent uplift of the Karakoram.
Structural culminations of midcrustal rocks occur in the K2 and Broad Peak areas within Carboniferous-Lower Cretaceous sediments of the Gasherbrum Range. Metamorphism of the K2 gneiss (dominantly biotite-hornblende-K-feldspar orthogneiss) occurred during middle to Late Cretaceous time. Pegmatite dikes dated as 70 to 58 Ma (K-Ar-mica) cut the gneisses.
Key words: Metamorphism, magmatism, tectonics, Biafo, Baltoro, Central Karakoram.

S/135. Searle, M.P., Rex, A.J. Tirrul, R., Windley, B.F., Onge, M.S.T. & Hoffman, P., 1986. A geological profile across the Baltoro-Karakoram Range, N. Pakistan. Geological Bulletin, University of Peshawar 19, 1-12.

The Karakoram batholith along the Baltoro glacier transect separates a northern sedimentary domain with structural culminations of high-grade gneisses (K2 gneiss) from a southern high-grade metamorphic domain. The Baltoro plutonic units range in composition from biotite granodiorite to garnet bearing two-mica leucogranite; they have no mafic dyke and no volcanic component. The Baltoro granite is interpreted as being crustally derived from partial melting of deeper level rocks equivalent to the high-grade metamorphics in the south. The relationships between metamorphism, crustal-scale ductile shearing, migmatisation and magmatism are discussed.
Key words: Geology, structure, K2 gneiss, metamorphism, Baltoro granite, Magmatism.

S/136. Searle, M.P. & Tirrul, R., 1990. Structural and thermal evolutions of the Karakoram crust. In: Abstract volume, 5th Himalaya-Karakoram-Tibet Workshop, Milano, p.55.

Prior to the Eocene (ca. 50 Ma) collision of the Indian and Asian plates, the southern margin of Asia along the Karakoram plate was an Andean-type margin dominated by tonalitic-granodioritic magmatism of Jurassic-Lower Cretaceous age (Hushe gneiss, Muztagh Tower gneiss and K2 orthogneiss) and associated low pressure andalusite, staurolite and garnet grade metamorphism (M1). Following India-Asia collision, crustal shortening, thickening and regional Barrovian metamorphism (M2) occurred between 50-37 Ma. Thermobarometry of kyanite-grade metapelites indicate burial to depths of around 30-35 km. Simultaneous solution of the garnet-biotite geothermometer with the garnet-muscovite-biotite-plagioclase and garnet-Al2SiO5-quartz-plagioclase geobarometers indicates peak M2 P-T conditions of 696±20oC at 8.6kbars ±0.7kbars (860Mpa). Temperatures may have exceeded 700oC in sillimanite-grade metapelites to produce in situ partial melting and leucogranitic melt pods. Peak M2 metamorphism occurred prior to 37±0.8 Ma, the crystallization age of the Mango Gusar two mica granite pluton which crosscuts syn-metamorphic deformation fabrics.
Post M2 thermal relaxation followed from 37-23 Ma after which localized high heat concentrations at the base of the thickened crust caused widespread crustal melting and intrusion of the Baltoro granite batholith at 25-21 Ma, with compositions ranging from biotite monzogranite to garnet two-mica leucogranite. A high temperature-low pressure thermal aureole (M3) of contact metamorphism is synchronous in age with the 21±0.5 Ma zircon age of the Baltoro granite. Andalusite hornfels along the northern contact of the batholith (Mitre thermal aureole) indicates maximum pressures of 3.5 kbars (350 Mpa). A 75oC increase of temperature in kyanite-sillimanite grade gneisses approaching the granite contact along the Baltoro granite is modeled as the thermal upwarping of pre-37 Ma. Barrovian metamorphic M2 isogrades around the 21 Ma contact aureole M3 isotherms along the margins of the Baltoro batholith. A thermal model for the west Himalayan-Karakoram collision belt is presented based on a scaled crustal cross-section using all the available pressure, temperature, time and depth constraints.
Key words: Structure, thermal evolution, continental crust, Karakoram.

S/137. Searle, M.P. & Tirrul, R., 1991. Structural and thermal evolution of the Karakoram crust. Journal Geological Society, London, 148, 65-82.

Prior to the Eocene (c. 50 Ma) collision of the Indian and Asian plates, the southern margin of Asia along the Karakoram plate was an Andean-type margin dominated by tonalitic-granodioritic magmatism of Jurassic—Lower

Cretaceous age (Hushe gneiss, Muztagh Tower gneiss and K2 ortho-gneiss) and associated low pressure andalusite, staurolite and garnet grade metamorphism (M1). Following India-Asia collision, crustal shortening, thickening and regional Barrovian metamorphism (M2) occurred between 50–37 Ma. Thermobarometry of kyanite-grade metapelites indicate burial to depths of around 30–35 km. Simultaneous solution of the garnet-biotite geothermometer with the garnet-muscovite-biotite-plagioclase and garnet-AI2, SiO5,-quartz-plagioclase geobarometers indicates peak M2 P-T conditions of 696±20°C at 8.6±0.7kbar (860 MPa). Temperatures may have exceeded 700 °C in sillimanite-grade metapelites to produce in situ partial melting and leucogranitic melt pods. Peak M2 metamorphism occurred prior to 37 ±0.8 Ma, the crystallization age of the Mango Gusar two-mica granite pluton which cross-cuts syn-metamorphic deformation fabrics.

Post-M2 thermal relaxation followed from 37–25 Ma, after which localized high heat concentrations at the base of the thickened crust caused widespread crustal melting and intrusion of the Baltoro granite batholith at 25–21 Ma. A high temperature-low pressure thermal aureole (M3) along the northern contact is synchronous with the 21 ±0.5 Ma zircon age of the Baltoro granite. Andalusite hornfels along the northern contact of the batholith (Mitre thermal aureole) indicates maximum pressures of 3.75 Kbar (375 MPa). A 75 °C increase of temperature in kyanite-sillimanite grade gneisses approaching the southern granite contact of the Baltoro granite is interpreted as the thermal upwarping of pre-37 Ma Barrovian metamorphic M2 isograds around the 21 Ma contact aureole M3 isotherms.

Key words: Structure, thermal evolution, K2, metamorphism, Baltoro granite.

S/138. Searle, M.P., Tirrul, R., Rex, A.J. & Windley, B.F., 1985. A Geological transect across the Baltoro-Muztagh Karakoram from K2 to the Shigar valley. Abstract Volume, 1st Himalayan Workshop, Department of Geology, University of Leicester.

The Karakoram plate north of the Shyok suture zone consists of three major domains:

a northern sedimentary domain (Carboniferous-?Cretaceous) with structural culmination of high-grade metamorphic rocks (K2 gneiss; Falchan Kangri gneiss); the Karakoram granite batholith (KGB) and a southern high-grade metamorphic domain. These Karakoram rocks crop-out along the hanging-wall of major late-stage thrust-the Main Karakoram Thrust (MKT)- that dips north and places mid- to lower crustal rocks over unmetamorphosed sediments and volcanics of the Tethyan Shyok suture zone. The Shyok suture is thought to have closed during the mid- to late Cretaceous with deformation progressing southwards across Kohistan to the Salt Range during the Tertiary.

South of the Karakoram batholith along the Baltoro glacier- Braldu River transect a high-grade transect a high-grade metamorphic terrain consists of kyanite, sillimanite, andalusite, staurolite, garnet and corderite-bearing paragneisses and sillimanite-K-feldspar-bearing orthogneisses. Numerous garnet-biotite + muscovite + tourmaline + beryl leucogranitic dykes and veins intrude the metamorphic sequence. Garnet, hornblende, diopside, biotite-bearing marbles and amphibolites are interbanded within the sequence. Anthophyllite and jadeite bearing metamorphosed ophiolitic rocks with rare very fresh harzburgites (olivine + orthopyroxene + chrome spinel) occur in two localities within shale and marble units. Many of the higher peaks south of the Braldu gorge consist of andalusite schists with normal downward-increasing metamorphism.

North of the MKT lineations, defined by sillimanite and hornblende needles, plunge E or Se. Foliation in the Panmah, Biafo and Braldu valleys is folded around giant doubly-plunging dome structures which may be late-stage thrust culmination related to late brittle S and SW-directed thrusting along the MKT.

Key words: Geology, structure, K2 gneiss, metamorphism, Baltoro granite, Magmatism.

S/139. Searle, M.P. & Treloar, P.J., 1992. Conference Report: 7th Himalaya-Karakoram-Tibet Workshop. Journal Geological Society, London, 149, 1045-1047.

The first Himalayan Workshop held in Leicester University was so successful that it was then agreed to hold the informal conference and workshop annually. Subsequently the Himalayan Workshops were held in Vandoevre-les-Nancy, France in 1986, London (1987), Lausanne, Switzerland (1988), Milan, Italy (1990) and Grenoble, France (1991). The upsurge in research throughout the Himalayan and Tibetan region in the last ten years has warranted these annual meetings, and the dissemination of new research throughout the Himalayan community has been invaluable. This year the meeting' was held in the Department of Earth Sciences, Oxford University, under the auspices of The Geological Society, London from 6-8 April 1992. Over 120 participants from 15 countries attended.

Key words: Conference report, 7^{th} HKT, Oxford.

S/140. Searle, M.P. & Treloar, P.J., 1993. Himalayan Tectonics-an introduction. In: Treloar, P.J. & Searle, M.P. (Eds.), Himalayan Tectonics. Geological Society London, Special Publication 74, 1-7.

This is an introduction to the book edited by the two authors. It gives brief comments on the problem and the papers grouped under the headings Karakoram and Afghanistan, North and West Pakistan, Tethyan Himalaya, High Himalaya, Main Central Thrust, and Main Boundary Thrust, Lesser Himalaya and beyond. Papers dealing with interest area of the present document are summarized in an appropriate places.
Key words: Himalayan, tectonics, Karakoram, Afghanistan, Pakistan.

S/141. Searle, M.P. & Windley, B.F., 1986. Comment on "Thrust tectonics and the deep structure of the Pakistan Himalaya". Geology 14, 441-442.

Key words: Thrust tectonics, structure, Himalayas, Pakistan.

S/142. Searle, M.P., Windley, B.F., Coward, M.P., Cooper, D.J.W., Rex, A.J., Rex, D.C., Tingdong, L., Xuchang, X., Jan, M.Q., Thakur, V.C. & Kumar, S., 1987. The closing of Tethys and the tectonics of the Himalaya. Bulletin of Geological Society of America 98, 678-701.

Recent geological and geophysical data from southern Tibet allow refinement of models for the closing of southern (Neo-) Tethys and formation of the Himalaya. Shelf sediments of the Indian passive continental margin which pass northward into deep-sea Tethyan sediments of the Indus-Tsangpo suture zone were deposited in the Late Cretaceous. An Andean-type margin with a 2,500-km-long Trans-Himalayan (Kohistan-Ladakh-Gangdese) granitoid batholith formed parallel to the southern margin of the Lhasa block, together with extensive andesites, rhyolites, and ignimbrites (Lingzizong Formation). The southern part of the Lhasa block was uplifted, deformed, and eroded between the Cenomanian and the Eocene. In the western Himalaya, the Kohistan island arc became accreted to the northern plate at this time. The northern part of the Lhasa block was affected by Jurassic metamorphism and plutonism associated with the mid-Jurassic closure of the Bangong-Nujiang suture zone to the north.
The timing of collision between the two continental plates (ca. 50-40 Ma) marking the closing of Tethys is shown by (1) the change from marine (flysch-like) to continental (molasse-like) sedimentation in the Indus-Tsangpo suture zone, (2) the end of Gangdese I-type granitoid injection, (3) Eocene S-type anatectic granites and migmatites in the Lhasa block, and (4) the start of compressional tectonics in the Tibetan-Tethys and Indus-Tsangpo suture zone (south-facing folds, south-directed thrusts).
After the Eocene closure of Tethys, deformation spread southward across the Tibetan-Tethys zone to the High Himalaya. Deep crustal thrusting, Barrovian metamorphism, migmatization, and generation of Oligocene-Miocene leucogranites were accompanied by south-verging recumbent nappes inverting metamorphic isograds and by south-directed intracontinental shear zones associated with the Main Central thrust. Continued convergence in the late Tertiary resulted in large-scale north-directed backthrusting along the Indus-Tsangpo suture zone. More than 500 km shortening is recorded in the foreland thrust zones of the Indian plate, south of the suture, and > 150 km shortening is recorded across the Indian shelf (Zanskar Range) and the Indus suture in Ladakh. There was also large-scale shortening of the Karakoram and Tibetan microplates north of the suture; as much as 1,000 km shortening occurred in Tibet. The more recent deformation, however, involved the spreading of this thickened crust and the lateral motion of the Tibetan block along major approximately east-west–trending strike-slip fault zones.
Key words: Tethys, tectonics, Himalaya.

S/143. Secord, C. & Vyvyan, M., 1939. Reconnaissance of Rakaposhi and Kunyang Glacier. Himalayan Journal, 11, 156p.

As this account does not have an abstract, first few paragraphs of the report are given below.
The papers published below are the record of two parts of one brief expedition which was planned to explore the basin of the upper Kunyang glacier of the Hispar Muztagh. On the way Messrs. Secord and Vyvyan succumbed to

the temptations of Rakaposhi and explored its western approaches. Mr. Secord then had to return unexpectedly to England, and Mr. Vyvyan carried out single-handed a rather less ambitious reconnaissance of the Kunyang glacier.—Ed.
Rakaposhi (Campbell Secord).
Rakaposhi towers 20,000 feet above the Hunza and Gilgit rivers .which almost encircle it, and the first glimpse of it from Taliche, 40 miles away in the Indus valley, persuaded Michal Vyvyan and myself to have a closer look at it before proceeding to our intended destination up the Hispar glacier. After a day of pleasant ease at Gilgit, therefore, we set off early on the 4th July for a flying trip to the Jaglot nullah which would lead us into the recesses of the mountain's mighty western ramparts.1
It was exciting to be skilfully ferried across the raging Hunza river on a skin raft, but the 20 miles up its arid left bank seemed interminable on—or off—the decrepit ponies supplied to us with only one saddle between them. Hospitable villagers at Maturn Das compelled us to rest during the midday heat by hiding our ponies, providing shady couches and apricots galore, and talking volubly in Burushaski. It was a pleasant spot, perched high above the river, its stone-walled orchards oddly reminiscent of the Italian lake- district. The afternoon's monotony was abruptly terminated by a 6oo-foot climb straight up the cliffs fringing the river-bed, and we emerged on the edge of a lovely fertile hanging valley—our nullah, at last! The village of Jaglot lay nearby among well-cultivated fields, a startling contrast to the desert we had left below. We discarded the ponies and pushed on up three successive valley steps, camping, as night fell, beyond the uppermost hamlet, with morainal detritus visible in the narrowing gap beyond.
Intense curiosity roused us early next morning, and we walked rapidly upwards, following cattle-tracks along the beautifully treed moraines, as far as a high glacial mound at the junction of two affluents. A delicate cirque of 20,000-foot peaks enclosed the southern branch, but it was the view eastwards which riveted our attention. Rakaposhi soared nearly 16,000 feet directly above us, its western face a mass of tremendous ice-falls enclosed by north-western and south-western ridges of extraordinary beauty, which sprang from a large plateau lying at about 23,000 feet, and which extended at a very high level outwards almost as far as we stood. From the plateau rose the summit pyramid, about 2,500 feet high. It was a fine introduction to the high mountains of Asia.
Key words: Reconnaissance, Rakaposhi, Kunyang Glacier.

S/144. Seeber, L. & Armbruster, J., 1974. The syntaxial area between the Himalayas and the Pakistan Folded Belts. In: Tectonic Interpretation Based on Microseismic Data. Rep. 9. Mem. 11, 36p.

Key words: Structure, seismicity, syntaxis, folded belts, Himalayas, Pakistan.

S/145. Seeber, L. & Ambruster, J., 1979a. Seismicity of the Hazara Arc in Northern Pakistan, decollement versus basement faulting. In: Farah, A. & DeJong. K.A. (Eds.) Geodynamics of Pakistan. Geological Survey of Pakistan, Quetta, 131-147.

A telemetered seismic network in northern Pakistan covering most of the Hazara arc, the arcuate foreland thrust-fold belt between the Western Himalayan Syntaxis and the Sulaiman Range of Baluchistan, is producing a wealth of seismic data that give new insight into the tectonics of this area. The Indus-Kohistan Seismic Zone (IKSZ) and the Hazara Lower Seismic Zone (HLSZ) are parallel, deeply reaching faults buried under a 10 to 30 km thick layer, presumably a sedimentary or metasedimentary prism. The seismic zones appear to be straight northwestern extensions of the frontal faults of the Himalaya beyond the Western Himalayan Syntaxis where these faults bend sharply to the south at the surface. The IKSZ, by far the more active of the two seismic zones, is associated with underthrusting toward the northeast. A 12 km thick, mostly aseismic layer appears to flake off the underthrust basement and slide over the leading edge of the overthrsut block. In contrast, the HLSZ defines a steeply dipping basement fault that probably merges upward and southward with a shallow dipping surface of decollement between the basement and the sedimentary rock sequence that outcrops in the Salt Range.
The eastern portion of the geologically prominent Hazara fault corresponds with a zone of low seismicity during the network operation, from 1973 to 1977. However, a magnitude mb 5.2 (USGS) earthquake that occurred near Rawalpindi on February 14, 1977, caused severe damage and some loss of life. The hypocenters of the main shock and aftershocks indicate a rupture surface between 12 and 18 km depth; if extrapolated to the surface, the trace of the rupture plane almost coincides with the Hazara fault trace. The rupture plane dips to the southeast, and

experienced a left-lateral strike slip during the earthquake. This evidence indicates either that the adjacent section of the Hazara fault cannot be considered presently active as the northwestward-dipping thrust described from surface evidence, or that the February 14 rupture occurred below a decoupling layer and the effect of this active strike slip movement is not evident at the surface.

In the southern part of the Hazara arc, the northwestern portion of the Punjab Seismic Zone and the seismicity at the Trans-Indus Salt Range are associated with a set of parallel strike-slip faults striking north-northwest. This faulting involves the entire thickness of the crust (about 35 km) and can be traced at the surface across the Trans-Indus Salt Range. The low seismicity in the Potwar Plateau and in the Bannu basin indicate that the ongoing decollement is either occurring by aseismic creep, or by rare large earthquakes

Key words: Seismicity, decollement, faulting, Hazara, Northern Pakistan.

S/146. Seeber, L. & Ambruster, J., 1979b. Seismic hazards at the Tarbela Dam site from a model of the active tectonic and earthquake magnitude distribution. WAPDA/TAMS Report 10, 55p.

Consult Seeber et al. (1980) for further details.

Key words: Seismicity, hazards, Tarbela Dam, tectonics.

S/147. Seeber, L. & Ambruster, J., 1984. Some elements of continental subduction along the Himalayan front. Tectonophysics 105(1-4), 263-278.

Detachment tectonics, in which the subducting basement is not internally affected by thrusting; and a steady state system, in which the pattern of deformation and topography are invariant, uplift is balanced by erosion and the material can experience subsequent “phases” of deformation by migrating through the system, are proposed to be the fundamental mechanisms of convergence at the Himalayan arc. Both surface and subsurface data are more consistent with these concepts than with more familiar concepts widely used in current models: intracrustal thrusting and evolutionary tectonics, where superimposed phases of deformation are interpreted as distinct phases. The belt of intermediate-magnitude thrust-earthquakes, the topographic front at the High Himalaya and the Main Central Thrust (MCT) are associated with the same fundamental element, the basement thrust front (BTF), which traces a small circle in the central portion of the Himalayan arc. Fault plane solutions indicate thrusting in the radial direction of this arc. This radial convergence at the BTF implies that Tibet is extending laterally at a rate similar to the rate of convergence across the BTF. This extension cannot be unidirectional and must be parallel to the BTF, if the circular shape of the BTF is invariant.

Key words: Tectonics, thrusting, topography, uplift, erosion.

S/148. Seeber, L. Armbruster, J. & Farhatullah, S., 1980. Seismic activity at the Tarbela dam site and surrounding region. Geological Bulletin, University of Peshawar 13, 169-191.

The earthquake activity associated with the major faults of the Himalayan front in the Hazara arc region, including Tarbela dam, is discussed in terms of the active tectonic structure of this front. Moreover, the earthquake potential at the Tarbela site arising from the Indus fault system is evaluated by extrapolating the earthquake magnitude distribution.

The active tectonics associated with plate convergence in the Hazara arc region of the Western Himalayas has been modeled primarily by using earthquake data from the seismic network centered at Tarbela. The near-surface structural trends in Hazara are distinct and separated from the trends along the Himalayan front in the Kashmir by the Hazara-Kashmir syntaxis. In contrast, the deeper structures, which are active within the basement in Hazara, are continuous with and linear extensions of the northwest trending structures of the Himalayas in Kashmir. Thus, the arcuate structures in Hazara are only thin-skin. A major detachment fault decouples the sedimentary and metasedimentary layer of the thrust-and-fold belt from the underlying basement. The relative motion on the detachment obtained from seismic data is consistent with the southward vergence of the structures in this belt.

Three families of active faults recognized as potential sources of destructive earthquakes in the Hazara arc region and, in particular; at the Tarbela dam site: the basement faults; the detachment fault; and faults within the sedimentary layers. Available intensity and instrumental data indicate that the Himalayan Basement Thrust and associated transverse or tear faults are the locus of most of the epicenters; however, the largest ($M > 8$) and most damaging earthquakes occur on the Himalayan Detachment. The Hazara arc is included in the tectonic province of

the Himalayan front, thus the Basement Thrust and the Detachment are identified with corresponding structures in Hazara, and the earthquake potential is estimated accordingly.
A layer of thick Intracambrian salt is associated with the Detachment in the Hazara arc region. The low-strength properties of this layer may cause the slip on this portion of the Detachment to occur aseismically. In this case, major Detachment earthquakes analogous to those known from the central section the Himalayan front would not be expected in the Hazara region.
The sedimentary layer in the Tarbela network region of the Hazara arc is mostly aseismic except for the Tarbela seismic zone (TSZ), centered near the Tarbela dam site. This sharply defined volume of seismicity is probably associated with anomalous rock properties rather than an isolated zone of crustal deformation. Thus, the faults active within the TSZ may slip aseismically in the sedimentary layer outside the TSZ.
The maximum credible earthquake in the TSZ is assigned a magnitude 6,5, a maximum surface acceleration of 0.5g, and is associated with the surface rupture of one of the faults in the Indus valley at the Tarbela site. From a quantitative study of earthquake-magnitude distribution a repetition time of 1200 years is obtained for the maximum credible event. This implies a probability of 1/24 that this event will occur during a 50-year lifetime of the dam. The maximum probable earthquake at the Tarbela site in 50 years is a M=5.5 event. The rate of seismicity along the Indus fault system at the Tarbela site is 50 times higher than the average seismicity for the Hazara arc region. However, the level of seismicity on the TSZ is well below the seismicity associated with some of the other seismic zones within the Hazara arc. Most prominent among these is the IKSZ.
Key words: Seismicity, Tarbela Dam, tectonics.

S/149. Seeber, L. & Armbruster, J.G., 1983. Continental subduction along the northwestern and central portion of the Himalayan arc. Bollettino di Geofisica Teorica ed Applicata (Pamir-Himalaya Volume) 25, 409-425.

Three prominent features, 1) the topographic front of the High Himalayas, 2) the narrow belt of thrust earthquakes and 3) the Main Central Thrust are closely interrelated and are manifestations of the Basement Thrust Front (BTF), a fundamental element of active convergence along the Himalayan arc. These features and the BTF are continuous over 2500km and are correlated with the boundary between two portions of the overriding unit: the more rigid Tethyan slab, downdip from the BTF and upthrusted at this boundary (High Himalayas); and the less rigid sedimentary wedge, updip from the BTF and pervasively deformed (Lesser Himalayas and Sub Himalayas). The details of the subsurface active structures in the Hazara region, as deciphered from earthquake data from a local seismic network, are strikingly discordant to the surface structures and suggest a major subhorizontal detachment. Seismic hazard in the Hazara arc region depends largely on whether the active detachment in this region slips aseismically or by great earthquakes, as does the detachment along the rest of the Himalayan front.
For additional information, consult Seeber and Armbruster (1984).
Key words: Subduction, tectonics, Himalaya.

S/150. Seeber, L., Armbruster, J.G., Quittmeyer, R.C., Zeitler, P.K., Kidd, B., Edwards, M. & Koons, P.O., 1998. Northwest-directed shortening at Nanga Parbat: An active tectonic regime regionally controlled by strain partitioning along the Himalayan Arc and locally accelerated by topographic stress at the Indus River Gorge. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 178-180.

A very active regime of northwest-directed shortening in the Nanga Parbat area is manifested by both earthquake and geologic data, including brittle faults in crystalline rock and structures in Quaternary sedimentary rocks of the Indus and Gilgit valleys. Northwest and northeast directed shortening at Nanga Parbat and along the Himalayan front a few hundred km to the south, respectively, are at a wide angle and are thought to reflect distinct elements in the collisional regime. Northwest shortening at Nanga Parbat is interpreted as internal deformation within the Himalayan overriding block. At the scale of the Asia-India continent collision, northwest-directed shortening at the northwestern terminus of the Himalayan arc is interpreted as the result of strain partitioning along the arc. Earthquake focal mechanisms show radial convergence across the arc. Radial convergence with an undeforming footwall block (India) requires arc-parallel extension in the hangingwall block (Tibet), which is indeed geologically and seismologically observed. This "intraplate" deformation in Tibet is driven by strain partitioning. Relative to the

Himalayan arc, northwest convergence at the terminus of the back arc in Nanga Parbat is along strike and in the same direction as arc-parallel extension in Tibet, the main portion of the back arc, and may balance it out, at least in part. Thus, Nanga Parbat is interpreted to be structurally the western boundary of Tibet. Many earthquakes in and near the Nanga Parbat massif were recorded by the ~60-station network we deployed on and around the massif during 1996 and from a more modest deployment in 1995. 130 single-event focal mechanisms were quality selected from the 340 accurate hypocenters located in the vicinity of the massif (100x100 km). The massif is particularly active on the northwestern flank, where topographic relief is the largest. The seismicity is very shallow, from above sea level, to a maximum depth of 6 km asl where it is sharply cut off below the axis of the massif. Focal mechanisms suggest a subhorizontal detachment at this boundary. This detachment ramps up into a thrust fault toward the northwest aiming toward the mapped surface trace of the Lichar thrust. Transport on this structure is generally to the northwest. Footwall-block seismicity is limited to the western side of the NPA. Hangingwall-block antithetic thrusting is illuminated on the southeastern side of the massif and correlates with mapped structures. While we resolved some earthquakes on thrust faults, most of the observed seismicity is from a set of subparallel shallow normal faults striking west to southwest and dipping south to southeast. These faults accommodate extension approximately in the same direction as the transport on the underlying thrust fault. Seismogenic normal faulting is concentrated in the region with highest relief on the western limb of the antiform, between the Indus River and the Nanga Parbat ridge. This faulting can be interpreted as gravity-driven collapse of the eastern wall of the Indus gorge by book-shelf-like block rotation about horizontal-axes and also as flexural slip in the overturned northwestern limb of the Nanga Parbat anticline. The superposition of shallow horizontal extension above crustal shortening at Nanga Parbat may exemplify the effect of topographic stress in regions of convergence and mountain building. The rapid uplift of the Nanga Parbat massif is associated with the northwest-verging Nanga Parbat antiform (NPA) and the southeast-dipping Lichar thrust fault, which outcrops along the northwestern flank of the massif. The Lichar fault and the NPA are interpreted to be coupled active structures (a thrust fault and a fault-propagation fold) that accommodate much of the northwest shortening, but, generally, not all of it. Previous and ongoing work by others suggest a continuous belt of northwest shortening from the western Syntaxis to the Main Karakorum Thrust, for over 200km along strike of the NPA. Furthermore, preliminary results from a survey of brittle and Quaternary tectonic structures in the Indus and Gilgit valleys show west- to northwest-directed shortening in the Kohistan terrane, suggesting that this shortening is, generally, over a belt broader than the massif. Northwest shortening in Kohistan is coupled with two prominent Quaternary transcurrent fault zones, one along the Gilgit River valley, left-lateral and striking west-northwest, the other along the Indus River valley, right-lateral and striking west-southwest. These faults are interpreted to serve as accommodation structures separating broad belts of northwest shortening south of the Indus and north of the Gilgit rivers from a much narrower portion of the belt in between. Along the portion of the belt flanked by the Indus gorge and the outcroping Lichar thrust, shortening seems to be confined to the massif, within and east of the Indus Gorge. This tectonic model is supported by the earthquake data, which show a remarkable lack of seismicity west of the Indus River, across from the very active northwestern flank of the Nanga Parbat massif. This remarkable pattern of regional shortening is thought to stem from the effect of the Indus gorge on the tectonic regime. A very large stress is derived from the combined effect of the weight of the mountain and the lack of weight along the gorge. The tectonic regime responds to this superposed topographic stress by increasing the rate of slip on the Lichar thrust in an attempt to fill the gorge from below. This attempt is futile, given the effectiveness of the river to remove material and to maintain its grade. In this hypothesis, the northwest-directed shortening is taken up completely at the gorge, where the gorge is parallel to the massif. Effectively, therefore, the southwest trending portion of Indus River between the Astor and the Diamir confluences casts a stress shadow to the northwest and shunts the shortening. Topographically driven accelerated slip on the basal thrust along this portion of the gorge may also account for the height along the corresponding portion of the Nanga Parbat massif. Once established, the drainage pattern in active mountain building orogens may have a much greater effect on the tectonics than vice versa.

Key words: Seismicity, tectonics, crustal shortening, strain distribution, Nanga Parbat.

S/151. Seeber, L., Armbruster, J.G. & Quittmeyer, R.C., 1981. Seismicity and continental subduction in the Himalayan arc. In: Gupta, H. K. & Delany, F. (Eds.), Zagros-Hindu Kush-Himalaya Geodynamic Evolution. American Geophysical Union, Geodynamics Series 3, 215-242.

Consult Seeber and Armbruster (1984) for more information.

Key words: Seismicity, subduction, Himalayan, Geodynamics.

S/152. Seeber, L. & Gornitz, V., 1983. River profiles along the Himalayan arc as indicators of active tectonics. Tectonophysics 92(4), 335-367.

Longitudinal profiles along sixteen major transverse Himalayan rivers add important constraints to models of active continental subduction and its evolution. These profiles are characterized by a zone of relatively high gradient that cannot be associated with differential resistance to erosion in all cases. The base of the zone of increased gradients correlates with (1) the topographic front between the Lesser and High Himalayas, (2) the narrow belt of intermediate-magnitude thrust earthquakes, (3) the Main Central Thrust zone (MCT). These features define a small circle in the central portion of the Himalayan arc. These correlations suggest that the discontinuity in the river profiles and the other features are controlled by a major tectonic boundary between the rising High Himalayas and the Lesser Himalayas. No sharp increases in gradient are observed near the Main Boundary Thrust (MBT), except on a few rivers, such as the Jhelum or Kunhar, where the MBT lies close to both the MCT and the seismic belt. Thus, it is unlikely that the MBT is a major tectonic boundary. The diversion of river courses along the MBT and around anticlines in the Sub Himalayas has probably been caused by aggradation near the rosion-deposition boundary, upstream of uplifts in the Mahabharat range and Sub Himalayas.
A parallel is drawn between the Himalayas and New Guinea based on the hypothesis that continent-arc collision, of the type occurring in northern Australia, preceded continent-continent collision in the Himalayas. The present sedimentary/tectonic phase in New Guinea resembles the Subathu (Paleocene-Eocene) phase in the Himalayas. Incipient counterparts of the major Himalayan structures, including the MCT and the MBT, are recognized in New Guinea. The drainage patterns in the Himalayas and in New Guinea bear a similar relation to major structures. This suggests that (1) the tectonic evolution of the Himalayas has been rather uniform since early stages of collision, and (2) the Himalayan drainage was also formed at these early stages and is therefore antecedent to the rise of the High Himalayas.
Key words: Subduction, topography, seismicity, river profile, Himalayan arc.

S/153. Seeber, L. & Jacob, K.H., 1977. Micro earthquake survey of northern Pakistan, Preliminary results and tectonic implications. Symposium on Himalayan Geology, Paris, 1976. Himalayan Science de la Terre 268, 347-348.

Key words: Seismicity, tectonics, Tarbela Dam, Hazara, Pakistan.

S/154. Seeber, L. Jacob, K.H. & Armbruster, J.G., 1974a. Tectonics, design, earthquake and seismic risk for the Tarbela Dam Project, Pakistan. Dams Monitoring Organization, Report, 55p.

Key words: Seismicity, tectonics, Tarbela Dam, Hazara, Pakistan.

S/155. Seeber, L. Jacob, K.H. & Armbruster, J.G., 1974b. Microseismic study of Tarbela Dam, Hazara, Pakistan. Dams Monitoring Organization, Archives T-33/67, 23p.

Key words: Seismicity, Tarbela Dam, Hazara, Pakistan.

S/156. Seeber, L. & Pêcher, A., 1998. Strain partitioning along the Himalayan arc and the Nanga Parbat antiform. Geology 26, 791-794.

Shortening along the Himalayan arc of continental convergence is approximately in the radial direction. If the underthrusting foot-wall block (India) is not deformed, the hanging-wall block (Tibet) needs to stretch along the arc, as suggested by radial grabens in southern Tibet. In contrast, the Nanga Parbat–Haramosh massif and the western Himalayan syntaxis are part of a 250-km-long antiform that strikes in the radial direction (northeast) and verges northwest. The Nanga Parbat antiform is the structural and topographic expression of arc-parallel shortening that compensates for arc-parallel extension in southern Tibet. This shortening is predicted to be as high as 12 mm/yr.
Key words: Strain partitioning , structure, topography, Nanga Parbat.

S/157. Seeber, L., Quittmeyer, R.C. & Armbruster, J., 1979. Himalayan earthquake belts: Implications from network data from the western syntaxial area. In: Structural Geology of the Himalayas. Saklani, P.S. (ed.). 361–392

Key words: Earthquake, structure, geology, Himalayas.

S/158. Seeber, L., Quittmeyer, R.C. & Armbruster, J., 1980. Seismotectonics of Pakistan: A review of results from Network data and implications for the Central Himalaya. Geological Bulletin, University of Peshawar 13, 151-168.

Microearthquakes detected by two telemetered seismic networks in northern Pakistan reveal a decollement style of tectonics for the Hazara and northwest Punjab region. The three-dimensional distribution of seismicity and sediments and metasediments is decoupled from the basement. Below the decoupling surface major faults trend northwest. These faults are recognized as basement structures that are associated with the Himalayan arc, but that extend towards the northwest beyond the Hazara-Kashmir syntaxis. During the last six years, the period of network observations, the seismicity is mostly associated with the basement faults. Seismic activity within the decollement is generally low and the decoupling surface is either aseismic or associated with very low seismicity.
The results from northern Pakistan, together with recent seismicity along the Himalayan arc and information on great Indian earthquakes, are combined to derive a general model of Himalayan tectonics. A shallow thrust of gentle dip, termed the Detachment, underlies the Indo-Gangetic plain and the Lower Himalaya. Rupture of this fault, which separates the low-strength sedimentary wedge from the basement, results in great earthquakes that care devastation over a wide area, but occur only infrequently. Down-dip from the Detachment, beneath the higher, the thrust assumes a steeper dip and juxtaposes basement material of similar properties. Earthquakes occur more frequently on this portion of the fault, termed the Basement Thrust, but are smaller than the Detachment events. They can, however be damaging locally. The model suggests that much of the Indo-Gangetic plain underlain by the Detachment has a high seismic hazard. In the Hazara arc region of northern Pakistan the Detachment is associated with a thick layer of Infracambrian salt. In this region the Detachment may slip aseismically; however, slip by large infrequent earthquake cannot be ruled out.
Results from a seismic network centered on Quetta show that the Chaman fault, and the fault associated with the Quetta earthquake of 1935, are currently active. The segments that ruptured during the most recent large earthquakes on these faults, 1892 on the Chaman fault and 1935 on the Quetta fault, are relatively quiet at present. On both faults the current seismicity is concentrated near the ends of the ruptures associated with these earlier events, and indicates left-lateral strike-slip. In analogy with the San Andreas and Alpine fault system, in California and New Zealand, respectively, two distinct portions of the Chaman fault system are recognized. One, north of approximately 31ºN, trends obliquely to the regional slip vector and is probably characterized by infrequent great earthquakes. The other, south of 31ºN, has a strike subparallel to the regional slip vector and consists of a broad zone of faults that rupture in large, but not great, earthquakes.
Key words: Seismicity, tectonics, Chaman Fault, Hazara-Kashmir syntaxis..

S/159. Seilacher, A., 1983. Types of iron ores and their economic exploitation in Pakistan. 2nd National Seminar on Development of Mineral Resources, Peshawar, Proceedings.

Key words: Iron ores, economic geology, , exploitation, Pakistan.

S/160. Sverdrup, K.A., Schurter, G.J. & Cronin, V.S., 1994. Relocation analysis of earthquakes near Nanga Parbat-Haramosh massif, Northwest Himalaya, Pakistan. Geophysical Research Letters 21, 2331-2334.

Locations of earthquakes that have occurred between 1970 and 1988 in the northwest Himalaya of Pakistan, as computed by the ISC, were analyzed to improve knowledge of the spatial distribution of seismicity near the Nanga Parbat-Haramosh Massif (NPHM). A set of 15 earthquakes were relocated using the multiple-event relocation

technique of Jordan and Sverdrup (1981). Earthquake located using records from at least 25 to 30 stations tend to be well-located in the ISC database: smaller error ellipses and shorter distance of relocation. These analyses indicate that earthquakes with magnitudes m(sub b) greater than 4.0 have occurred since 1970 along the NPHM.
Key Words: Seismology, tectonics, Nanga Parbat-Haramosh Masif, Himalaya.

S/161. Shabbir, M. & Naeem, U.Z., 1976. Process development study of uranium-bearing carbonatite-uranium ore processing. Proceedings Advance Group Meeting Washington, 67-75; IAEA Vienna.

Key words: Uranium processing, carbonatite.

S/162. Shad, A.M., 1983-85. Geotechnical studies of landslides along Murree-Kohala and Murree-Bhurban Road, District Rawal Pindi. M.Sc. Thesis, Punjab University, Lahore, 121p.

The Murree Kohala road one of the most important road of the country which provides facilities of communication between Pakistan and Azad Kashmir, crossing over the Jhelum river at Kohala. This road is also important for defence point of view. The slopes along the Murree Kohala road are very unstable, especially kassari to Phagwalai village. The condition of the Murree -Kohala road is satisfactory where a good driver can drive every type of vehicle at the speed of 40-50 kmls/hour, except for the landslide areas. At Murree Kohala road three major slides were selected for study namely Kasseni (K_o, K_1' K_2' K_3), Norgali (N_1' N_2) and Eliot (A_1, A_2). These are between lower topa to Eliot which are also marked on the map. The second road which join Kohala is starting from Jhikkagali via Burban which meet the Murree Kohala road near phagwani Village. There is also a slide near Kashmiri Bazar which is shown on the map. The project area is lying in the Murree Formation which is mainly composed of Shale, mudstone and sandstone. The detailed geological mapping of the active landslides area were carried out on, the map, sandstone, mudstone and shale with specific symbol on the map. The samples were collected
Key words: Geotechnical, landslides, Murree, Kohala, Rawalpindi.

S/163. Shafeeq, A., 1972. Geochemistry and physical properties of chromites from Pakistan. Ph.D. Thesis, Punjab University, Lahore.

Key words: Geochemistry, chromites.

S/164. Shafiq, M., 1972. Geology of Bibiore Sahibabad area, Dir district, with special emphasis on Leuco–Amphibolite and Granodiorite. M.Sc. Thesis. Punjab University, Lahore, 90p.

The area is occupied by light coloured and often banded epidote amphibolites, which are intruded by granitic rocks. The geology, geomorphology and petrography of the rocks is presented.
Key words: Geomorphology, leuco-amphibolite, granodiorite, Dir.

S/165. Shah, A., 1995. Petrography and geochemistry of the rocks from the acidic volcanic belt, North of Peshawar plain, N.W.F.P., M.Phil. Thesis, University of Peshawar, 72p.

Acidic microporphyries of Late Paleozoic age are intimately associated with appreciably larger volumes of acidic plutonic rocks of alkaline igneous province of Peshawar Plain. Field evidences and their partial intercalation in the metasedimentary sequence of Jaffar Kandao and Baroach Formations suggest an Early Carboniferous age.
Very coarse to fine-grained felsic phenocryst in fine-grained to glassy felsic groundmass clearly imparts a porphyritic texture to these rocks. On the basis of modal and chemical composition, majority of these rocks are classified as rhyolites on one side and basalt (now greenschist) on the other. Variables and their ratios based on major and minor elements classify these rocks as A-type, mildly alkaline and peraluminous in character. On various tectonomagmatic discrimination diagrams, these rocks show a within plate continental rift environment, and this character is also supported by Hf/Th, Hf/Ta and concentration in Zr and Ta. Sensitivity of Th, Hf and Ta due to crustal contamination is seen in tectonomagmatic discrimination triangular diagrams based on these three elements.

Eu-anomaly displays fluid-solid rock interaction confirming soda metasomatism due to late magmatic phases in these rocks.
Key words: Petrography, geochemistry, volcanic belt, Peshawar.

S/166. Shah, H., 1990. Stream sediment study of Ushu and Gabral rivers for heavy minerals, north of Kalam, Swat District, NWFP, Pakistan. Geological Survey of Pakistan, Information Release 451.

Key words: Stream sediments, heavy minerals, Ushu, Gabral, Kalam, Swat District.

S/167. Shah, H., 1994. Stream sediments of Ushu and Gabral rivers for heavy minerals, North of Kalam, Swat district, N.W.F.P., Pakistan. Geological Survey of Pakistan, Information Release,451.

Hand-panning survey in an area of about 1083 square miles in the lower part of Kohistan bordering Swat district was carried out to study the distribution of heavy minerals in the alluvial of Ushu and Gabral rivers.
The area under examination is underlain by various types of plutonic, volcanic and metasedimentary rocks. The plutons are represented by norites, diorites and the associated rocks of the Kohistan Basic Complex. Metasedimentary suite is represented by quartzite, various types of schists, phyllites and semi crystalline limestone of the Kalam Group. Whereas volcanics are represented by rhyolite and dacite of the Utror Group.
Microscopic examination of heavy suite reveals hornblende, opaque minerals, garnet, biotite, hypersthene and augite. These constitute bulk of the detrital heavy minerals. Whereas sphene, silliminite, cassiterite, leucoxena and tourmaline are present in some slides. Among the opaque minerals magnetite, titanomagnetite, pyrite, chalcopyrite, arsenopyrite, limonite and i1minite were tentatively diagnosed. Radiometric analysis of the hand-panned concentrates reveals presence of no radioactive mineral. Search for valuable fluorescent minerals has also been carried out and except zircon no other mineral has been detected under UV-lamp of short waves lamp.
Key words: Heavy minerals, Ushu, Gabral, Swat.

S/168. Shah, H. & Said, M., 1990. Geology of Thana quadrangle, Swat district, NWFP., Pakistan., Geological Survey of Pakistan, Information Release, 476.

This area occurs to the south of the MMT and its northern part is drained by the Swat River. It is occupied by metamorphosed politic and calcareous rocks which contain granitic intrusions. Field features, structure and lithology of the rocks is presented, along with a geological map.
Key words: Geology, geomorphology, Thana quadrangle, Malakand Agency, Swat.

S/169. Shah, J., 1992. Some observations on the regeneration of vegetation and stabilization of scree slopes in Hunza Valley. Proceedings, National Seminar on Progress of Geography in Pakistan, University of Peshawar, 84-85.

A brief account of the type of debris and tallus is given, with mention of those near Pasu, Aliabad, Gulmet, Khanabad and Chauperson. This is followed by data on the existing flora and species, together with some recommendation for stabilization of scree slopes.
Key words: Vegetation, scree slope, stabilization, Pasu, Chapursan, Hunza.

S/170. Shah, K., Shahabuddin, Hassan, B. & Ahmed, M.S.A., 1967. Studies on Resin from Makerwal Coal. Pakistan Journal of Scientific & Industrial Research, 10(3), 212-215.

Makerwal coal is known to contain a high percentage of resins which are recoverable by solvent extraction. Alternative methods of recovery reported earlier show a wide degree of variation in the yield of resins and the quality of coal residue. An attempt has been made to evaluate these methods, by studying separately the behaviour

of original coal, solvent extracted resins and the coal residue from solvent extraction, on superheated steam treatment and carbonisation.
It was found that on superheated steam treatment at 300-330°C these resins were only partially recoverable while on carbonisation extensive cracking of the resins was observed. The experimental data from the present work and critical review of the earlier work in this direction has clarified some of the hitherto reported anomalies of the behaviour of Makerwal coal.
Key words: Coal, Resins, Makerwal, Trans-Indus Salt Range.

S/171. Shah, M.A., 1991-92. The geology and mapping of Muzaffarabad area from Yadgar to Chattar Kalas with special emphasis on geotechnical properties of rock aggregates in the investigated area. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 53p.

The geological and mineralogical characteristic of Rara limestone has been investigated to evaluate the properties of limestone as concrete aggregate. The Crushing Value, Impact Value, Loss Angle 'S', Specific gravity, water absorption and shape of the particles are comparable to recommended B. S standards with few acceptions. At places rocks are highly crushed and deleterious material in the rock aggregate is very high. Mineralogically the iron content (25%), muscovite (7%) and dolomite (2%) are unacceptable. The alkali concrete aggregate reaction involves argillaceous dolomitic limestones, clays, argillitics and very far in south expansive cherts were found. It is common in the gravel derived from various limestone formations in the area. Siliceous limestones are investigated from lower plair and Majuhan and in some instances, appear to be a major factor in concrete deterioration. The classical areas of alkali carbonate reaction occur in lower plair and Darwana Nalah. The iron content in the presence of water, argillites and clays associated with alkali expansive reactions in concrete have been described.
Key words: Geology, geotechnical, aggregates, Muaffarabad, Azad Kashmir.

S/172. Shah, M.A. & Anwar, J., 1981. Regional geology of Chili Bagh west of Kohat, N.W.F.P., M.Sc. Thesis, Department of Geology, University of Peshawar, 41p.

The rocks of the area range in age from Eocene (represented by the Panoba Shale, Kuldana Formation, and Kohat Formation) to Miocene (represented by the Murree Formation) with a disconformity between them. The Panoba Shale has a varied lithology of clay, shale, and marl and was deposited in deltaic environments.
The Kohat Formation is divisible in a lower Kaladhand Limestone Member, a middle Sadkal Shale Member and an Upper Habih Rahi Limestone Member. These were deposited in moderately deep to shallow marine environments. The Murree Formation is represented by clay and sandstone in the area, and was deposited im the lacustrine environments.
The area exhibits remarkable deformational structural features the study of which revealed a series of symmetrical and asymmetrical, cylindrical and non-cylindrical folds. A fault with major strike slip components, joints and other major structural features, were also observed, studied, and marked on the map. The cross bedding is characteristic of Murree Formation.
The rocks of the area have been subjected to intense chemical weathering and rapid rate of erosion in the geological past. Deep erosional work of the various agencies is the past have cut most of the intensely folded anticlines, the cores of which are now exposed.
Key words: Geology, Chili Bagh, Kohat.

S/173. Shah, M.A. & Din, W., 1976. Study of water logged and saline land of Kafoor Dheri area, Peshawar. M.Sc. Thesis, Peshawar University.

Key words: Water logging, salinity, Kafoor Dheri, Peshawar.

S/174. Shah, M.A., Hashmatullah, & Khan, R.A., 2000. Structure and stratigraphy of Chichali Nala, Surghar Range, Pakistan. M.Sc. Thesis, University of Peshawar, 62p.

Key words: Structure, stratigraphy, Chichali Nala, Surghar Range, Trans-Indus Salt Range..

S/175. Shah, M.A. & Ihsanullah, 1969. Geology of the southern part of Warsak area. M.Sc. Thesis Peshawar University, 80p.

This is a geological and petrographic account of the area. The rocks comprise schists, metagabbro sheets and alkaline granite. They seem to form a synclinal structure.
Key words: Geology, Warsak Area.

S/176. Shah, M.M. & Ahmad, Z., 1998. Style of deformation and petroleum prospects of Jhatta area, Talagang, Potwar Plateau, Pakistan. M.Sc. Thesis, University of Peshawar, 110p.

Key words: Deformation, petroleum prospects, Talagang, Potwar Plateau.

S/177. Shah, M.R., 2001. Paleoenvironment, sedimentology & economic aspects of the Hangu Formation in Kohat-Potwar & Hazara area. Ph.D. thesis. NCE Geology, University of Peshawar.

The Hangu Formation of early Paleocene age is widely distributed in the hill ranges of Kohat-Samana, Surghar, Attock-Cherat, Hazara and Salt Range areas of north Pakistan. The formation is comprised of thin to thick-bedded sandstone, siltstone with thin interbeds of limestone and shale. The rocks are characterized by horizontal lamination, graded bedding, cross stratification and bioturbation.
The formation occupies a significant stratigraphic position as it marks the Cretaceous-Tertiary (K-T) boundary. This stratigraphic boundary is in the form of a major unconformity at the base of the Paleocene in north central Pakistan and adjacent north western India, defined by laterite, ferruginous pisolites, and bauxite or local erosional unconformities. The lower contact of the formation marks varied erosional phases in different parts of the north Pakistan. Stratigraphically it overlies the Cretaceous Kawagarh Formation at Samana, Kalachitta and Hazara, whereas in Surghar Range it overlies the Lumshiwal Formation. The hiatus is even more pronounced in the Salt Range area, where it overlies the Lumshiwal, Samanasuk, Datta, Mianwali, Chhidru, Wargal, Amb, Sardhai formations and Warchha Sandstone of Cretaceous, Jurassic, Triassic and Permian ages respectively. In Cherat and Balakot area the formation rests over the Dakhner Formation of Precambrian and Abbottabad Formation of Cambrian age. This indicates a major unconformity in these areas progressively increasing eastward.
From the study of different stratigraphic sections the formation can be subdivided in to a number of lithostratigraphic units and lithofacies based on the lithological variations and sedimentary structures. The important lithofacies recognized in these areas are; 1) Lateritic/Bauxitic lithofacies. 2) Cross-bedded sandstone lithofacies. 3) Bioclastic limestone lithofacies. 4) Coal, carbonaceous shale lithofacies. 5) Bioturbated quartzose sandstone lithofacies. Lithofacies analysis and petrographic studies of the Hangu Formation indicate that transgressive shoreline environments deposited the formation, which is partly represented by terrestrial to coastal swampy conditions and partly by shoreface to offshore (shelf) environments of deposition.
The upper and basal parts of the formation contain economic minerals like coal, laterite, bauxite, silica sand and fairly good source rock potential for hydrocarbon generation. The coal is found in the Samana Range, Surghar Range and Attock-Cherat Range but is missing in Salt Range, Kalachitta and Hazara areas. The coal is dull to shining black in colour, grades from high volatile B to C bituminous in rank and is in the form of lenses, stringers and lenticular beds. The laterite and bauxite developed at the base of the formation in the study area is found as discontinuous beds, lenses, sheets and pockets. The laterite is found in Samana Range, Surghar Range, Attock-Cherat, Kalachitta, Salt Range and Hazara while bauxite is confined to Salt Range area. The silica sand, which is present in the upper, middle and lower parts of the formation, is well developed in the Samana Range, moderately developed in the Surghar Range and is poorly developed in the western Salt Range. Source rock potential for hydrocarbon generation is developed in Surghar, Salt Range and Attock-Cherat Ranges.
Key words: Stratigraphy, paleoenvironments, lithofacies, Hangu, Kohat-Potwar, Hazara.

S/178. Shah, M.R., Abbasi, I.A. & Haneef, M., 1999. Lithostratigraphy of the K-T boundary in north Pakistan. Additional abstracts, IGCP 421, North Gondwanan mid-Palaeozoic Bioevent/Biogeography Pattern in Relation to Crustal Dynamics, Peshawar Meeting, 1p.

Key words: Lithostratigraphy, biogeography, K-T boundary, North Pakistan.

S/179. Shah, M.R., Abbasi I.A. & Haneef, M., 2000. Stratigraphy and lithofacies architecture of the Early Paleocene rocks of the Northern Pakistan. Abstracts, Third South Asia Geological Congress, Lahore, p.52.

Key words: Stratigraphy, lithofacies, Paleocene, Northern Pakistan.

S/180. Shah, M.R., Abbasi I.A. & Haneef, M., 2001. Facies and paleoenvironment of the Hangu Formation (Paleocene), N. Pakistan. Abstracts, 4th Pakistan Geological Congress, Islamabad, 29-30.

The Hangu Formation of Early Paleocene age is widely distributed in N. Pakistan. It is comprised of thin to thick-bedded sandstone, siltstone with thin limestone/shale interbeds and thin coal seams, containing a wide variety of sedimentary structures (Shah et al., 1993). The thickness of the formation varies from 97m at the stratotype to 1m in the Eastern Salt Range.

As a part of this study, 19 stratigraphic sections of the formation were studied and described along the entire belt of the outcrop in the Salt Range, Attock-Cherat Range, Kohat-Potwar and Hazara areas. The purpose of this study is to establish the stratigraphic relationships, identify lithofacies and interpret the depositional environments. Five lithofacies of the formation are recognized on the basis of lithological variations and distinct depositional fabric (Shah et al., 1999). These lithofacies include; FILF-1 (Laterite/Bauxite Lithofacies): This lithofacies marks the base of the formation and is comprised of laterite, lateritic clay, shale, bauxite and bauxitic clay, as discontinuous bodies, pockets and lenses. The laterite is well developed through out, while bauxite is confined to the Central Salt Range.

HLF-2 (Cross-bedded Sandstone Lithofacies): This lithofacies is dominantly comprised of sandstone in Kohat-Samana area and sandstone, siltstone, clay and limestone in Surghar Range and Salt Range. The lithofacies is cross-bedded. HLF-3 (Bioclastic Limestone Lithofacies): This lithofacies is represented by skeletal wacke packstone and is only present in the Surghar Range and Salt Range. It is interbedded in siltstone and shale. FLLF-4 (Coal/Carbonaceous Shale Lithofacies): Coal, carbonaceous shale and sandstone lithofacies is restricted to Hangu, Makarwal and Cherat areas. This lithofacies is found in the upper part at the Hangu section, while at Makarwal and Cherat it is found in the lower and middle parts.

HLF-5 (Bioturbated Quartzose Sandstone Lithofacies): This is the topmost lithofacies of the formation and is comprised of highly bioturbated sandstone, siltstone and clays. The lithofacie occurs widely in the study area.

The lithofacies interpretation of the Hangu Formation reveals that the formation represent deposition in near-shore, beach-barrier environments. HILF-1 represents non-marine terrestrial (sub-aerial exposures) environments. HLF-2 represents beach/foreshore environments deposition. HLF-3 is deposited in paralic (back-barrier) environments. HLF-4 is interpreted to deposited in shallow marine/lagoonal environments, while HLF-5 represents shoreface environments of deposition.

Key words: Lithofacies, paleoenvironment, sandstone, stratigraphy, coal, Hangu Formation.

S/181. Shah, M.R., Abbasi I.A., Haneef, M. & Hussain, A., 1997. Lithofacies and depositional environment of the Hangu Formation (Paleocene) in northern Pakistan. Abstracts, 3rd Pakistan Geological Congress, University of Peshawar, p.58.

Consult the preceding account.

Key words: Lithofacies, paleoenvironment, sandstone, coal, Hangu Formation.

S/182. Shah, M.R., Abbasi I.A., Haneef, M. & Khan, A., 1993. Nature, origin and mode of occurrence of Hangu-Kachai area coal, district Kohat, NWFP, Pakistan: A preliminary study. Geological Bulletin, University of Peshawar 26, 87-94.

Coal showings are known from the Hangu Formation of Paleocene age in the Hangu-Kachai area, northwest of Kohat. The Hangu Formation is well developed in this area and is comprised of quartzitic sandstone with minor intercalations of shale. The coal seam is developed near the upper contact of the Hangu Formation with the overlying lockhart limestone. Preliminary exploratory drilling of the Hangu Formation in the area have revealed the presence of coal. The coal is dull to shinning black and ranges from high volatile B to C bituminous in rank. The Hangu area coal occurs in the form of discontinuous stringers and lenses and is less than 2 meters thick.
The average analytical results on as received basis indicate, the coal bed contains 0.52 % moisture, 14.2 % ash, 4.2% sulpher, 53 % fixed carbon and 32.64 % volatile matter. Based on the average BTU/lb and fixed carbon content of the Hangu-Kachai coal samples collected from the field, with minor exception of variation in color, the Hangu coal is analogous to the known coals of the Balochistan and the Salt Range areas. On the basis of its stratigraphic position, mode of origin and structure, the Hangu-Kachai coal is comparable with the Makarwal coal of the Surghar Range. Detailed exploratory studies are proposed to evaluate the nature and extent of the Hangu-Kachai area coal.
Key words: Coal, **s**andstone, Hangu Formation, Kachai, Hangu.

S/183. Shah, M.T., 1986. Petrochemistry of the rocks from Shergarh Sar area, Allai Kohistan, Northern Pakistan. M.Phil. Thesis, University of Peshawar, 221p.

The Shergarh Sar area in Allai Kohistan is located at the junction between the Indo-Pakistan plate and the Kohistan island arc block. Rocks of the area are distinguished into three petro-tectonic units: (1) The Kohistan island arc sequence, (2) The Indus suture mélange zone, and (3) The Indo-Pakistan subcontinent sequence.
Amphibolites are the most abundant rocks in the Kohistan island arc sequence. These are distinguished into epidote-amphibolites and garnet epidote-amphibolites. The Indus suture mélange zone mainly comprises ultramafics (clinopyroxenite, peridotite and serpentinite), pillow lavas, greenschist rocks, and blueschist facies metagraywacke. The Indo-Pakistan subcontinent sequence includes granite gneiss, thin bedded crystalline limestone, and schists. In the present work, the field features, petrography, and chemistry of the constituent rock units are discussed in detail.
The potential usefulness of the observed petrochemical indices from the constituent rocks in the studied suite is elucidated as tectonic finger prints and genetic indicators in this thesis. The major and trace element constraints of amphibolites, suggest their derivation from a basic igneous parent of tholeiitic character developed in an island arc type environment. The intimately associated igneous and metamorphic rocks within the Indus suture mélange zone owe their development to different processes in varied tectonic environments. The chemistry of the ultramafics suggests the comagmatic nature of the constituent rocks, and their development by the partial melting of mantle of peridotitic composition. Lavas in the Indus suture mélange zone are compact, mostly glassy or very fine grained. These are characterized by pillow structures, and frequently show incorporation of angular to rounded fragments and blocks of carbonate rock. Their major and trace element analyses closely correspond to tholeiitic rocks produced by partial melting process in an island arc type environment. Chemistry of greenschist rocks, occurring in north western part of the studied area, suggests their derivation from a basic parent through metamorphism. Assessment of the chemical data in related chemico-tectonic systems favour origination of their parent material in typical oceanic environments.
Petrography and mineral chemistry of the blueschist facies metagraywacke from the studied area are compared with that of the equivalent rocks occurring in Shangla (Swat) and Ladakh. P-T conditions of metamorphism are calculated. Details of thin section and chemical study oppose oscillatory transition in metamorphic conditions, as noted in Shangla, or retrogression as found in similar rocks from eastern Ladakh.
Key words: Petrography, geochemistry, suture zone, Shergarh Sar area, Allai, Kohistan.

S/184. Shah, M.T., 1991. Geochemistry, mineralogy and petrology of sulfide mineralization and associated rocks around Besham and Dir, Northern Pakistan. Ph.D. dissertation, University of South Carolina, Columbia.

Key words: Geochemistry, mineralogy, petrology, Besham, Dir.

S/185. Shah, M.T., 1992a. Validity of sphalerite geobarometry and garnet-biotite geothermometry to estimate P-T conditions of metamorphism for the sediments-hosted base metal deposits in Besham area, northern Pakistan. Geological Bulletin, University of Peshawar 25, 67-71.

Regionally metamorphosed sediment-hosted stratiform exhalative type base metal deposits are exposed in the Lahore and Pazang properties of Besham area at the northern margin of the Indian plate. Sphalerite geobarometer and garnet-biotite geothermometer were used calculate the P-T conditions of metamorphism. These geothermobarometer yielded most convincing results for the studied deposits. These deposits and the host meta-sediments were subjected to amphibolite facies metamorphism with a metamorphic temperature of 585 ± 250C and a pressure of 8 ± 2 kb.
Key words: Sphalerite, geobarometry, geothermometry, metamorphism, metasediments, Besham, Kohistan.

S/186. Shah, M.T., 1992b. Tourmaline as an evidence of exhalative origin for Besham base metal deposits in northern Pakistan. Geological Bulletin, University of Peshawar 25, 123-126.

Tourmaline occurs as an accessory phase in the metaquarzite/meta-arkose unit of the Pazang group in Besham area. The chemistry of different tourmaline grains varies within the same sample but there is no change in composition within a single grain. These tourmalines have an intermediate composition between schorl and dravite. This composition along with FeO/FeO+MgO ratio for the studied tourmaline grains is unlike those of granitic terrain and can be comparable to that of the tourmaline found in association with submarine exhalative massive sulfide deposits.
Key words: Tourmaline, base metal, mineralization, Besham, Kohistan.

S/187. Shah, M.T., 1993a. A note on the chalcopyrite disease in sphalerite in the volcanic-hosted copper mineralization in Dir area, Northern Pakistan. Acta Mineralogica Pakistanica 7, 82-84.

Key words: Chalcopyrite, sphalerite, copper, mineralization, Dir, Pakistan.

S/188. Shah, M.T., 1993b. Skarnization of the massive sulfide ores and associated rocks of the Pazang group in Besham area at the northern margin of Indo-Pakistan plate. Acta Mineralogica Pakistanica 7, 68-78.

Proterozoic sediment-hosted massive sulfide ores occur in the highly deformed and metamorphosed rocks of the Pazang group in the Besham area, District Kohistan. The massive sulfide ores and associated rocks of the Pazang group were subjected to skarnization after their deposition. Both magnesian and calcic skarns were formed. As a result, the Mn-rich skarn minerals (i.e. clinopyroxenes, pyroxenoids, garnet, olivine and serpentine) have been developed within these rocks. The chemistry of these minerals suggest that the protoliths for both calcic and magnesian skarn were probably impure limestone and dolomite respective with intercalations of umber, chert and clays.
Key words: Proterozoic, massive sulfide, pazang group, chemistry, Besham, Kohistan.

S/189. Shah, M.T., 1994. A note on the bornite-chalcopyrite intergrowth texture in the volcanic-hosted copper mineralization in the Dir area, northern Pakistan. Geological Bulletin, University of Peshawar 27, 125-126.

Various experimental studies have been carried out to understand the possible bornite-chalcopyrite intergrowth texture. The bladed and lenticular shape intergrowth of chalcopyrite in the studied bornite can be termed as widmastatten texture of Schwartz (1931) and Durazzo and Taylor (1982). This type of intergrowth texture can possibly be the product of either: 1. Replacement of bornite by chalcopyrite or 2. Exolution from anomalous bornite during heating in a temperature range c. 200-2500C. In this case the chalcopyrite exolution lamillae in the bornite matrix of the studied rocks may have probably been produced due to the rapid growth of chalcopyrite in a highly supersaturated bornite matrix with chalcopyrite > 25%.
Key words: Texture, chalcopyrite, exolution, matrix, copper mineralization, Dir.

S/190. Shah, M.T., 1995a. Metallic mineral deposits of northern part of Pakistan "Souvenir, International symposium and field workshop on phosphorites and other industrial minerals; SEGMITE-UNESCO joint organization, Abbottabad, Pakistan.

Key words: Metallic mineral, phosphorite,.

S/191. Shah, M. T., 1995b. Mineralogy, texture and geochemistry of the volcanic-hosted hydrothermal copper mineralization in the Dir area, northern Pakistan. In: Abst., vol. Dissanayake, C. B., Almond, D. C., and Cooray, P. G., (Eds.), Second South Asia Geol. Cong., Colombo, Sri Lanka, p.176.

Consult the following for further information.
Key words: Mineralogy, texture, geochemistry, hydrothermal, copper mineralization, Dir.

S/192. Shah, M.T., 1997a. Mineralogy, texture and geochemistry of the volcanic-hosted hydrothermal copper mineralization in Dir area, Kohistan arc terrane, northern Pakistan. In: Wijayananda, N.P., Cooray, P.G. & Mosley, P. (Eds), Geology in South Asia-II, Geological Survey and Mines Bureau, Sri Lanka, Professional Paper 7, 263-280.

Copper mineralization in the Dir area is related to a hydrothermal activity, which is mainly confined to the metavolcanic sequence within the Kohistan island arc in Pakistan. The sequence is composed predominantly of basaltic-andesite and andesite with subordinate basalt, dacite, rhyolite and pyroclastic breccia. Chalcopyrite is the main copper-bearing phase. Subordinate Cu-phases are bornite, chalcocite and covellite. Electron microprobe analysis indicates the pure nature of these ore phases. Malachite and azurite showings are conspicuous along he shear zones. A variable gain and loss of MnO, Na2O, K2O and P2O5 are noticed in the mineralized metavolcanics, which show an enrichment of Cu, Zn, Mo, Cd, Ag and Au. Both mineralized metavolcanics and mineralized quartz veins have a high 18O signature. This suggests the involvement of isotopically heavy or-forming fluid in the alteration and copper mineralization in these volcanics. This fluid has an estimated 18O isotopic composition of 5.1 per mil, which could be the magmatic water introduced by the granodiorite or diorite intrusion below the metavolcanic sequence.
Key words: Mineralogy, texture, geochemistry, hydrothermal, copper mineralization, Dir.

S/193. Shah, M.T., 1997b. Mineralogy, chemistry and genesis of the Proterozoic base metal deposits at the northern margin of the Indian plate in Besham area, Northern Pakistan. Abstracts, National Symposium on Economic Geology of Pakistan, Islamabad, 1p.

Consult the following account.
Key words: Mineralogy, chemistry, genesis, base metals, Proterozoic, Indian plate, Besham, Kohistan.

S/194. Shah, M.T., 1997c. Mineralogy, chemistry and genesis of the Proterozoic base metal deposits at the northern margin of the Indian plate in Besham area, Himalaya, Northern Pakistan. In: Hussain, S.S. & Akbar, H.D. (Eds.), Proceedings, National Symposium on Economic Geology of Pakistan, 1997, Islamabad, 11-57.

The Himalayan mountain range is a geological manifestation of the collision of northward moving Indian plate with the Asiatic plate. Kohistan arc terrane is sandwiched between these two plates and is bounded by two major thrust faults. Rocks of the northern margin of the Indian plate have a complex tectono-metamorphic history with poly-phase deformation and metamorphism. These are mainly composed of the Proterozoic basement gneisses and schists, which are overlain by several sequences of metasediments of Phanerozoic age. These rocks have been

divided into Besham, Pazang and Karora groups. The first two groups are a part of the basement complex and the third one is composed of a cover of metasediments that unconformably overlie the basement complex.
Base metal mineralization in the rocks of the Indian Plate occurs along its northern margin in the footwall of Main Mantle Thrust (MMT) around Besham and is confined to the Pazang group. The rocks of the Pazang group are distinguished into Pelitic formation, Sulphide formation and Meta-quartzite/Meta-arkose formation from bottom to top. The Sulphide formation having Zn-Pb mineralization constitutes the distinct portion of the Pazang group and is the subject of present research.
Mn-rich clinopyroxenes, pyroxenoids and Mn-rich garnets are the common skarn minerals. Quartz, feldspars, biotite, muscovite, hornblende, phlogopite, epidote and carbonates are present in variable amount in each rock unit. Tourmaline, zircon, apatite, sphene and pyrophanite occur as accessories. Olivine, serpentine and phlogopite are commonly developed in the magnetite-rich carbonates. Among the ores, sphalerite, pyrrhotite, pyrite and galena are the main sulphides with minor amount of chalcopyrite and melnikovite. Magnetite is the major oxide present in these rocks. Mineralogy and chemistry of various silicates and sulphides and the whole rock major and trace elements geochemistry provided some clues regarding the paragenesis of massive sulphide ores.
Lead isotopic gave model ages of 2120-2199 Ma (Proterozoic) for both the Pazang and Lahor deposits. These deposits are more primitive in terms of ages and have lower μ values relative to the well-known sediment-hosted deposits elsewhere in the world. The non-radiogenic isotopic composition and the homogeneity of the ore lead in both Pazang and Lahor ores suggest a well-mixed common source and similar processes for the formation of these ores.
Zn-Pb stratiform mineralization in Besham area occurs in a highly deformed and metamorphosed terrane. Most of the textural features suggest that the mineralization predate the deformation and metamorphism. Both deformation and metamorphism have caused remobilization and crystallization of various ore phases to the present situation. Igneous metasomatic skarn has played an important role in the formation of Mn-rich clinopyroxenes, garnet and pyroxenoids along with Cu, Mo and W mineralization, within the rocks of the Pazang group. Massive sulphide ores and the host rocks are subjected to the upper amphibolite facies metamorphism with a metamorphic temperature of 583±35oC and pressure of 8±2 Kbars.
The mineralogy, petrology and geochemistry of various ore bodies and their lead isotopic ratios, lack of volcanic rocks and lack of footwall hydrothermal alteration favor a distal submarine exhalative origin for the Besham Zn-Pb ore bodies. These deposits can be classified as sedimentary exhalative stratiform zinc-lead.
Key words: Mineralogy, chemistry, genesis, base metals, Proterozoic, Indian plate, Besham, Kohistan

S/195. Shah, M.T., 1997d. The geological setting of the metamorphosed Proterozoic massive sulfide deposits at the northern margin of the Indian plate in Besham area, northern Pakistan. Franks M. Vokes 70 years anniv. Symposium on Formation and Metamorphism of massive sulfides, Norway. (Abstract).

Consult the preceding account.
Key words: Mineralogy, chemistry, genesis, base metals, Proterozoic, Indian plate, Besham, Kohistan

S/196. Shah, M.T. & Danishwar, S., 1997. High fluoride content and its source of contamination in the drinking water of Kheshki (District Nowshera) and Narangi (District Swabi) area of N.W.F.P., Pakistan. Colloqium on Geology and Human Life, (Abstract) p.44.

Key words: Fluoride contamination, drinking water, Nowshera, Swabi.

S/197. Shah, M.T. & Gohar, A., 2000. Feasibility study of Eocene limestone of Kohat Formation (District Kohat, N.W.F.P., Pakistan) for its use as concrete aggregates. Abstracts, Third South Asia Geological Congress, Lahore, p.51.

Key words: Concrete aggregate, Eocene, limestone, Kohat.

S/198. Shah, M.T. & Hamidullah, S., 1994. Field and mineralogical constraints of the Dir metavolcanic sequence, Kohistan arc terrane, northern Pakistan. Geological Bulletin, University of Peshawar 27, 43-55.

The Dir metavolcanic sequence, a part of the Dir group, constitutes a NE-SW trending belt within the northwestern portion of the Kohistan island arc in the western Himalaya of northern Pakistan. This sequence is dominantly composed of basaltic-andesite and andesite with subordinate basalt, dacite, rhyolite, and pyroclastic breccia. These rocks are foliated and sheared along local faults and also have small intrusions at places.
Porphyritic textures are dominant, with less common aphyric and seriate textures. Plagioclase (An 10-42) is ubiquitous in all the members of the sequence and occurs as phenocrysts and in groundmass. K-feldspar and quartz predominate both as phenocrysts of the dacites and rhyolite. Chlorite, epidote, and actinolite are the most common metamorphic phases; hornblende, muscovite, biotite, kaolinite, sericite, carbonate, and opaques occur rarely. Phase assemblages and chemistry suggest predominant greenschist facies metamorphism with epidote-amphibolite facies conditions attained locally.
Key words: Metavolcanic, geochemistry, metamorphism, Dir group, Kohistan arc.

S/199. Shah, M.T., Haq, I. & Hamidullah, S., 2000. Geology and geochemistry of the rocks of Yushiri valley, District Dir, Northern Pakistan. Geological Bulletin, University of Peshawar 33, 53-78.

The study area is lying in the north-western portion of the Kohistan arc terrane. This terrane is bounded by two suture zones of regional extent at its northern and southern sides, believed to be formed by obliteration of ancient oceanic basin. This arc experienced its first collision at its northern margin with the Karakorum plate at 90-80 Ma, and its second collision at the southern margin during Early Eocene with the Indian plate. Rocks of the study area are distinguished into two main lithological units: (1) Amphibolites and (2) Metadiorites/metagranodiorites. The amphibolites occupy the southern part of the studied area while metadiorite/rnetagranodiorites are exposed in the northern part of the study area. Both these rock units have intrusive contacts and exhibit local faulting and shearing. The amphibolites also host small patches of slightly metamorphosed gabbro-norites. The amphibolites are generally massive but also exhibit banding at places. They are intruded by quartz and quartzo-feldspathic veins especially in areas where shearing and faulting are intense. They are also intruded by the metadiorite / metagranodiorite in the form of small plugs. The metadiorites / granodiorites are medium to coarse-grained, massive in character and have xenoliths of amphibolites. Copper mineralization in the form of dissiminated grains of tetrahydrite and chalcopyrite and supergene enrichment in the form of malachite and azurite occur within quartz veins in limited areas. Amphibolites are mainly composed of hornblende and plagioclase with subordinate amount of quartz and alkali feldspar. Biotite, muscovite, chlorite, epidote, apatite, sphene, rutile, calcite and opaque occur as accessories. The metagabbro-norites contain plagioclase, orthopyroxene and clinopyroxene as the dominant mineral constituents. The metadiorite, quartz-diorite and metagranodiorite are dominantly composed of plagioclase with variable proportion of quartz and alkali feldspar. The other minor constituents include biotite, hornblende, muscovite, apatite, sphene, zircon, garnet and opaque.
Chemically the amphibolites and metagabbro-norites are comagmatic. Their chemical characteristics favor the igneous parentage (i. e., host gabbro-norite) for the studied amphibolites. The major and trace elements study of these rocks suggests that these are of calc-alkaline nature and are formed by the arc magma within the subduction related environment. The chemical characteristics of the granitoid rocks (metadiorite/metagranodiorite) suggest that these are comagmatic and have close affinity towards the calcalkaline rocks, developed in island arc type of set up. Both the amphibolites and gabbro-norites could be related to either Kamila amphibolites belt or Chilas Complex. The studied granitoids are, however, correlated with the stage II pluton of the Kohistan batholith.
Key words: Geochemistry, amphibolites, diorites, Yusheri Valley, Dir.

S/200. Shah, M.T., Ikramuddin, M. & Shervais, J.W., 1991. Thallium in copper-bearing quartz veins and associated metavolcanics from the Dir area, northern Pakistan. GAC-MAC-SEG meeting, Toronto, Canada.

Key words: Thallium, quartz veins, metavolcanics, Dir.

S/201. Shah, M.T., Ikramuddin, M. & Shervais, J.W., 1994. Behaviour of Tl relative to K, Rb, Sr and Ba in mineralized and unmineralized metavolcanics from the Dir area, northern Pakistan. Mineralium Deposita 29(5), 422-426.

Copper mineralization in the Dir area of northern Pakistan is confined to the quartz veins and associated with hydrothermally altered metavolcanics. Chalcopyrite is the main copper-bearing phase with subordinate amounts of bornite, chalcocite, covellite, malachite and azurite. Both mineralized quartz veins and associated unmineralized (least altered) and mineralized (strongly altered) metavolcanics have been analyzed for Cu, Au, Ag, Tl, K, Rb, Ba and Sr. An increase of Cu, Au, Ag, Rb/Sr and Tl/Sr, and a decrease of Sr and K/Rb is observed in both mineralized metavolcanics and mineralized quartz veins. Thallium shows lithophile behaviour in the Dir metavolcanics and no chalcophile behaviour was observed. The Tl/Sr ratio might be an indirect guide for the exploration of volcanic-hosted hydrothermal copper deposits.
Key words: Copper mineralization, thalium, geochemistry, metavolcanics, Dir.

S/202. Shah, M.T. & Jan, M.Q., 1993. Mineralogical constraints of the Shergarh Sar amphibolites, Allai Kohistan, northern Pakistan. Geological Bulletin, University of Peshawar 26, 59-73.

Shergarh Sar amphibolites, a part of the southern amphibolite belt, widely exposed in the area around Bana in Allai Kohistan. Epidote-amphibolite is the main unit with scattered patches of garnet-bearing variety. Amphibole, epidote and, in some, garnet are the main phases with minor amount of quartz, plagioclase, clinopyroxene, opaque oxides and rutile. Amphiboles range in composition from tchermakitic-hornblende to actinolite with magnesio-hornblende as an intermediate phase. This transition is marked by decrease in Al Ti, alkalies and Fe^{2+}/Mg ratio and increase in Si. Epidote occurs as large crystals (both zoned and unzoned) with low Ps contents (9-15) and as small granular aggregates with high Ps contents (17-27). Garnet occurs sporadically in the form of porphyroblasts and is found in association with leucocratic veins. It is chemically unzoned and is predominantly made up of almandine-grossular-pyrope solid solution. Plagioclase ranges from An27 to pure albite and clinopyroxene is chemically homogenous diopside.
Petrographic observations and thermobarometry suggest that the rocks were initially equilibrated under amphibolite facies with overprinting of greenschist facies assemblage. This retrogression may have been facilitated by shearing during the obduction (uplift-cooling) of the rocks along the Indus suture following their Eocene collision with the Indian plate.
Key words: Mineralogy, amphibolites, petrography, metamorphism, Allai, Kohistan.

S/203. Shah, M.T. & Khan, A., 1997. Mineralogy, geochemistry and genesis of the Mn-deposits and associated metacherts of Sadgai and Shuidar area, North Waziristan, N.W.F.P., Pakistan. Abstracts, 3rd Pakistan Geological Congress, University of Peshawar, p.59.

For further information, consult the following account.
Key words: Geochemistry, Mn-deposits, North Waziristan.

S/204. Shah, M.T. & Khan, A., 1999. Geochemistry and origin of Mn-deposits in the Waziristan ophiolite complex, North Waziristan, Pakistan. Mineralium Deposita 34, 697-704.

The Waziristan ophiolite complex is located along the western margin of the Indian plate in northwestern Pakistan. The Mn-deposits in the Saidgi and Shuidar areas are part of this ophiolite complex. These deposits, both banded and massive in nature, are hosted by metachert and are generally overlying metavolcanics. Braunite and cryptocrystalline quartz are the main constituents of the manganese ores in both areas. Hematite occurs in the Shuidar deposits as a minor phase. Metacherts are microcrystalline quartz, chalcedony, and lesser hematite. Chemically, the studied Mn-deposits and associated metacherts are very similar to those formed by submarine

hydrothermal effusive processes. The deposits originated along sea-floor spreading centers (mid-ocean ridges) within the Neo-Tethys Ocean and were later obducted as part of the Waziristan ophiolite complex.
Key words: Geochemistry, ophiolite, Mn-deposits, chalcedony, North Waziristan.

S/205. Shah, M.T., Latif, A. & Aurangzed, 1980. Major element abundances in volcanic rocks from Kalam volcanic zone, Swat. M.Sc. Thesis, University of Peshawar, 56p.

Andesite and salic eruptives of calc-alkaline affinity in the Kalam volcanic zone constitute the upper part of the 'Kohistan sequence (Tahirkheli et al., 1970) developed in the western branch of the Himalayan syntaxis between 71°E and 75° E. The sequence is interpreted as a complete cross section of a mature island are formed by subduction during Mesozoic in the southern part of the Neotethys and obducted onto the Indian plate in Upper Cretacoous time (Bard et al., 1080). The Kohistan sequence includes a thick complex of amphibolites, hypersthene gabbros, pyroxene diorites, hornblende diorites, granodiorites, metasediments and volcanic rocks.
The potential usefulness of the geochemical parameters of the extrusive rocks from the Kalam area, Swat as tectonic fingerprints and gentic indicators is discussed in this paper. There is a close correspondence between the available petrochemical indices of genetic significance of tho studied suite to the calc-alkaline volcanics in western and southwestern pacific regions, which substantiates earlier workers designation ef an island arc environment in the Kohistan Himalaya during Mesossoic time.
Key words: Geochemistry, volcanic rocks, Kalam, Swat.

S/206. Shah, M.T. & Lechler, P.J., 2001. Stream sediment exploration for base and precious metal in the Dir and Swat Kohistan, northern Pakistan. Journal of Asian Earth Sciences 19, p.60.

Key words: Stream sediments, precious metal, exploration, Dir, Swat.

S/207. Shah, M.T. & Lechler, P.J., 2002. Gold anomalies in the Dir and Swat Kohistan, northern Pakistan. Journal of Science & Technology, University of Peshawar, 26, 1-6.

The major portion of the study area is comprised of rocks of the Kohistan Island arc while the rest of the area is composed of the rocks of the Indo-Pakistan plate. Both these terrains are separated by the Indus suture mélange zone, which represents the collision suture between the Indo-Pakistan and Eurasian plates.
Geochemical exploration for gold has been carried out by collecting heavy mineral panned- concentrates and stream sediment samples from various drainage basins of the study area. Mineralogical studies of the panned-concentrates suggest the presence of gold in the form of piece, speck and color in certain drainage basins, however, no nugget of gold has been found. The characteristics of these gold particles suggest that these have been transported from nearby source. The concentration of gold, obtained in various drainage basins, has been processed through geo- statistical map analysis technique, which has delineated anomalous areas of most interest for further
Key words: Geochemistry, gold, Kohistan, Dir, Swat.

S/208. Shah, M.T. & Majid, M., 1985. Major and trace element variations in the lavas of Sherghar Sar area and their significance with respect to the Kohistan tectonic anomaly. Geological Bulletin University of Peshawar, 18, 163-188.

A belt of dark-green volcanics along with serpentinite, peridotite, pyroxenite and greenschist marks the spatial disposition of the Indus suture zone in Allai Kohistan of Hazara division. Major and trace element analyses of selected lava samples are used to investigate geochemical variations in the Shergarh Sar Pashtu village section of the volcanic belt. The lavas are mostly glassy but occasionally show phenocrysts of plagioclase, clinopyroxene and, very rarely, brown hornblende. On the basis of normative mineralogy, two compositional groups, e.g. olivine tholeiite and quartz tholeiite, are identified. Fractionation control of the observed phenocrysts over the major and trace element distribution in the lavas is established through the solutions of chemical data in the C.M.A.S. model and conventional two-dimensional plots.
The major and trace element constraints of the studied lavas are corresponding more closely to tholeiites developed in the island arc type environments and substantiate, through a chemical comparison, the assumed prevalence of

such structure(s) in the Tethys ocean before the complete closure as proposed in the tectonic models of the Himalayan development.
Key words: Geochemistry, volcanics, tectonic, Shergarh Sar, Kohistan.

S/209. Shah, M.T. & Majid, M., 1992. Petrology and chemistry of the ultramafic rocks from the Allai Kohistan section of the Indus suture zone in Hazara, Northern, Pakistan. Acta Mineralogica Pakistanica 6, 73-84.

Rocks of the Shergarh Sar area, a part of the Allai Kohistan are divisible into three petrotectone units: (1) Kohistan Island Arc sequence, (2) Indus Suture Zone, (3) Indo-Pakistan subcontinent sequence. The Indus Suture Zone in this area comprises an elongated belt of ultramafic rocks, pillow lavas, greenschists, blueschists and metasediments that have been obducted onto the Indo-Pakistan plate. Ultramafics (clinopyroxene, peridotite and serpentinite) exhibit strong shearing or cataclasis. Clinopyroxene and olivine are the dominant primary phases and are partially or completely altered to serpentine, fibrous amphibole, chlorite, magnetite and chromite. Among serpentine, both antigorite and chrysotile of syntectonic and post tectonic behavior have been distinguished. The effects of serpentinization on the whole-rock chemistry is indicated by the release and introduction of certain elements during the process. The constituent rocks are comagmatic and probably represent a dismembered ophiolite suite.
Key words: Petrology, geochemistry, ultramafic rocks, ophiolite, Indus Suture, Allai, Kohistan.

S/210. Shah, M.T., Majid, M. & Hamidullah, S., 1992. Petrochemistry of amphibolites from the Shergarh Sar area, Allai Kohistan, N. Pakistan. Abstracts, First South Asia Geological Congress, Islamabad, p.37.

Consult the following account for further information.
Key words: Petrography, amphibolites, tectonics, geochemistry, Allai Kohistan

S/211. Shah, M.T., Majid, M., Hamidullah, S. & Shervais, J.W., 1992. Petrochemistry of amphibolites from the Shergarh Sar area, Allai Kohistan, N. Pakistan. Kashmir Journal of Geology 10, 123-139.

Shergarh Sar Area, a part of the Allai Kohistan is located at the closure of the Indo-Pakistan and Kohistan island arc block. Rocks of the area are distinguished into three petrotectonic units. 1-the Kohistan island arc sequence 2-the Indus mélange zone and 3-the Indo-Pakistan subcontinent sequence. Amphibolites are the most abundant rocks exposed in the area and are considered to be a part of the southern amphibolite attributed to the metamorphic segregation processes. Mineralogically these rocks are distinguished as epidote amphibolite and garnet epidote-amphibolites. Amphibole + epidote + clinopyroxene + actinolite + chlorite+ quartz + opaque is the main mineral assemblage. Garnet occurs sporadically in these rocks. The textural features are indicative of retrogression from epidote-amphibolite to green schist facies conditions. The major and trace element constraints of these amphibolites, suggest their derivation from basic igneous parent of tholeiitic character developed in the island arc type of environment.
Key words: Petrography, amphibolites, tectonics, geochemistry, Allai Kohistan.

S/212. Shah, M.T. & Sarwar, A., 1998. Litho and stream sediments survey for gold and base metals in areas around Timargara and Samarbagh, District Dir , northern Pakistan. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 180-181.

The area of study (about 900-km2) is lying within the Kohistan arc terrane in the northern part of Pakistan. It is located immediately north of the Main Mantle Thrust (MMT) in Dir district. It has a complex geology and is mainly composed of amphibolites, metadiorites, metagabbro-norites, metagranodiorites, metagranites and metavolcanics with subordinate amount of hornblendites, ultramafites and tonalites. The area has already been investigated for preliminary geology, however, no detail geochemical investigation has been carried out for precious and base metals mineralization. This study is mainly based on rocks and stream sediments (both pan-concentrates and -80 mesh fine fraction) geochemical survey for gold and base metals in order to delineate areas likely to contain mineralization and be worthy of follow-up work.

The area has been divided in to 56 drainage cells ranging from 2-50 km^2 with an average density of about one site per 15 km^2. From each cell a pan concentrate and -80 mesh fine fraction were collected for mineralogical and geochemical studies. The visible gold as piece (>0.5mm), speck (0.5-0.3mm) and color (<0.3mm) was identified in the pan concentrates of certain streams, mainly in the north eastern and north western portion of the study area. However, no nugget of gold has been noticed in the pan-concentrates. The specks and colors are generally angular to subangular, sometime irregular to rectangular in shape and bright yellow in color. The pan concentrates are dominantly composed of magnetite whereas zircon, quartz, pyroxene, garnet, hornblende, feldspar, tourmaline, chromite and rock fragments occur as minor constituents. The floats were also examined for alteration and other geological phenomenon at each site.

Samples of Rocks and stream sediments (both pan concentrates and fine fraction) have been analyzed for Au, Ag, Cu, Zn, Pb, Co, Ni, and Cr. The geochemical data have been displayed and evaluated by considering various geostatistical methods. Geochemical maps have also been prepared on the basis of single and multi-elements consideration in order to pin point areas of most interest. These studies show that pan-concentrates have higher concentration of base metals as compared to that of fine fraction and are, therefore, silicate-bound rather than sulfide-bound in stream sediments. The higher concentration of Cu, Pb, Zn, Ni, Cr, Co and Ag could be related to the bed rock rather than to specific mineralization in the area. The anomalous gold, however, could not be directly related to the bed rock but it could possibly be related to the existence of gold-bearing mineralization, most probably in the form of quartz veins, in the north and north-eastern part of Samarbagh. Further detail geochemical survey is, therefore, recommended for follow-up in the region.

Key words: Stream sediments, geochemistry, base metals, gold, Dir.

S/213. Shah, M.T., Sarwar, A. & Ahmad, W., 1999. Geochemical exploration for gold and base metals in part of Dir area, Kohistan arc terrane, northern Pakistan. Geological Society of America. Abstracts with Programs, Annual Meeting, p.46.

Consult the preceding and following accounts for further information.

Key words: Geochemistry, exploration, gold, base metal, Dir, Northern Pakistan.

S/214. Shah, M.T., Sarwar, A., Ahmad, W. & Siddiqui, S.A., 1998. Litho and stream sediment's geochemical studies for gold and base metals in area around Timaragara and Samarbagh, District Dir, Northern Pakistan. Acta Mineralogica Pakistanica 9, 37-54.

The area of study (about 900-km2) lies within the Kohistan arc terrane in the northern part of Pakistan. It is located immediately north of the Main Mantel Thrust (MMT) in Dir district. It has a complex geology and is mainly composed of amphibolites, metadiorites, metagabbro-norites, metagranodiorites, metagranites and metavolcanics with subordinate amount of hornblendites, ultramafites and tonalites. The area has already been investigated for preliminary geology; however, no detail geochemical investigation has been carried out for precious and base metals mineralization. This study has main emphasis on the rocks and stream sediments (both pan-concentrate and –80 mesh fine fraction) geochemical survey for gold and base metals in order to delineate areas likely to contain mineralization and be worthy of follow-up work.

The area has been divided in to 56 drainage cells ranging from 2-50 km2 with an average density of about one site per 15 km2. From each cell a pan-concentrate and –80mesh fine fraction were collected for mineralogical and geochemical studies. The visible gold as piece (>0.5mm), speck (0.53mm) and color (<0.3mm) was identified in the pan-concentrates of certain steams, mainly in the north eastern and northwestern portion of the study area. However, no nugget of gold has been noticed in the pan-concentrates. The specks and colors are generally angular to sub-angular, sometime irregular to rectangular in shape and bright yellow in color. The pan-concentrates are dominantly composed of magnetite whereas zircon, quartz, pyroxene, garnet, hornblende, feldspar, tourmaline, chromite and rock fragments occur as minor constituents. The floats were also examined for alteration and other geological phenomenon at each site.

Samples of Rocks and stream sediments (both pan-concentrates and fine fraction) have been analyzed for Au, Ag, Cu, Zn, Pb, Co, Ni, and Cr. The geochemical data have been displayed and evaluated by considering various

geostatistical methods. Geochemical maps have also been prepared on the basis of single and multi-elements consideration in order to pin point areas of most interest. These studies show that pan-concentrates have higher concentration of base metals as compared to that of fine fraction and are, therefore, silicate-bounded rather than sulfide-bound in stream sediments. The higher concentration of Cu, Pb, Zn, Ni, Cr, Co and Ag could be related to the bedrock rather than to specific mineralization in the area. The anomalous gold, however, could not be directly related to the bedrock but it could possibly be related to the existence of gold-bearing mineralization, most probably in the form of quartz veins, in the north and north-eastern part of Samarbagh area. Further detail geochemical survey is, therefore, recommended for follow-up in the region.
Key words: Stream sediments, base metal, gold, Dir.

S/215. Shah, M.T. & Shervais, J.W., 1990. Petrochemical evolution of the Dir metavolcanic sequence, Kohistan island arc, northern Pakistan. Geological Society of America Abstracts with programs, Annual Meeting Dallas, Texas.

Key words: Metavolcanics, petrochemistry, Kohistan island arc, Dir.

S/216. Shah, M.T. & Shervais, J.W., 1996. Mafic volcanism and the petrologic evolution of the Dir-Utror metavolcanic sequence, Kohistan arc Terrane, Northern Pakistan. Abstract volume, 11th Himalaya-Karakoram-Tibet Workshop, Flagstaff, Arizona (USA), 133.

The Dir-Utror volcanic series forms a NE-SW trending belt within the northwestern portion of the Kohistan island arc terrane in the western Himalayas of northern Pakistan. The Kohistan arc terrane comprises a diverse suite of volcanic, plutonic and subordinat4e sedimentary rocks of Late Mesozoic to Tertiary age, developed prior to and after suturing of the Indo-Pakistan and Asiatic continental blocks. The Dir-Utror volcanic series near Dir is dominated by basaltic-andesite and andesite, with subordinate basalt, high-Mg basalt, dacite, and rhyolite. Porphyritic textures are dominant in the lavas, with less common aphyric and seriate textures. Pyroclastic breccias are common locally and may represent near vent facies. Plagioclase is the dominant phenocryst in mafic to intermediate rocks, Kfeldspar and quartz phenocrysts predominate in the dacites and rhyolites. Chlorite, epidote, albite and actinolite are the most common metamorphic phases; blue-green amphibole, andesine, muscovite, biotite, kaolinite, sericite, carbonate, and opaques arc widespread but less abundant. Phase assemblages and chemistry suggest predominant greenschist facies metamorphism with epidote-amphibolite facies conditions attained locally.
Whole rock major element compositions define a calc-alkaline trend: CaO, FeO, MgO, TiO2, Al2O3, V, Cr, Ni and Sc all decrease with increasing silica, whereas alkalis, Rb, Ba, and Y increase (Figure 1). MORB-normalized trace element concentrations show enrichment of the low-field strength incompatible elements (Ce, La, Ba, Rb, K) and deep negative Nb, P, and Ti anomalies – patterns typical of subduction related magmas. Mafic volcanic rocks plot in fields for calc-alkaline volcanics on trace element discrimination diagrams, showing that pre-existing oceanic crust is not preserved here. All rocks are LREE-enriched, with La=16-112*chondrite, La/Lu=2.6 to 9.8*chondrite, and Eu/Eu*=0.5 to 0.9 (Figure 2). Dacite and rhyolites have the lowest La/Lu ratios and highest Eu/Eu* ratios, reflecting the dominant role of plagioclase fractionation of the more mafic lavas; chondrite-normalized REE patterns for these andesite cross those of the basaltic andesites, indicating that these lavas cannot be related to a common parent.
The high proportion of mafic lavas is similar to that observed in the Aleutian arc and rules out involvement of older continental crust. The scarcity of more evolved felsic volcanics (dacite, rhyolite) can be explained by the nature of underlying crust, which consists of accreted intra-oceanic arc volcanic and plutonic rocks, and is mafic relative to normal continental margins. Andesites with high La, La/Lu, K2O, and Rb may be crustal melts. The REE pattern for some andesites cross the chondrite-normalized patterns of dacites and rhyolites, showing that these rocks cannot be related by fractional crystallization, assimilation, or magma-mixing. The REE systematics of these andesites are compatible with an origin by crustal anatexis, leaving a refractory residue mineralogically similar to high pressure mafic and ultramafic granulites of the Jijal Complex. We suggest that the garnet-rich granulites of the Jijal Complex represent the restites formed during this crustal melting.
Key words: Mafic volcanics, petrology, Jijal Complex, Utror volcanic, Kohistan arc.

S/217. Shah, M.T. & Shervais, J.W., 1997. Oxygen isotope geochemistry of the Dir metavolcanic sequence and associated copper mineralization in Kohistan arc terrane, northern Pakistan. The Nucleus 34, 49-55.

Dir metavolcanic sequence constitutes a northeast southwest trending belt within the northwestern portion of the Kohistan arc terrane. This sequence is dominantly composed of basaltic-andesite and andesite with subordinate basalts, dacite, rhyolite and pyroclastic breccia. Copper mineralization in the Dir area is mainly confined to the quartz veins and associated hydrothermally altered metavolcanics. Chalcopyrite is the main copper-bearing phase with subordinate amount of bornite. chalcocite, covellite, malachite and azurite in bath mineralized quartz veins and associated mineralized metavolcanics.

Both mineralized metavolcanics and mineralized quartz veins have high $\delta^{18}O$ signature. This suggest the involvement of isotopically heavy ore forming fluid in the zonation and copper mineralization in these volcanics. This fluid has the estimated $\delta^{18}O$ isotopic composition of 5.1 per million which could be the magmatic water introduced by the granodiorite or diorite intrusion below the metavolcanic sequence.

Key words: Geochemistry, oxygen isotope, metavolcanics, copper mineralization, Kohistan arc.

S/218. Shah, M.T. & Shervais, J.W., 1999. The Dir-Utror metavolcanic sequence, Kohistan arc terrane, northern Pakistan. Journal of Asian Earth Sciences 17, 459-475.

The Dir-Utror volcanic series forms a NE-SW trending belt within the northwestern portion of the Kohistan island arc terrane in the western Himalayas of northern Pakistan. The Kohistan arc terrane comprises a diverse suite of volcanic, plutonic, and subordinate sedimentary rocks of late Mesozoic to Tertiary age, developed prior to and after suturing of the Indo-Pakistan and Asiatic continental blocks. The Dir-Utror volcanic series near Dir is dominated by basaltic-andesite and andesite, with subordinate basalt, high-MgO basalt, dacite and rhyolite. Porphyritic textures are dominant, with less common aphyric and seriate textures. Plagioclase is the dominant phenocryst in mafic to intermediate rocks, K-feldspar and quartz phenocrysts predominate in the dacites and rhyolites. Chlorite, epidote, albite, and actinolite are the most common metamorphic phases; blue-green amphibole, andesine, muscovite, biotite, kaolinite, sericite, carbonate, and opaques are widespread but less abundant. Phase assemblages and chemistry suggest predominant greenschist facies metamorphism with epidote-amphibolite facies conditions attained locally.

Whole rock major element composition define a calc-alkaline trend: CaO, FeO, MgO, TiO_2, Al_2O_3, V, Cr, Ni, and Sc all decrease with increasing silica, whereas alkalis, Rb, Ba, and Y increase. MORB-normalized trace element concentrations show enrichment of the low-field strength incompatible elements (Ce, La, Ba, Rb, K) and deep negative Nb, P, and Ti anomalies-patterns typical of subduction related magmas. Mafic volcanic rocks plot in fields for calc-alkaline volcanics on trace element discrimination diagrams, showing that pre-existing oceanic crust is not preserved here. All rocks are LREE-enriched, with La=16-112*chondrite, La/Lu=2.6-9.8*chondrite, Eu/Eu*=0.5-0.9. Dacites and rhyolites have the lowest La/Lu and Eu/Eu* ratios, reflecting the dominant role of plagioclase fractionation in their formation. Some andesites have La/Lu ratios which are too high to result from fractionation of the more mafic lavas; chondrite-normalized REE patterns for these andesites cross those of the basaltic andesites, indication that these lavas cannot be related to a common parent.

The high proportion of mafic lavas rules out older continental curst as the main source of the volcanic rocks. The scarcity of more evolved felsic volcanics (dacite, rhyolite) can be explained by the nature of the underlying crust, which consist of accreted inter-oceanic arc volcanic and plutonic rocks, and is mafic relative to normal continental margins. Andesites with high La, La/Lu, K_2O, and Rb may be crustal melts; we suggest that garnet-rich high-pressure granulites similar to those exposed in the Jijal complex may be restites formed during partial melting of the crust.

Key words: Geochemistry, basalt, andesite, Jijal complex, Utror volcanics, Dir.

S/219. Shah, M.T., Shervais, J.W. & Ikramuddin, M., 1991. Geochemistry of metavolcanics and associated Cu-mineralization in the Dir area of the Kohistan island arc, N. Pakistan. Geological Society America, Abstract with Programs, Annual Meeting, Sanfransico, California.

Key words: Mineralogy, metavolcanics, geochemistry, copper mineralization, Kohistan island arc, Dir.

S/220. Shah, M.T., Shervais, J.W. & Ikramuddin, M., 1994. The Dir meta-volcanic sequence: Calcalkaline magmatism in the Kohistan arc terrane, northern Pakistan. Geological Bulletin, University of Peshawar 27, 9-27.

A variably deformed and metamorphosed NE-SW trending belt of Dir metavolcanic sequence is exposed within the north-western portion of the Kohistan arc terrane. The sequence is mainly composed of massive and sheared volcanics and pyroclastic breccia. The petrochemical indices suggest that they are dominantly basaltic-andesite and andesite with subordinate basalt, dacite and rhyolite in composition.
Whole rock major element compositions define a calc-alkaline trend: CaO, FeO, MgO, TiO2, Al2O3, V, Cr, Ni and Sc all decrease with increasing silica, whereas alkalis Rb, Ba, and Y increase. Mafic to intermediate volcanic rocks show calc-alkaline affinities on petrotectonic diagrams. Chondrite-normalized REE patterns are LREE-enriched. Dacites and rhyolites have the lowest La/Lu ratios and highest Eu /Eu* ratios, reflecting the dominant role of plagioclase fractionation in their formation. MORB-normalized spider diagrams show progressive enrichment of the low-field strength incompatible elements (Ce, La, Ba, Rb, K) and a distinct negative Nb anomaly; patterns typical of subduction related magmas.
It is suggested that the high-Mg basalt of the Dir area is primitive in nature and could be the representative of the primary magnesian liquid formed by the partial melting of mantle wedge at the base of the Kohistan arc terrane. This liquid may have fractionated the other members of the sequence especially low magnesia basalt and basaltic-andesite.
Key words: Calcalkaline magmatism, Kohistan island arc, Dir.

S/221. Shah, M.T., Thorpe, R.I. & Siddique, S.A., 1992. Lead isotope signature of the Proterozoic sediment-hosted base metal deposits at the margin of the Indian plate in Besham area, northern Pakistan. Geological Bulletin, University of Peshawar 25, 59-65.

Proterozoic base metal deposits in the rocks of the Indian plate occur along its northern margin at the Pazang and Lahor properties near Besham. These are stratiform exhalative type deposits, which are highly deformed and regionally metamorphosed. Lead isotope studies were carried out on these deposits. Lead isotope ratio yield model ages of 2120-2199 Ma (Proterozoic) for both the Pazang and Lahor deposits. The assumed minimum age of mineralization is 2077 Ma, as suggested by the secondary isochron. These deposits are more primitive in terms of age and have lower μ values relative to the well-known sediment-hosted deposits elsewhere in the world. The non-radiogenic isotopic composition and the homogeneity of the ore lead in both Pazang and Lahor ores suggest a well-mixed common source and similar processes for the formation of these ores.
Key words: Pb isotope, base metal deposits, Pazang, Besham, Kohistan.

S/222. Shah, M.Y., 1997. Gold-silver and base metal prospect south of Skardu and part of northern Deosai Plateau, District Skardu, Northern Pakistan. Abstracts, National Symposium on Economic Geology of Pakistan, Islamabad, 1p.

A cost effective geochemical exploration methodology based on panned concentrate and minus 80 mesh samples from contiguous measured drainage cells in south of Skardu. Northern Pakistan have established an area of 613 sq. kms as highly potential target for occurrence of precious and base metals. Based on visual gold counts in the panned concentrate samples and supported by a range of chemical analyses of pan con. and minus 80 mesh samples. a total of 64 anomalous values for gold. silver. copper. lead, zinc, cobalt. bismuth and nickel has been evolved above the threshold values already set for Northern Areas, in individual drainage cell areas ranging from 6-54 sq. kms. Field observations of the alteration types. prevailing mineralization pattern and chemical analyses of a few outcrop chip samples in the prospect area also provide terra firma for detailed exploration to locate source rock/s for precious and base metals.
Key words: Geochemistry, gold, silver, base metals, Skardu, Deosai.

S/223. Shah, M.Y. & Shah, H., 1973. Heavy minerals in the alluvials of Ushu and Gabral Rivers and their tributaries, Swat Kohistan, North West Frontier Province. M.Sc. Thesis, Peshawar University.

Key words: Heavy minerals, alluvial, Ushu, Gabral, Swat Kohistan.

S/224. Shah, R.A., Akhtar, S.M. & Amin, M., 1974. Studies on the effect of particle size on the upgradation of chromite from Dargai area, Pakistan. Pakistan Journal of Scientific and Industrial Research 17, 152-153.

Key words: Chromite processing, Dargai, Malakand Agency.

S/225. Shah, R.A. & Khan, A.H., 1979. Occurrence utilization and potential of gypsum in Pakistan. Pakistan Council of Scientific and Industrial Research, Monograph, 46p.

Key words: Gypsum, economic geology, Pakistan.

S/226. Shah, R.A., Khan, A.H. & Qazi, M.A., 1979. Prospects of steel making from indigenous iron ore. International Seminar Exploitation Technology, Peshawar, 123p.

Key words: Steel, technology, iron ore.

S/227. Shah, R.A., Naz, M.A., Naqvi, A.A. & Safdar, M., 1964. A study of Swat kaolinite. Pakistan Journal of Scientific and Industrial Research 7, 183-187.

Key words: Kaolinite, Swat.

S/228. Shah, S. & Khan, M.S., 2000. Structure, stratigraphy and statistical studies of the Siwalik group of an area between Kotli and Mirpur, Azad Kashmir. M.Sc. Thesis, University of Peshawar, 148p.

A thick sequence of molasse sediments of the Siwalik group, exposed in part of the area between Mirpur and Kotli district of Azad Kashmir are objective of this report. Amongst the major geological aspects, stratigraphy structure, petrography and statistical analysis have been dealt in detail.
Stratigraphically these sediments, ranging in age from late Miocene to Pleistocene are divided into
I Upper Siwalik - Soan Formation (Late Pliocene to early Pleistocene).
II Middle Siwalik
(a) Dhok Pathan Formation (early to middle Pliocene)
(b) Nagri Formation (Early Pliocene)
III lower Siwalik - Chinji Formation, (Late Miocene).
The Siwalik group comprises sandstone, shale, and conglomerate. The Chinji Formation is composed of reddish shale and subordinate sandstone beds. In the Nagri Formation Sandstone is predominant with occasional shale beds. The Dhok Pathan Formation is marked by alternating sandstone and clay bed.
Structurally the area is folded into six anticlines and synclines with same trend of fold axis. These folds are of open type. Brief petrographic study show that sandstone comprises of quartz, feldspar, mica, calcite, hornblend, rock fragments, and minor amounts of apatite garnet, zircon, chlorite, sphene and ore. Kyanite and staurolite are other rare mineral. Sieve analyses of sixteen samples Indicates that dominant clastic fraction in medium to fine moderately sorted, positively skewed and steeply peaked. Average values of various statistical measures obtained are:

Sorting	Skewneaa	Kurtoaia	Mean
0.968	0.246	1.076	2.437

There is no systematic horizontal or vertical variation in different statistical measures but present a rather zigzag pattern which indicates that the material of variable size was brought to the basin between each cycle.
Key words: Structure, stratigraphy, siwalik, Kotli-Mirpur, Azad Kashmir.

S/229. Shah, S.A.R., 1976. Petrology of Harnoi-Khwar valley area, Swat. M.Sc. Thesis, Peshawar University, 83p.

Key words: Petrography, geology, Harnoi Khwar, Swat.

S/230. Shah, S.H., 1980. Lead investigation Thelichi area, Gilgit District. Geological Survey of Pakistan, Information Release 114, 20p.

Two principal mineralized zones exist along the Thalichi Gah, where small scale mining has been done, as small adits. The mine located in the Thalichi Gah named "nala Mine" consists of small and thin veins of lead-zinc ore; while the other mine located at the top of a hill between Thalichi Gah and its northern tributary named "Davide Mine", consists of small and thin veins of lead-coper ore. In general, the veins in both mines, measure less than 5 cms. In thickness and not more than 9.5 meters exposed length; with steep dip. In Shukisoh area lead-copper has been mined from the phyllitic gauge zone, where mineralization occurs as very small veinlets and disseminated grains.
Key words: Lead mineralization, Thelichi, Gilgit.

S/231. Shah, S.H., Khan, K.S. & Shah, S., 1982. Cement raw materials in Gilgit Agency. Geological Survey of Pakistan, Information Release 168, 38p. 2 figurs. 9 plates.

Key words: Cement, raw material, Gilgit.

S/232. Shah, S.H., Khan, K.S.A., Khan, N.A. & Khan, M.S.Z., 1987. Geology and mineral investigation of the Thor quadrangle (Topographic Map, 43-E/15; Scale, 1:50,000), Diamir district, Northern Areas, Pakistan. Geological Survey of Pakistan, Information Release No. 289, 21p.

The Thor quadrangle lies within the southern portion of the Kohistan island arc sequence, which is bounded by the two megashears, the Main Mantle Thrust (MMT) towards the south and the Main Karakoram Thrust (MKT) towards north. The MMT zone, lies a few kilometres south of this quadrangle (out of map). The major lithological zones within the quadrangle include the southern amphibolite belt (Kamila amphibolites), the pyroxene granulites, the Thurli ultramafics and Kohistan granodiorite. The Kamila amphibolites, with both banded and massive varieties, trending almost east-west: with southward dips, have sporadic granitoid intrusions related to the Kohistan granodiorite. These granitoid intrusions of both massive and gneissic texture, range in size from small pockets to that of stocks. The pyroxene granulite belt of noritic composition, degranulitized in its southern portion at its contact with the Kamila amphibolites, is believed to have been crystallized from a tholeiitic magma in a continental margin or island arc location, metamorphosed at a depth of more than 40 kms and finally tectonically emplaced in its present position as remobilized crystalline material. The degranulitized portion consists of plagioclase, hornblende, biotite and quartz, formed as a result of the retrograde metamorphism of the previous noritic complex. A small oval - shaped ultramafic body, mainly composed of dunite, troctolite and peridotite with basic dykes, has been tectonically emplaced within the pyroxene granulites after the main metamorphism during the collision of the Indian - Asian landmasses, but before the two uplifted to their present positions. This ultramafic suite is believed to represent a portion of oceanic crust and upper mantle. A syncline trending NE-SW, is present within the pyroxenite granulite. Small exposures of buff coloured micaceous and silty clay are locally present on both banks of the Indus River.
The ultramafic suites although favourable for crystallization and segregation of metallic minerals, because of composition and localized stratiform nature, are almost devoid of any significant mineralization.
Key words: Geology, minerals, Thor quadrangle, Diamir.

S/233. Shah, S.H. & Khan, N.A., 1999. Geochemistry of sulphide bearing zones in Shigar-Skardu area, Skardu District, Baltistan. Geological Survey of Pakistan, Information Release 691.

Key words: Geochemistry, sulphide, Shigar-Skardu.

S/234. Shah, S.H., Khan, N.A., & Khan, M.S.Z., 1987. Geology, geochemistry and mineral investigation of the Skardu quadrangle (43 M/11), Baltistan district, Northern Areas, Pakistan. Geological Survey of Pakistan, Information Release 290.

Regional geological mapping at the scale of 1:50000, of the Skardu - Shigar area was carried out during the field season 1983-84 as a part of the geological Survey of Pakistan's continuing programme of regional geological mapping of Pakistan, and particularly of the Northern Areas.
The Skardu - Shiga area, covered by topographic sheet 43-M/11 is underlain by the rocks of the Katzarh Formation, the Greenstone complex, the Yasin group, the Burj-La Formation, basic complex, the Deosai volcanics, the Ladakh intrusives, and the unconsolidated deposits of moraines, terrace and recent alluvium & sand dunes.
The Katzarh Formation of Early Cretaceous age consists of various grade schists, phyllites, slates and shale. The greenstone complex of Early Cretaceous age consists mainly of gneiss, marble schist and green tuffaceous slate, intruded by various mafic and intermediate igneous rocks. The Yasin group of Early Cretaceous age consist of massive, dolomitic limestone, limestone, quartzite, and carbonate schists and shale. The Burj-La formation of Late Cretaceous age consist of black slate, phyllites, tuffaceosu slate, argillaceous breccia. The Basic complex of Cretaceous – Eocene age consists of amphibolite, hornblendite, pyroxenite, uralite gabbro, diorite and schists. The Deosai volcanics of Late Cretaceous age consist of green andesite and andesite porphyry, dacite and dacite porphyry, rhyolite porphyry, and tuffaceosu slate. Most of the rocks are metamorphosed in low grades. The Ladakh Intrusives of Early Eocene to Miocene – Pliocene age consists of quartz diorite, diorite, granodiorite, muscovite granite, two mica granite, pegmatite and aplites. Some gabbroic and ultramafic rocks in the form of dykes are also present in places. The unconsolidated rocks in Skardu-Shigar area consists of unsorted glacial morains, river alluvium, and eolian sand deposits in the form of dunes.
The Greenstone complex has faulted contacts both with the underlying Katzarh formation and the overlying Yasin group. The Deosai volcanics are faulted against the underlying Burj-La formation. Folds and faults of varying scales of magnitude are common in the mapped area.
Copper showings in the form of crack fillings and disseminated grains are present in the Deosai volcanics, located in the Shagari Kalan Lung, Shagari Bala Lung and Irgilun Lugma. Marble bands are exposed at the base of the Greenstone complex on both banks of the Shigar River, and continued eastwards beyond the Shigar Lunma. A bed of quartzite within the yasin group is present on both banks of the Mustafabad Lungma.
Key words: Mapping, stratigraphy, Cretaceous, Miocene, Skardu quadrangle.

S/235. Shah, S.H., Khan, N.A. & Latif, M., 1986. Geology and pegmatites of the Gilgit-Jaglot-Hanuchal area, Gilgit District, Northern Areas. Geological Survey of Pakistan, Information Release 273.

A large number of pegmatites were checked physically in the field. In most cases grab, samples were taken, but channel samples of some zoned pegmatites were also collected.
The pegmatites are generally scattered but there is a large concentration of them from Parri upto Shuta along the Skardu road. In the investigated area about 1200 pegmatites have been observed, which range in dimensions from mere one centimetre stringers and veinlets to about 9 metres in thickness and from a few metres to about 175 metres in length. Pegmatites run both along and a across host rocks but they mostly occur as dykes. Their general trend is east-west. The host rocks for the pegmatites are meta tuff, diorite, granodiorite, para- amphibolite, ortho-amphibolite and the meta-sedimentary schistose rocks
Most of the pegmatites are simple but some are zoned. The zoned pegmatites mostly consist of wall zone, intermediate zone and core. In some pegmatites, intermediate zone can be further subdivided into two subzones. The zones are not essentially symmetrical with each other, some heterogeneous pegmatites were also found, viz. hornblende pegmatites in Shuta area.

Most of the pegmatites are intrusive in nature whereas around Parri the recrystallized pegmatites are also developed from the acidic intrusive rocks mostly from granodiorite and aplite under the action of volatiles. Most of the pegmatites are barren, except a few in which some economically important minerals are noted, viz, microcline, biotite, beryl, radioactive mineral and amazonite. Beryl has been found in the biotite- bearing pegmatites only. Such economically important minerals are found only as surface traces in pegmatites which seem to be uneconomical except the beryl-bearing pegmatites at Konadas, Station (Sn, 13), Jalalabad (Sn.37) and amazonite-bearing pegmatites at Jaglot (Sn. 46) which are worth further exploration. Low radioactivity in some samples from Parri, Skardu road, and Jaglot area was noted which measures from 434 to 2,774 counts per hour.

Key words: Geology, pegmatites, Jaglot, Gilgit.

S/236. Shah, S.H. & Khan, R., 1998. Geology and mineral investigations of the Jaglot–Bunji quadrangle (43 I/10), Gilgit- Diamir – Skardu Districts, Northern Areas, Pakistan, Geological Survey of Pakistan, Information Release 547, 39p.

The investigated area lies towards SE corner of the Kohistan Island Arc sequence, which is bordered by the Nanga-Parbat Haramosh massif of the Indian mass, having remobilized cataclastic metamorphosed and granitized gneisses. Direct collision of the Indian mass occurred with the Eurasian mass, along the Nanga Parbat-Haramosh massif spur, thus dividing the Kohistan-Ladakh island arc in two parts -the Kohistan island arc and the Ladakh island arc. In the investigated area, the rocks of the Indian mass started subducting under the rocks of the Kohistan Island arc, during the Early Eocene, along a megashear the Main Mantle Thrust (MMT). The MMT zone, in the investigated area, generally measures 200 m -300 m in width, while in the Lichar surroundings it is truncated and disturbed by the Raikot fault and also concealed under scree. The subduction of the Indian mass under the island arc, resulted in severe tectonism, thrusting, folding, formation of a cordillera type folded mountain chain, along with profuse intrusion of subduction related granitoids in the island arc sequence.
The Cretaceous island arc volcanogenic rocks were intermixed with the Jurassic to Cretaceous flysch type intra arc metasediments with subsequent multi-phase and diversified type magmatism of granitoids in the Kohistan island arc. The first phase of this magmatism commenced in Late Cretaceous (Albian) while its third and final stage, representing a swarm of acidic dykes and pegmatites, in the Indus-Gilgit confluence area, occurred during Oligocene and even Miocene (Patterson and Windley, 1985). The earlier acidic intrusions were metamorphosed to orthogneisses. Three Himalayan orogenic episodes from Late Paleocene to Pliocene/Pleistocene caused strong diastrophism, resulting in the formation of different sets of foliation and lineation and metamorphism. Large deposit of white, saccharoidal marble is present in Thelichi area. Some metalliferous hornblendites and volcanics, mineralized pegmatites, scattered multi coloured sulphide deposits and placer gold showings, all make the investigated area economically significant.
Key words: Kohistan Island Arc, MMT, Gilgit, Diamir, Skardu.

S/237. Shah, S.H. & Khan, R., 1999a. Geology of Mehdi Abad quadrangle (43 M/16), Skardu District, Northern Areas, Pakistan. Geological Survey of Pakistan, Information Release 686.

Key words: Geology, Mehdi Abad, Skardu.

S/238. Shah, S.H. & Khan, R., 1999b. Geology of Baghicha quadrangle (43 M/6), Skardu District, Northern Areas, Pakistan. Geological Survey of Pakistan, Information Release 688.

Key words: Geology, Baghicha quadrangle, Skardu.

S/239. Shah, S.H., Khan, R., Khan, N.A. & Latif, M., 1999. Geology of the Satpara quadrangle (43 M/12), Skardu District, Northern Areas, Pakistan. Geological Survey of Pakistan, Information Release 689, 15p.

The Satpara quadrangle covers the Survey of Pakistan topographic sheet No. 43-M/12 and lies in the Ladakh island arc. The mapped area covers the eastern portion of the gigantic Deosai Plateau having average elevation of about 4,000m above the sea level.
The investigated area is underlain by the flysch type metasediments, the metavolcanics and the plutonics. The calcareous metasediments are exposed as small outcrops within the pelitic metasediments, and supposed to have originated as a result of isolated depositional basin environments. The unconsolidated sediments cover the valley slopes, as well as, have vast exposures over the Deosai Plateau. The intra-arc metasediments and metavolcanics, were subsequently subjected to magmatism of calc-alkaline nature. This magmatism occurred in three phases during Late Cretaceous to Miocene (Petterson and Windley, 1985). The granitoids of the investigated area, cover mostly the second phase magmatism which are subduction related and Andean type in origin.
Three Himalayan orogenic episodes from Late Paleocene to Pliocene/Pleistocene caused diastrophism and tectonism, resulting the formation of different set of foliation, and lineation. Local folding and faulting within metasediments and metavolcanics occurred, but the mapped area lacks any regional controlled megastructure. Ferrugenous fault breccia, exposed at the shahtung baihk, resulted the weak zone along which iron rich solutions impregnated the countryrock volcanics. However, iron (Fe_2O_3) content is surprisingly low, from 5.75% to 7.75%.
The sulphide showing at the Shikar Nala mouth, contain stringers, small pods and thin veinlets having mineralization of pyrite, chalcopyrite and manganese dendrites, Such sulphide mineralization is sparse, scattered and as low percentage by volume in the Deosai volcanics, These factors make it uneconomical. Small marble exposures are located in the remote and unapproachable areas, which make it uneconomical due to transportation problems.
Key words: Geology, Satpara quadrangle, Skardu.

S/240. Shah, S.H. & Khan, S., 1980. Geology and geochemistry of part of Hunza area, Gilgit Agency. Geological Survey of Pakistan, Information Release 115, 44p.

Reconnaissance geological mapping and geochemical investigations were carried at 1:250000 scale during September and October, 1975 from Bulchi das to Khunjerab in the Upper Hunza Valley, lying in topographic sheets 42 L and 42 P. during this field season, the reconnaissance mapping was done mostly along the Karakoram Highway.
Two mountain ranges running approximately east-west Karakoram in the south and Hinduraj in the north. These mountain ranges consist of acidic igneous rocks viz. granite/granodiorite. The region between these ranges consists of sedimentary and metasedimentary rocks including limestone, slate, gneiss, schist and quartzite of probably Upper Carboniferous to Jurassic age. Fossils in the limestone and the slate are not common. Folding within sedimentary and metasedimentary rocks can be seen at some localities.
The contact of the Karakoram granodiorite with the Pasu slate is faulted, but with the metamorphic rocks of the Baltit group it is intrusive. The high grade metamorphic rocks garnet-mica schist, and coarsely crystalline marble, probably indicate thermodynamic regional metamorphism caused by the intrusion of the two huge silicic batholith (Karakoram & Hinduraj) composed mainly of biotite-granodiorite.
Key words: Geology, geochemistry, Hunza, Karakoram, Hinduraj.

S/241. Shah, S.H. & Shah, S.S., 1984. Geology and mineral investigation of Parri quadrangle (43 I/9), Gilgit district, Northern Areas, Pakistan. Geological Survey of Pakistan, Information Release 224.

The investigated area lies within the Kohistan island arc sequence, bordered by two megashears viz. the Main Mantle Thrust (MMT) on southern side and the Main Karakorum Thrust (MKT) on northern side. Towards eastern extremity of the quadrangle, the bedded variety of Kamila amphibolite is exposed, which was considered a part of the Salkhalas, by previous workers. The rocks of the Greenstone complex are developed on the northern periphery of the Kohistan island arc; while the Kamila amphibolite, which form the base of the arc is the product of an intraoceanic subduction in the fore-arc basin. The Nanga Parbat-Haramosh massif which lies towards southeast of the quadrangle, is largely composed of more or less intensely metamorphosed metasediments of the Salkhala formation.
The area around the Gilgit-Indus Rivers confluence is composed of hornblende granodiorite, melanochratic diorite, inclusions and xenoliths of amphibolite, hornblendic para gneiss and ortho-amphibolite bodies of various dimensions. These rocks are perhaps the result of assimilation and hybridization processes occurring along the

marginal zones of the Kailas granodiorite batholith. The effects of dynamothermal metamorphism are more pronounced along the marginal zone of the batholith and resulted the formation of paragneiss and granite gneiss. Such rock types are common in the neighbouring Nanga Parbat. Tectonically, the area has been greatly disturbed which resulted a number of anticlines and synclines associated with faults. Due to proximity with the Main Mantle Thrust (MMT), the Hurban area has been severely affected by tight folding and faulting.
The intrusions of pegmatites along with the granitic and aplitic dykes and sills are quite profuse from Jalalabad along Gilgit River, and Shuta along Indus River, down streamwards upto Jaglot (out of the quadrangle). The pegmatites are mostly uneconomical, with the exception of some showings of beryl near Jalalabad alkali feldspar near Aftab camp, which may prove to be of economic significance by later detailed exploration. Significant stratified sulphide zones alongwith a gossan, have been observed in the Bilchhar and Cinnakar areas, which need further prospecting. Workable marble deposit is present in the Hurban -Shahbatot area, within the metasedimentary rocks of the Kamila amphibolite. The reserve estimation has been calculated with the following formula (Mc Kinstry, 1968, p.60). Reserves (in metric tons) = Volume in m^3 x Sp. Gravity. (The specific gravity for marble takens to be 2.7).
Key words: Geology, mineralogy, Parri quadrangle, Gilgit.

S/242. Shah, S.H., Zaidi, M.M. & Shafique, M., 1986. Reconnaissance geology of Tangir–Darel–Khanbari area, Diamir district, Northern Area, Pakistan. Geological Survey of Pakistan, Records, 78.

This is a detailed mapping of some the most inaccessible area in the Kohistan terrane, namely, the valleys of Tangir, Darel and Khanbari. Theses valleys cross the boundary between the Chilas Complex and the Kohistan Batholith. The map shows that screens of metamorphosed volcaosedimentary rocks, biotite-feldspar gneisses and schists occur in a terrain mainly occupied by gabbronorite, olivine gabbro (minor), varieties of quartz diorites and monzonite. Field features and petrographic characteristics for the rocks are given.
Key words: Geological mapping, norite, diorite, granite, Central Kohistan, Diamir.

S/243. Shah, S.H., Zaidi, M.M. & Shafique, M., 1987. Geology of Tangir-Darel Khanbari area, Diamir District, Northern Areas, Pakistan. Geological Survey of Pakistan, Record 78.

The area contains metamorphosed volcano-sedimentary rocks and norite. The former comprise migmatised amphibolite, gneiss, schist and quartzite derived from argillaceous/ tuffaceous material. These have been intruded by mafic to felsic rocks, olivine gabbro (oldest), the diorite, quartz diorite, quartz monzonite, granodiorite dykes and felsic pegmatites. Pyroxene-quartz diorite seems to be a product of hybridization of meta-norite by quartz diorite magma. The pegmatites contain radioactive and tungsten minerals in trace amounts. There are eight tables, three maps and three cross sections.
Key words: Metavolcanics, paragneisses, Tangir, Darel, Khanbari, Chilas complex, Kohistan arc.

S/244. Shah, S.H.A., 1976. A brief note on the metamorphism and pre-existing structures of the section between Thakot and Shatial Bridge. Geological Bulletin, Punjab University 12, 105-107.

Key words: Metamorphism, structures, Thakot, Shatial.

S/245. Shah, S.H.A., 1984a. Stratigraphic observations of laterites in Pakistan and oscillation and movement of the Eurasian and Indian Blocks. Geological Bulletin, University of Peshawar 17, 101-108.

The laterite beds in Pakistan are found in isolated zones of outcrops but are spread a wide area in the country. They can be divided stratigraphically into four age groups: Upper Devonian of Chitral district; Jurassic of Punjab and Baluchistan; Cretaceous –Paleocene of Punjab, Baluchistan and Sind; and Oligocene of Sibi. Laterites are also found as thin layers or ferrogenous coating in the Siwalik group of rocks.

The mode of formation of the laterites indicates conditions of sub-aerial wreathing or oxidation. It has been observed that rocks rich in ferromagnesian minerals on oxidation gave rise to thicker beds of laterites having higher percentage of iron. Some interesting information regarding the movement of plates have been provided by these laterite layers when studied on regional scale.
Key words: Stratigraphy, Eurasia, Indian block.

S/246. Shah, S.H.A., 1984b. The ophiolite belt and suture traces in Pakistan. Geological Bulletin, University of Peshawar 17, 113-117.

The paper deals with the four ophiolite belt as indicated by the occurrences of ultramafic rocks, pillow lavas, greenschists, pyroclasts and basaltic flows. Of these four belts, three are indicative of suture zones while one is related with a deep fracture through which ultramafic magma along with other types has intruded.
Key words: Ophiolite, ultramafic, suture zones, Fracture.

S/247. Shah, S.H.A. & Abdullah, S.K.M., 1961. Raw material for ceramic in Swat, West Pakistan. Natural Resources (University of Karachi) 1(2), 41-44.

Key words: Ceramic, Raw material, Swat.

S/248. Shah, S.H.A. & Afridi, M.R., 1970-71. The petrographic studies of dolerite intrusions in the Palaeozoic Formation of Attock-Cherat Range and Nowshera reef, W. Pakistan. M.Sc. Thesis, University of Peshawar, 40p.

The authors have described the petrography of the dolerite intrusions in the Palaeozoic formations of the Attock slate series, and the Nowshera Reef Complex.
The intrusions are in the form of lensoid sills except a few dykes in the Nowshera Reef complex. They measure from a few feet to as much as 10 feet in thickness. Mineralogically they are composed of plagioclase, pyroxene, ilmenite and Magnetite. The constant accessories are quartz, calcite, chlorite, epidote. The rare accessories are hornblende and apatite. From this study the authors have concluded that the rocks crystallised from a tholeiitic magma. Mineralogically they are the same and may be correlated to the Cretaceous ultrabasic intrusions.
Key words: Petrography, dolerite, Paleozoic, Attock-Cherat, Nowshera Reef.

S/249. Shah, S.H.A., Arbab, M.S.H. & Siddiqi, R.A., 1977. Preliminary observation of ERTS imagery for the geological studies of northern and northwestern areas of Pakistan. CENTO Workshop on Applications of Remote Sensing Data and Methods, Lahore, 1975. US Geological Survey, (IR) CEN-10, 150-153.

Key words: Geology, ERTS imagery, Northern Pakistan.

S/250. Shah, S.H.A., Malik, M.A. & Ahmed, S., 1997. Neogen molasses sediments of Potwar Plateau, Pakistan their implications for petroleum generation and exploration. Abstracts, 3rd GEOSAS Workshop on Siwaliks of South Asia, Islamabad. Geological Survey of Pakistan, Records 109, 42-47.

The Potwar Plateau lies in the northern Pakistan and is confined by the Kala Chitta and Margalla Hills to the north and the Salt Range to the south. It is bounded by the Jhelum River to the east and the Indus River and Kohat Plateau to the west.
The Potwar Plateau is part of the Himalayan foreland fold- and thrust-belt system formed due to the ongoing collision between the Eurasian and Indian Plates that started in Early to Middle Eocene time (Stoneley, 1974). This is the principal oil producing province of Pakistan. Oil is produced from pre-Neogene carbonates and sandstones.

The Neogene molasse sediments which are the focus of this study are represented by the Miocene Rawalpindi Group and Pliocene-Pleistocene Siwalik Group. The Neogene rocks are as thick as 6400 m (Fatmi et al., 1984). The stratigraphy of the Neogene molasse sediments has been studied extensively (Burbank and Raynolds, 1988; and Johnson et al., 1986). These sediments which comprise conglomerate, sandstone, siltstone and shale were derived from the southward advancing upthrusted Himalayan mountain ranges and were deposited in a network of fluvio-deltaic system in the adjoining foredeep area. Rapid rates of sedimentation ranging from 20 to 50 cm/ 1,000 years have been established (Raynolds and Johnson, 1985).

Drilling in the Potwar Plateau has revealed abnormally high formation pressures in the Neogene molasse sediments. These abnormal pressures in the Neogene rocks are in cases as high as lithostatic. Pressure gradients above lithostatic have been reported in the Adhi area (Malick, 1979). Undercompaction and tectonic stresses have been considered the main causes of these abnormal pressures in the Potwar Plateau (Malick, 1979; Sahay and Fertl, 1988; and Kadri, 1991). But the possibility of structural deformation as being one of the causes cannot be ruled out as well. Based on the mudweight and drilling exponent data, formation pressures in the Neogene sediments increase from the north to south. In the north Potwar drilling has revealed pressure gradients in the range of 0.5 to 0.65 psi/ft. (Fig 2), whereas pressure gradients approaching lithostatic have been found in the central and eastern Potwar regions (Fig.3). These overpressured zones seem to be widely distributed in the Potwar area. They constitute severe drilling and safety hazards thereby significantly increasing drilling costs and in some cases they also have resulted in the abandonment of the wells prior to reaching the target reservoirs.

On the contrary, the Neogene molasses sediments have played a vital role in the hydrocarbon generation in the Potwar region. Maturity modeling (Fig. 4) suggest that the Neogene molasse deposits have provided the required depth of burial to bring about the maturation of the source rock to generate and expel hydrocarbon to the traps. These overpressured Neogene molasses sediments have also provided effective sealing mechanism for the entrapment of oil in the Potwar region. A major part of the Potwar oil is sealed below the Neogene molasses deposits.

Key words: Neogene molasse, conglomerate, petroleum, Potwar Plateu.

S/251. Shah, S.M.A., 1966. Thesis on geology and petrology of Thakot–Shang area (Swat, Hazara) with special emphasis on Schistose Rocks. M.Sc. Thesis. Geology Department, Punjab University, Lahore.

Key words: Geology, petrology, schist, Thakot-Shang, Swat, Hazara.

S/252. Shah, S.M.A. & Wahabudin, M., 1976. Study of the waterlogged and saline land of Kafur Dehri area, N.W.F.P., M.Sc. Thesis, University of Peshawar, 41p.

This report covers field work, and comparison of data obtained by the authors with data achieved by the WAPDA during session 1974-1975. It has been established from lithologic-log of the test wells drilled in the Kafurdheri area that the sub-surface geology of this area is very complex and great variation can be expected from place to place. But generally the area is underlain by unconsolidated deposits of Quaternary age comprising of gravels, sand with silts, and clay.

The analysis of shallow-water and soil samples show that the shallow-groundwater of the area is generally of calcium-magnesium-bicarbonate type and cover about 70 percent of the total area (30,031 acres). The soils in the thesis area are mainly developed from the material contributed by the adjoining hills of Khyber Agency and are medium to fine texture with very weak to moderate

Structure. The soil salinity is localised and mainly confined to the area around Palam-dhari, Kafurdheri and Shahi Bala villages. The affected area is non-alkali-saline soil and are not supposed to present any difficulties in reclamation.

The main objective of the present work of WAPDA is to remove the constraint of water-logged and salinity, for this purpose it is proposed to remodel the present drainage system and to install about 73 tube - wells of capacity 1 - 2 cubics to the Kafur-Dheri area, so that the water table would be established at 15 feet below natural surface.

Key words: Waterlogging, salinity, Peshawar.

S/253. Shah, S.M.I., 1962. Bentonite deposits of Pakistan. CENTO Symposium on Industrial Rocks and Minerals, Lahore,

Key words: Bentonite deposits, Pakistan.

S/254. Shah, S.M.I., 1969. Discovery of Palaeozoic rocks in the Khyber Agency. Geological Survey Pakistan, Geonews 1(3), 31-34.

Key words: Paleozoic, Khyber Agency.

S/255. Shah, S.M.I., 1977a. Precambrian and Palaeozoic. In: Shah, S.M.I. (ed.), Stratigraphy of Pakistan. Geological Survey of Pakistan, Memoir 12, 1-29.

Key words: Precambrian, Paleozoic, stratigraphy.

S/256. Shah, S.M.I. (ed.), 1977b. Stratigraphy of Pakistan. Geological Survey of Pakistan, Memoirs 12, 138p.

This monograph gives information on Precambrian to Quaternary stratigraphy and mineral deposits (including gemstones of Pakistan) by seven contributors lithological description has been given for various formations together with other pertinent data and a large number of important references. Grade, tonnage and localities for the mineral deposits have been given. Folder consists of correlation charts, maps and a table of major mineral deposits.
Key words: Stratigraphy, mineral deposits, gemstones.

S/257. Shah, S.M.I., 1977c. Precambrian. In: Shah, S.M.I. (ed.)., Stratigraphy of Pakistan. Geological Survey of Pakistan, Memoir 12, 1-5.

Key words: Stratigraphy, Precambrian.

S/258. Shah, S.M.I., 1977d. Palaeozoic. In: Shah, S.M.I. (ed.)., Stratigraphy of Pakistan. Geological Survey of Pakistan, Memoir 12, 5-28.

Key words: Stratigraphy, Paleozoic.

S/259. Shah, S.M.I., 1978a. Recent discovery of Palaeozoic rocks in the northern parts of Pakistan. UN Publications MRDS, 42(IV), 6p.

Key words: Stratigraphy, Paleozoic, Pakistan.

S/260. Shah, S.M.I., 1978b. Current status of stratigraphic correlation in Pakistan. UN Publications MRDS, 42(IV).

Key words: Stratigraphy, correlation, Pakistan.

S/261. Shah, S.M.I., 1980. Progress of geodynamics in Pakistan. Geological Bulletin, University of Peshawar 13, 1-4.

Key words: Geodynamics, Pakistan.

S/262. Shah, S.M.I., 1984. Siwaliks: An introduction. In: Shah, S.M.I. & Pilbeam, D. (Eds.), Contributions to the Geology of Siwaliks of Pakistan. Geological Survey of Pakistan, Memoir 11, I-IV.

Key words: Geology, siwaliks, Pakistan.

S/263. Shah, S.M.I., 1978. Geology of Pakistan. In: Fairbridge, R.W. (Chief ed.), Encyclopedia of World Regional Geology. Volume 2, Eastern Hemisphere.

The part I includes Western Hemisphere (including Antarctica and Australia), which is out of the area of this publication, thus is excluded. The volume 2 includes the geology of Pakistan. No further information was available to the authors of this book.
Key words: Geology, Pakistan.

S/264. Shah, S.M.I. & Bhutta, A.I., 1988. Geology of coal occurrences of Kotli District, Azad Jammu and Kashmir. Geological Survey of Pakistan, Information Release, 310, 29p.

Key words: Coal, Kotli, Azad Kashmir.

S/265. Shah, S.M.I. & Pilbeam, D. (Eds.), 1984. Contributions to the Geology of Siwaliks of Pakistan. Geological Survey of Pakistan, , Memoir 11, 77p.

Key words: Siwaliks, Pakistan.

S/266. Shah, S.M.I., Raza, S.M. & Sheikh, K.A., 1985. Field Guide to the Siwalik Hominoid Sites, Potwar Plateau. Geological Survey of Pakistan, Information Release 248.

The uplift and erosion of the Himalayas during the Neogene has resulted in an extensive apron of freshwater sediments deposited in the sublatitudinal foredeep developed at the margins of the mountain front. These clastic sediments of fairly homogenous composition are generally known as the Siwalik Group. The area where they are defined and are best known is the Potwar Plateau of Pakistan.
The Siwalik rocks of the Potwar Plateau and the adjoining regions of Jammu and Himachal Pardesh have remained the focus of intensive studies for the last more than 100 years. Because of the continuity of sedimentation spanning over much of the Neogene time and for the reasons that these rock units contain diverse and important assemblage of fossil vertebrates, the Siwaliks of Pakistan are ideally suited for the collection of late Tertiary vertebrate fauna. During the past hundred years these deposits have attracted most of the celebrated vertebrate Paleontologists of the world. Although large and small mammal taxa recorded in the Siwaliks are also found in the Neogene of Africa, Europe, Central Asia and North America, but the Siwaliks are unique to provide fossiliferous strata forming long and continuous stratigraphic sequences and offer clear superposition of the fossil localities. The Siwaliks, therefore are key to the land-mammal stages of Southern Asia and subsequently the recent studies are proving to be critically important for refining the Neogene vertebrate chronology of the Old World.
Since 1973, various aspects of the geology, paleontology and paleoanthropology of the Siwaliks of Potwar Plateau have been studied by research groups from the Geological Survey of Pakistan, Peshawar University,
Harvard University, Dartmouth College, Lamont-Doherty Geological Observatories, and the University of Arizona. The studies have been done in three separate areas - the Chinji-Nagri area, the Hasnot -Tatrot area, and the Khaur area. Each area contains the type-section of one or more of the classic Siwalik formations.
Material collected in Pakistan from 14 to 8 Ma B.P., greatly expanded our knowledge of this group; previously unknown parts are now represented, in particular post cranial remains which are so important in the post cranial anatomical studies and even for precise taxonomical emplacement of these species. New finds of hominoids from other parts of the world have greatly enhanced the phyletic knowledge and understanding of the stages of hominoid evolution after about 5 million years ago, prior to that time, an enormous gap still exists; i. e. the time between 8 to 4 m.y, spans this gap. Fortunately a large area in Pakistan is occupied by the continental sediments of this age.

Provided the said stock did not extinct after 8 m. y. in Pakistan; it is believed, that a thorough search in the Siwaliks, where so many reasons combine to indicate greater probability of success, will hopefully yield material so crucial to the understanding of the critical phases of hominoid evolution.
Key words: Hominoids, Potwar Plateau, siwaliks.

S/267. Shah, S.M.I., Siddiqui, R.A. & Talent, J.A., 1980. Geology of the eastern Khyber Agency, North Western Frontier Province. Geological Survey of Pakistan, Records 44, 31p.

Geological investigation of the eastern part of the Khyber Agency has shown that four major stratigraphic units can be identified and mapped. The youngest, the Khyber Limestone of Carboniferous to Permian age, overlies the Ali Masjid Formation of Late Devonian age. Shagai Limestone of Silurian Devonian age underlies the Ali Masjid Formation and the oldest unit is the Landi Kotal Formation of ? Ordovician-Silurian age.
All the formations have wide spread exposures in the eastern part of the map area, Detailed search for fauna indicated that sections of these formations along the Khyber highway proved barren while those of the western part of the map area are fossiliferous. This being the case the upper two formations are richly fossiliferous while the lower formations are rarely fossiliferous. Structurally the area is very complex, frequent folding followed by faulting complicates stratigraphic interpretation of the area.
Key words: Khyber Agency, stratigraphy.

S/268. Shah, S.M.I. et al., 1985. Paleoanthropology. Geological Survey of Pakistan, Information Release 248.

Key words: Paleoanthropology, siwaliks.

S/269. Shah, S.R.A., 1990-92. Geological mapping and evaluation geotechnical properties of decorative stones of Nauseri-Muzaffarabad and Garhi Habibulllah area Neelum valley, Azad Kashmir. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 1-116.

The geotechnical properties, dynamic and static test results are presented for three types of rocks ranging in age from pre-Cambrian to Permian. Attention was drawn to the different geotechnical properties of these rocks and hence, the variation in their stability as decorative stones. Comparison was made between a number of the static properties of the rocks and the geotechnical performance. The study emphasizes the importance of those properties relevant to particu1application as building or decorative stones. An indication is given of the suitability of these rocks to the main construction geomaterial uses, building stones, riprap, decorative, stone, roadstone, aggregate dressing and concrete. The geotechnical properties like compressive strength, crushing strength, water absorption, water content, soundness, Abrasion resistance, Porosity and specific gravity evaluation suggest that the rocks are suitable for decorative purposes.
Key words: Mapping, geotechnical properties, decorative stones, Garhi Habibullah, Neelum Valley, Mansehra, Azad Kashmir.

S/270. Shah, S.S. & Khan, S., 1970. Geology of part of Swat between Khwaza Khela and Lillunai. M.Sc. Thesis, Peshawar University.

This is a report of the geological, work, covering about 20 sq.m of Khwaza Khela area. The purpose of this work is to study the nature of the contact between the Upper Swat Hornblendic Group and the lower Swat-Buner Schistose Group of Martin et al (1962), and to study the Hornblendic Group in some detail. Most of the area is covered by the Hornblendic Group, which is classified into: -

1) Banded Gneisse
2) Amphibolite
3) Diorite
4) Minor alpine ultramafics and pegmatites

The rocks are regionally metamorphosed, hornblende and Epidot are very common minerals (along with feldspar). The schistose group is represented by;-
1) Green Schist
2) Phyllite schists
3) Garnet-mica schist

The Hornblendic Group strikes North-East and dips North-West, whereas the Schistose Group strikes North-South. Close to the contact, variations are common in the dip and strike due to thrusting. The area is a continuation of the western part of the Himalayan mountain. Age of the Hornblendite Group is so far not certain but mostly agreed upon Precambrian, while the Schistose Group is proposed to be Silluro-Devonian age.
Key words: Geology, Khawaza Khela, Swat.

S/271. Shah, S.Z., Muhammad, T., Shafiq, M. & Wais, M., 1997. Structure and stratigraphy of a part of Kohat Plateau, northeast of Mittha-Khel, District Karak, N.W.F.P., Pakistan. M.Sc. Thesis, Department of Geology, University of Peshawar, 53p.

The exposed rocks of the area under study range in age from Eocene to Pliocene and belong to the Chharat, Rawalpindi and Siwalik groups. The Chharat Group is represented by the Jatta Gypsum, Kuldana and Kohat formations. The Kohat Formation is unconformably overlain by the Kamlial Formation of Rawalpindi Group which is in turn overlain by the Chinji and Nagri Formations of the Siwalik Group. The proposed structural model which is based on detailed field traverses shows large scale south-verging folds and a series of hinterland dipping fore thrusts and foreland dipping back thrusts, emerging from a basal decollement located within the Jatta Gypsum. The structural geometry of all these faults have resulted in the development of imbricate structure in the eastern part of the mapped area and a pop-up structure in the western part. The imbricate structure comprises of two fault-bounded horses which repeat the stratigraphic units of the area. The pop-up structure is bounded by a fore and back thrust with opposing vergence directions. The structural geometry of the area is typical of the foreland fold and thrust belt and the sequence of faulting is from interior to exterior i.e. break forward sequence of faulting.
Key words: Stratigraphy, structure, Kohat Plateau, Karak, Pakistan.

S/272. Shah, Z., 1978. Mineralogy and petrology of the Loe-Shilman carbonatite complex, Khyber Agency. M.Sc. Thesis, University of Peshawar, 35p.

Key words: Mineralogy, petrology, carbonatite complex, Loe-Shilman, Khyber Agency.

S/273. Shahid, M., 1995. Depositional environments of the Misri Banda and Panjpir Formation, Peshawar Basin, NWFP. M.Phil. Thesis, University of Peshawar, 44p.

The Early to Late Ordovician Misri Banda Formation of Peshawar basin is an approximately 280 meters thick siliciclastic sequence of interbedded fine to medium grained quartz arenites and shales. On the basis of sandstone to shale ratios, bed thickness and characteristics, sedimentary structures, five lithofacies are recognised. These are lithofacies MBl, basal conglomerate and sandstone lithofacies; MB2 cross laminated sandstone lithofacies; MB3 medium grained quartz arenite lithofacies MB4 laminated shale lithofacies and MB5, sandstone interbedded with shale lithofacies. These lithofacies are interpreted to have been deposited in foreshore (intertidal) to shelf below the storm wave base. Lithofacies MB1 was essentially deposited on beach to foreshore environments. The lithofacies MB2 was deposited in a shoreface set up and lithofacies MB3 on foreshore. Lithofacies MB4 and MB5 were deposited in shelf environment. The forinerone in deeper and below storm wave base while the last one in a comparatively shallow set up. The deposition of these lithofacies when viewed in a chronological order indicates transgressive regressive trends of the sea at the time of their deposition.
Similarly five lithofacies were identified in about a 800 meters thick Panjpir Formation of Silurian age. These are lithofacies PF7, argillite; PF2, papery laminated shale with sandstone lensoid bodies; PF3, argillite with interbeds to sandstone; PF4, bioturbated quartz arenite and PF5, calcareous sandstone and sandy limestone with dark grey shale. These lithofacies are interpreted to have been deposited in shelf to foreshore set up. Lithofacies PFJ was deposited in shelf with partially restricted environments which prevailed up to the deposition of lithofacies PF2. However, the

environments became open and shallower during the deposition of lithofacies PF3 and PF4 which were deposited in shallow shelf and foreshore set up respectively. The deposition of lithofacies PF5, as interpreted, in restricted shelf indicates another deepening episode. The overall stratigraphic arrangements of the lithofacies of Misri Banda Formation and Panjpir Formation with MB1 the oldest and PF5 the youngest lithofacies, suggest several transgressive and regressive episodes and therefore several parasequence boundaries are identified within these formations.
Key words: Depositional environment, Misri Banda Formation, Panjpir Formation, Peshawar Basin.

S/274. Shahid, M., Tanoli, S.K., Haneef, M. & Jaswal, T.M., 1997. Lithofacies and depositional environments of Misri Banda Formation (Ordovician), Peshawar Basin, Pakistan. Abstracts, 3rd Pakistan Geological Congress, University of Peshawar, p.60.

The Early to Late Ordovician Misri Banda Formation of Peshawar basin is an approximately 280 meters thick siliciclastic sequence of interbedded, fine to medium grained, quartz arenites and shales. On the basis of sandstone to shale ratios, bed thickness/geometry and sedimentary structures, five lithofacies are recognised. These are lithofacies MBI, basal conglomerate and sandstone; MB2, cross laminated sandstone; MB3, medium grained quartz arenite; MB4, laminated shale and; MB5, sandstone interbedded with shale. These lithofacies are interpreted to have been deposited in from foreshore (intertidal) to shelf environments. Lithofacies MB 1 was essentially deposited on beach to foreshore environments. The MB2 was deposited in a shoreface set up and MB3 on foreshore. Lithofacies MB4 and MB5 were deposited in shelf environment. The former one in deeper and below storm wave base while the last one in a comparatively shallow set up. Lithofacies MB2 and MB3 are repeated several times in Misri Banda Formation. The deposition and repetitions of these lithofacies, when viewed in a chronological order, indicates several transgressive/regressive trends of the sea at the time of their deposition.
Key words: Depositional environment, Misri Banda Formation, Panjpir Formation, Peshawar Basin.

S/275. Shahid, M., Tanoli, S.K., Haneef, M. & Rehman, K., 1997. Lithofacies and depositional environments of Panjpir Formation (Silurian), Peshawar Basin, Pakistan. Abstracts, 3rd Pakistan Geological Congress, University of Peshawar, p.61.

About 800 meters thick Panjpir Formation (Silurian) of Peshawar basin is dominantly argillite and shale with crinoidal limestone and arenite. Five lithofacies are identified on the basis of lithology, bed thickness/geometry and sedimentary structures. These are lithofacies PFI, argillite; PF2, papery laminated shale with sandstone lensoid bodies; PF3, argillite with interbeds of sandstone; PF4, bioturbated quartz arenite and PF5, calcareous sandstone and sandy limestone with dark grey shale. These lithofacies are interpreted to have been deposited in shelf to foreshore set up. Lithofacies PFI was deposited in shelf with partially restricted environments which prevailed up to the deposition of lithofacies PF2. However, the environments became open and shallower during the deposition of lithofacies PF3 and PF4 which were deposited in shallow shelf and foreshore set up, respectively. The deposition of lithofacies PF5, as interpreted in restricted shelf, indicates another deepening episode.
Key words: Depositional environment, Misri Banda Formation, Panjpir Formation, Peshawar Basin.

S/276. Shahid, N.K., 1964. Geology of Rajdhawari pegmatites, Oghi subdivision, Hazara District, West Pakistan. Geological Survey of Pakistan, Information Release 19, 188p.

Key words: Geology, petrography, **p**egmatites, Mansehra, Hazara.

S/277. Shahid, S., 1986-88. Stratigraphic studies of Jabri Area southern Hazara. M.Sc. Thesis, Punjab University, Lahore, 129p.

Key words: Stratigraphy, Hazara.

S/278. Shahnawaz, R., Chaudhry, M.N., Ghazanfar, M. & Sameeni, S.J., 1993. Reconnaissance microfacies studies of Margala Hill Limestone, Jabri Area, Southern Hazara, Pakistan. Pakistan Journal of Hydrocarbon Research, 5 (1&2), 53-62, 2pls.

Key words: Reconnaissance, microfacies, Margala Hill Limestone, Hazara.

S/279. Shahnawaz, R.K., Chaudhry, M.N., Ghazanfar, M. & Sameeni, S.J., 1992. A reconnaissance microfacies studies of Margalla Hill limestone, Jabri area, southern Hazara, Pakistan. Abstracts, 1st South Asia Geological Congress, Islamabad, p.54.

Key words: Reconnaissance, microfacies, Margalla Hill limestone, Hazara.

S/280. Shahzad, M.S., 1992-94. Sedimentary petrology/sedimentology of early Paleocene Lockhart limestone of Changla Gali and lihtostructural mapping of Barian area Hazara, North West Himalaya, Pakistan. M.Sc. Thesis, Punjab University, Lahore, 96p.

A comprehensive study of Geology and Structure of Barian area (Distt. Abbotrabad) is presented with special emphasis on the sedimentology of Lockhart Limestone of Early Paleocene age. Large scale (1:21120) geological mapping of a small segment (50 square km) of Attock Hazara fold and Thrust Belt (AHFTB) of Lesser Himalaya in Barian area within the geographic coordinates: longitudes, 73° 21' 45" to 73° 25' 15": Latitude, 33° 55' to 33° 59' 30" has carried out. The project area comprises nearly 50 sq. km on both sides of the Murree-Khaira Gali road. The Murree Ayubia road passes through the area. The lithostratigraphic units range in age from Middle Jurassic Samanasuk formation to the Murree Formation of Early Miocene age. Structurally, the area is comprised of a number of major fold structures and faults. The core of the Chhumbi Anticlinorium in the extreme north west of the area comprises of M. folds with near vertica1 tight synclinal in folds of Lumshiwal Sandstone. At Darya Gali, there is an opposing vergence of folds across MBT (Darya Gali fault). A number of closely spaced faults together constitute the Khaira Gali Fault zone in the southeast in the core region of Chhumbi Anticlinorium. A detailed study of sedimentary petrology of Lockhart Limestone of Early Paleocene has been carried out to unrave1 the environment of deposition and diagenesis of the Lockhart Limestone was deposited on open shelf. It has been divided into lower wackstone and an upper packstone facies which in turn contains sixteen microfacies. However, the lower wackstone indicates lower nutrient supply due to which the biological activity was relatively at lower level. The upper packstone facies marks an increase in the supply of nutrients proliferation of biological activity.
Key words: Sedimentary petrology, sedimentology, Paleocene, Lockhart limestone, mapping, Abbottabad.

S/281. Shahzad, T., 1994-96. Geotechnical studies along Pakistan Motorway project Kallar Kahar and Chakri Area & Geological mapping of Khanpur Dam area Haripur, Hazara District, Pakistan. M.Sc. Thesis, Punjab University, Lahore, 98p.

Key words: Geotechnical, mapping, Kallar Kahar, Khanpur Dam, Haripur.

S/282. Shaikh, P.I., 1976. Geology and petrology of Dainyor–Hini area, Gilgit Agency. M.Sc. Thesis, Punjab University, Lahore.

Key words: Petrology, Dainyor, Gilgit.

S/283. Shakoor, A., 1976a. The geology of Muzaffarabad–Nauseri area, Azad Kashmir, with comments of the engineering behavior of the rocks exposed. Geological Bulletin, University of Punjab 12, 78-89.

Detailed geological mapping of about 200 sq. miles of Muzaffarabad – Nauseri area has been done on a scale of 1″: 0.263miles. In all, seven rock units have been differentiated. Location, contact relationships, lithology, structure, and engineering behavior of each of these rocks are described briefly. Nauseri Granite gneiss has been mapped and described for the first time. The regional structure of the area has been described.
Key words: Engineering geology, granite gneiss, maps, Azad Kashmir.

S/284. Shakoor, A., 1976b. A preliminary study of landslides and bridge failures along Muzaffarabad-Nauseri-Tithwal road of Azad-Kashmir. Geological Bulletin, University of Punjab 13, 99-106.

A 35 miles long stretch of Nilum valley road, from Muzaffarabad to Jargi, has been investigated to study landslides, bridge failures, and other problems associated with this important but badly maintained road. A map showing geology on both sides of the road has been prepared and the areas, which are most susceptible to slope failure, are delineated along the road. Also the portions where retaining walls are needed have been marked. Suggestions for improving the present condition of the road are also made at the end of the paper.
Key words: Engineering geology, granite gneiss, Azad Kashmir.

S/285. Shakoor, A., 1986-88. Geology and petrology of the Eastern Chilas calc-alkaline complex in the vicinity of Chilas (District Diamar) with special emphasis on petrogenesis of the rock units. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan 105p.

A geological map of 301 sq. km. between Pain Ges Gah Helor Gah in the north of the Indus River and Thuly Gah in the south in Chilas area is presented at the scale of 1:25,000 on toposheet No's 43 E/15, 43 I/9 and 43 I/7 issued by the survey of Pakistan. Most of the project area lies in the vicinity of the north side of the eastern Chilas Complex. The exposed sequence of rocks in the project area is a part of the northern limb of the Chilas Complex, where ultramafic rocks occur in the core of the anticline and is overlain by norite, gabbronorite and diorites. This is capped by metadiorites of Early Jurassic age which is a part of Kamila Amphibolite. Field and petrographic study show that the rocks of the Chilas Complex are formed with in a separate magma chamber and igneous in nature. There is a younger silt like leuco dioritic pluton emplaced in metadiorite. The leuco diorite hosts a small ultramafic body which has probably been formed by a magmatic protrusion of ultramafic composition and is not related to ultramafic rocks in core of the Chilas Complex.
Key words: Petrology, petrography,petrogenesis, Chilas complex, Kohistan arc.

S/286. Shakoor, A., 1987. A preliminary survey of landslide hazards along the Karakorum Highway, northern Pakistan. Annual Meeting, Association of Engineering Geologists 30, p.50.
Consult Shakoor (1994) for additional information.

Key words: Landslides, KKH.

S/287. Shakoor, A., 1992. A Preliminary evaluation of landslide hazard along the Karakoram Highway, Northeastern Pakistan. Abstracts, First South Asia Geological Congress, Islamabad, p.37.

Consult the following account for further details.
Key words: Landslides, KKH.

S/288. Shakoor, A., 1994. A Preliminary evaluation of landslide hazard along the Karakoram Highway, Northeastern Pakistan. In: Ahmed, R. & Sheikh, A.M. (Eds.), Geology in South Asia--I. Proceedings of the First South Asia Geological Congress, Islamabad, 1992. Hydrocarbon Development Institute of Pakistan, Islamabad, 347-353.

The Karakoram Highway, known as the world's highest and the most difficult road ever built, is a 500 mile (800 km) long road that links Islamabad, the capital of Pakistan, to the Xinjiang Province in China. It took 25,000 workers nearly 20 years to construct the Karakoram Highway which first runs along the Indus River from Thakot to Gilgit, and then along the Hunza River to the Chinese boarder. Twenty-nine million cubic yards of rock had to be moved during the construction stage. The highway cuts across three major ranges including some other world's highest mountains, and ascends from an elevation of 5,000 ft (1,515 m) near Thakot to over 16,000 ft (4,800 m) near Khunjerab Pass at the Chinese boarder.
Landslides and other forms of slope failure have been the most serious problem along the Karakoram Highway both during and after its construction. Over 1,000 people died during the construction of this road, mostly due to landslides and rock falls. Since its opening to heavy traffic in 1979, it has seldom been free from, obstruction caused by landslides, many of which resulted in fatal accidents. The presence of a large variety of highly jointed rock types, loosely deposited glacial sediments, extremely high and steep slopes, melt and occasional occurrence of large earthquakes are the important factors that contribute to slope failures along the Karakoram Highway. Rock falls, plane failures, wedge failures, toppling slumps, debris slides, debris flows and mudflows are common along the Highway. The largest and the most devastating failures occur in the glacial deposits. Examples of these various types of slope movement are presented.
Key words: Landslides, KKH.

S/289. Shakoor, A. & Chaudhry, M.N., 1965. Geology of Khaki area, Hazara. M.Sc. Thesis, Punjab University, Lahore.

Key words: Maps, geology, Hazara.

S/290. Shams, 1979-81. Lithostructural mapping of Kalapani, Kathwal, Kakul Area, District Abbottabad. M.Sc. Thesis, Punjab University, Lahore, 235p.

The project area (Kakul, Kathwal and Kalapani) lies on the western flank of the Hazara Kashmir syntaxial bend of erosional cycle is of youth stage. The weathering of chemical nature mainly aided by mechanical action of water ice in winters. The valleys are mostly 'V' shaped. On the basis of climatic conditions and other physiographic features, it is concluded that the mapped area is in 'Maritime' morphogenetic region.
The rocks of the area were deposited in the Himalayan part of Tethys geosyncline and range in age from Mesozoic to Tertiary, along with Hazara Formation of Precambrian Era. All the rocks of the project area are sedimentary in origin. The Hazara Formation however, is affectedly metamorphism. The area is interrupted by two disconformities marked by laterite, one between Samana Suk Formation and Chichali Formation and others between Kawagarh Formation and Hangu Formation.
An attempt is made to reconstruct the depositional environments of the formation in detail. For the ancient environmental analysis different factors are brought under consideration.
Petrographic analysis of the rock samples has been made to construct the ancient geological environments of deposition and is also used to determine the economic value of the rocks. The geological history of the area is constructed on the basis of detailed study of structure, tectonics, depositional environments, fossils and sedimentary structures.
The structure of the area is complex. The folds are asymmetric recumbent and overturned with their axis in NE-SW directions. The general strike of the formation is NE-SW, but may change locally. Faults are of reverse and pseudonormal type. A brief description of tectonic behaviour of each rock unit also described. The structure of the area under consideration is the result of Himalayan Orogeny.
Key words: Geomorphology, weathering, metamorphism, Hazara Formation, Kakul, Abbottabad.

S/291. Shams, F.A., 1956a. Some of the recently discovered mineral species. Pakistan Journal of Science 8, 38-40.

Key words: Minerals, new discovery.

S/292. Shams, F.A., 1956b. Dunite occurrence near Chilas, Gilgit Agency. Abstract volume, 8th All Pakistan, Science Conference, Lahore.

Key words: Ultramafics, dunite, Chilas.

S/293. Shams, F.A., 1961. A preliminary account of the geology of the Mansehra area, District Hazara, West Pakistan. Geological Bulletin, Punjab University 1, 57-63.

A preliminary map and a short account of the geology and the regional structures of the Mansehra area are presented. The area consists mainly of regionally metamorphosed arenaceous schists and quartzites; and granites and granite gneiss of varying age. Dolerite intrusions are common; and much of the area is covered by alluvium. Preliminary studies indicate that the older granites were emplaced as sheets and the younger granite intruded as a small cross-cutting plug-like body.
Key words: Maps, structure, metamorphism, granite, dolerites, Mansehra.

S/294. Shams, F.A., 1963a. Reaction in and around a calcareous xenolith lying within the granite-gneiss of Manglaur, Swat state West Pakistan. Geological Bulletin, Punjab University 3, 7-18.

The results of mineralogical and petrographic studies of an inclusion, lying within the Swat granite-gneiss and now composed mainly of skarns, are described in relation to the geological environment. The probable reactions that took place under the influence of the granite are discussed. It is concluded that combined thermal and metasomatic contact action must be assumed to have occurred if the present mineralogy of the xenolith with its skarns is to be accounted for.
Key words: Mineralogy, petrography, skarn, granite, Swat.

S/295. Shams, F.A., 1963b. The effect of thermal metamorphism upon calcareous nodules in the quartz-mica schists of the Mansehra area, Hazara District, West Pakistan. Geological Bulletin, Punjab University 3, 25-27.

The results of a petrographic study of a band of calcareous nodules, situated within the quartz-rich mica schists near the southern contact of the Mansehra granite, are described. Under the thermal influence of the granite, reactions and recrystallizations took place, which are further discussed.
Key words: Petrography, metamorphism, granites, Mansehra.

S/296. Shams, F.A., 1963c. An inky blue beryl from Swat State. Geological Bulletin, Punjab University 3. p31.

Some time ago, three crystals of an inky-blue mineral were sent from Swat State to the writer for identification. The mineral was quickly identified as a species of beryl but its unusual colour suggested further study. Megascopically, all the three fragments of crystal show perfect hexagonal symmetry with occasional unequal development of prism faces. The terminal faces are not present, having been broken off during extraction from the rock. The fresh interiors show traces of a whitish material, identified microscopically as quartz, zonally distributed and extinguishing simultaneously. In plane-polarised light, the beryl is markedly pleochroic from colourless to bluish. Under crossed polars a very fine cross-hatched twinning of the microcline type is seen. Also seen is a haphazard, non-uniform and patchy extinction; the areas with weaker illumination yield perfect uniaxial interference figures while the others show a distinct biaxial nature with a 2V of 10° to 15); this feature was also noted in the green beryl (emerald) of Swat by Davies (1962). In the present example, the dual optical character may mean, either that the hexagonal symmetry is simulated by means of a fine polysynthetic twinning of aragonite type (Winchell, 1951), or that the higher symmetry originated at a higher temperature and broke down on cooling. Refractive index measurements on these crystals, in white light, gave; w=1.607 and € = 1.599 (both±0.001), while the majority of beryls have w values within the range 1.568 to 1.602 (Winchell, 1951). This inky-blue beryl is similar to one described by Schallar et a1.

(1962), from Arizona, U. S. A., which was reported to contain an unusually high cesium content and to be low in lithium. The mineral is being further studied.
Key words: Gems, beryl, Swat.

S/297. Shams, F.A., 1963d. Lead mineralization in Abbottabad area, Hazara District, West Pakistan. Economic Geology 58, 605-608.

Description is given of thin veins containing lead in Hazara slates of Abbottabad area.
Key words: Mineralization, Hazara slates, Abbottabad,

S/298. Shams, F.A., 1964. Kyanite pseudomorphing andalusite in hornfelsed pelitic schists of Amb State, West Pakistan. Geological Bulletin, Punjab University 4, 23-28.

Kyanite pseudomorphs after andalusite have been discovered in certain contact metamorphic rocks of the Amb State area. These show no evidence of the action of shearing stress and appear to have developed under conditions of strong hydrostatic pressure, following thermal metamorphism of the pelitic rocks. Theoretical implications are discussed.
Key words: Pseudomorphs, metamorphic rocks, Kynanite, Amb state, Hazara.

S/299. Shams, F.A., 1965a. Mineral differentiation in crenulated schists. Geological Bulletin, Punjab University 5, 48-50.

A kind of metamorphic differentiation of quartz and mica in crenulated schists has recently been explained by Rast (1965 p. 89-90) on the basis of migration of mica minerals towards areas of maxi- mum flexure. On the other hand, Nicholson (1 966) I p. 209-210) has attributed mobility of silica towards less strained areas of the fold hinges, thus leaving behind a mica enrichment in the flanks. In addition to these minerals, silicates containing iron, magnesium and aluminium also show noteworthy behaviour. Rast (loc. cit. p. 90) has commented that "The siting of porphyroblasts containing iron, magnesium and aluminium is strongly influenced by phyllonitic minerals. The common over-growth of garnet on the limbs of flexures suggests a common nucleation on the biotite (or muscovite) of the flexures". Thus it is suggested that the crystallization of garnet, and presumably of other such basic silicates, is determined only by the pre-location of biotite etc. and that they themselves do not show any particular behaviour while the rock is suffering crenulation folding. The writer's observations is based on work in the Mansehra-Amb State areas of northern West Pakistan, do not lend support to this idea. The present note is intended to draw attention to certain interesting pieces of evidence which have a bearing on the problem. In the Mansehra-Amb State areas, regionally metamorphosed pelitic to psammitic schists had suffered refolding during a tectonic phase connected with the Himalayan orogeny; syntectonic growth and neocrystallization of garnet, staurolite and chlorite being common. Due to their some- what equidimensional porphyroblastic nature, 7 the pre-existing garnet crystals appear to have suffered rotation with continued growth and are mostly located near or in the crestal regions of the folds, as if the old schistosity had flowed around them. The garnet crystallization that took place during crenulation led to the growth of distinct shells around the pre-existing crystals; the shells enclose inclusions of groundmass minerals in the helicytic fashion. In addition a new generation of garnets arose within similar regions of the folds.
Key words: Schists, metamorphic rocks, differentiations.

S/300. Shams, F.A., 1965b. An occurrence of kyanite pseudomorphs after andalusite from Amb State, West Pakistan. Mineralogical Magazine 35, 669-670.

The Arab State area makes part of the western limb of a regional syntaxial arc of the north-western Himalayas. It consists of politic and psammitic schists and quartzites, intruded by granitic gneiss, while the whole area is cut sporadically by doleritic minor bodies. The highest grade of metamorphism reached by the schists is marked by almandine garnet while andalusite and cordierite-bearing hornfelses are developed at the granite contact. Nothing has yet been published on this area although a preliminary account on the adjoining Mansehra area has been published (Shams, 1961). Recently, during field investigation of the aureole rocks near Choian (grid 896394 1" topographic sheet No. 43B/15, Survey of Pakistan), certain hornfelses were found in which the andalusite had

suffered transformation into kyanite in such a manner that the original shape and twinning of the andalusite are remarkably well preserved. These rocks are heavy, tough and dark coloured and, in addition to pseudomorphs, consist of quartz, muscovite, biotite, garnet, and tourmaline etc. The pseudomorphs lie preferably within weak foliation planes of the rock and show rough parallelism of their longer dimensions, although all orientations are present (fig. 1). Their size varies from very tiny to as big as 2"X ~"X a,, and rarely even bigger individuals are present. Their surface is generally coated with a brownish micaceous material while the freshly broken surfaces show the typical bluish colour of kyanite. Inside the pseudomorphs the kyanite blades are arranged in completely haphazard manner, minor amounts of quartz and muscovite are also present, the latter being at, least partly of alteration origin. The kyanite gave: a 1"713,/3 1"720, F 1"725 (all • measured in filtered white light), 2Va -- ~ 82 ~ sp. gr. = 3"43. The shape and the interpenetration twinning of the andalusite is so well preserved (fig. 2) that shearing stress, in the sense of Harker (1939), does not appear to have played any significant role during pseudomorphism. On the basis of field observations, it is concluded that the inversion took place when the hornfelsed meta-sediments were acted upon by confined hydrostatic pressure that had developed during the FIGS. 1 and 2 : fig. 1 (left). Sketch of a rock bearing kyanite pseudomorphs after andalusite. Note a broken crystal at the top. FIG. 2 (right). Photograph of kyanite pseudomorph after twinned and Musite expansion of the granite body. This mode of formation compares well with that of the Southern Rhodesian pseudomorphs (Workman and Cowperthwaite, 1963) and proves that Harker's theory of stress dependence of the transformation, andalusite to kyanite, is not of universal application. This inversion can take place under the influence of pure hydrostatic pressure as well.
Key words: Pseudomorphs, metamorphic rocks, kynanite, Amb state, Hazara.

S/301. Shams, F.A., 1965c. Uranium prospecting in Pakistan. Science Chronical 3, 23-24.

Key words: Radioactive minerals, uranium.

S/302. Shams, F.A., 1965d. Magmatic granitization of batholithic dimensions as exemplified in the Mansehra area, Hazara district, West Pakistan. Abstracts, 17th All Pakistan, Science Conference, Karachi.

Key words: Magmatism, granitization, Mansehra.

S/303. Shams, F.A., 1967a. The petrology of some chloritoid and staurolite-bearing schists from the Mansehra-Amb State-area, Northern West Pakistan. Geological Bulletin, Punjab University 6, 1-9.

Petrographic description is given of some chloritoid and staurolite-bearing pelitic schists from the Mansehra-Amb State area, Northern West Pakistan. Textural evidence suggests possibility of the following reactions:

H_2 (Mg, Fe)$_2$ Al_2SiO_9+ 2H_2 KAl_3 Si_3 O_{12} + Fe_2O_3 = 4 H_2(Mg,Fe)Al_2SiO_7+3SiO_2+ KOH$H_2KAl_3Si_3O_{12}$ +
Amesitic Chlorite Muscovite Hematite Chloritoid Quartz Muscovite

2H_2K (Mg,Fe)$_3$ $AlSi_3O_{12}$ = 2H_2FeAl_2 SiO_7+ H2K Mg_3 Al Si_3O_{12} + 4 SiO_2+ K_2O+FeO
Biotite Staurolite Phlogopite Quartz Ore

Petrochemistry of the rocks is discussed. The ratio FeO+MnO+/FeO+MgO for the co-existing chloritoid and staurolite is 0.89 and 0.87 respectively, which suggests that there can be only a very narrow P – T range of co-existence of these minerals.
Key words: Petrology, chloritoid, schists, Amb state, Mansehra.

S/304. Shams, F.A., 1967b. A note on radiometric ages of the micas from granites of Mansehra-Amb State area, northern West Pakistan. Geological Bulletin, Punjab University 6, 89-90.

One of the controversial aspects of Himalayan geology is age of the granitic intrusions that form voluminous outcrops along almost all the Himalayan belt. Right from the beginning of geological work in the Himalayas, it was generally felt that these intrusives bodies could be grouped into two types (Pascoe, 1963:
(i) dominantly foliated calc-alkaline granites, with essential biotite and/or hornblende and subordinate muscovite, and accessory ore, gar- net, apatite, tourmaline and zircon. This was called the Central Gneiss or the Himalayan Gneiss. It occurs as sheet-like bodies which form continuous outcrops over long areas and show remarkable parallelism between their strike and dip and that of the foliation of the enclosing strata, and (ii) dominently unfoliated sodaclase granites with essential muscovite, tourmaline and some- time hornblende, and subordinate biotite and accessory garnet, epidote and ore minerals. In the field, they occur as small plutons or sheet- like bodies that are rather sporadically distributed and frequently intrude the Central Gneiss.
Perusal of the literature shows that there has never been any major difference of opinion about the age of second group of granites; assuming their essentially unfoliated nature, they are believed to have been emplaced during the period of waning Himalayan orogeny, and are loosely called Tertiary granites, although as Pascoe (1oc cit.) writes "the actual evidence- of such sofar found is not as widespread as it was at first supposed" (p. 420). The controversy turned upon the question of the-age of the Central Gneiss. The proposed ages range from Palaeozoic (Carboniferous, Auden (1932); Infra-Triassic, Middlemiss (1896) to Tertiary (Tertiary, Hayden (1907); early Miocene, MacMahon (1833). These ideas were based on the general concepts of the writers rather than direct evidence. On record, how- ever, is an important discovery, made by Auden (op.cit.) of a granitic pebble in the breccia at the base of the "Purple Series" of Garhwal.
Lithologically, this pebble was found to be identical to the Arwa granite, a member of the Central Gneiss, and therefore Auden claimed that the Central Gneiss cannot be younger than Carboniferous. According to Wadia (1939) there are three types of granites in Kashmir Himalayas : (i) A biotite granite, most widespread from Kashmir to Assam, (ii) A hornblende granite, less common than (i) but similar in structure and composition. It is thought to be post-Cretaceous, as it was found to be intrusive into an orbitolina limestone at the head of the Burzil valley.
No age is suggested for the biotite granite, but it is considered to be earlier than the hornblende granite; it will be pre-Cretaceous anyway, and (iii) Tourmaline granite, more recent than (i) and (ii) as it intrudes them. Misch (1949) has been concerned with the Nanga Parbat granites. He claims that the various types, as described by him and earlier recognized by Wadia (1939), have so close affinites that no real age sequence can be found. According to him the granite of Nanga Parbat is a product of syntectonic granitization while the tourmaline granites are the product of the continuation of this process in the post-tectonic period. It follows from this that the main granite is post-Cretaceous and the tourmaline granites are much younger.
Key words: Chronology, radiometric ages, granites, Mansehra.

S/305. Shams, F.A., 1967c. The granites of Mansehra-Amb State area and the associated metamorphic rocks West Pakistan. Ph.D. Thesis, Punjab University, Lahore.

This is a detailed study of the granitic rocks of the Mansehra-Amb State area, and the regionally metamorphosed rocks through which the granites are emplaced. Several varieties of granite have been identified and described. The work is a good example of field and petrographic studies. Many of the papers by the author are either the outcome of, or contributed to this work.
Key words: Granites, metamorphic rocks, Amb state, Mansehra.

S/306. Shams, F.A., 1967d. Chess-board albite in the Mansehra-Amb State area, northern West Pakistan. Pakistan Journal of Scientific Research (Punjab Univ.) 19, 79-82.

Key words: Granites, chess-board albite, Amb state, Mansehra.

S/307. Shams, F.A., 1968. The role of granitic bodies in the syntaxis of the Northwest Himalayas. Abstracts, 22nd All Pakistan Science Conference, Dacca.

Key words: Granites, Himalayan syntaxis..

S/308. Shams, F.A., 1969. The geology of the Mansehra-Amb state area, northern West Pakistan. Geological Bulletin, Punjab University 8, 1-32.

About 600 square miles of area, covering large part of Mansehra sub-division of the Hazara District and the adjoining Amb State, in northern part of the West Pakistan, has been mapped and an original geological map, on the scale of 1 inch to 1 mile has been prepared.
The area constitutes the hard crystalline core of a major syntaxial loop of the northwest Himalayas and is composed of semi-pelitic to psammitic schists and quartzites that have suffered regional metamorphism up to kyanite grade of the Barrovian type. These schists bound a large granitic complex composed of an older group of gneissic (the Susalgali gneiss) to granitiod rocks (The Mansehra granite and the andalusite-bearing granites), ranging from granite to granodiorite, and a younger group of sodclase granites (The Hakale granite, Karkala granite etc.). In addition, there are a large number of aplites and pegmatites, and a few porphyry dykes are met with. Dolerites cut the entire plutonic complex and are met with as ophitic dolerites, epidiorites and amphibolites, depending upon their age of emplacement. Details of field observations and laboratory studies are given as far as the general geological aspects of the area are concerned.
Key words: Geological map, granites, gneiss, metamorphic rocks, Amb state, Mansehra.

S/309. Shams, F.A., 1972. Glaucophane-bearing rocks from near Topsin, Swat-First record from Pakistan. Pakistan Journal of Scientific Research 24, 343-345.

Brief description is given of the first-ever discovery of glaucophane bearing rocks from Pakistan. Chemical analyses of two rocks with different mineral assemblages are given, alongwith optical data of the mineral.
Key words: Glaucophane schists, high-p metamorphism, Indus Suture, Swat.

S/310. Shams, F.A., 1975. The petrology of Thak valley, Gilgit Agency, northern Pakistan. Accademia Nazionale dei Lincei Rendiconti 59(8), 453-464.

The geology and petrography of the Thak valley between tarla Babusar and Indus river is described. Major element analyses are given for 13 rocks. The area is occupied, from south to north by, diorite group, veined diorite, and norite with bodies of dunite and ultramafic brecchia. The rocks have been considered to be tholiitic in nature.
Key words: Diorite, norite**,** ultramfic rocks, petrography, geochemistry, Thak valley, Chilas.

S/311. Shams, F.A., 1978a. A note on the obliqueties of some potash feldspars from the Hazara granitic complex, NW Himalaya, Pakistan. Geological Bulletin, Punjab University 15, 70-72.

Obliqueties of some potash feldspars, extracted from major members of Hazara granitic complex, were estimated with the help of X-ray diffractometry. The results are in harmony with the conclusions drawn from extensive field and laboratory investigations as to the permeation – granitization origin of the granitic complex.
Key words: Obliqueties, K-feldspar, granitic complex, Hazara.

S/312. Shams, F.A., 1978b. Mechanical analysis of the so-called “clay” near Ahl, District Hazara, North West Frontier Province, Pakistan. Pakistan Journal of Scientific Research (Punjab University) 7, 87-93.

Key words: Clay, mechanical analyses, Mansehra, Hazara.

S/313. Shams, F.A., 1980a. Origin of the Shangla blueschists, Swat Himalaya, Pakistan. Geological Bulletin, University of Peshawar 13, 67-70.

Chemical analyses of two metasedimentary and one meta-igneous type blueschist rocks from Swat suggest that the former type is hypersodic as compared with many of the world occurrences. The blue amphibole is crossite of

appropriate chemical composition. The rocks are believed to be of metasomatic origin, having suffered soda activity of pore fluids. A yet younger phase of soda activity originated from serpentinization of the Alpurai ultramafic mass and was responsible for growth of the albite prophyroblasts that contain helicytic trails of the blue amphibole.
The blueschist zone is taken to make a typical fossil trenchplate subduction suture in terms of theories of global tectonics. Radiometric age of muscovite from a metasedimentary blueschist type is 84 ± 1.7 m.y. or upper Coniacian, which compares suitably with other ages obtained from the region. The presence of this early Alpine subduction zone of the Swat Himalaya is taken to represent the continuation of the Indus Suture Line.
Key words: Metasediments, blueschists, Shangla, Swat, Himalaya.

S/314. Shams, F.A., 1980b. Geological evolution of the Himalayan "Central Gneiss" and its implications. Abstracts, 26th International Geological Congress, Paris, 1, p.89.

Key words: Gneiss, Mansehra, Himalaya.

S/315. Shams, F.A., 1980c. Ready Reckoner for Mineral industry in Pakistan. Oriental Enterprise Publications, Lahore, 90p.

This is a useful book. It gives all the relevant information about economic minerals of Pakistan and their industrial uses.
Key words: Minerals, uses, industry, Pakistan.

S/316. Shams, F.A., 1980d. An anatectic liquid of granitic composition from Hazara Himalayas, Pakistan and its petrogenetic importance. Accademia Nazionale dei Lincei 68, 207-215.

Three sills of granitic porphyry near Mansehra are considered to be anatectic in origin. Six chemical analyses are given.
Key words: Petrogenesis, geochemistry, anatexis, Mansehra granites, Himalaya.

S/317. Shams, F.A., 1981. Some phenomena within contact zones of the Hazara granitic complex, NW Himalayas, Pakistan. Geological Bulletin, Punjab University 16, 146-162.

Concise description is given of some important phenomena observed within contact zones between various outcrops of the Hazara granitic complex and the associated metamorphic formations. Briefly, these are recorded as thermal, structural metamorphic and hydrothermal effects, which have important bearing on origin and evolution of the granitic complex with regional implications to other parts of the Himalayas.
Key words: Hazara granitic complex, metamorphic, hydrothermal, Himalaya.

S/318. Shams, F.A. (ed.), 1983a. Granites of Himalayas, Karakorum and Hindukush. Institute of Geology, Punjab University, Lahore, Pakistan, 427p.

This is a major compilation of papers from international authors on granitic magmatism in the Himalaya, Karakoram and Hindukush region. Individual papers relevant to the present work are annotated at appropriate places.
Key words: Books, granites, Karakoram, Himalaya, Hindukush.

S/319. Shams, F.A., 1983b. Granites of N.W. Himalayas in Pakistan. In: Shams, F.A. (ed.), Granites of Himalayas, Karakoram and Hindukush. Institute of Geology, Punjab University, Lahore, 75-121.

A general review is given of the mode of occurrence, lithological subdivision, mineralogical and geochemical compositions of major granitic complexes of the NW Himalayas in Pakistan. Variation and comparative studies are utilized to interpret origin and mutual relationship among the granites. It is concluded that regional granitization

leading to anatexis had been a repeated cycle in the evolution of the granitic complexes starting with the Caledonian upheaval. Dominent are the pre-Himalayan granites while true Himalayan granites are subordinate. Pegamtitic phases are important elements in correlative petrology and shows regional application of the petrogenetic scheme proposed herewith. The process of granitisation and tectonic mobilization had been active within zones of decreased pressures due to up-warping produced as a result of northwards drift of the Indo-Pak plate. Besides internal homogenization, pre-existing rock formations suffered addition and exchange of material with the environments and the mantle-derived fluids. A special lineage of this process lead to the formation of alkaline complexes. The phenomena of reversed metamorphism is explained and the status of granitic areas as thermal highs and capable of originating tectonics is presented. Comments are made on mineral potential of granitic complexes of the Himalayas. Absolute age data are utilized in support.
Key words: Granites, NW Himalaya, Pakistan.

S/320. Shams, F.A., 1983c. Workshop on Stratigraphy of Pakistan. Age relations of granitic bodies of the Himalayas and Karakorum. Geological Bulletin, Punjab University Special Issue 18, Lahore.

Key words: Geochronology, granites, Himalaya, Karakorum, Hindu Kush.

S/321. Shams, F.A., 1983d. Plate tectonic model for the Himalayas and uranium mineralization. In: Shams, F.A. (ed.), Granites of Himalayas, Karakoram and Hindukush. Institute of Geology, Punjab University, Lahore, 299-307.

On the basis of plate tectonic model for the Himalayas and information drawn from regional geophysical surveys, speculations have been attempted regarding regions and rock formations that may have inherent potential for Uranium mineralization. Attention has been given particularly to granitic complexes on the basis of their nature of origin and mode of emplacement in relation to geotectonic episodes. Available data on some of the known Uranium occurrences have been utilized in support and suggestions are made.
Key words: Plate tectonics, uranium, mineralization, Karakoram, Himalaya, Hindukush.

S/322. Shams, F.A., 1984a. Granites of the northwest Himalayas in Pakistan. Abstracts, First Geological Congress, Lahore, 56-57.

For further information, consult Shams (1983b).
Key words: Granites, Karakoram, Himalaya, Hindukush.

S/323. Shams, F.A., 1984b. Do the Dir-Swat volcanic zones indicates split in Indo-Pak plates? Abstracts, First Geological Congress, Lahore, p.72.

In the western part of the so called Kohistan Zone in Dir and Swat, there are the belts of volcanics that do not extend eastwards over the entire length of the Kohistan Zone, although most of the other lithologies do so, such as amphibolites, norites-gabbros, diorites etc. The origin of the volcanics in Western sub-zone indicates great depths reached by the subducting Indo-Pak plate, leading to fusion of rocks and generation of magma. The eastern sub-zone no such occurrence of volcanic rocks in may indicate that eastern portion of the subducting plate reached shallower depths. If true, then the Indo-Pak plate is considered to have split, with western portion reaching greater depths as compared with the eastern portion that attained shallower depths on subduction. The line of split may coincide with the Indus re-entrant and this may also explain the restricted occurrence of blueschists and the nature of obducted Jijal block. Implications are commented upon.
Key words: Plate tectonics, volcanics, Dir, Swat, Kohistan.

S/324. Shams, F.A., 1986a. The Indus-Kohistan suture zone and blueschist metamorphism in N.W. Pakistan and its implications. Abstracts, Symposium/Workshop on Plate Tectonics and Crust of Pakistan. Institute of Geology, Punjab University, Lahore, 24-25.

Blueschist metamorphism along the Indus-Kohistan Zone was discovered in 1971 (Shams, 1972) from Swat Himalayas, while many more occurrences are now known from other parts of IKS-IS-ITS zone of the Himalayas. This unique phenomenon is believed to confirm the activity of a subduction zone. Although many plate tectonic models have been proposed regarding the origin of the Himalayas and many sutures have been suggested in northern Pakistan yet petrotectonic importance of the blueschists have not been well recognized so far. It is noteworthy that such rocks have not been discovered from the Karakorum (or Northern) Thrust zone or from the Main Boundary Thrust (MBT) which has been claimed as a Palaeozoic suture recently (Nawaz and Ghazanfar, Abs. 24). This may mean that blueschist metamorphic conditions were not prevalent along these tectonic zones. On the other hand, Permian absolute ages from Chilas and Dras (in Kashmir)basics hint towards rift status of the IKS-IS, comparable in age to the Panjal rift that is referred generally to Hercynian epirogenic movements.
On the basis of field, petrochemical and age data, it is tempting to propose that northern Pakistan (and its geologic-tectonic extensions) represents a region of tectonic pilling up of rifted longitudinal slices of Indo-Pak plate. It was only along the IS that subduction occurred while other narrow zones of longitudinal seas closed by compressional movements. The 1KB (and IS~ITS) appears to have been reactivated during Jurassic-Cretaceous, like the MBT which is now claimed being reactivated. Although the sequence of closure of various sutures is disputed and views differ even diametrically yet the subduction-zone status of the 1KB-IS-ITS is accepted by all. Therefore, the principle of pregradation of tectonic sutures southwards is not violated even in view of complex history of evolution of orogens North of the Indo-Pak plate. Various evidence and views are critically reviewed.
Key words: Metamorphism, blueschist, Indus suture, Indus Kohistan.

S/325. Shams, F.A., 1986b. Plate tectonics and crustal geology of northern Pakistan. Episodes 9, p.184.

This is a report of a conference, the abstracts of which are presented elsewhere in this work. The geotectonic map of northern Pakistan is given.
Key words: Plate tectonics, Northern Pakistan.

S/326. Shams, F.A., 1987a. Geology of Pakistan. In: Shams, F.A. & Khan, K. (Eds.), Resources Potential of Mountainous Regions of Pakistan. Centre for Integrated Mountain Research, Punjab University, Lahore, 20-26.

Key words: Pakistan geology.

S/327. Shams, F.A., 1987b. Mineral resources of mountainous regions of Pakistan. In: Shams, F.A. & Khan, K. (Eds.), Resources Potential of Mountaineous Regions of Pakistan. Centre for Integrated Mountain Research, Punjab University, Lahore, 39-44.

Key words: Mineral resources, mountainous region.

S/328. Shams, F.A., 1991a. Plate tectonics, granite emplacement and mineralization. Abstracts, 1st Postgraduate Training Course in Plate Tectonics, Punjab University, Lahore, p.5.

Key words: Plate tectonics, mineralization, granites.

S/329. Shams, F.A., 1991b. Erosion in the Yasin valley, Northern Areas. Culture Area Karakorum, Newsletter 1, p.9. Tubingen.

Key words: Erosion, Yasin valley, Gilgit.

S/330. Shams, F.A., 1991c. Erosion in the Yasin valley, Northern Areas. Mountnews 5, p.31, Lahore.

Key words: Erosion, Yasin valley, Gilgit.

S/331. Shams, F.A., 1992a. Granites and granitization in Himalayas and Karakoram. Abstracts, First South Asia Geological Congress, Islamabad, p.38.

Key words: Granites, Himalaya, Karakoram.

S/332. Shams, F.A., 1992b. Granites, granitic gneisses and granitization in the NW Himalayas. Mountnews 5, 49-51.

Key words: Granites, gneisses, Himalaya.

S/333. Shams, F.A., 1992c. Tectonic factor in mass erosion, Northern Areas, Pakistan. In: Shams, F.A. (ed.), Culture Area Karakorum Research Project in the Northern Areas, Pakistan. Proceedings of the Pak-German joint Workshop, December 1991, Lahore. 219-226.

Key words: Tectonics, mass erosion, Himalaya.

S/334. Shams, F.A., 1992-93. Plate tectonics and origin of NW Himalayas. Regional Postgraduate Training Course in Plate Tectonics, Punjab University, 17-22.

The origin of the NW Himalaya is briefly described in the light of Plate tectonics. Short comments are given on Indo – Pakistan plate, Karakoram block, the Main Mantle Thrust zone, Chalt ophiolitic mélange and major groups of rocks in the Kohistan arc. Included in the latter are the amphibolite belt, Jijal complex, Chilas complex, Kohistan batholith, Rakaposhi volcanics, and Yasin group.
Key words: Plate tectonics, Himalaya.

S/335. Shams, F.A., 1995a. Metallic raw materials. In: Bender, F.K. & Raza, H.A. (Eds.), Geology of Pakistan, Gebruder Borntraeger, 234-257.

The metallic mineral resources of Pakistan are described in this paper.
Key words: Metallic mineral, raw material.

S/336. Shams, F.A., 1995b. Natural hazards on the Karakorum Highway, northern Pakistan. In: Stellrecht, I. (ed.), Pak-German Workshop on Problems of Comparative High Mountain Research with regard to the Karakorum, Tubingen October 1992. Culture Area Karakorum, Occasional Paper 2, 22-32.

Karakoram Highway has been frequently affected by natural hazards. These include surges of glaciers and snow avalanches in the north, land slides and rock failure, rain-affected slopes, floods, and active faults.
Key words: Hazards, KKH.

S/337. Shams, F.A. & Ahmad, S., 1979a. Petrochemistry of some granitic rocks from the Nanga Parbat massif, NW Himalaya, Pakistan. Geological Bulletin, University of Peshawar 11, 181-187.

Petrographic notes and chemical analyses are given for ten granitic rocks from the Nanga Parbat massif, northwestern Himalayas. Chemical and normative variation diagrams are used to show that the granitic rocks originated through alkali metasomatism of metasediments, a specific chemical change being controlled by original composition of the particular lithologic facies. Scanty previous data are included for comparison.
Key words: Petrography, geochemistry, granites, Nanga Parbat massif, Himalaya.

S/338. Shams, F.A. & Ahmad, S., 1979b. The petrochemistry of the Thak valley igneous complex, District Diamir, northern area, Pakistan. Pakistan Journal of Scientific Research Punjab University, 31, 145-150.

Consult Shams, 1975 above.
Key words: Diorite, norite**, u**ltramfic rocks, petrography, geochemistry, Thak valley, Chilas.

S/339. Shams, F.A. & Ahmed, Z., 1968. Petrology of the basic minor intrusives of the Mansehra-Amb State area, northern West Pakistan. Part 1–The Dolerites. Geological Bulletin, Punjab University 7, 45-56.

The dolerite members of the basic minor intrusives, of the Mansehra-Amb State Area, have been subjected to detailed petrographic and mineralogical investigations. In addition to modal variation of various constituent minerals, pyroxene minerals have been studied to understand their relationship in co-existence. The chemical nature of the dolerites and their trend in mineralogical phase variations are comparable to those of the well known tholeiitic provinces of the world. An outstanding feature of pyroxenes of these dolerites is that their maximum magnesian content is higher than most of the known cases of similar origin.
This is the first detailed study of dolerites of the Mansehra-Amb State Area.
Key words: Petrology, dolerites, Amb state, Mansehra.

S/340. Shams, F.A., Chaudhry, M.N., Ahmad, N., Shaikh, R.A. Saleemi, A.A., Ahmad, S., Dean, A.Z., Sarwar, M. & Hyderi, I.H., 1984. The Punjab University expedition to Baltistan, NE Pakistan. Geological Bulletin, Punjab University 19, 1-68.

Report is given of geology and petrology of the northeastern part of the Shigar valley, Baltistan, including structural and geomorphologic information. An original geological map on 1:12,500 scale is presented on the basis of an expedition carried out during the summer, 1982. Significant achievements are briefly stated including economic mineral resources of the area. The program was part of the University Centenary Celebration planned by the Institution. The project will continue for a few years.
Key words: Petrology, structure, geomorphology, mineral resources, Baltistan.

S/341. Shams, F.A., Jones, G.C. & Kempe, D.R.C., 1980. Blueschists from Topsin, Swat District, NW Pakistan. Mineralogical Magazine 43, 941-942.

BLUESCHIST rocks, the first to be found in Pakistan, were reported by Shams (1972) from near Topsin (34^0 53.5' N.; 72^0 34-5' E.) and also by Desio (1977) from Shangla, a nearby locality also in Swat District, northern Pakistan. Recently, further occurrences were reported from the area by Tahirkheli (1979). The rocks form part of the so-called Lower Swat-Buner Schistose Group of Palaeozoic age (Martin *et al.,* I962). To the north the blueschists are bounded by an amphibolite zone which is succeeded by a basic complex, considered to have suffered regional metamorphism up to the granulite facies (Jan and Kempe, i973; Jan, 1979a, b). On the north-east is an alpine-type serpentinite mass thought to be a tectonically emplaced block (Jan, 1979c). Phyllite and quartzose mica schists outcrop to the east and

west, also belonging to the Lower Swat-Buner Schistose Group. To the southwest, the blueschist rock body thins out and disappears under alluvial cover. A major regional thrust immediately to the north of the Schistose Group, the so-called Patan Line, has been accepted as marking the edge of the subduction zone related to the suturing of the colliding Indian and Eurasian lithospheric plates (Desio, 1977). This thrust has since been renamed the Main Mantle Thrust by Tahirkheli *et al.* 0979), who regard it as the zone of obduction of the basic complex (the Kohistan Sequence) on to the Indian plate. This has increased the importance of the discovery of the blueschists and warrants an account of their petrology. One type of rock (14348; Table I) is schistose, greenish grey in colour, and strongly foliated with shiny, slickensided surfaces. The blue amphibole is associated with micaceous folia, along with quartz, albite, muscovite, garnet, chlorite, epidote and traces of tourmaline, rutile, sphene and apatite. A younger phase of albite (0.03% CaO) forms porphyroblasts which contain trails of matrix minerals as well as of the blue amphibole. The other type of rock (14363) is a heterogeneous, dark bluish black metadolerite, variously composed of a granular aggregate of epidote, chlorite, garnet, quartz, and minor sphene and rutile, with blue amphibole forming clusters of large crystals. The chemical compositions of the two rock types are given in Table I, along with their amphibole compositions and structural formulae. Plotting of the amphibole compositions in the Mg/(Mg + Fe 2) *versus* $Fe^{3+}/(Fe^{3+}A1^{vi)}$ diagram (fig. I) for the glaucophane-riebeckite group shows them to be crossites comparing closely with four compositions from Deer *et aI.* 0963). Thus, the blueschist rocks from Topsin illustrate typical assemblages such as are taken to mark plate subduction or obduction zones in fold mountain belts (Ernst, ~975), as in the Himalayas (cf. Farah and DeJong, I979). Their discovery shows that the anomalous status attributed to the Himalayas as collision-type mountains lacking blueschist metamorphism (Powell and Conaghan, I973) is no longer applicable.
Key words: Blueschists, geochemistry, mineral chemistry, Swat. .

S/342. Shams, F.A. & Mahmood, A., 1984. Plate-tectonic model for northern Pakistan and mineralization regims. Abstracts First Pakistan Geological Congress, Lahore, p.73.

Key words: Plate tectonics, mineralization.

S/343. Shams, F.A., Mahmood, A., Mirza, K.J., Mirza, Z.A., Ahmad, Z.A. & Siddiqui, M.A., 1983. Petrology of Shamozai area, District Dir and Swat NW Pakistan. Kashmir Journal of Geology 1, 55-60.

The first detailed description of the Shamozai area, districts Dir and Swat is given on the basis of 1: 10,000 mapping of about 206 km2 North of the River Swat and including Southern edges of the Hornblendite Complex, Kohistan Zone. Petrographic and mineralogical details of various units are given. The structural features of the area and problems of metamorphism are briefly discussed.
Key words: Petrography, metamorphism, Shamozai, Swat.

S/344. Shams, F.A. & Rehman F., 1966. The petrochemistry of the granitic complex of the Mansehra-Amb state area, northern West Pakistan. Pakistan Journal of Scientific Research (Punjab University) 1, 47-55. 68- p.150.

The granitic complex of the Mansehra-Amb State area is composed of an older group of granitic gneisses and granitoid granites, and a younger group of tourmaline-bearing granites; in addition, a large n d = r of aplitic and porphyry bodies are also associated. Representative specimens of each rock type have been analysed chemically and the petrochemical data is interpreted in conjunction with the results of field and petrographic investigations.
Key words: Petrography, chemistry, granites, Amb, Mansehra.

S/345. Shams, F.A. & Rehman, F., 1966-67. Tungsten molybdenum mineralization north of Oghi, Hazara District, West Pakistan. Pakistan Journal of Scientific Research (Punjab University) 2, 41-46.

Key words: Mineralization, Tungsten, Molybdenum, Mansehra.

S/346. Shams, F.A. & Rehman, F., 1967. An estimation of temperatures of formation of some granitic rocks of the Mansehra-Amb state area, Northern West Pakistan, and its bearing on their petrogenesis. Geological Bulletin, Punjab University 6, 39-43.

Temperatures of formation of some granitic rock of the Mansehra-Amb State area have been estimated on the basis of mineralogical reactions and transformations, and by Barth's method of two-feldspar geothermometry. The estimated temperatures range from 580ºC to 670ºC and therefore, are in the range of granitic magmas both as products of differentiation as well as that of anataxis.
Key words: Temperature estimation, chemistry, granites, Amb, Mansehra.

S/347. Shams, F.A. & Rehman, F., 1969. Study of metasomatism across a granite contact near lower Batrasi Tehsil Mansehra, District Hazara, Pakistan. Pakistan Journal of Scientific Research (Punjab University) 5, 1-12.

Field evidence of metasomatism of the metamorphic rocks had the contact with a facies of the Mansehra granite has been followed with laboratory investigations and the results are discussed.
Key words: Metasomatism, Mansehra granites.

S/348. Shams, F.A. & Rehman, F., 1973. A note on copper mineralization near Baldher, Haripur, District Hazara, North West Frontier Province, Pakistan. Geological Bulletin, Punjab University 10, 95-96.

Rare copper staining of the Hazara Slates has been known for some time but only in 1971 worth- while zone of mineralization was located near Baldher (Long. 73'6'; Lat. 33'59') about 9 miles N-E of Haripur (Fig. 1). The place was visited by authors in April, 1972. The mineralized zone represents a belt of fault breccia in the Hazara Slate Formation of Palaeozoic age. The latter are represented by khaki to steel grey coloured fine-grained slates that texturally show a status near to phyllites. Thin bands of greenish and purplish slates are sporadically present. Mineralogically, these are composed of varying proportions of quartz, muscovite, bleached biotite, chlorite, feldspar, tourmaline and ore grains etc. No detailed account of petrography of these rocks is available in literature, nevertheless, it is of no direct bearing to present problem in its restricted sense.
The fault breccia zones are recognisable due to the presence of rock rubble and conspicuous ochery colour of limonite. The angular rock fragments are strongly fractured and stained by limonite while the central portion of the breccia zone is occupied by greyish white, coarse quartz-rich material; copper mineralization is generally associated with the latter rocks. In thin section, the quartz rich breccia-zone rocks show strong cataclastic texture, composed of large strained quartz grains bordered by fine-grained strain free quartz. Wherever fractures run through the rock, quartz shows growth outward from its margins; the fractures themselves are generally healed by limonite. In addition to dominant quartz, irregularly distributed angular fragments of slate are present, which show a weak preferred orientation in specimens sampled near walls of the breccia zones. General coarsening of the rock fragments along fractures running through them is frequently seen. Such fractures, both in quartz-rich areas as well as in rock fragments, are quartz grains; occasionally intergranular spaces occasionally filled by bright green malachite, lined as well carry malachite. 111 frequent cases, galena outwardly by limonite is associated although it shows tendency to occur separately from copper mineralized areas of the breccia zone rocks.
The elemental copper content of 5 representative specimens ranges from 0.34% to 2.35% (determined by dithizone method). The primary copper mineral is chalcopyrite which alters to cuprite to malachite. Pyrrhotite is generally associated and makes veins and bands that contains tiny chalcopyrite grains. The chalcopyrite areas show boxwork alteration to reddish limonite with a thin marginal zone of pyrrhotite around chalcopyrite.
The malachite is associated with ore minerals in such a manner that its thin veins appear issuing from alteration zones and penetrating the host material. The malachite preferably fills openings in slate fragments parallel to foliation and fractures in large It appears that chalcopyrite is the primary ore and its content will increase with depth, as has been supported by exploratory digging to a vertical depth of about 10 feet. Further work is in progress.
Key words: Mineralization, copper, Haripur, Hazara.

S/349. Shamsi, K.A., 1964. Geology and structure of Khanpur-Kirala, area. M.Sc. Thesis. Geology Department, Punjab University, Lahore.

Key words: Structure, geology, Khanpur.

S/350. Sharma K.K., 1983. Transhimalayan granitoids of Ladakh and Karakorum range, Ladakh Himalaya. In Granites of Himalayas, Karakorum and Hindu-Kush, F.A. Shams ed., Punjab University, Lahore, Pakistan, 341–354.

Key words: Granitoids, Karakoram, Ladakh, Himalaya.

S/351. Sharma, K.K., 1991. Geology and geodynamic evolution of the Himalayan collision zone: a synthesis. Physics and Chemistry of the Earth 18, 431-439.

The great mountain ranges of the Himalaya and the Karakoram and the highest plateau of Tibet are the earth's unique features which according to general consensus came into being due to the successive accretions of various isolated continental and arc terranes with the converging Indian and Eurasian land masses during Late Mesozoic-Early Tertiary. The regions which were terracognita till seventies aroused global interest to generate field and laboratory data for the better understanding the geological history and the geodynamic evolution of these spectacular features. The data generated in the past two decades suggest that four major terranes Kun- lun, Qiangtang, Lhasa and Himalaya have accreted successively with one another along Litian-Jinsha suture, Banggong-Nujiang suture and Indus-Zangbo suture, respectively (see Inset Map-1 of the compiled geological map). More detailed studies of these collision zones are likely to provide information to reconstruct the chronology of various events, as has been possible to some extent in the case of the Himalayan collision zone. A number of micro-terranes, such as the Kohistan island arc, the Ladakh island arc and the Gangdise continental arc, evolved and sutured in different stages and at different times, resulting in the Himalayan collision zone. The information on other collision zones occurring to the north of this zone is also increasing and a multi-disciplinary effort by Chinese (Academia Sinica) and British (Royal Society London) scientists during June, 1985 (Chang Chengfa et al., 1988) has further added to our knowledge of these collision zones. This attempt followed the successful endeavour of the Chinese and French scientists who carried out joint studies during 1981 in the southern Tibetan region of the Lhasa sector of the Himalayan collision zone. In the classical concept of the plate tectonics and orogeny, the rifting of the continental lithosphere initiates under a hot convecting column which ultimately drives the rifted continent blocks apart with opening of the sea and creation of the oceanic crust in-between the separated blocks. At some stage of its growth, the oceanic crust starts subducting to give rise to an island arc or a continental arc depending upon Mariana or Chilean type subduction.
Key words: Geodynamics, India, Eurasia, Mesozoic, Tertiary.

S/352. Sharma, K.K., 1994. Geological map of the Himalayan collision zone. 101 (H.L.O.) Printing Group of Survey of India.

This map covers the area of the greater Himalayan region from the eastern syntaxis upto Kabul and show all the major lithologies. There are also five inset maps showing tectonic features, distribution of metamorphic belts, granitoids and volcanic rocks.
Key words: Geological map, Karakoram, Himalaya.

S/353. Sharma, K.K. & Gupta, K.R., 1978. Some observations on the geology of the Indus and Shyok Valley, Ladakh: In: Recent Researches in Geology 7, Hindustan Publications Corporation, Delhi, 133-143.

Key words: Geology, sutures zones, Indus, Shyoke.

S/354. Sharma, K.K., Sharma, O.P., Choubey, V.M. & Nagpaul, K.K., 1981. Age of Ladakh-Deosai granite batholith, Trans-Himalaya. Current Science 50, 819-821.

Key words: Granitic batholith, Ladakh, Deosai, Trans Himalaya.

S/355. Sharma, K.K. & Virdi, N.S., 1997. Extensions and analogues of Lesser and Higher Himalaya vis-à-vis the status of the Main Central Thrust in the NW Himalaya - comparative study in the Indian and Pakistan segments. Abstracts, 3rd Pakistan Geological Congress, University of Peshawar, p.62.

Key words: MCT, Lesser Himalaya, Higher Himalaya, India, Pakistan.

S/356. Shaukat, M. & Sattar, A., 1986. Geology and structure of the central part of Attock-Cherat Range. M. Sc. Thesis, Peshawar University.

Key words: Structure, petrology, Attock-Cherat range, NWFP.

S/357. Sheikh, A.A., 1988-90. Geological mapping and economic geology of the metamorphic rocks (Gokdarra-Ghaligai), Swat District. M.Sc. Thesis, Punjab University, Lahore, 84p.

The detailed geological map of the project area has been prepared. The project area has been mapped on a scale 1" = 12500" = 12,500'. This thesis consists of two sections. Section No.1 deals with the general geology of the project area. Introduction, Physiography, Structural Geology & Tectonics and the lithologic units of the project area have been discussed in this part. In Section No.2, Petrography, Chemical analysis, Petrogenesis, Discussion on Petrogenesis, Economic Geology and SOME THING, NEW ONE (Dolomite/Wollastonite Skarn) in the project area is discussed. The project area is consisting upon the metasedimentary and metamorphic rocks which lie in the Higher Himalaya Crystallines of the MMT Zone. The rock units belong to Lower Swat Buner Schistose Group and are of Lower Palaeozoic age.
Key words: Mapping, metamorphic rocks, economic geology, Swat.

S/358. Sheikh, A.M., 1983-85. Litho-structural studies of Fitni-Bhirina-Paniali and Haddo Bandi Area, District Mansehra. M.Sc. Thesis, Punjab University, Lahore, 162p.

There is a specific relationship between the geological structures, landforms and the climate. This relationship can be worked out by qualitative as well as quantitative analysis of the topographic map. The most commonly exposed lithologies in the project area are schists from chlorite to garnet grade, Susalgali granite gneiss, Mansehra granite, quartzites and hornfelses. The rocks of the project area have been classified into nine lithologic units for the sake of mapping purposes at a scale of 9.2 Cm. to a kilometer on 5.8 inch to a mile. The area is deformed by different deformation phases, among which three are recognized on mesoscopic as well as microscopic scale and area is characterized by heterogeneous deformation. The rocks have been folded isoclinally and later being refolded into open folds. The area lies in the zone of brittle deformation and show extensive fracturing instead of folding. Mesoscopic and microscopic deformational features are well developed in the area. The rocks exhibit effects of polymetamorphism. The thermal metamorphism is superimposed on the regional metamorphism.
Key words: Lithology, structure, Mansehra, Hazara.

S/359. Sheikh, I.A., 1973-74. Engineering geology of Muzaffarabad-Tithwal, Azad Kashmir. M.Sc. Thesis, Punjab University, Lahore.

Field mapping of about 200 miles2 of the Neelum Valley area from Muzaffarabad area to Jari have been done on a scale of 1″=0.263 miles. Nauseri granite gneiss has been identified and mapped for the first time. A description of

the location, aerial extent, contact relationships, lithology and petrography, structural features and engineering behavior of each of the rock types shown on the map is given. This is followed by separate chapter on the structure of the area.
A detailed study of the existing Muzaffarabad-Tithwal road has been made with respect to its alignment and the problems associated with it such as those of landsliding, bridge instability and poor drainage. The rocks exposed at the proposed Nuraseri bridge site have been studied and engineering tests have been performed on the samples taken. A careful study of the slopes at this site was also made. On this basis the proposed site has been evaluated and its feasibility is worked out. In the end a summary of the whole study recommendations is given.
Key words: Engineering geology, structure, petrography, granite gneiss, Neelum valley, Muzaffarabad.

S/360. Sheikh, K.A., 1996. Use of magnetic reversal timelines in ancient fluvial systems: A case study of Miocene Chinji Formation, Potwar Plateau, Pakistan. Extended Abstracts, International Seminar on Paleomagnetic Studies in Himalaya-Karakoram Collision Belt and Surrounding Continents, November 20-21, 1996, Islamabad. Geosciences Lab, Geological Survey of Pakistan, Islamabad, p.78.

Key words: Geodynamics, India, Eurasia, Mesozoic, Tertiary.

S/361. Sheikh, K.A., 1997. Use of magnetic reversal timelines in ancient fluvial systems: A case study of Miocene Chinji Formation, Potwar Plateau, Pakistan. In: Khadim, I.M., Zaman, H. & Yoshida, M. (Eds.), Paleomagnetism of Collision Belts. Geoscience Laboratory, Geological Survey of Pakistan, Islamabad, 129-141.

Magnetic polarity stratigraphy and sedimentology of the lower part of the Middle Miocene Chinji Formation at its stratotype is discussed. The area lies on the southern flank of the Soan Synclinorium, south of Chinji village between Chittaparwala section in the east, to Huch Nala section in the west, some 16 km apart along the strike. The Chinji Formation is composed dominantly of red to reddish brown siltstone and mudstone with subordinate light grayish green to gray sandstone. Two laterally continuous sand body units, namely the Rainbow Sandstone and the Obstacle Sandstone were traced in the lower part of Chinji Formation to correlate Chittapanvala section to Huch Nala section. In order to check the isochroneity of these trace units, seven short lithostratigraphic sections each 150 m thick on average, spanning over the interval bracketed by the two sandstone bodies were measured and paleomagetic sites were chosen at an average of 7 m in each section. Magnetic reversal timelines and polarity zones in each section were established and correlated with the Chittaparwala magnetic polarity section. Reversal timelines (named TI through T7) were traced between the Chittaparwala and Huch Nala section, i.e., 13.88 to 12.33 Ma. The Rainbow Sandstone throughout its lateral extent in the area remains within the reversal timelines T2 and T3 (13.88 to 13.46 Ma). The upper sandbody, the Obstacle Sandstone, lying about 120 m above the Rainbow Sandstone, gives a much complex history of fluvial system spanning between T4 to T7 (13.21-12.33 Ma). The sedimentary details and isochron of the Rainbow and Obstacle sandbodies indicate different channel belts and floodplain mosaic. It can be postulated that the fluvial system represented by the Rainbow sandbody was dominated by coexistence of more than one major river draining the area. The Obstacle sandbody suggests perhaps switching of the same river system westward through time. The mean sedimentation rate for the Lower Chinji Formation is 0.13 d y r . The mean rate of lateral migration of the river system w k h deposited the Obstacle sandstone is 1.7 cm/yr approximately.
Key words: Paleomagnetism, Chinji Formation, Miocene, fluvial system, siwaliks, Potwar Plateau.

S/362. Sheikh, K.A., Friend, P.F., Raza, M.S. & Shah, S.M.I., 1992. Magnetic polarity stratigraphy of type Chinji Formation and its implications on sedimentation. Abstracts, First South Asia Geological Congress, Islamabad, p.67.

Key words: Magnetic polarity, sedimentation, Chinji Formation, siwaliks, Potwar Plateau.

S/363. Sheikh, K.A. & Shah, S.M.I., 1984. Paleocurrent directions of Chinji Formation in Pakistan. In: Shah, S.M.I. & Pilbeam, D., (Eds.), Geological Survey of Pakistan, Memoir 11, 75-77.

Key words: Paleocurrent, Chinji Formation, siwaliks, Potwar Plateau.

S/364. Sheikh, K.M., 1985-87. Geology of Dunga Gali-Barian Area, District Abbottabda. M.Sc. Thesis, Punjab University, Lahore, 103p.

This report incorporates a comprehensive geological study of nearly 25-km2 area between Dunga Gali and Barian on the Murree-Abbottabad road. The study includes stratigraphically the rock units range from Upper Jurassic to Eocene and represent the sequence of the Hazara Province of the Kohat-Potwar Basin. It is primarily a limestone-shale sequence reflecting a stable shelf facies. Structurally, the area shows the development of a few synclinoria and anticlinora, within which a generally tight parallel to similar asymmetric to overturn style of folding predominates. A number of dipslip-strike faults both of the normal and reverse type is present. A petrographic study of all rock units, based on fairly representative field sampling, is also present.
Key words: Stratigraphy, Jurassic, Eocene, Abbottabad.

S/365. Sheikh, N., Qureshi, M.Y. & Rahman, R., 1967. A study of the indigenous manganese ores. Pakistan Journal of Scientific Research 19, 61-66.

Key words: Manganese ore.

S/366. Sheikh, R.A., 1973. Lithostructural mapping of Darra Adam Khel area, District Kohat with special emphasis on stratigraphic studies and depositional environments. Field Report/Thesis, Punjab University, 80p.

Key words: Stratigraphy, depositional environment, mapping, structure, Darra Adam Khel, Kohat.

S/367. Sheikh, R.A., 1984. Stratigraphy and tectonic style of Darra Adam Khel area, District Kohat. Abstracts, First Pakistan Geological Congress, Lahore, p.51.

Key words: Stratigraphy, tectonics, structure, Darra Adam Khel, Kohat.

S/368. Sheikh, R.A., Butt, A.A. & Qureshi, M.K.A., 1997a. Microfacies analysis and diagensis of the Kingriali Formation, Kala Chitta Range, northern Pakistan. Abstracts, 3rd Pakistan Geological Congress, University of Peshawar, p.62.

Key words: Microfacies, diagenesis, Kingriali Formation, Kala Chitta Rrange.

S/369. Sheikh, R.A., Butt, A.A. & Qureshi, M.K.A., 1997b. Microfacies analysis and diagensis of the Jurassic Samana Suk Formation from Sangar Gali and Thai areas, Abbottabad District, northern Pakistan. Abstracts, 3rd Pakistan Geological Congress, University of Peshawar, p.63.

Key words: Microfacies, diagenesis, Samana Suk Formation, Jurassic, Abbottabad.

S/370. Sheikh, W.A., 1985-87. Geological studies of Khanspur Dewal Area with special emphasis on mineralogy and petrology. M.Sc. Thesis, Punjab University, Lahore, 94p.

This report gives an account of geological studies of Khanspur and Dewal Area with emphasis on mineralogy and petrology. The prescribed area lies to the north of Murree in extreme east of Abbottabad and southeast of Muzaffarabad. The area is approximately 56 sq. km. for which geological mapping was done on lithostratigraphic basis, at the scale 0f 1:10,000.The stratigraphic succession ranges from Datta Formation to Murree Formation (From Jurassic to Miocene). The lithology is mainly limestones, shales, and sandstone with intercalations of marl and clay.
Extensive sampling of the rocks was done and studied afterwards in laboratory. In the Chapter of Petrography, the microscopic and megascopic studies of each formation are given. The percentage of each mineral content is also given. Sedimentary structures, tectonics and economical mineral deposits of project area have been discussed in separate chapters.
Key words: Geology, stratigraphy, Khanaspur.

S/371. Sheldon, R.P., 1966. Reconnaissance evaluation of West Pakistan for phosphate rocks. US Geological Survey/Geological Survey of Pakistan, Information Release PK-32, 20p.

Key words: Reconnaissance, phosphate, West Pakistan.

S/372. Shi, Y. & Wang, W., 1980. Research on snow cover in China and the avalanche phenomena of Batura glacier in Pakistan. Journal of Glaciology 26, 25-30.

This paper summarizes the state of research in China on snow cover, snow-drift control, and avalanche defences, and also reports the results of observations of avalanching above Batura Glacier, Pakistan, during two expeditions.
Key words: Glaciers, snow cover, avalanche, Batura, Karakoram.

S/373. Shi, Y., Wang, W. & Zhang, X., 1980. Forecasting the change of the Batura glacier this and the next centuries. In: Professional Papers on the Batura Glacier, Karakoram Mountains, 191-207. Beijing. Science Press.

Key words: Glaciers, Batura, Karakoram.

S/374. Shi, Y. & Zhang, X. 1981. Batura Glacier of Karakorum Mountain, an example of the complex type glacier. In: Proceedings of the Symposium on Qinghai-Xizang (Tibet) Plateau, Geological and Ecological Studies of Qinghai-Xizang, 2: 1619-1624.

Key words: Glaciers, Batura, Karakoram.

S/375. Shi, Y. & Zhang, X., 1984. Some studies of the Batura glacier in the Karakoram Mountains. In: Miller, K.J., (ed.). The International Karakoram Project, I, 51-63. Cambridge University Press: Great Britain.

Key words: Glaciers, Batura, Karakoram.

S/376. Shi, Y. & Zhang, X., 1978. Historical variations in the advance and retreat of the Batura glacier in the Karakoram Shan. Acta Geographica Sinica, 33(1): 7-13.

Key words: Glaciers, Batura, Karakoram.

S/377. Shipton, E., 1939. Map of Hispar-Biafo glacier regions (Karakoram Himalaya). Royal Geographical Society, London.

Key words: Glaciers, maps, Hispar, Biafo, Karakoram.

S/378. Shipton, E., 1940. Karakoram, 1939. The Geographical Journal 95, 409-427.

Key words: Karakoram.

S/379. Shipton, E. & Yeates, E.W., 1950. Hispar-Biafo Glacial Regions (Karakoram Himalaya). Royal Geographic Society, London.

Key words: Map, Hispar, Biafo, Karakoram.

S/380. Shroder, J.F., 1984. Batura glacier terminus, 1984, Karakorum Himalaya. Geological Bulletin, University of Peshawar 17, 119-126.

Batura Glacier in northwest Karakorum Himalaya has received considerable attention in the past decade because of some unusual characteristics and its effects on the Karakorum Highway between China and Pakistan. Chinese glaciologists found evidence that the Batura terminus would advance in the present decades and retreat in the 1990's. The predicted advance has not begun and instead the frontal ice cliff has downwasted and the cliff above the main meltwater channel has backwasted.
Key words: Glaciers, Batura, Karakoram.

S/381. Shroder, J.F., 1989a. Geomorphic development of the western Himalayas. Geological Bulletin, University of Peshawar 22, 127-151.

Evolution of the drainage system of the western Himalayas was controlled by antecedence, superposition, capture, ponding, avulsion, and faulting following collision and suturing of the Kohistan-Ladakh island arc between the Indian and Eurasian Terranes. The Indus River arose sometime in the middle Tertiary from an area of eroded volcanics near Mt. Kailas in Tibet and established a course to a ancestral " Sindh estuarine" embayment about 300 km north of the present delta. Neither the old idea of a northwest-flowing "Indobrahm" river in the Himalayan foredeep, nor the newer postulate of an east-flowing ancestral diverse drainage directions. Instead the Indus River seems to have established itself along the axis of the island arc system, and in the Haramosh-Nanga Parbat area is was deflected south in an apparent sinistral sense along the Main Mantle Thrust. Subsequent reversal of motion produced a later dextral offset along the Raikot fault. The river was deflected similarly as it crosses the Kalabagh fault through the Salt Range.
Consideration of relations between uplift rates and erosion shows that the Himalayas are at least six times lower than the theoretical maximum, indicating that balance is achieved by discontinuous pulses of rapid uplift alternating with longer periods of quiescence, as well as by variable rates of channel incision and slope processes of erosion. Calculation of long-term sediment deposition in the Indian Ocean equates to a denudation rate of 0.2 mm/yr. Short-term present day rates are 1-1.8 mm/yr. Present uplift of Nanga Parbat is about 5 mm/yr. and is nearly balanced by denudation at Raikot Glacier of 4 mm/yr.
In Pleistocene at least three episodes of glacial advance left thick valley-fill sections that allow definition of Quaternary events. The early stage is indurated lower Jalipur tillites that lack clasts from Nanga Parbat and show that uplift had not yet exposed the massif. Overlying heterogeneous upper Jalipur valley-fill sedimentary rock is younger than 1-2 mm/yr and is overturned or overridden by basement faulting in places. The middle stage is two or more tills intercalated within variable sediments, including thick lacustrine deposits at Gilgit and Skardu. The last stage consists of three or more separate advances that retain moraine topography. At Nanga Parbat and several other places, transverse glaciers at this time blocked the Indus to produce prominent lake deposits. Some of these ice dams failed and produced catastrophic floods and emplacement of the Punjab erratics at the mountain front. in Holocene time numerous glacial fluctuations and surges have occurred and are being monitored. Both glacial advances and major slope failures across rivers have occurred throughout the western Himalaya in historic time and have produced large impoundments, the dams of which failed subsequently and produced catastrophic floods.
Key words: Geomorphology, drainage, Indus river, Pleistocene, Quaternary, Himalaya.

S/382. Shroder, J.F., 1989b. Hazards of the Himalaya. American Scientist 77, 564-573.

Key words: Hazards, Himalaya.

S/383. Shroder, J.F., 1992a. Himalaya to the Sea: Geomorphology and the Quaternary of Pakistan in the regional context. In: Shroder, J.F. (ed.), Himalaya to the Sea: Geology, geomorphology and the Quaternary. Routledge, London, 1-42.

Pakistan is characterized by a highly varied geomorphological landscape. Caught up in continental collision both in the north and west, the area of Pakistan consists of 1. the Karakoram, Hindukush and Himalayan ranges in the North, 2. Suleman and Kirthar mountain range in the west and southwest, 3. Makran coastal ranges in the south along the Arabian sea, 4. Indus plain in the East, and 5. Thar desert in the southeast. Much of the plane area of the country belongs to the Indus river drainage system. This paper describes geomorphology and Quaternary sediments of the country.
Key words: Geomorphology, Quaternary, Himalaya.

S/384. Shroder, J.F. (ed.), 1992b. Himalaya to the Sea: Geology, geomorphology and the Quaternary. Routledge, London.

This is a compilation of a number of articles on the late Tertiary and Quaternary tectonic evolution and geomorphology of the Himalayan mountain ranges.
Key words: Books, geomorphology, Quaternary, Himalaya.

S/385. Shroder, J.F., 2002. Satellite-image analysis of glaciers of Northern Pakistan. In: Williams, R.S. Jr. & Ferrigno, J.R. (Eds.), Satellite Image Atlas of Glaciers of the World. US Geological Survey, Professional Paper 1386.

Key words: Glaciers, remote sensing, North Pakistan.

S/386. Shroder, J.F., Bishop, M.P., Copland, L. & Sloan, V.F., 2002. Debris - covered glaciers and rock glaciers in the Nanga Parbat, Himalaya. Geografska Annaler, 82 A (1): 17-31.

Key words: Glaciers, debris, Nanga Parbat, Himalaya.

S/387. Shorder, J.F. Jr., 1984a. Comparison of tectonic and metallogenic provinces of Afghanistan to Pakistan. Abstracts, First Geological Congress, Lahore, p.20.

Different ideas of tectonic and metallogenic zonation, and difficulties in communication between geologists working in Pakistan and Afghanistan over the last twenty years have limited exchange of information. Detailed work in Afghanistan shows 21 metallogenic zones with 37 associated ore districts. Also recorded are 1432 mineral resource locations classified as: (1) large and medium deposits; (2) small deposits; (3) occurrences; (4) showings; as well as 306 broadly defined mechanical mineralogical haloes. This comprehensive resource analysis was organized around the geosynclinal concepts of Russian work with metallogenesis but is herein adjusted to a plate-tectonic framework and compared to the new tectonic zonation of Pakistan. Cross-border correlation of tectonic zones and metallogenic provinces could be useful in exploration strategy in Pakistan.
Key words: Tectonics, metallogeny, Afghanistan, Pakistan.

S/388. Shroder, J.F. Jr., 1984b. Comparison of tectonic and metallogenic provinces of Afghanistan to Pakistan. Geological Bulletin, University of Peshawar 17, 87-100.

Consult the preceding account.
Key words: Tectonics, metallogeny, Afghanistan, Pakistan.

S/389. Shroder, J.F., Jr., 1998. Slope failure and denudation in the western Himalaya. Geomorphology 26, 81-105.

Slope failures, glaciers, and rivers constitute the three main agents of denudation in the Himalaya. Failure of slopes is strongly controlled by bedrock geology, especially at plate terrane boundaries, although climatic and seismic controls of failure also occur. Slope-failure complexes in the western Himalaya studied for this report include the Pakhar, Kaghan, Nanga Parbat, and Atabad Hunza areas, with 23 different slope failures reported within all the complexes. Quantification of denudation by mass movement requires measurement of volumes and determination of timing of sediment emplacement and removal where possible, to obtain better data on recurrence intervals and total geomorphic work performed in formation of the landscape. The relation of mass movement to overall denudation by glaciers and rivers, and its role in catastrophic floods and debris entrainment is assessed.
Key words: Slope failure, denudation, Himalaya.

S/390. Shroder, J.F., Jr. & Bishop, M.P., 1995. Denudation of Nanga Parbat Himalaya, Pakistan. Abstract Volume, 10th Himalaya-Karakoram-Tibet Workshop, ETH Zurich, Switzerland.

Conflicting ideas about cause and effect of uplift and erosion of the Himalaya require careful assessment of a variety of tectonic and isostatic uplift mechanisms, coupled with detailed studies of associated denudation. Thermobarometric and geochronologic work by others shows that uplift and unroofing of the Nanga Parbat massif along peripheral faults have accelerated through the Quaternary to over 5 mm yr-1, perhaps even to twice that rate. Climate fluctuations and rapid denudation have also been suggested as a cause of decompression melting, high grade metamorphism and injection of young leucogranites. Erosion of Raikot, Buldar, Astor, Sachen, Rupal, Tarshing, Diamir, and Patro valleys is being assessed by us to determine present-day and past denudation rates. Mass movement, glacier and river erosion are regarded as the chief denudation agents, but catastrophic flood-flushing of sediments from behind multiple glacier and slope-failure dams is thought to have been an efficient and major contributing factor in several valleys as well. Erosion of the Raikot valley (8125 - 1125 m altitude; 128 km2 area) on the immense north face of Nanga Parbat is being analyzed most extensively using: (1) erosion surfaces reconstructed from several surviving remnants; (2) most probable durations of erosion; (3) geomorphologic mapping of landforms, sediment transfers, and sediment stores, and (4) measurement of modern process rates. Glacial erosion in middle altitudes dominated in later Pleistocene, but perhaps less so in earlier Pleistocene, possibly before the mountain had achieved its present altitude. The Silver Saddle ice cap on an erosion surface at upper altitudes (~7500 m), and basal ice several thousand meters downslope, are cold based and relatively nonerosive. During Pleistocene colder periods this zone of reduced erosion may have extended to lower elevations than today, but the Raikot Glacier also then extended down into the Indus valley, either as a glacier out of phase with other ice expansions, or as a tributary to trunk valley ice. At present the Raikot Glacier terminus ends at ~3200 m, and little terminal moraine exits there, which suggests efficient transfer of glacial debris load to riverine transport. Below the active Raikot River has eroded a deep gorge across the Raikot Fault and into the Indus River. Present-day denudation rates of warm-based ice at the modem Raikot glacier terminus have been measured by others at ~4.6-6.9 mm yr-1. Also, cosmogenic isotope exposure ages by others on nearby Indus strath terraces show incision rates of 6-8 mm yr-1. Erosion-rate variation in the Raikot and other basins in late Quaternary was most probably episodic, but our time-averaged hypsometric analyses give varying average rates of 3-7 mm yr-1, with an overall rate of 4-5 mm yr-1 as the most consistent with the evidence. Ongoing comprehensive field measurements are expected to produce more detailed and robust measure of denudation for the entire massif.
Key words: Tectonics, denudation, Himalaya.

S/391. Shorder, J.F.Jr. & Bishop, M.P., 1998. Mass movement in the Himalaya: new insights and research directions. Geomorphology 26, 13-35.

Ongoing studies that relate tectonics to the processes at the surface of Earth show that many more sources of information about agents of shallow denudation, such as mass movement, are required to comprehend the long term erosion that leads to deep denudation over geologic time. Mass movement in the Himalaya is scale-dependent, from

the massive extension of whole mountain ranges (gravity tectonics), through the sackung failure of single peaks, to the smallest slope failures. Generally, denudation of the Himalayan orogen begins with slope failure onto glaciers and into river valleys and continues by glacial and fluvial transport. The maximum size of stable slopes and mean angles of slope that are produced by these failures are complex and controlled by a variety of factors, including mass strength of the rocks, stress fields, angles of internal friction controlled by rock type, cohesion that includes the control of rock temperature, bulk unit weight of rock, and discontinuities. The processes of mass movement in the Himalaya have been described many times for the past two centuries. Recently, developments in a variety of fields have been introduced to assess the character of mass movement. Geomorphometry, remote sensing, digital elevation models, and geographic information system technology are revolutionizing the study of mass movement in the Himalaya.
Keywords: Mass movement, tectonics, denudation, Himalaya.

S/392. Shroder, J.F.Jr. & Bishop, M.P., 1999. Indus to the sea: evolution of the system and Himalayan Geomorphology. In: Meadows, A. & Meadows, P. (Eds.), The Indus River, Biodiversity, Resources Humankind, Linnean Society of London, 231-248.

The Indus River originated more than thirty million years ago, shortly after the collision of the Indian and Eurasian plates, on the slopes of the Mt. Kailas massif, itself a remnant of debris eroded from igneous rocks produced by the collision. Thereafter the river was caught and entrained across the Ladakh and Kohistan island arcs between the rising edges of the colliding plates. Lateral motions on faults formed along the plate boundaries later caused the river to be offset significantly at several locations. As the plates continued to converge, the ancestral Indus eventually broke out to the south at the Nanga Parbat-Haramosh syntaxis. Large quantities of sediment were deposited by the river in foreland basins in front of the range; a vast braidplain was spread out between the Indus and its five tributaries in the Punjab, and the river extended its delta progressively south into the ocean. During the world-wide glacier increases of the Pleistocene, lower sea levels led to entrenchment of the lower Indus into its delta and braidplain. Resedimentation of these entrenchments after the Pleistocene allowed numerous lateral channel migrations, one of which apparently isolated Mohenjo Daro. Water withdrawals upstream now reduce sediment carried to the river mouth so much that the delta is being degraded through erosion.
The Indus sediment cascade, produced by extreme erosion rates that are among the world’s highest, has progressively unroofed the range since collision and uplift. This deep exhumation was caused mainly by long term mass wasting, glaciation, and river erosion which mobilized and removed sediment from the Himalayas via the Indus River. The high mountain geomorphology, produced by fluctuating earth surface processes throughout the many climate changes of Quaternary time, is being studied actively to further our understanding of the upper and middle Indus watershed. The Batura Glacier area of Hunza, the Raikot Glacier area of Nanga Parbat, and the Baltoro Glacier area of K2 mountain are the special focus of our ongoing denudation research.
Key words: Indus River, collision, Kohistan.

S/393. Shroder, J.F. Jr. & Bishop, M.P., 2000. Unroofing of the Nanga Parbat Himalaya. In: Khan, M.A., Treloar, P.J., Searle, M.P. & Jan, M.Q. (Eds.), Tectonics of the Nanga Parbat Syntaxis and the Western Himalaya. Geological Society, London, Special Publication 170, 163-179.

The rapid erosional unroofing of the Nanga Parbat Himalaya in late Cenozoic time is thought to have initiated when the Indus River, initially flowing somewhat north and well to the west of its present location, was captured and diverted south close to the massif of today extensional structures and downfaulted topography across the Kohistan-Ladakh island arc terrane. It is hypothesized that the Nanga Parbat pop-up structure was initiated at c. 12-10 Ma, as tectonic aneurysm caused by rapid incision by the Indus River and other surface processes. Because of this subsequent rapid unroofing of the region, however, the oldest sediments to record erosion in the immediate region of Nanga Parbat are <200 ka old: most sediments and our cosmogenic and ISRL exposure dates are more than five times younger. Diverse field measurements of rate of local incision and areal denudation for mass movement, glacial, river and catastrophic floods for the past c. 55 ka are highly differential but internally replicative and externally consistent with research indicating long-term, severe denudation. Averaged rates of maximum incision at more than 15 points around the massif are 22 mm ± 11 mm a-1. Late Pleistocene surface processes at Nanga Parbat were capable of erosional unroofing of the massif sufficiently vigorous to produce the pronounced relief of today.

Key words: Indus River, tectonics, Nanga Parbat, Himalaya.

S/394. Shroder, J.F. Jr., Bishop, M.P. & Schepp, R., 1998. Catastrophic flood flushing of sediment, western Himalaya, Pakistan. In: Kalvoda, J. and Rosenfeld, C.L. (Eds.), Geomorphological Hazards in High Mountain Areas. Kluwer Academic Publishers, Dordrecht, 27–48.

Key words: Sediments, floods, Himalaya.

S/395. Shroder. J.F. Jr., Bishop, M.P., Quade, J., Philips, W. & Maston, R., 1995. Denudation of Nanga Parbat Himalaya. Abstracts, International Symposium on Himalayan Suture Zone of Pakistan. Pakistan Museum of Natural History, Islamabad, p.15.

Recognition of rapid uplift of Nanga Parbat (8125m) has led to new understandings of associated casual mechanics of deep crustal processes in fact, it has even been suggested that denudation processes have produced rapid unroofing, decompression melting at depth, injection of Lecucogranites, and metamorphism. Thus high frequency – high magnitude earth surface processes of slope failure, glaciation, river flow, and catastrophic flooding active for only about a million years in middle to late Quaternary time may have caused these lithologic and structural effects. An international group of scholars, headed by Peter Zeitler, original discoverer of rapid uplift of Nanga Parbat, will analyse the mountain range over the next three years. The denudation research group expects to continue to use standard techniques of geomorphologic mapping, remote sensing, geographic information system, quaternary stratigraphy, and new methods of cosmogenic radionuclides dating to analyse the amounts, rates and chronology of denudation of the Nanga Parbat Himalaya through the quaternary.
Key words: Denudation, Nanga Parbat, Himalaya.

S/396. Shroder. J.F., Jr., Bishop, M.P., Quade, J., Phillips, W., Nieland, P.H. & Schmidt, A.M., 1996. Dendrogeomorphology and denudation efficiency, Nanga Parbat Himalaya. Abstract volume, 11th Himalaya-Karakoram-Tibet Workshop, Flagstaff, Arizona (USA), 135-136.

Denudation of the Nanga Parbat Himalaya throughout the Quaternary period has been extremely rapid, perhaps enough to produce decompression melting, injection of leucogranites and high-grade metamorphism. Elucidation of magnitude and timing of denudation provides constraints upon these bedrock processes. Denudation processes of many kinds occur on Nanga Parbat but those of chief interest here are mass movement, glaciation, rivers, and catastrophic flood flushing of sediment from ice- and slop-failure-dammed lakes. Remote sensing and geographic information system mapping and analysis of modern process distributions and measurement of rates enable establishment of contemporary sediment fluxes from which to better estimate past denudation quantities. Assessment of these past denudation amounts is constrained temporally through cosmogenic radionuclide dating, carbon-14 dating, soil development, and the principles of dendrogeomorphology. Nanga Parbat is well suited to the use of tree ring dating, mainly in its middle elevations (200-4000m), where geomorphic processes are most diverse and most active, and there coniferous and birch forests can provide standard process-event-response chronologies. Mass movement and glacial processes have affected hundreds of trees on the mountain, particularly in the Diamir, Patro, Raikot, Buldar, Astor, and Sachen valleys.
We report here our results from the Sachen and Raikot valleys where we have analyzed the distribution, timing, and volume of debris flows, several kinds of catastrophic breakout floods, glacier downwasting events, the backwasting of glacier termini, and glacial advances. These data enable better understanding of the transfer of sediment of one process-mechanics regime to another; especially the transfer efficiency of sediment from glaciers to rivers. Depending upon various topographic and geomorphic conditions, the glaciers of Nanga Parbat are moderately to highly efficient in transferring their sediment load to rivers. Raikot glacier is highly efficient, whereas Sachen glacier has a lower efficiency. Other things being equal, more efficient transfer occurs in those glacier valleys where: (1) there is a high ratio between plentiful cold-based, protective ice, and limited warm-based, erosive ice so there is not as much sediment; (2) firn-field glacier nourishment is dominant, which provides maximum ice flux; (3) debris sources and feed limited; (4) supraglacial loads are thinner; (5) outburst floods that remove sediment are more common; (6) the steep terminus zone increases sediment transfer energetics; (7) ice velocity and glacier sediment

discharge are relatively lower at the terminus; (8) there is a laterally migratory subglacial drainage portal at the terminus; (9) high meltwater discharge occurs; (10) a narrow valley occurs in the glacier terminus zone which restricts the moraine and enables its removal. Less efficient sediment transfer occurs: (1) where a low ratio occurs between the more limited cold-based, protective ice, and the more plentiful warm-based, erosive ice so that there is a significant increase in debris; (2) where ice- and snow-avalanche glacier supply predominates so that not as much total glacier ice forms; (3) where debris supply is so enhanced by ice- and snow-avalanches that fluvial regimes are overwhelmed; (4) where plentiful source slopes of mass movement and avalanche rock debris exist; (5) where there is a thicker supraglacial debris load; (6) where outburst floods are restricted; (7) in valleys with a gentler gradient, hence with less potential process-systems energetics; (8) with a fixed drainage portal at the terminus so that material accumulates in other areas; (9) with generally low meltwater discharge; and (10) in wide valleys at the glacier terminus where the ice can spread out moraine. In some cases, dendrogeomorphology in those areas of different transfer efficiencies enables determination of relative and absolute magnitudes of denudation quantities.

Dendrogeomorphology was used to study denudation in the Raikot basin in the north and south Biale debris flow basin, as well as on both sides of the terminus of highly transfer efficient Raikot glacier. The Biale basins on the West Side of the Raikot glacier have experienced catastrophic precipitation events on a ~67-year return cycle, with major tree-corrading events in 1923 and 1990. In the approximately 5000 years since the Neoglacial moraines were emplaced at the base of these basins, some 75 of these events can reasonably be expected to have occurred; less when the monsoon was restricted, more when it was dominant. It can be seen in these cases that although the debris does not leave the mountain directly because it tends to be trapped in the ablation valleys behind the lateral moraines, still it is initially mobilized into these temporary storages that are more easily removed by ice and water late. Recessional moraines of the Raikot glacier occur as thin loops of rocky debris around the front and sides of the terminus. The timing of emplacement of these landforms is defined by tree-ring succession dates and historical records. Our data on glacier velocity and supraglacial debris load proved estimates of the total volume of debris that should have been imported in the time allotted into the open space between the recessional moraine and the present terminus. That total amount of debris, less that of the remaining moraine constitutes missing debris transferred into the Raikot River and generally entirely off the mountain.

In late 1993 or early 1994, the subglacial drainage system of the Raikot glacier became blocked and stopped the Raikot river. After a number of months of restricted water discharge, a catastrophic breakout flood burst from four new portal; three on the west side and one on top of the ice near the terminus, before returning to the original portal on the west side of the terminus. This event mobilized considerable supraglacial debris at the terminus, as well as debris form along the west side of the glacier, the ablation valley, the Neoglacial (NG) and Little Ice Age (LIA) moraines, and a small portion of the most distal of the Biale debris flow sediment. All this sediment was transported into, and flushed from the mountain in, the main Raikot River that became re-established close to its original position. In aggregate our data from the Raikot basin on the huge and active north face of Nanga Parbat suggest that denudation on this portion of the mountain is highly active now and has been even more so in the past. For example, we see from our preliminary cosmogenic dates on the high older moraines of >125,000 years age, that the ancestral Raikot glacier was eight times wider and thicker than it is now. Although we are as yet uncertain about the fluctuating altitude of the cold-based/warm-based transition zone that would have controlled the cold, protective ice zone above the warmer, erosive ice zone underneath, still we can see that with the high ice activity of the recent past, a proportional scaling upwards of denudation values in the past is reasonable.

Sachen glacier on the east side of Nanga Parbat has no firn accumulation zone in direct contact with the terminus, unlike that of the huge Raikot system on the north side of Nanga Parbat, and instead is almost entirely fed by ice avalanches from high up the mountain. The lower efficiency of Sachen glacier is exemplified by the huge lateral and recessional NG and LIA moraine storages and the last glacier is maximum (LGM) in its valley. These moraines are tree-covered and deal for dendrogeomorphologic work. For example, event-response chronology shows that a minor ice advance and catastrophic breakout flood are known to have occurred on the north frontal lobe in the late 1920's but the volume of sediment moved was small. The data suggest that significant denudation from this area could only be accomplished in times of major glaciation and through major catastrophic flood flushing at those times. Otherwise sediment tends to accumulate in long term storages. In terms of the overall denudation of the Astor valley to which the Sachen valley is tributary, more efficient removal of sediment would have occurred when LGM ice was in the Astor valley below Sachen, or when large breakout floods occurred from a Sachen ice dam across the Astor river valley. In sum, facilitated by dendrogeomorphology as a part of the full analytical package being applied to this interesting problem.

Key words: Geomorphology, denudation, Nanga Parbat, Himalaya.

S/397. Shroder, J.F., Jr. & Khan, M.S., 1990. Quaternary glaciation of Karakoram and Nanga Parbat, Himalaya. Abstracts, 2nd Pakistan Geological Congress, University of Peshawar, 17-18.

Controversy and agreement between Pakistani, American and British workers on the extent and timing of Pleistocene glaciation in the western Himalaya are highlighted or resolved in our work through recognition of three main glacial stages, and several glacial stages. The early glaciation, or Shanoz stage, includes glaciated high-level erosion surfaces, the Bunthang till in Skardu and perhaps other tillites. The Jalipur tillite is glacially and tectonically indurated and deformed. We judge it evidence of an oldest glaciation and equivalent to Shanoz and Bunthang, but British workers consider it to be youngest only. The middle glaciation, or Yunz stage, includes a number of tills, perhaps had two major stages, and extended the farthest down the Indus of any glaciation. The last glaciation is subdivided into several stages, the most important of which is the Borit Jheel. We consider it to have terminated in the Dak Chaukt or Dianyor moraine at Gilgit, whereas the British workers think it terminated near Chilas and to be equivalent to the Jalipur. A problem has been their lack of acknowledgment of our prior work to which they have had access directly from us. Proper reinterpretation of these contentious issues is critical because of the importance of ongoing studies of absolute uplift rates. In as much as uplift rates are commonly calculated as a function of cooling rates as minerals pass through annealing isotherms at depth, the paleo-configuration of the isothermal surfaces of this region is required for assessment. With present-day relief in the Karakoram and Nanga Parbat Himalaya on the order of 6-7 km, the descending cool waters in fractured and faulted glacials valleys; the rising thermal waters along the Raikot and other faults; the paleotopography, and the glacial and non-glacial histories all have controlled the paleo-isothermometry which is the focus of our present research.
Key words: Glaciation, Nanga Parbat, Quaternary, Karakoram, Himalaya.

S/398. Shroder, J.F. Jr., Khan, M.S., Lawrence, R.D., Madin, I.P. & Higgins, S.M., 1989. Quaternary glacial chronology and neotectonics in the Himalaya of north Pakistan. In: Malinconico L. & Lillie, R.J. (Eds.), Geology and Tectonics of the Western Himalayas. Geological Society of America, Special Paper 232, 275-294.

Thick deposits preserved in deep valleys in the Indus, Gilgit, and Hunza River Basins, and a variety of dates, allow new definition of Quaternary events In the Karakoram and Nanga Parbat Himalaya. An unusually long record for an actively eroding high mountain area is recognized in three major episodes of glaciation during Pleistocene time. An early glaciation is represented by the indurated lower Jalipur tillites and heterogeneous upper Jalipur valley-fill sedimentary rock younger than 1 to 2 Ma, which are folded, overturned, or overridden by rapid movement on the dextral-reverse Raikot fault. This is associated with high overall uplift rates of the Nanga Parbat-Haramosh massif during late Cenozoic time. The middle glaciation is represented by two tills intercalated within variable sediments, including thick lacustrine units dipping as much as 43^0 along the fault. The Indus -Shatial till of the early middle glaciation records the farthest advance of Pleistocene glaciers down the Indus River valley. The last glaciation apparently occurred after about 140,000 yr ago and consists of three to four or more separate advances, as recorded by morainle topography. The most prominent of these is the Dianyor moraine near Gilgit, which was produced by a major longitudinal glacier. Near Haramosh and downstream at Nanga Parbat, Shatial, and elsewhere, transverse glaciers blocked the Indus River to produce lake deposits now dipping as much as 6^0 near the fault. Catastrophic floods from [allure of the ice dams, and possibly landslide dams as well, emplaced some Punjab erraties and sediments that may have been re-worked into loesses and other sediments at the mountain front.
Key words: Glaciation, chronology, Nanga Parbat, Quaternary, Himalaya.

S/399. Shroder, J.F.Jr., Owen, L. & Derbyshire, E., 1993. Quaternary glaciation of the Karakoram Mountains and Nanga Parbat Himalaya. In: Shroder, J.F.Jr. (Eds.), Himalaya to the Sea: Geology, Geomorphology, and the Quaternary. Routledge, London, 132-158.

The Karakoram mountain ranges and the adjacent Nanga Parbat of the Northwest Himalaya to its south constitute one of the most glaciated areas in the world. This area is drained by the Indus river system, much of which is fed by the glaciers. The geomorphology of the area is essentially controlled by exhumation, rapid erosion and glaciation. This has resulted in large quantities of Quaternary sedimentary deposits, the subject of this paper.
Key words: Glaciation, Nanga Parbat, Quaternary, Karakorum, Himalaya.

S/400. Shroder, J.F.Jr., Scheppy, R. & Bishop, M.P., 1999. Denudation of small alpine basins, Nanga Parbat Himalaya. Arctic, Antarctic and Alpine Research 31, 99-105.

Key words: Denudation, Alpine basins, Nanga Parbat, Himalaya.

S/401. Shu, P.Y. & Lin, B.Z., 1984. Stress field and plate motion in the Karakoram and surrounding regions. In: Miller, K. J. (ed.). The International Karakoram Project 2, 185-199. Cambridge University Press.

The spatial distribution of earthquakes in the Karakoram and surrounding regions is studied, along with focal mechanisms, macroseismic evidence and faulting patterns. From these data stress field in the region is inferred. Finally, relations with pate motions are discussed.
Key words: Earthquakes, seismicity, Karakoram.

S/402. Shuaib, S.M., 1973. Subsurface petrographic study of joints in variegated siltstone-sandstone and Khairabad limestone, Pakistan. American Association of Petroleum Geologists Bulletin 57 (9), 1775-1778.

Petrographic methods for the determination of joint parameters such as volume density of joints, and joint porosity and permeability have been applied to selected core samples from the Nuryal 1 well drilled in the Potwar region of West Pakistan.
Joint porosity and permeability data from Jurassic variegated siltstone-sandstone and Paleocene Khairabad Limestone from selected core sections of the Nuryal 1 well at depths between 4,662 and 4,751 m indicate the presence of fairly effective reservoir potential in Jurassic variegated siltstone-sandstone and effective reservoir beds in the Paleocene Khairabad Limestone.
Key words: Petrography, siltstone, sandstone, limestone, Khairabad, NWFP.

S/403. Shuaib, S.M., 1978. Correlation of Permian, Triassic, Jurassic sandstone formations in Potwar region on the basis of nonopaque heavy minerals. National Seminar on Development of Mineral Resources, Lahore March 6-9, 1978, 56-66.

Key words: Heavy minerals, Permian, Triassic, Jurassic, Potwar.

S/404. Shuaib, S.M., 1981. Investigation of prospecting areas and horizons of Oil and Gas in Pakistan. Geological Bulletin, Punjab University 16, 37-42.

Belt, of Potwar-Sulaiman-Kirthar foredeeps along with adjoining uplifts and highs in Punjab Sind plains and Mekran Coastal areas are considered important for the exploration and prospecting oil and Gas reservoirs in Protoquarzite to orthoquartzite sandstones and fractured limestones belonging to Paleozoic, Mesozoic and Paleogene ages. These contain all the geological features which are characteristic for oil and gas bearing regions namely thick sedimentary sequences; presence of regional and local traps for hydrocarbons; almost all the oil and gas seepages including mud-volcanoes, and so for all the discovered off and gas fields. Prospecting areas are discussed in the light of the wells drilled and tectonic movements.
Key words: Hydrocarbons, prospecting, Potwar, Kirthar.

S/405. Shuja, T.A., 1966. Geology of Hazara area. Field Report/Thesis, Punjab University, 67p.

Key words: Stratigraphy, Hazara.

S/406. Shuja, T.A., 1983a. A study of thermal springs of northern Pakistan. Geological Survey of Pakistan, Information Release 179.

Key words: Thermal springs, Northern Pakistan.

S/407. Shuja, T.A., 1983b. Geothermal resources and possibility of their development in Pakistan. Geological Bulletin, Punjab University 18, 22-23.

The paper discusses exploitation potential of geothermal sources of energy. Describing various types of sources, comments are made on Pakistan's status in this connection.
Key words: Geothermal resources.

S/408. Shuja, T.A., 1984. Role of geothermal energy in Pakistan. Abstracts, First Geological Congress, Lahore, p.6.

Keeping in view the limited reserves of fossil fuels and souring energy demands, the need has been felt to develop alternate energy resources. Among alternate resources, geothermal energy occupies an important place. Geothermal energy has been developed in 30 countries mainly for generation of electricity. This is cheap and renewable energy resource located in remote areas where poor accessibility hampers development.
Evidence of geothermal activity in the form of hot springs is found in Northern areas, Chagai District (Baluchistan), Dadu District (Sind) and in Azad Kashmir. Geothermal resource studies in Gilgit and Hunza Agencies indicate the presence of high temperature geothermal fluids (1200C— 2000C). Similarly sub-surface temperatures in Chagai have been estimated to range from (1500C - 1750C). Temperature as high as 1600C has been found at Lakhra during drilling. Large concentration of thermal springs in Dadu also Merits attention.
Key words: Geothermal energy.

S/409. Shuja, T.A., 1986. Geothermal areas in Pakistan. Geothermics 15, 719-723.

In this paper an attempt has been made to correlate the tectonic and geologic features with surface manifestations of geothermal activity in Pakistan to delineate prospective areas for exploration and development of geothermal energy. Underthrusting of the Arabian plate beneath the Eurasian plate has resulted in the formation of Chagai volcanic arc which extends into Iran. Quaternary volcanics in this environment, along with the presence of thermal springs, is an important geotectonic feature revealing the possible existence of geothermal fields. Geothermal activity in the northern areas of Pakistan, as evidenced by thermal springs, is the likely result of collision and underthrusting of the Indian plate beneath the Eurasian plate. Numerous hot springs are found along the Main Mantle thrust and the Main Karakorum thrust in Chilas and Hunza areas respectively. The concentration of hot springs in Sind Province is also indicative of geothermal activity. A string of thermal seepages and springs following the alignment of the Syntaxial Bend in Punjab Province is also noteworthy from the geothermal viewpoint. In Baluchistan Province (southwest Pakistan), Hamun-e-Mushkhel, a graben structure, also shows geothermal prospects on the basis of aeromagnetic studies.
Key words: Geothermal energy.

S/410. Shuja, T.A., 1999. Engineering geological studies along the Chakdara Dir road, NWFP, Pakistan. Geological Survey of Pakistan, Information Release 702.

Key words: Engineering geology, Chakdara-Dir road.

S/411. Shuja, T.A., Asrarullah, & Khan, A.L., 1984. Prospect of geothermal energy in Pakistan. Geological Survey of Pakistan, Information Release 242.

Consult Shuja, T.A. (1984, 1986) for further informations.
Key words: Geothermal energy.

S/412. Shirahase, T., 1996. Outline of joint studies on the Chilas complex. Proceedings of Geoscience Colloquium (Geoscience Lab, Geological Survey of Pakistan, Islamabad) Geological Survey of Pakistan Islamabad 14, 35-38.

This paper gives an outline of joint studies and earlier publications on the Chilas complex.
Key words: Chilas complex, Kohistan.

S/413. Shirahase, T., Kubo, K. & Kausar, A.B., 1996. Outline of joint cooperative studies on the Kohistan area, northern Pakistan. In: Kausar, A.B. & Yajima, J. (Eds.), Geology, Geochemistry, Economic Geology and Rock Magnetism of the Kohistan Arc. Proceedings of Geoscience Colloquium, Geoscience Lab, Geological Survey of Pakistan, Islamabad 15, 3-14.

Key words: Kohistan.

S/414. Siddiqi, F.A., Abbas, S.A. & Amin, M., 1967. Talc deposits of Jamrud, Khyber Agency. Pakistan Journal of Scientific and Industrial Research 10, 300-303.

Key words: Talc deposits, Jamrud, Khyber Agency.

S/415. Siddiqi, F.A,. Ahmad, N., Qaiser, M. A. & Amin, M., 1988. Lead-zinc ore of Kohistan, Hazara, Pakistan. Pakistan Journal of Scientific and Industrial Research 31, 487-490.

The Kohistan Pb-Zn mineralization occurs as veins and disseminations of sphalerite, galena and pyrite in Besham at a distance of about 150 km from Abbottabad. Igneous and metamorphic rocks are the main rocks exposed in this geologically complex area. The petrology, chemical and X-ray studies reveal that the major minerals are quartz, galena and sphalerite with minor chalcopyrite.
Key words: Mineral deposits, Lead-Zinc, Kohistan.

S/416. Siddiqi, F.A. & Akhter, S.M., 1965. Mineralogy of the alluvial sand of the Kabul River, near Charsadda. Pakistan Journal of Scientific and Industrial Research 8, 245-248.

Heavy minerals from washed alluvial sand of the Kabul river in the Doab area near Charsadda are described. The main minerals present are magnetite, garnet and ilmenite but hypersthene, clinopyroxene hornblende are also present. Radioactive minerals are either absent or present in very insignificant amount.
Key words: Mineralogy, heavy minerals, alluvial sand, Charsadda.

S/417. Siddiqi, F.A., Alauddin, M., Khan, H., Nasreen, S. & Hussain, A., 1986. Studies on quartizite deposits of Nowshera and Swabi area, Peshawar Division, Pakistan. Pakistan Journal of Scientific and Industrial Research 29, 327-331.

Key words: Quartzite deposits, Misri Banda, Nowshera, Swabi.

S/418. Siddiqi, M.I., 1984. Geology of Tarlidomal Shonthar area, Neelum valley, Azad Kashmir. Kashmir Journal of Geology 2, 116- on ward.

The area studied is about 80 km2. It lies NNE of Muzaffarabad at a distances of 173 km. The mapped area lies between 74º 24’ 50”-74º 32’ 50” longitudes and 34º 54’ 40”- 35º latitudes it covers parts of Survey of Pakistan toposheet No.43 j/5 & 43 j/9. The rocks of the area are of Salkhala Formation. The Salkhala Formation is a metamorphic complex of variegated lithology comprising of schist (chlorite-garnet grade), amphibolites, quartzite

and marble. Granite gneiss is emplaced in Salkhala Formation and is in turn intruded by pegmatites and quartz veins. Regional metamorphism and accompany penetrative deformation, post-date the granite intrusion, because the granite itself is involved in the deformation. Field evidences and Laboratory studies favor magmatic origin for granite bodies.
The area is tectonically disturbed being involved in Himalayan orogeny. The major faults are the Shonthar Nar fault and Daliwala fault. The Shonthar Nar fault trends NE-SE. Shonthar Nar Valley runs more or less along the trace of this fault. Daliwala fault may be considered a dip-slip-strike fault along the eastern margin of Uti Domel granite body. Regional metamorphism and tectonic effect has imparted well-developed secondary foliations and gneissosity in the rocks of the area. Minor folds are numerous. These are close and tight folds and reflect the intensity of forces involved in their formation. Jointing is abundant in the rocks. Tension and shear joints are encountered in granite gneiss, marble and schists. The mineral occurrences in the area under review include Graphite, marble gemstone (Ruby, Topaz, Aquamarine, Quartz etc.) and mica etc.
Key words: Mapping, structure, Salkhalas, Azad Kashmir.

S/419. Siddiqi, R.A., 1973a. A note on silica sand deposits of Khisore and Marwat Ranges, D. I. Khan Division, N.W.F.P., Pakistan. Geological Survey of Pakistan, Information Release 57, 18p.

Large deposits of silica sand are found in the basal Part of Datta Formation (Jurassic) in Khisore and Marwat Ranges, D.I. Khan Division, N.W.F.P. The total length of the outcrop is 10.5 (4miles in Khisore range and 6.5 miles. Marwat Range). Its thickness vaies from 50 feet to 70 feet. The total reserves upto a workable dip depth of 100 feet are estimated to be 20 million tons.
Silica sand is medium to fine grained. Sieve analysis of grain size from two channels indicate that grains between 20 and 100 mesh, which are necessary for glass making, constitute 57.34% and 75.55% of the two samples respectively.
Chemical analysis of ten channel samples from two sections each from Marwat and Khisore range show that SiO2 content ranges from 76.61 to 96.99% and Fe2O3 from .67% to 4.5%. This shows that silica content and iron, alumina impurities vary a great deal and that quality zoning of the outcrop is unavoidable.
The deposits are easily approachable and at present are being querried near Chunda, 5 miles south of Pezu. The silica sand is being supplied to glass manufacturers of Sind.
The deposit appears capable of meeting the requirements of a modest scale glass industry in N.W.F.P. for the production of ambar and green glass. However, it is recommended that large scale mapping and close interval channel sampling may be carried out for detailed chemical analyses and study of the deposit for possible variation in its quality.
Key words: Silica sand, Khisore Range, Marwat Range, DI Khan

S/420. Siddiqi, R.A., 1973b. Limestone resources of Kohat area, N.W.F.P., Pakistan. Geological Survey of Pakistan, Information Release 58, 21p.

Huge limestone deposits are found in Kohat area. They range in age from Jurassic to Eocene. Chemical analyses show that the most suitable limestone for Cement Industry and for sugar refining is of Kohat Formation, (Eocene). Reserve estimate of Eocene limestone, within a radius of 20 miles from Kohat town is 7000 million tons upto 200 feet above surface. The Outcrops are very close to the communication lines. Plenty of water, power and labour is available. Other raw materials for cement industry, such as gypsum and clay are also available abundantly. Most of the limestone is high grade- and has more than 50% CaO and less than 3% of MgO. Babri Banda, about 5 miles from Kohat on Kohat-Rawalpindi Road, is suggested for setting up a cement factory.
Key words: Limestone, Kohat.

S/421. Siddiqi, R.A. & Saleem, M., 1976. Preliminary report on the discovery of sulphide mineralization in Sawar area, Kotli District, Azad Kashmir. Geological Survey of Pakistan, Information Release 93.

Sulphide mineralization of possible replacement lode type has been found in a shear zone in the Muzaffarabad formation of Permian-Carboniferous age, near Sawar, Kotli District, Azad Kashmir. The metal content of a channel rock sample from the oxidized zone (table-1) is as under:-

Pb	Ag	Zn	Cu	Ni	Au
3.76%	5 gms/ton	0.24%	0.15%	0.003%	5 centigram/ton

An area of 4900 sq. meters was studied and the geochemical anomalies of 224 soil samples, have indicated mineralization covering about 350 sq. meters. The high anomalous areas indicating mineralization are aligned in north west south east direction.

Geochemical values between the median and the threshold, covering an area of about 3000 sq. meters, are also of interest with regard to further work. Further geochemical investigations of a regional nature are in progress and their results would be presented in a final report.

Key words: Sulphide mineralization, Kotli, Azad Kashmir.

S/422. Siddiqui, A.F.K., 1970. Petrology of Timurgara area, Dir. M.Sc. Thesis. Geology Department, Punjab University, Lahore, 80p.

Key words: Petrology, Timargara, Dir.

S/423. Siddiqui, F., Khan, H., Ahmad, N. & Khan, R.W., 1992. Mineralogical and chemical studies of feldspars from Swat and Hazara in NWFP, Pakistan. Pakistan Journal of Scientific and Industrial Research 35, 14-00.

Petrological, X-ray diffraction and chemical studies of feldspar samples from the Hazara and Swat in NWFP established the presence of soda-spars and potash-spars. Moreover, these two types of feldspar are amenable to commercial exploitation for use in glass and ceramic industries.

Key words: Mineralogy, chemistry, feldspar, Swat, Hazara.

S/424. Siddiqui, F.A., 1967. Note on the discovery of carbonatite rocks in the Chamla area, Swat State, West Pakistan. Geological Bulletin, Punjab University 6, 85-88.

Following the discovery of an alkaline rock complex in Swat (Siddiqui, 1965), detailed mapping of the area was undertaken and presence of some "calcite" veins in the syenite was noticed by A. Shakoor and two M.Sc. students of the Geology Department, Panjab University. This information was passed on to the author who visited the area during August 1966, and found that the veins, mentioned above, contained pyroxene and feldspar in addition to carbonate minerals. Subsequent petrographic work showed that the pyroxene was aegiritic in nature and that apatite was also present in abundance. The field relations and mineralogy of the rock was thus found to have features similar to some known carbonatite rocks. For further confirmation, two samples were submitted to Dr. T. Deans of the Institute of Geological Sciences, Great Britain, who arranged their X-ray fluorescence analysis at his laboratory (Special Report No. 252, 1967). The results showed heavy traces of Ba, Sr and the rare earths Ce and Y, with minor traces of La (See Table No.1). On the basis of these investigations it was concluded that these rocks are in fact carbonatite and an announcement to the effect was made in the Commonwealth Liaison Office Newsletter for October and November 1967. The present note is intended to report further progress on the work being conducted by the author. The rocks have been named as the "Naranji Kandao Carbonatite" in reference to the place where the occurrence was first noticed.

Key words: Mapping, alkaline rocks, carbonatite, Swat.

S/425. Siddiqui, F.A., 1973. Alkaline rocks of ijolatic affinity from Tarbela Dam area, Hazara District. Geological Survey of Pakistan, Geonews 3, p.17.

Key words: Alkaline rocks, Tarbela, Hazara.

S/426. Siddiqui, F.A., 1977. Ore microscopy of pyrrhotite-pyrite-chalcopyrite vein from Pattan, Indus Kohistan, Pakistan. Geological Bulletin, Punjab University 14, 95-96.

During an investigation of the geology of the lower part of Indus Kohistan, "a fifteen feet thick brecciated zone" located in a road cut about 2 -miles north of Pattan (Long: 730 l' ; Lat : 35° 12/) and containing "quartz feldspar and arsenopyrite" was noted by Jan & Tahirkhe1i (1969). At the author's request Jan kindly provided -specimens of the vein for ore microscopic studies. A brief account of the mineralogy and ore petrography of the specimens is given in this paper.
Key words: Ore microscopy, pyrite, Pattan, Indus Kohistan.

S/427. Siddiqui, F.A., Chaudhry, M.N. & Shakoor, A., 1970. Geology and petrology of the feldspathoidal syenites and pegmatites of the Koga area, Chamla valley, Swat, West Pakistan. Geological Bulletin, Punjab University 7, 1-29.

The feldspathoidal syenites and associated rocks of the Koga area, first reported by Siddiqui (1965), are described in detail. The area lies in the west central portion of a large intrusion of the so-called Ambela Granitic Complex, which occupies much of the Buner, Chamla and Khudukhel areas of the southern Swat.
In the Koga area, three main petrologic types have been distinguished. 1. A calc-alkaline body named Chingalai granodiorite gneiss. 2. Per-alkaline syenites and granites called Babaji Syenites and characterized by granitoid texture and abundance of basic xenoliths. 3. Feldspathoidal syenites called Koga syenites. The contact of type 1 and 2 is occupied by a fault zone. The Koga syenites are intrusive in both 1 and 2 and are similar to Babaji syenites in that both have aegirine, abundance ilmenite, sphene and apatite as common constituents. These minerals occur only as accessories in the Chingalai granodiorite gneiss. Babaji syenites appear to be co-magmatic with the Koga syenites. The Koga syenites occupy a roughly oval shape area with irregular outlines. Field, petrographic and chemical investigations indicate the following sequence of formation: Per-alkaline syenites (with or without quartz)-nepheline syenites-nepheline sodalite syenite- carbonatite. Thus the trend is one of progressive desilication with differentiation. Flow structure is common indication that the under-saturated magma was emplaced as a viscous mush with alkali feldspar crystals suspended in a liquid capable of crystallizing nepheline.
Key words: Petrology, petrography, alkali syenite, Koga, Swat.

S/428. Siddiqui, N.K., 2000. Remote sensing for prediction of floods in Jhelum River and the significance of Kashmir valley-the Pir Panjal depression. Abstracts, Third South Asia Geological Congress, Lahore, p.74.

Key words: Remote sensing, flood prediction, Kashmir, Punjab.

S/429. Siddiqui, R.A., 1992. Pakistan main dhati maadni imkanat. Geological Survey of Pakistan, Mineral Information Release 10.

Key words: Metallic minerals (in Urdu)

S/430. Siddiqui, R.A. & Shah, S.M.I., 1995. Mineral occurrences in the Eastern Khyber Agency, NWFP. Geological Survey of Pakistan, Mineral Information series 18, 28p.

Preliminary investigation for economic minerals was conducted in the Khyber Agency. Samples were collected and analysed in the Geological Survey of Pakistan. The results obtained are encouraging. Radioactive minerals have been detected in some of the rocks having a considerable extension. Iron mineralization at Misrikhel, good quality dolomite of western LoeShilman, and large quantities of black mica in the eastern Loe Shilman are some among other potential prospects, recommended for detailed exploration. The formations in the Khyber Agency change

facies, some of them rapidly in a short distance. (Change of environment and source, coupled with the episode of metamorphism, makes the entire Khyber Agency worthwhile for detailed mineral exploration.)
Key words: Minerals, Khyber Agency, NWFP.

S/431. Siddiqui, R.H., 1996. Mineralogy of late quaternary Haro river Loess-paleosol deposits, Attock district, Punjab, Pakistan. Proceedings of geoscience colloquium, geoscience lab, GSP, Islamabad, 14, 107-115.

XRD analyses of 24 samples show the presence of quartz, calcite, albite, vermiculite, dickite, with hornblende, gypsum and halite in some samples. The presence of the latter two minerals suggest deposition in hot and arid climate.
Key words: Late quaternary, loess-paleosol deposits, mineralogy, Attock.

S/432. Siddiqui, S.F.A., 1965. Alkaline rocks of Swat, Chamla. Geological Bulletin, Punjab University 5, 52.

Our field investigations into the origin of certain zircon pegmatites, originally reported in Martin et al. (1962, p. 9) have brought to light the presence of rocks of nepheline syenite and related composition, which may be connected with this occurrence; some of the rocks bear sodalite, aegirite, and other alkaline minerals. This is probably the first recorded occurrence of these rocks in Pakistan. Work is now going on with a view to mapping the area of interest to determine the nature, form and extent of the alkaline bodies and to ascertain whether there is any genetic connection with the riebeckite porphyries of Shewa, Mardan District. The occurrences are located near Ambela, Swat State.
Key words: Mapping, alkaline rocks, Swat.

S/433. Sigogneau, R.D. & Russel, D.E., 1983. A new dichobunid artiodactyl (mammalia) from the Eocene of north-west Pakistan; III, reconstitution du moulage endocranin. Proceedings of the Koniankliijke Nederlandse Akademie van Wetenschappen, Series B: Palaeontology, Geology, Physics and Chemistry 86, 319-330.

Key words: Palaeontology, mammals, Eocene.

S/434. Sikhani, S.N., 1990-92. Geological mapping and evaluation of geotechnical properties of Cambrian to Eocene rocks of Nauseri area, Muzaffarabad Azad Kashmir and Garhi Habibullah, Mansehra, Pakistan. Institute of Applied Geology, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, M.Sc. Thesis, 1-78.

The geotechnical, Petrographical, Chemical and lithological characteristics and dynamic and static test results are presented for Cambrian to Eocene Rocks. Comparison is made between a number of static properties of the rocks and their geotechnical performance, particularly during evaluation of different geotechnical properties with changing mechanical, chemical, mineralogical and environmental conditions. The samples (Cambrian) were taken from dolomite quarries near yadgar, Panjal Volcanics (Permian) from Nauseri area and limestone (Eocene) from Yadgar quarries. The Test results presented suggest that the Panjal Volcanics and limestones are suitable as construction raw material for riprap, aggregates, subbase and concrete. The dolomite is fine to medium grained with high magnesium Contents and is useful for industry. The use of dolomite as construction raw material. The Panjal volcanics have high iron content and is harmful to be used as construction raw material in tropical region.
Key words: Mapping, geotechnical properties, Cambrian-Eocene, Mansehra, Azad Kashmir.

S/435. Sillitoe, R.H., 1976. Metallogenic evolution of a collisional mountain belt in Pakistan (A preliminary analysis). Geological Survey of Pakistan, Record 34, 16p.

Consult the following account.

Key words: Metallogeny, collisional mountain belts.

S/436. Sillitoe, R.H., 1978. Metallogenic evolution of a collisional mountain belt in Pakistan: A preliminary analysis. Journal of the Geological Society, London 135, 377-387.

Five post-Palaeozoic metallogenic environments are recognized in Pakistan and adjoining regions: 1. Mississippi Valley-type fluorite, barite and barite-galena deposits generated in Jurassic limestones on the northern miogeoclinal margin of the Indian Shield, perhaps during incipient rifting heralding India's separation from Gondwanaland; 2. chromite deposits in serpentinized dunite, manganese-oxide deposits in layer-1 sediments and a cupriferous massive sulphide occurrence in layer-2 basalts generated within an ophiolite complex at a Tethyan oceanic spreading centre; 3. porphyry copper–molybdenum, manto-type copper, Kuroko-type massive sulphide, vein copper, contact–metasomatic copper and iron, and volcanogenic iron deposits generated in Cretaceous-Cenozoic times by intrusive and extrusive calc-alkaline magmatism along the southern edge of the Iran-Afghanistan microcontinental plate during northward subduction; 4. stibnite occurrences emplaced in the intracontinental Chaman transform fault system during post-early Miocene times; and 5. sandstone-type uranium deposits in Siwalik molasse-type sediments shed during post-early Miocene uplift of the Himalaya. Juxtaposition of the miogeoclinal, ophiolitic and Cretaceous calc-alkaline metallogenic provinces resulted from suturing of the Indian plate with the southeastern margin of the Iran-Afghanistan microcontinent, representing final closure of eastern Tethys. Subsequent renewed northward motion of the Indian plate, causing crustal shortening and uplift along its northern edge, produced the transform-fault and molasse-basin provinces and, along the Makran segment of the plate boundary unaffected by continental collision, the post-early Miocene calc-alkaline province.
Key words: Metallogeny, collisional mountain belts.

S/437. Sillitoe, R.H., 1979. Speculations on Himalayan metallogeny based on evidence from Pakistan. In: Farah, A. & DeJong, K.A. (Eds.), Geodynamics of Pakistan: Geological Survey of Pakistan, 167-179.

Sillitoe (1978) recognized five discrete metallogenic environments in Pakistani Baluchistan. They are related to a shelf-carbonate succession, an ophiolite suite, a subduction-related calc-alkaline magmatic arc, an intracontinental transform fault zone, and a molasse basin. None of these environments is well represented further to the northeast, in the Himalayan region. However, minor ophiolitic chromite in the Indus suture zone, molasse-contained uranium in the Subhimalaya, and contact-metasomatic magnetite of probab1e subduction origin in the north-west Himalaya are recorded. Potential would seem to exist for discovery of other ophiolitic ore types and, in the Lower and Tibetan Himalaya shelf carbonates, of Mississippi valley-type deposits. Subduction-related base and precious-metal mineralization IS not likely to be Widespread In much of the Himalaya but may be encountered in the Transhimalaya and, north of the southern branch of the Indus suture zone in the northwest Himalayan region.
Based largely on evidence from the northwest part, post-Palaeozoic mineralization in the Himalaya, Including regions immediately north of the Indus suture , is believed to be dominated by minor polymetallic occurrences of Neogene age carrying mainly copper, lead, barite, gold, and antimony of metamorphic origin, and by gemstones, along with some fluorite and possibly rare-earths and minor base metals, generated by anatectic leucogranites, Metamorphic mineralization is attributed to precipitation in dilatent sites by fluids expelled from sedimentary rocks undergoing regional metamorphism, either during thrusting and/or during uplift. The anatectic leucogranites are believed to be poorly mineralized compared with subduction-related intrusives because their source 'magmas, generated by partial melting of basement rocks during continental underthrusting, were water-saturated and therefore consolidated at depths of perhaps 10 km without possessing subvolcanic or volcanic equivalents; the magmas also may have been intrinsically poor in metals. Both these Neogene metallogenic environments were imposed by the process of thrust progradation whereby renewed post-Eocene northward motion of the Indian plate was taken up on a series of major, low-angle thrusts within its leading edge, with activity migrating progressively with time (prograding) southwards from the Indus collisional suture . In Baluchistan, post-collisional northward motion of India was taken up on the Chaman transform fault zone so that thrust propagation was relatively unimportant. .
It would appear that the metallogeny accompanying continental collision and its related later effect is on a small scale and that the major ore types, such as porphyry copper, epithermal precious metal and Kuroko-type massive sulphide deposits, found in Cordilleran or island-arc settings above subduction zones, are unlikely to be found.

Exploration programmes should take account of these speculative conclusions and should therefore perhaps concentrate on pre-Mesozoic ore types fortuitously incorporated in the mountain belt, relatively important examples of which are found at Rangpo, Sikkim and Asker, Uttar Pradesh.
Key words: Metallogeny, Himalaya.

S/438. Silvestri, A., 1934a. De petris, saxis et foxilibus paleozoici superioris a Missione Italica Geograpifica in Caracorum inventis. Scientiarium Nuncius Radiophonicus 30, 28 Mart, 1934.

Key words: Paleozoic, geography, Italian mission, Karakoram.

S/439. Silvestri, A., 1934b. Rocce e fossili del Paleozioco superiore raccolti della Spediozione Geograpifica Italiana nel Caracorum (1929): P.I, Le Rocce. Memorie della Potificia Accademia Romana di Novi Lincei, Series 3(1), 33-48.

Key words: Paleozoic, geography, Italian Expedition, Karakoram.

S/440. Silvestri, A., 1935. Rocce e fossili del Paleozioco superiore raccolti della Spediozione Italiana Geograpifica nel Caracorum (1929): P.II, I fossili. Memorie della Potificia Accademia Romana di Novi Lincei, Series 3(2), 79-117.

Key words: Paleozoic, geography, Italian Expedition, Karakoram.

S/441. Sinha, A.K., 1997. Subduction tectonics of plates and accretion of Karakoram terrane in the northern high mountain region of Indian Sub-Continent. Abstracts, 3rd Pakistan Geological Congress, University of Peshawar, p.65.

Key words: Tectonics, plate movement, orogeny, accretion, Karakoram.

S/442. Smith, F.H., 1895. On the geology of the Tochi valley. Records of the Geological Survey of India 28(3), 106-110.

This may be amongst the earliest accounts of this part of the tribal Area of present day Pakistan. Following are a few paragraphs from the records.

Bannu District.-One of the four trans-Indus Districts of the North-West Frontier Province, lying between 32^0 16' and 33^0 5' N. and 70^0 23' and 71^0 16' E., with an area of 1,670 square miles. The District forms a basin drained by two rivers from the hills of Waziristan, the Kurram and the Gambila or Tochi, which unite at Lakki and flow into the Indus south of Kalabagh. It is shut in on every side by mountains: on the north by those in the Teri tahsil Physical aspects. of Kohat District; on the east by the southern extremity of the Maidani Pahar or Khattak Niazi range and the northern spur of the Marwat range, which separate the District from the Isa Khel tahsil of Mianwali District in the Punjab; on the south-east and south the Marwat and Bhittanni ranges divide it from Dera Ismail Khan; and on the west and north-west lie Waziristan and independent territory inhabited by the Bhittanni tribe. These hills nowhere attain any great height. The highest point of the Maidani range at its centre, near the hamlet and valley of Maidan, has an altitude of only 4,256 feet. The Marwat range culminates in Sheikh Budin, the hill which rises abruptly from its south-west end to a height of 4,5I6 feet, and forms the summer retreat for this District and Dera Ismail Khan. From these ranges numerous spurs jut out into the Bannu plains, but no other hills break their level expanse. Of the rivers the larger is the Kurram, which, entering the District at its north- western corner close to Bannu town, runs at first south-east, then south, and finally winds eastward through the Darra Tang or 'narrow gorge' which lies between the extremities of the Maidani Pahar and Marwat ranges. The Tochi river enters the District about 6 miles south of the Kurram and flows in the same direction, gradually drawing closer to it until their streams unite about 6 or 7 miles west of the Darra Tang. Between these rivers, and on the left bank of the Kurram in

the upper portion of its course, lie the only tracts which are perennially irrigated. For the first Io miles of its passage through the District the Kurram runs between banks of stiff clay which rise abruptly to a height of 10 to 30 feet, and its bed is full of stones and boulders; but lower down it spreads over long stretches of marsh land. Its flow is rapid, but it is highly charged with a rich silt which renders it most valuable for irrigation. At the south-east edge the western flanks of the hills bounding Mianwali and Dera Ismail Khan Districts expose Tertiary lower Siwalik soft sandstone and upper Siwalik conglomerates,-a thickness of which dips regularly under the alluvium and gravels forming the greater part of the great Bannu plain. On its western side the border area has been examined along one line of route only, namely, the Tochi valley. Here long ridges striking north and south expose upper and lower Siwaliks, Nummulitic limestone, sandstone and shales, some Mesozoic limestone in the ridge east of Miram Shah, and a great mass of Tertiary igneous rocks (diorites, gabbros, and serpentines) west of Muhammad Khel. In the irrigated portions of the District trees abound of the same species as are common in Peshawar; elsewhere there is little but thorny shrubs of the same kinds as are found in Kohat. The more common plants are Reptonia buxifolia, Dodonaea viscosa, Capparis aphylla, Flacourtia sapida, F. sepiaria, several species of Grew/a, Zizyphus nummularia, Acacia Jacquemontii, Alhagi camelorum, Crotalaria Burhia, Prosopis spicigera, several species of Tamarix, Nerium odorum, Rhazya stricta, Calotropis procera, Penriploca aph/l/a, Tecoma undulata, Lycium europaeum, lVithania coagulans, IV somnifera, Nannorhops Ritchieana, Fagonia, Tribulus, Peganum Harmala, Calligonum pologonoides, Polygonum aviculare, P. plebejum, Rumex vesicarius, Chrozophora plicata, and species of Aristida, Anthistiria, Cenchrus, and Permnisetum.
Bears occasionally come from Waziristan and leopards still frequent the hills, while hyenas are sometimes found where there are ravines. Wolves are common, rewards having been paid for destroying 168 from 1900 to 1904. The Sulaimani markhor is found on all the higher hills, including Sheikh Budin. Uridl are also to be found on the hills, and 'ravine deer' (gazelle) in the neighbourhood of Jani Khel. The general elevation of the plains is about 1,000 feet, and the temperature would be much the same all over the District did not special local causes affect it. Trees, excessive irrigation round the town, and the closeness of the hills combine to make Bannu moist and close in the hot season, and to equalize the temperature throughout the twenty-four hours. The sandy plain of Marwat is hotter by day and cooler by night, and far more healthy in spite of the intense heat. Fevers are common from September to November, and respiratory diseases cause considerable mortality. The annual rainfall averages 12 inches, rarely rising above 16, but at Bannu in 1891-2 less than 5 inches fell in the year. The fall is frequently unseasonable. The population of Bannu is, and has been for many centuries, essentially Afghan. There are, however, remains which tell of an older Hindu population, and afford proof that the District came within the pale of the Ancient Graeco-Bactrian civilization of the Punjab.
Key words: Geology, Tochi, Waziristan.

S/443. Smith, H.A., 1993. Characterization and timing of metamorphism within the Indo-Asian suture zone, Himalayas, Northern Pakistan. Ph.D. Thesis, Dartmouth College, Hanover, 196p.

Key words: Metamorphism, India-Asian suture zone, Himalaya.

S/444. Smith, H.A. & Chamberlain, C.P., 1992. Evidence for late Eocene anataxis within the Indian plate as a result of Eocene Himalayan orogeny. Abstract Volume, 7th Himalaya-Karakoram Workshop, Department of Earth Sciences, Oxford University, England, 84.

Our geologic mapping in the upper Kaghan Valley of northwestern Pakistan has focused on the Indian plate rocks defining the footwall of the Main Mantle Thrust These rocks exhibit structural and mineralogic changes related to the south-directed obduction of the Kohistan Island Are onto the Indian plate, thought to originate with the onset of continental collision at approximately 50 Myr (Patriat and Achache. Nature, 311:615-621, 1984). As a first step to answering some of the petrologic questions relating to this tectonic event, we sought emplacement ages for a narrow band of leucogranites near the village of Naran that extend far 4-km. cutting across lithologic boundaries within the Indian basement
Because of the likelihood of xenocrystic components in these melts, we made use of the capabilities of the SHRIMP facility at Australia National University. With the ability to analyze a 20-30 micron spot on an individual grain. SHRIMP U-Pb zircon analyses can avoid obvious inherited cores and instead provide ages for rims presumably grown as a result of the most recent igneous event. We analysed a number of zircons from each of 4 leucogranite

samples in the Kaghan Valley. The youngest ages for each of these 4 samples cluster at 40-45 Myr. These ages are notably older than any leucogranite ages from the greater Himalaya.
Both the structural setting and the mineralogy of leucogranite in the Kaghan Valley are similar to other Himalayan leucogranites. Our leucogranites outcrop in the hanging wall of a pronounced shear zone (the Oghi Shear) which thrust amphibolite-grade basement rocks over low grade, graphitic metasediments of the Salkhala Formation. This structure is thought to be correlative with the MCT, the hanging wall of which hosts other Himalayan leucogranites. However, each of the previous studies of Himalayan leucogranites has used the occurrence of undeformed leucogranites that crosscut the foliation to constrain the minimum age of deformation. In the Kaghan Valley, we find that the leucogranites are deformed.
Thus our relatively old leucogranite ages obviously do not constrain the minimum age of deformation. What they do illustrate is unexpectedly early igneous activity in die Indian plate. That this igneous activity is not simply an isolated, local phenomena is shown by zircon U-Pb ages of 43 Myr, similarly obtained using SHRIMP, from the Malakand Granite near Swat, 300 km to the west.
Taken together, our ages of 40-45 Myr from leucogranites and the Malakand Granite require that igneous activity began within 10 Myr following the onset of Eocene collision between the Indian subcontinent and Asia. While the generation of melts this soon after collision may seem unusual, numerical modeling suggests that water-saturated melts can be expected 0-20 Myr following initial tectonic thickening, given appropriate fluid fluxes.
Key words: Himalayan metamorphism, magmatism, Indian plate, Kaghan valley.

S/445. Smith, H.A., Chamberlain, C.P. & Zeitler, P.K., 1990a. Young monazite ages from schists: Dating metamorphism in the Nanga Parbat Syntaxis, Himalayas, Northwestern Pakistan. Abstracts, International Conference on Geochronology, Cosmochronology, and Isotope Geochemistry. September 25, 1990, Canberra.

Key words: Metamorphism, geochronology, Nanga Parbat syntaxis, Himalaya.

S/446. Smith, H.A., Chamberlain, C.P. & Zeitler, P.K., 1990b. Young monazite U-Pb ages from schists in the Nanga Parbat Syntaxis, Himalayas, Northwestern Pakistan. Geological Society of America, Abstracts with Programs 22, p.27.

Key words: Metamorphism, geochronology, U-Pb, Nanga Parbat syntaxis, Himalaya.

S/447. Smith, H.A., Chamberlain, C.P. & Zeitler, P.K., 1992. Documentation of Neogene regional metamorphism in the Himalayas of Pakistan using U-Pb monazite. Earth and Planetary Science Letters 133, 93-105.

In the Himalayas, investigators have constrained the timing of metamorphism associated with the Eocene orogeny through the use of cooling ages on a number of minerals. The majority of such studies give minimum metamorphic ages of ~ 30–40 Ma, largely confirming theoretical studies predicting peak metamorphic conditions occurring tens of millions of years after large-scale collision. In northwestern Pakistan, however, the Nanga Parbat-Haramosh Massif (NPHM) exhibits much more recent activity, with rapid and accelerating cooling over the past 10 Ma. The NPHM also exhibits unexpectedly recent igneous activity: three leucogranite dikes give minimum zircon U-Pb ages of 7, 5 and 2.3 Ma. The problem we address in this paper is whether the thermal structure suggested by recent leucogranite production at depth is discernible in the shallower metamorphic rocks of the NPHM. To date metamorphism, we have used the U-(Th)-Pb system in monazite, a common accessory mineral in high-grade metamorphic rocks which can be a viable metamorphic geochronometer, dating the formation of the mineral under moderate metamorphic conditions. Monazite separated from schists and gneisses of the NPHM gives U-Pb ages of 4–11 Ma. We interpret these young ages as evidence for Neogene metamorphism affecting the NPHM, an event heretofore unsuspected in the greater Himalaya and only intimated in the NPHM. This recent metamorphism roughly coincided with leucogranite production at depth and with the onset of high denudation rates. As such, our conclusions offer important constraints on further modeling of similarly anomalous behavior within tectonically active regions, suggesting that any reasonable model should strive to explain the relationship between recent, rapid uplift and coincident recent metamorphism.

Key words: Metamorphism, geochronology, U-Pb, Himalaya.

S/448. Smith, H.A., Chamberlain, C.P. & Zeitler, P.K., 1993. Relationship between deformation and monazite ages-two counter examples in the Himalaya. EOS 74(16), p.123.

Monazite has found use as a geochronometer for metamorphic processes, processes intimately coupled with deformation in developing orogens. While the role deformation might play in initially forming monazite is unknown, the prograde metamorphism of pelites has been shown to result in the genesis of metamorphic monazite. The U-Pb system in such monazite then gives a direct age for onset of metamorphism, as well as offering constraints on the timing of deformation.
In Pakistan, we have used such ideas in two separate regions: the Nanga Parbat-Haramosh massif (NPHM) of the Indian plate and in the Karakorum range of the Asian plate. Although it has been shown that the NPHM is a region of rapid, accelerating uplift and denudation over the past 10 Ma, expectations were that the timing of Himalayan metamorphism would be broadly similar to that shown for the central Himalayas: mineral cooling ages there give younger bounds on the age of metamorphism of ~30-40 Ma. However, metamorphic rocks of the NPHM gives much younger monazite U- Pb ages of 4-11 Ma. We have been able to confirm none of the known scenarios for resetting the U-Pb system in monazite. Instead, we find independent corroborating evidence of Neogene metamorphism: young zircon U-Pb ages from leucogranite dikes and from the metasediments, as well as consistently younger fission-track ages.
Such is not the case for the Karakorum. Undeformed, post-metamorphic igneous units constrain deformation and metamorphism to being older than ~35 Ma, while 2 upper amphibolite facies metamorphic samples give concordant U-Pb monazite ages of 6-7 Ma. Although other geochronologic data are scarce, such young ages are enigmatic. We will use these two counter-examples to speculate on the viability of the U-Pb system in monazite as influenced by thermal and deformational perturbations.
Key words: Deformation, geochronology, orogeny, metamorphism, Nanga Parbat syntaxis.

S/449. Smith, H.A., Chamberlain, C.P. & Zeitler, P.K., 1994. Timing and duration of Himalayan metamorphism within the Indian Plate, Northwestern Himalaya, Pakistan. Journal of Geology 103, 493-508.

Key words: Metamorphism, geochronology, Indian plate, Himalaya.

S/450. Snee, L.W. & Rosenberg, P.S., 1985. Nappe structure in a crustal scale duplex in Swat, Pakistan. Geological Society of America, Bulletin, Abstract with Program, 17, p.640.

Key words: Structure, nappes, duplex, Swat, NWFP.

S/451. Snee, L.W., Foord, E.E., Hill, B. & Carter, S.J., 1989. Regional chemical differences among emeralds and host rocks of Pakistan and Afghanistan: implications for the origin of emerald. In: Kazmi, A.H. & Snee, L.W. (Eds.), Emeralds of Pakistan: Geology, Gemology and Genesis, 93-123. Van Nostrand Reinhold, New York.

This account has no abstract. It gives a brief of chemical differences between emeralds of Pakistan and Afghanistan. Emphasis is given on chemistry of the emeralds found in these areas. The authors have concluded that the emeralds of Pakistan, like the other emeralds of the world, are green in color due to the substitution of chromium to aluminum in the beryl structure. Pakistan emeralds are unique as they contain large amount of iron, megnisium and sodium.
Emeralds from different areas in Pakistan and Afghanistan are chemically different. Swat, Mohmand, Khaltaro, and panjsher emeralds show small but distinct differences in aluminum, magnesium, sodium, chromium, vanadium, and scandium. Emeralds are clearly a reflection of the chemistry of both host rocks and mineralizing fluid.
Key words: Gemology, emerald, chemistry, Afghanistan, Pakistan.

S/452. Snee, L.W. & Kazmi, A.H., 1989. Origin and classification of Pakistani and world emeralds deposits. In: Kazmi, A.H. & Snee, L.W. (Eds.), Emeralds of Pakistan: Geology, Gemology and Genesis, 229-236. Van Nostrand Reinhold, New York.

Emerald, the result of the substitution of a small amount of chromium for aluminum in the beryl crystal structure (Deer and others, 1986), is the product of special geological conditions.
Even though beryl is the most common mineral that has beryllium as a major constituent, it is itself rare and is generally found in significant abundance only in late-stage igneous rocks, such as pegmatites. Beryl is rare because beryllium (with an ionic charge of +2) has both a small atomic radius (0.3 A; Shannon and Prewitt, 1969; hence it is excluded from the crystal structure of most minerals) and a small crustal abundance (less than 5 ppm as estimated by Wedcpohl, 1978, or less than 3.5 ppm according to Beus, 1965). Emerald is even scarcer because chromium, the coloring agent of emerald, and beryllium are geochemically incompatible. Chromium is found only in significant amounts in "primitive" rocks such as ultramafic igneous rocks; in these, beryllium is absent. Thus, special circumstances are necessary to bring chromium and beryllium together and therefore, emerald is one of the rarest and most precious gemstones.
In Pakistan, a series of special geological events resulted in the formation of emerald. In the first three chapters of this book, we summarize the large-scale events. In chapters four through seven, we discuss additional clues on the origin of the emeralds; these clues are revealed in physical and chemical characteristics of the emeralds as well as in the morphology and physicochcmical conditions of the formation of tiny inclusions within the crystals. In chapter 8, we review the geology of other known world emerald deposits. In all, an intriguing picture about the general geologic setting and the origin of not only Pakistani, but world emeralds is unfolding. In this final chapter, the characteristics of Pakistani emeralds are summarized and are used to formulate a theory on their origin. Next, a classification scheme based on the general geologic setting of world emeralds is proposed and discussed and is developed into an hypothesis for the origin of all emeralds. Finally, we propose some additional studies that would shed new light on the origin of emeralds.
Key words: Gemology, emerald, chemistry, Pakistan.

S/453. Snelgrove, A.K., 1979. Migrations of the Indus River, Pakistan, in response to plate tectonic motions. Journal of the Geological Society of India 20, 392-403.

Key words: Plate tectonics, Indus River, Pakistan.

S/454. Sohail, A., 1987-89. Geotechnical studies for landslide problems along the Murree Kohala Road. M.Sc. Thesis, Punjab University, Lahore, 111p.

Landslides are widespread in many countries and cause great economic losses especially when engineering constructions are designed and erected without knowing the stability conditions of the slopes.
The greater frequency of landslides provoked by construction works, as compared with the past is probably due to several reasons:
-The interference with natural slopes is more intensive because of the rising boldness and extent of structures.
-The mechanization of earthworks accelerates excavation but excludes the possibility of sorting the rock material.
-The selection of building sites is generally restricted to the less favourable ones which were avoided by previous builders etc.
Landslides are closely connected with the geological conditions of the area. Generally speaking Pakistan has a very intricate geological history with active tectonic zones. Frequently occurring landslides, in different parts of the country create problems for government and local people. The area between Murree and Kohala is the site of very diverse sliding Phenomena. (especially along the road). Landslides endanger settlements, high roads, public utilities etc. The Murree Kohala Road has great national importance from strategic and regular communications view point. This shortest possible route between Pakistan and Azad Kashmir is promoting the facilities of communications for development of the linked areas and the supply of basic needs. The Murree -Kohala Road crosses the Jhelum River at Kohala through Kohala Bridge and a stretch of about six kilometers is along the Jhelum River from Basian to Kohala. This road is also important from defence point of view. There is another road which starts from Jhikagali via Bhurban and joins the Murree -Kohala Road near Basian via Bush Road is named as Khaquan Abbasi Road (due

to late Khaquan Abbasi). The entire area through which road passes is the rugged mountainous terrain having sub humid to semi arid climate conditions. As far as the slopes of the project area are concerned, the major part of the road is on the escarpment face and variety of slope conditions exist in the area. The condition of the Murree -Kohala road is satisfactory where a good driver can drive every type of vehicle at the speed of 40-50 kmls/hour, except for the landslide areas.
Key words: Hazards, landslides, geotechnical, Azad Kashmir.

S/455. Sohail, M., 1981-83. Lithostructural mapping and biostratigraphic study of Burikhel Bandakha Area (western Salt Range), District Mianwali. Institute of Geology, Punjab University, Lahore, M.Sc. Thesis, 1-100.

Detailed Lithostructural Mapping and Biostratigraphic study of Barikhel- Bandakha Area (Western Salt Range) District Mianwali, has been done at 1:10,000. Area is exclusively a sedimentary terrain. Stratigraphy along with micropaleontology of certain formations is described. In addition to this macrofauna have been described. Lateral extension of liminic permean coal is noted. Tectonic style of the area is described with the help of structural details i.e. study of folds, faults and joints etc.
Key words: Lithostructure, biostratigraphy, Salt Range, Mianwali.

S/456. Sohan, I.G., 1959a. Early Tertiary ostracodes from West Pakistan. Geological Survey of Pakistan, Memoirs 3(1), 91p.

Key words: Palaeontology, ostracode, Tertiary.

S/457. Sohan, I.G., 1959b. Lower Tertiary ostracodes from Pakistan. Geological Survey of Pakistan, Memoir 3(2).

Key words: Palaeontology, ostracode, Tertiary.

S/458. Sohn, I.G., 1970. Early Triassic marine ostracodes from the Salt Range and Surghar Range, West Pakistan. In: Kummel, B. & Teichert, C. (Eds.), Stratigraphy Boundary Problems, Permian and Triassic of Pakistan. University of Kansas, Geology Department, Special Publication 4, 193-206.

Key words: Palaeontology, ostracode, Triassic, Surghar Range, Salt Range.

S/459. Sokolov, B.A. & Shah, S.H.A., 1966. Major tectonic features of Pakistan. Part 1, West Pakistan. Pakistan Journal of Scientific and Industrial Research 4, 175-199.

The junction of the foredeep with border folds of Attock-Hazara are in along the whole southern rim of the Himalayan folded system. Morphologically, the Kohat part of the Rawalpindi zone west of Indus River represents a system of narrow fractured anticlines and relatively wide synclines.
The Karakoram median mass “is made of Pre-Palaeozoic granites of various types, gneisses, crystalline schists and other highly metamorphosed rocks. Along the northern and southern margins of the median mass the narrow, limited by faults, strings of outcrops of Upper Palaeozoic, Mesozoic and even younger rocks appear outside the boundaries of Pakistan.
The igneous activity is of considerable extent in the Cretaceous period, and is expressed as a wide spread intrusions of granitic and graondioritic and is expressed as widespread intrusions of granitic and granodioritic rocks as less of more basic diorite, gabbro and ultrabasic rocks.
Key words: Tectonics, Attock-Hazara.

S/460. Spadea R.P., 1975. Description of the specimen of metamorphic and plutonic rocks from the Lake Shiwa area. In: Desio, A. (ed.), Italian Expeditions to the Karakorum and Hindu Kush. Petrographic Appendix, 582-596. Brill, Leiden.

Key words: Metamorphic rocks, plutonic rocks, Karakoram.

S/461. Spath, L.F., 1930. The fossil fauna of Samana Range and some neighbouring areas; Part-5, the Lower Cretaceous Ammonoidea; with notes on Albian Cephalopoda from Hazara. Geological Survey of India, Memoirs, Palaeontologica Indica (New Series) 15(5), 50-66.

Key words: Cretaceous, ammonoidea, fauna, cephalopoda, Hazara, Samana Range, Hangu.

S/462. Spath, L.F., 1934. The Jurassic and Cretaceous ammonites and belemnites of Attock district. Geological Survey of India, Memoirs, Palaeontologica Indica (New Series) 20(4), 1-39.

The ammonites and belemnites described in this paper come from a number of localities in the Attock district, in the extreme north-west of the Punjab, on the borders of the North-West Frontier Province. They were sent to me marked partly Basal Giumal beds (the Jurassic and Spiti shales species), partly Upper Giumal beds (the Albiau forms and some indeterminable belmenites). These cephalopods were accompanied by a number of brachiopods, also pelecipods and gastropods, which are being described by Miss H. M. Muir-Wood and by Mr. L. R. Cox 'respectively. The fauna has already been referred to in my Revision of the Jurassic Cephalopoda of Kachh, hut the publication, in the meantime, of other works, especially on Upper Jurassic successions, makes it desirable to discuss the stratigraphic results afresh and in more detail in a final chapter.
I have to record my grateful acknowledgments to the past and present Directors of the Geological Survey of India in Calcutta (Sir Edwin Pascoe and Dr. L. L. Fermor) for entrusting me with the description of these interesting forms ; also to the Keeper of the Geology Department of the British museum (Natural History), Dr. MT. D. Lang, for.-giving me all facilities in connection with the study of the collections. I should like similarly to acknowledge the help and continually receiving from colleagues all over the world by consignments of new material, literature or information, even if it may not seem to be directly concerned with the area here discussed. The measurements of ammonites are given in the usual order :--(l) diameter in millimetres, (2) whole-height, (3) whole-thickness, (4) width of umbilicus in percentages of the diameter. The localities are referred to under numbers 1-12 in the specific descriptions to avoid lengthy repetitions, but they are given in full in Chapter 111. Since a number of the species here recorded have been
described from Kachh, the synonymies are also generally condensed. A full list of literature on the subject is given in the last part of my Revision of the Jurassic Cephalopoda of Kachh.
Key words: Ammonites, belemnites, Jurassic, Cretaceous, Attock.

S/463. Spath, L.F., 1939. The Cephalopoda of the neocomian belemnite beds of the Salt Range. Geological Survey of India, Memoirs, Palaeontologica Indica, New Series, 25, Memoir 1, 1-154, 25 pls.

Key words: Cephalopoda, belemnite, Salt Range.

S/464. Spencer-Cervato, C. & Spencer, D.A., 1991. Stable isotope analysis of the carbonates in the Higher and Lesser Tethyan Himalayan, North Pakistan. Abstract Volume, 6th Himalaya-Karakoram-Tibet workshop, Grenoble, France, 87.

The Upper Kaghan nappe in the NW Himalaya of Pakistan consists of a lower granitoid basement with two cover units: first, a metagraywake unit of Lower Paleozoic age and second, a Tethyan sedimentary sequence which has at its base the Permian Panjal Traps, which are continental tholeiitic to mildly alkaline basaltic lavas that evolved in the passive continental margin of neo-Tethys. Syn-depositional limestone (new-marble) intercalations occur between

the lava flows. These marbles show extensive extensional structures, associated with the rifting and subsequent extrusion of the lavas themselves. Due to the high grade of metamorphism under which the whole nappe has undergone (eclogite-amphibolite facies metamorphism) only a few fossils were found to indicate the age of the unit.
Previous geochemical correlations between the Higher Himalayan-Tethyan Panjal volcanics with known Lesser Himalayan-Tethyan Panjal volcanics in Kaghan Valley revealed that a correlation between the two units could be made. Carbon and oxygen isotope analyses on the marbles between the lavas, as well as those above the analytical groups consist of the Higher Himalayan Panjal Traps (HHPT), Lesser Himalayan Panjal Traps (LHPT), Higher Himalayan Tethyan Triassic series (HHTSS) and the Lesser Himalayan Triassic Rara Formation (LHTRF).
Preliminary analyses show that the marbles from the Panjal Trap units give a marine carbon isotope signature whilst the younger sedimentary series gave a different result. Such stable isotopic correlation is only possible because of the well-defined nature of the units being studied, and that the actual stratigraphic correlations with other documented sections are available. It is therefore considered as a powerful tool in the analysis and reconstruction of similar sedimentary environments that have subsequently undergone different tectonic histories.
Key words: Isotopes, carbonates, Himalaya.

S/465. Spencer-Cervato, C. & Spencer, D.A., 1992. Petrographic and isotopic study of the marbles from upper Kaghan valley, NW Himalaya, Pakistan. Proceedings of the Symposium on the Himalayan Geology, Shimane University, Japan, 56-58.

Key words: Isotopes, petrography, marbles, Himalaya.

S/466. Spencer, C.H., 1996. Gypsum plaster in Pakistan: Past, present and future. Proceedings, Second SEGMITE International Conference on Export Oriented Development of Mineral Resources and Mineral Based Industries, Karachi, 1994, p.199.

Key words: Mineral resources, gypsum plaster.

S/467. Spencer, D.A., 1988. Deformation of the Main Mantle Thrust zone at Babusar Pass, Karakorum, Himalaya, Pakistan. M.Sc. thesis, Imperial College, University of London.

Key words: Deformation, MMT, Babusar, Karakoram, Himalaya.

S/468. Spencer, D.A., 1991a. Different shortening histories between the 'syntaxial' and 'non-syntaxial' areas of the Himalayan belt. Abstract Volume, 6th Himalaya-Karakoram-Tibet workshop, Grenoble, France, 79-80.

Recent plate tectonic models of Himalayan deformation (e.g. Dewey et al., 1989) are, as yet, the most advanced suggested for the understanding of the collision zone. North of the Indus Suture, they show that shortening accommodation is not homogenous along the length of the mountain chain but varies: crustal thickening and uplift of the Tibetan plateau essentially occurring in north of the Central parts of the Himalaya and indentation with strike-slip faulting occurring in the Karakoram and Pamir region. Similarly, south of the suture, different amounts of shortening by thrusting are suggested to have occurred, although this does not explain how the structurally anomalous syntaxes are formed, their different structural, metamorphic and tectonic histories nor why they are confined to certain area of the Himalaya.
It is suggested that the deformational history south of the suture is primarily influenced by the shape of the Indian plate promontory in the NW Himalaya and the lack of the promontory in the Central Himalaya. The effect of this promontory resulted in the initiation of subduction in the NW parts of the Himalayan belt and reaches the greatest depths for the Indian plate, as evidenced by high pressure eclogite and blueschist facies metamorphism, which are conspicuously lacking in the Central Himalaya. Also, the occurrence of extensional tectonics in the Central Himalaya and its absence in the NW Himalaya probably also attests to differential uplift histories.
The effect of the initial collision of the promontory caused in the Indian plate to rotate anticlockwise in a force field adjustment. This rotation produced a change of tectonic transport shortening direction within the promontory and

subsequently led to large scale superimposed folding which explains syntaxial formation. By contrast, the central Himalayas were more of a ‘head-on’ collision with shortening easier north of the suture by plateau uplift and then by thrusting south of the suture.

Of fundamental importance in this interpretation is basically the argument about whether the Indian plate promontory actually exists and, if so, its shape. Indentation tectonics in the Pamirs with sinistral faulting on the western boundary and dextral faulting on the eastern boundary, deflection of Asian sutures older than Himalayan age, anticlockwise rotation of the Indian plate, the outline of the Higher Himalayan Crystalline, occurrence of syntaxes and differential rates of collision rates from NW to NE along the belt all attest to presence of a promontory and the subsequent progressive eastward closure of the suture. A ‘triangular’ shape for the promontory is thought to be the most appropriate.

It is obvious that the promontory did not act as a rigid indenter as thrusting occurred south of the suture. Similarly, during the uplift of the nappes, folding played a major part in the shortening history, in some cases producing a ‘Panini’ sheet-like deformation in the more internal units. Examples of fold interference are presented from the Hazara-Kashmir, Kaghan and Nanga Parbat-Haramosh Syntaxes, as well as basin and dome patterns in the Upper Kaghan area and are mainly due to a horizontal, anticlockwise translation of deformation, comparable and probably coeval with the movements of the Indian plate. Small-scale structures, as well as the metamorphic and geochronological considerations (Poignant, this volume) correlate well these modifications.

It is therefore suggested that folding is a crucial accommodation feature south of the suture in the syntaxial areas of the Himalaya and has been mainly neglected in shortening history models of the mountain belt. Slight modifications are therefore applicable to explain the deformational features south of the suture, where folding, as well as thrusting, are thought to be of great importance in the understanding of the different shortening histories between the ‘syntaxial’ and ‘non-syntaxial’ areas of the Himalayan belt.

Key words: Deformation, syntaxis, Himalaya.

S/469. Spencer, D.A., 1991b. Wie hoch konnen sich die gipfel des Himalaya-Gebirges heben? Erdwissenschaften Heute. ETH (Zurich) Bulletin 232, p.40.

Key words: Orogeny, Himalaya.

S/470. Spencer, D.A., 1991c. Evidence for the deepest and earliest derived nappe of the Indian plate, NW Himalaya, Pakistan. Proceedings of the Symposium on Himalayan Geology, Shimane University, Japan, 51-55.

Key words: Indian Plate, Himalaya.

S/471. Spencer, D.A., 1992a. Geochemistry of the peraluminous Higher Himalayan Crystalline Granite Basement, Upper Kaghan, Pakistan. Abstract Volume, 7th Himalaya-Karakoram Workshop, Department of Earth Sciences, Oxford University, England, 126.

The Higher Himalayan Crystalline Basement of Upper Kaghan Valley consists of granites of possible Precambrian (?) age. It is well represented in all parts of the Upper Kaghan nappe due to superposed folding that exposes different structural levels of the unit in both amphibolite and eclogite fades conditions. Major and trace element analysis of a variety of granites types show fairly consistent geochemical analysis. but with a differentiation trend.

Analyses are presented in three chemical mineralogical diagrams (Debon and Le Fort, 1983). In a Q-P diagram. the samples plot on the granite to adammellite sector. Characteristic mineral (A/B) plots show a distinctive trend from granite to granodiorite in the distribution line attitude of the representative points from the association. The slope (ie. the direction of its major evolutionary trend) Is negative and in contrast to that seen in the Leucogranite of Upper Kaghan and Zanskar which are vertical (parallel to A = Al - (K + Na + 2Ca). although with a negative trend when plotted together). The Higher Himalayan Crystalline Granites broadly correspond to the ‘Cafemic’ type of association. Quartz-rich and quartz-poor associations occur with samples plotting above and below the critical line and the colour Index ranges from leuco- to mesocratic. Most samples plot in the peraluminous domain and outside the leucocratic field (B>38.8). In the Q-B-F diagram. none of the samples plot In the leucocratic field but occur

between the Q/Q + F of 20-45%. A negative correlation between Na20 and K20 occurs with (Na20 + K20) varying from 6.12-9.52.
Major and trace element spider diagrams, with normalizations according to Thompson et al. (1984) and, for comparison, to the Bhutan Leucogranite Mean Standard Deviations, were made. Thompson normalisations show distinctive depletion in Sr. P and Ti with a general negative trend. Bhutan normalisations show rather constant depletion and enrichment amongst the samples themselves, compared to the standard deviation. Distinctive enrichment occur for Ba, Sr. Sc, Y. Zr, Ti and Zn, whilst depletion occurs for Na, K. Ca. Rb, P. Pb and Co. These patterns may reflect a highly evolved source for the protolith and to generate these concentrations, evolved continental material is needed.
An interesting comparison to the leucogranites of Kaghan can be made. Whilst the characteristic mineral diagrams show distinct differences between the basement and the leucogranite, there are some similarities in peaks between them on the spider diagram. The leucogranites were obviously derived from the basement rocks in Kaghan. A-F-M plots are certainly differentiated (F:A = 0.12-0.69) and follow the calc-alkaline differentiation trend, as seen for example in the granitoid rocks of the Trans-Himalayan Batholith. All trace element variation diagrams (Zr, Y. Ba and Rb) with increasing Si02 show a magmatic differentiation trend. On the A-C-F diagram, all points plot in the Type 1 field (Al rich) with the most distinguishable feature of these granites being the Al Content Number (Al2O3 / Na2O + K2O + CaO) all being greater than one (Al content ranges = 1.33 - 1.77). All the granites are therefore peraluminous. By contrast, a Ca-K-Na plot shows a distinctive trend with most having a poor Ca content (Ca<1.5: range 0.16 - 1.38). Other variation diagrams (Pb/SiO2: Pb/Ba; Y/Fe2O3 and Zr/P2O5) also show a distinctive grouping but differentiation of the Higher Himalayan Crystalline Granites compared to the Leucogranite. Further discrimination diagrams (Nb/SiO2 Nb/Y; Rb/(Y + Nb); Y/SiO2 and Rb/SiO2) all put the granites very distinctly into the field of within-plate granites.
The Higher Himalayan Crystalline Granites therefore appear to show very clear geochemical major and trace element characteristics. They were the obvious source of anatectic melting for the Himalayan-aged leucogranite by movement along the Main Central Thrust. Their aluminous content is distinctive and suggests a S-type origin forming in a within-plate environment.
Key words: Geochemistry, Higher Himalayan crystallines, Kaghan valley, Himalaya.

S/472. Spencer, D.A., 1992b. Himalayan eclogite exhumation by fold superposition. Abstract Volume, 7th Himalaya-Karakoram Workshop, Department of Earth Sciences, Oxford University, England, 127.

Superposed folds are common features in orogenic belts that can occur on a variety of scales ranging from micro- to megascopic (e.g. Loch Monar in the Caledontan orogenic belt and the syntaxes of the Appalachians and Himalaya orogenic belt). Their formation is usually accentuated by the occurrence of competence differences between different lithologies, as well as between different units, such as a basement and cover. When the scale of these differences is regional rather than local (as for example In the Higher Himalayan Crystalline of Northern Pakistan and the Lepontine Alps of Central Switzerland), It is possible that the differential local amplitudes of the superposed folds may play an important role in its exhumation history. This is especially so where the interference patterns are thought to be related to formation in an environment of primary origin (such as plate motion) rather than of secondary origin (accommodation features or changes In principal stress directions due to strain localization).
The Upper Kaghan Nappe of the NW Himalaya Is of crucial importance for the understanding of the deep-seated orogenic processes associated with the Himalayan collision. Bounded by the Main Central Thrust to the south and the Indus Suture to the north, this Higher Himalayan and Tethyan tectonic unit thus represents exposures of the deepest part of the Indian plate. Evidence of the deep subduction and subsequent differential exhumation of the nappe by thrusting along the MCT, erosion, Isostasy and fold superposition is shown by the presence within the nappe of an oval shaped area of eclogite facies metamorphism of some 150 km^2. Surrounding this high-pressure zone, with decreasing pressure isobar contours, but constant temperature conditions, are found rocks with amphibolite fades. Pressure-temperature estimations, based on microprobe analysis of mineral composition In the eclogites, gives T=650±500C at pressures of P=15 kbar. This equates to depths of formation of around 55-60 km at Eo-Himalayan times. In contrast, at the southwest front of the nappe, amphibolite fades assemblages of staurolite-almandine with kyanite-sillimanite suggest T=550-650^{0}C at P=8 kbar equating to a depth of formation at 30-km. Within the nappe itself, therefore, there seems to exist a relative horizontal pressure gradient that must have formed at different vertical depths In the order of 25 km. taking the minimum possible difference of differential exhumation. Thus, not only was the nappe subducted to different levels, it must have been exhumed at different rates as well. No

internal imbrications (uplift faults), shear zones or major discontinuities. nor extensional structures surrounding the eclogite-amphibolite fades transition have been found within the nappe. An alternative mechanism of exhumation is therefore proposed. The structural evolution of the High Himalayan and Tethyan units in Pakistan show a remarkable similarity to the Pennine style of nappe formation and deformation In the Alps: be. an initial development of large scale recumbent folds followed by complex large scale refolding subsequent to nappe emplacement. In the Higher Himalaya of Kaghan, where ductile deformation was the main process of deformation, evidence suggests that a polyphase ductile - penetrative overprinting occurred after the original nappe forming movement. This led to the development of a system of major post-nappe folds, which were superposed on, and deformed structures related to an earlier Himalayan history of deformation. As with the Pennine nappes of the European Alps, the post-nappe folds can be subdivided into two groups: main Himalayan folds and late Himalayan folds. The late folds are superimposed on the main Himalayan folds with type 1 or 3 interference patterns giving very large scale domes, which are found In the syntaxes, as well as basins and domes In the areas between the syntaxes. such as that in Upper Kaghan. The formation of the second phase basin and domes on the original nappe forming structure is a form of buckling anisotropy, as the earlier formed nappe-style recumbent sheet folds influence the subsequent preferred axes of buckling of the later superposed folds. The refolding is perpendicular to the nappe forming stretching lineation direction and the tectonic shortening direction is parallel to the first main phase Himalayan fold axial planes. The amplitudes of the folds of the latter structures are smaller than those of the recumbent style folds, emphasising that the nappe movements contribute to the overall uplift. However, subsequent horizontal compression on the nappe appears to have been a far more effective uplift mechanism, albeit localised to the amplification of the refolded isobars, than the differential shear accompanying the nappe forming movements. The dimensions of the late stage folds can be derived from their wavelength (W) and amplitude (A). Wavelength determinations between two Inflection points from a cross section parallel to the tectonic shortening direction responsible for their formation, gives a wavelength approximation of 10-km. The tightness of the folds, derived from tangents to the fold surface through the inflection points, gives an average interlimb angle within the close range (70o-30o) of 40o. By using Fourier coefficient analysis, the amplitude of the fold can be derived at 14-km. When the basins and domes are considered together (eclogites are also found in some basin depressions) this figure of 28 km (2 x Amplitude) is certainly within the ballpark of differential uplift within the nappe. Amplification rates of the folds in such an environment were probably not constant and may have been slow during the early continental collision tectonic history. Rather, the eclogite exhumation would be at a maximum during the latter part of the tectonic history. Overall, it may account for some 20-30% of the total vertical uplift, especially in the case of the Upper Kaghan Nappe in the Himalayas where the first confirmed high-pressure metamorphism was found within the Indian Plate of the Himalayan Belt.
Key words: Eclogite, exhumation, Kaghan valley, Himalaya.

S/473. Spencer, D.A., 1992c. Fold superposition as a mechanism of Himalayan rock exhumation. Abstracts, First South Asia Geological Congress, Islamabad, 65-66.

Key words: Exhumation, tectonics, Himalaya.

S/474. Spencer, D.A., 1992d. Continental collision in the Northwest Himalayan Tethyan Region. Abstracts, First South Asia Geological Congress, Islamabad, p.42.

Consult the following account and Spencer (1994a).
Key words: Continental collision, Himalaya.

S/475. Spencer, D.A., 1993a. What was the timing of the Himalayan continent-continent collision (45, 50, 55, 60 OR 65 Ma.)? Constraints from eclogites. Abstract with Programes, Geological Society of America, p.A-121.

The Himalayan collision may have been diachronous from west to east. A promontory collision may have caused the earlier and deeper subduction in the northwest Himalaya and account for variation in initial Collison timing. Earliest collision may have occurred at the KT boundary.
Key words: Continental collision, eclogite, Kaghan valley, Himalaya.

S/476. Spencer, D.A., 1993b. Tectonics of the Higher-and Tethyan Himalaya, upper Kaghan valley, Northwestern Himalaya, Pakistan: implications of an early collisional, high pressure (eclogite facies) metamorphism to the Himalayan belt. Doctoral Dissertation ETH nr.10194.

Key words: Continental collision, eclogite, Kaghan valley, Himalaya.

S/477. Spencer, D.A., 1994a. Continental collision in the Northwest Himalayan Tethyan Region. In: Ahmed, R. & Sheikh, A.M. (Eds.), Geology in South Asia--I. Proceedings of the First South Asia Geological Congress, Islamabad, 1992. Hydrocarbon Development Institute of Pakistan, Islamabad, 185-202.

The plate motion that is associated with the formation of the Himalayan Orogenic belts has been studied from many different aspects. In general, the collision of the Indian and Asian plates has essentially been described as a “head-on”, north-south collision of India into Asia with virtually no significant component of compression parallel to the plate boundaries. This is generally accepted by many worker to have occurred in Eocene times (55-40 Ma) and very few have argued that collision was significantly earlier by up to 10-25 Ma. Interpretations of strain partitioning in the Himalayan collisional belt have been made by numerous authors who emphasized that the Himalayas themselves only took up some one-third of the shortening, the other two thirds being accommodated in the Asian Plate itself. There are five main methods by which the collision of the Indian into the Asian Plate has been accommodated (extrusion (strike-slip) tectonics, uplift and crustal thickening, thrusting, extension and folding). The structural evidence from a simple “head-on”, south-north collision in the Northwest Himalayan region is not apparently convincing when many of the localized tectonic variations are considered. In view of the localized exhumation anomalies that are now found in the Northwest Himalayan region (Upper Kaghan eclogites, Nanga Parbat granulite facies metamorphism, Shang La blueschists etc.) and their associated basinal depressions (Kashmir Basin, Peshawar Basin, Skardu in intermontane Basin). It is interpreted that this may all attest to differential exhumation and subsidence for different localities in the Himalayas. These occurrences may be localized in space yet they should be explained, on a broader scale, to regional variations in the plate movements. Numerous variations along strike of the Himalayan belt can be documented in the Asian and Indian Plates. These observations, combined with the fact of the remarkable linearity of the units of Himalayan Orogen, suggest that they were diachronous. The diachroneity is suggested to be due to the rather gradual changes along strike of the major Himalayan units. Much evidence suggests a promontory collision in the Northwest Himalayan has occurred. The indentation promontory of the Indian block may have had a “triangular” shape. The promontory would be the first part of the crust to suduct and effectively go to the deepest level and attain the highest pressure for any part of the collision zone. The recognition of the eclogite facies metamorphism is suggested to be an important factor in the understanding of the timing of the Himalayan collision. Upper Kaghan may be the “tip of the iceberg” in terms of the extent of the eclogite facies metamorphism.
Key words: Continental collision, eclogite, Kaghan valley, Himalaya.

S/478. Spencer, D.A., 1994b. Volatile alteration and metamorphic facies: Release of H_2O and CO_2 in the Panjal traps of the NW Himalaya. Journal of Nepal Geological Society 10 (Abstract Volume, 9th Himalaya-Karakoram-Tibet Workshop, Kathmandu), 12-129.

Whilst the bulk rock geochemistry of a basalt, subjected to progressively increasing metamorphic grade, may remain on the whole isochemical, it has been long known that volatiles would have to be released and cannot remain constant. Three volatiles which should change through an increase in metamorphic grade are H2O, CO2 and O2. The various metamorphic grades of the Panjal Traps in the NW Himalayas (unmetamorphosed, greenschist, amphibolite and eclogite facies) provide an ideal opportunity to test these ideas and possibly act as chemical indicators of the state of alteration of the rock. Direct and indirect determination of CO2 and H20 were made on numerous samples.
Direct determination of CO2 content in a rock sample has been made by coulometric titration for five main groups: Zanskar Tethyan Shelf - Panjal Trap basalts (Ba); Lesser Himalaya - Panjal Trap Basalts (PJ); Higher Himalaya Second Cover: a -Panjal Trap amphibolites (A): Higher Himalaya Second Cover: a - Panjal Trap Dolerites (D) and

Higher Himalaya Second Cover: a - Panjal Trap eclogites (E). The main observation on the occurrence of % CO_2 in the Panjal Traps with increasing metamorphic grade is that there is a decrease in % CO_2 content that appears to be fairly gradual. This therefore suggests that with increasing metamorphism, CO_2 is being driven off by decarbonation reactions.
Estimation of the volatile content in a sample can be made by the simple weight loss on ignition, and used as a method of indirect determination of H20. The loss on ignition and the H20(+FeO) in the Panjal Traps show that with an increase in metamorphic grade there is a decrease in the L.O.I and H_2O(+FeO) content that appears to be fairly gradual. This therefore suggests that with increasing metamorphism, volatiles are being driven off by dehydration reactions.
Comparison of the results of this work with the results of some published theoretical calculations are made for the wt. % H_2O of a subducting, and therefore dehydrating, oceanic crust or tholeiitic basalt. Here, predictions were made by combining calculated pressure- temperature paths with a model of metabasalt phase equilibria, where a progression (for the upper parts of the oceanic crust) pass through greenschist to amphibolite to eclogite facies. The agreement between these two independently produced sets of data is clearly apparent.
Key words: Metamorphism, geochemistry, Panjal traps, Himalaya.

S/479. Spencer, D.A., 1994c. Where is (Is there a?) Main Central Thrust in the NW Himalayas of Pakistan? Journal of Nepal Geological Society 10, Abstract Volume, 9th Himalaya-Karakoram-Tibet Workshop, Kathmandu, 129-130.

The term "Main Central Thrust" was first introduced into Himalayan terminology by Heim and Gansser in 1939. They described the detachment as a tectonic contact surface between a terrigenous-carbonate autochthon and an overlying metamorphic complex of mica schists and gneisses. It generally dips towards the north and is not a single tectonic discontinuity, but rather a thick shear zone, in places ranging from 5-20 km. It is associated with a strong stretching lineation, strong foliation, and high strains. Still today, much discussion occurs about whether the Main Central Thrust is actually one or two or three thrust surfaces, especially in the Central Himalaya of India and Nepal. As the Main Central Thrust is widely accepted as the intracontinental thrust that separates the Higher and Lesser Himalaya, its recognition is therefore implicit in using these unit names in the Pakistan Himalaya. Any description of the Main Central Thrust must be associated with accompanying structural, metamorphic, stratigraphic and tectonic considerations, which have been well defined in other parts of the Himalayas. For any location of the Main Central Thrust to therefore be accepted, it must comply with all, if not most, of these considerations and not just part of it. Therefore, a description or location of a possible Main Central Thrust cannot be considered without comparing on a regional scale what the implications of this definition mean.
The location of any "Main Central Thrust" in the Pakistan area of the Northwest Himalayan region is likely to remain controversial for some time. This is simply because the area where the Main Central Thrust was last seen, to the south of the Kashmir Basin, was some 100-km away from the next suggested location in Neelum and Kaghan Valleys. This intervening area between the last known location and any new suggested location is only scantily mapped in part. This is due to a border dispute between the countries of Pakistan and India regarding tile Kashmir region.
The first occurrence of the Main Central Thrust at Batal, Kaghan Valley, was described by Chaudhry and Ghazanfar in 1986. Since then, ten other suggestions of locations of the "Main Central Thrust" have been made in Pakistan. Whilst it is obvious that not all of these interpretations can be correct, a review of their indicative features is given for discussion. It is also important to note that other workers in the NW Himalayas suggest that the terminology of the "Main Central Thrust" and the associated " Higher- and Lesser Himalaya" be discontinued completely in this region.
Suggested "Main Central Thrust" locations in Pakistan are:
A Main Central Thrust on the western side of the Nanga Parbat Syntaxis
The Shontargali Thrust is an analogue of the Main Central Thrust
The Panjal Fault is, in part, the equivalent of the Main Central Thrust
The Mansehra and Panjal Thrusts are coeval to the Main Central Thrust
The Balakot Shear Zone is the equivalent of the Main Central Thrust
The Oghi Thrust is the equivalent of the Main Central Thrust
The Luat Fault is the equivalent of the Main Central Thrust
Main Central Thrust is located in the lower part of Neelum Valley
Main Central Thrust is the northward continuation of the Batal Fault

Main Central Thrust is folded to form the Kaghan Syntaxis

Only one position of the Main Central Thrust, at Batal in the Kaghan Valley which was the one first recognized by Chaudhry and Ghazanfar in 1986, is generally accepted by the majority of northwest Himalayan workers (who do believe in a continuation of the MCT) as the correct location for a major tectonic contact which might correlate with the Main Central Thrust.

Key words: Tectonics, MCT, Himalaya.

S/480. Spencer, D.A., 1994d. Tectonics of the Higher and Tethyan Himalayan, Upper Kaghan Valley, NW Himalaya, Pakistan. Journal of Nepal Geological Society 10, Abstract Volume, 9th Himalaya-Karakoram-Tibet Workshop, Kathmandu, 132-134.

This presentation will aim to summarize the work that has been done in Upper Kaghan over the last few years, to outline existing problems and to attempt to categorise this area in a Himalayan framework (Spencer, 1993). The Upper Kaghan Nappe is tectonically situated in the western syntaxis area of the Northwest Himalaya, NE Pakistan. It belongs to the Higher Himalaya and, as such, it is here delimited by the Main Central Thrust at its base and the Indus Suture at its structurally highest position. The nappe is suggested to be unusual from the generally accepted concepts of other known regions of the Higher Himalaya. Stratigraphically, the Higher Himalaya basement (granite intruding into minor, older metasediments) is overlain by two Tethyan lithological covers (Lower Palaeozoic to Triassic?), which were also metamorphosed during the Himalayan orogeny. Structurally, numerous macrostructural measurements (planar, planar-linear, folds, faults etc.) define at least two major phases of deformation - the first associated with the nappe forming event and the latter deforming the recumbent folds to form a superposed type 1 or 3 interference pattern. Very high strain can be recorded associated with the early ductile deformation. The Indus suture shows only evidence of a late-stage "top-to-the-south" thrust sense of shear, although this is suggested to overprint an earlier extensional movement along the suture zone. This, and the late-stage interference folds (suggested to act as a mechanism for increased erosion by advancing relative uplift), act as the exhumation processes for one of the most unusual features that have been found in Upper Kaghan: the eclogites.

The eclogites of Upper Kaghan show Xjd contents of omphacite of up to 0.431, which retrogress to diopside. All garnets are almandine-rich (Xalm = 0.460 - 0.592) and coexist with sodic calcic and alkalis amphiboles, phengite and rutile. Garnet -clinopyroxene Fe2+ Mg exchange thermometry calculates a mean temperature of formation of 650oC ± 50oC. Garnet-phengite (Fe2+-Mg) exchange thermometry suggests 658oC ± 17oC – 676oC ± 38oC. The jadeite + quartz and the phengite Si4+ barometer indicates pressures up to 17.5 kbar, suggesting depths of formation of some 60-km, the deepest known rocks yet to be found that were exhumed by the Himalayan orogenesis. Retrogressive exhumation took place at decreasing temperatures. Three stages of metamorphism are suggested: Ml - rapid increase of pressure and temperature associated with the subducting Indian plate; M2 a decompressional event with decreasing pressure and temperature associated with a stable geotherm; M3 a retrogressive phase associated with overprinted greenschist facies metamorphism. The metamorphic conditions in the nappe are not constant with evidence of isothemic but non-isobaric gradient from the core to the outer sheets of the nappe.

Cathodoluminescence observations on the carbonates of the second Tethyan cover show that at least part of the calcite is not the product of dolomite decarbonation but that tremolite and diopside are closely related to the existing calcite composition. Sedimentary structures only seen in cathodoluminescence suggests a shallow shelf sea environment of formation for the Panjal trap carbonates. XRD calculations of the mineralogical content of the carbonates distinguish between the stratigraphic lower calcite-rich carbonates and the stratigraphic higher dolomite-rich samples, although, the "Permian Carbonates" contain minor calcian dolomite (Mg39Ca61CO3).

Geochemically, the basement feeder and cover flow eclogites and amphibolites (as well as the Lesser Himalaya and the unmetamorphosed Panjal Traps) show remarkable similar element abundances and discriminate to tholeiitic (to sub-alkalic), within plate, continental flood basalts. The Higher Himalayan basement is a peraluminous, "S"-type granite forming in a within-plate environment with signatures that closely correlate to the Mansehra granite. The peraluminous Higher Himalayan leucogranites show many similarities with the Higher Himalayan basement and appear to be derived from the basement granites. δ18O and δ13C isotopes on the carbonates of the Higher Himalaya second cover of upper Kaghan show a distinctive chemo-stratigraphical trend between the known and suggested Permian/Triassic sequences, suggesting stratigraphic affiliation. With increase of the grade in metamorphism, both show a regular successive depletion in the means from a δ13C of +2.3% to -1.5% PDB and δ18O of +20.3% to +16.7% SMOW. Isotope depletion ratios essentially depend on carbonate mineralogical content. Negative shifts of carbon isotopes at the assumed Permian - Triassic boundary of Zanskar are also found. Radioactive isotope ages of samples from the Upper Kaghan nappe are: 147Sm/143Nd ana1ysis of garnet and clinopyroxene in eclogite gives an age of 49±6 Ma (εNd = +2.6); 87Rb/87Sr analysis of phengite, garnet and clinopyroxene in eclogite gives an age of 43 ± 1 (initial 87Sr/86Sr ratio of 0.70900 ± 0.00004); 238U/2O6Pb analysis of rutile in eclogite gives ages of 39 - 40 +1 40K/40Ar analysis of hornblende and biotite in amphibolite and eclogite range from 35.2 ± 1.4 Ma to 42.7 ± 1.4 Ma for hornblende and 26.3 ± 0.7 Ma for biotite. 39Ar/40Ar analysis of phengite and amphibole in eclogite suggests that excess argon was incorporated as they define ages of >106 Ma for amphibole and 81 Ma for phengite. Caution is suggested when using the 39Ar/40Ar method for high-pressure samples. 147Sm/143Nd whole rock analysis of basalts, metabasalts, amphibolite, amphibolite-eclogites and eclogites, which pertain to give the extrusion age of the Panjal Traps, are 337 Ma (εNd = +3.2) although the M.S.W.D. is high. Whole rock 143Nd/144Nd analyses of the amphibolites and eclogites of Upper Kaghan (and the Panjal Traps of the Lesser Himalaya and Zanskar) identify them as tholeiitic continental flood basalts. εNd t = 270 varies between -9.9 to +4.9 with the more positive values occurring at the higher metamorphic grades. Minor continental crust contamination is present with a mixing curve evolution. Whole rock initial 87Sr/86Sr ratios range from 0.70559 ± 3 to 0.71643 ± 4 (with one exceptionally high 0.73829 ± 3) again suggesting signatures that evolved through the continental crust as tholeiitic, continental flood basalts. Using this new data and published literature data, the cooling history of the Upper Kaghan nappe is determined at 13º –14ºC/Ma. Structural subdivisions of the nappe by core and outer sheet indicate a "rapid - slow - rapid" cooling history rather than a constant cooling history as determined for the nappe as a whole. The cooling history of Upper Kaghan is very different to that of the Nanga Parbat and Besham areas. It is also very different to the East Central Kohistan Island arc.

Fluid inclusion studies on the eclogites and quartzites in upper Kaghan show the presence of three systems of secondary inclusions: H_2O-CO_2-NaC1, H_2O-CO_2-CH_4 and CO_2. Isochore calculations show that they were all the product of late stage metamorphic retrogression that led to the liberation of CO_2 and H_2O which formed in an early less dense phase followed by a late higher density phase. Tectonically, the Upper Kaghan nappe shows variation in exhumation rates from the outer sheet to the core of 0.75 - 1.3 mm/year. It is related to a model of anti-clockwise change in the tectonic transport direction, which has been earlier ascribed to the structural evolution of the Hazara-Kashmir and Kaghan syntaxis. The finding of this early, high pressure phase of eclogite facies metamorphism renews speculations that an initial Indian plate impingement occurred in the Northwest Himalayan region at around 65 Ma and that successive west - east suturing of the Indian and Asian plate continents occurred subsequently in the Central and Eastern Himalaya.

Key words: Tectonics, Kaghan valley, Himalaya.

S/481. Spencer, D.A., 1995a. Where is (Is there a?) Main Central Thrust in the NW Himalayas of Pakistan. Journal of Nepal Geological Society 11, 63-72.

The term 'Main Central Thrust' was first introduced into Himalayan terminology in 1939. Still today, much discussion exists about whether the Main Central Thrust is actually one, two or three thrust surfaces, especially in the Central Himalaya of India and Nepal. As the Main Central Thrust is widely accepted as the intracontinental thrust that separates the Higher and Lesser Himalaya, its recognition is therefore implicit in using these unit names in the Pakistan Himalayas. The location of any 'Main Central Thrust' in the Pakistan area of the Northwest Himalayan region is likely to remain controversial for some time. This is simply because the area where the Main Central Thrust was last seen, to the south of the Kashmir Basin, was some 100 km away from the next suggested location in the Neelum and Kaghan Valleys. This intervening area between the last known location and any new suggested location is only scantily mapped in part. Eleven suggestions of locations of the 'Main Central Thrust' have been made in Pakistan and a review of their indicative features is given for discussion. Only one position of the Main Central Thrust, at Batal in the Kaghan Valley, is generally accepted by the majority of northwest Himalayan workers (who do believe in continuation of the MCT) as the correct location for a major tectonic contact which might correlate with the Main Central Thrust.

Key words: Tectonics, MCT, Himalaya.

S/482. Spencer, D.A., 1995b. Volatile alteration and metamorphic facies: Release of H_2O and CO_2 in the Panjal volcanics of the NW Himalaya. Journal of Nepal Geological Society 11, 89-102.

Whilst the bulk rock geochemistry of a basalt, subjected to progressively increasing metamorphic grade, may remain on the whole isochemical, it has been known that volatiles are likely to be released. Three volatiles which should change through an increase in metamorphic grade are H2O, CO2 and O2. The various metamorphic grades of the Panjal Volcanics in the NW Himalayas (unmetamorphosed, greenschist, amphibolite and ecologite facies) provide an ideal opportunity to test these ideas and possibly act as chemical indicators of the prograde metamorphism. Direct and indirect determination of CO2 and H2O were made on numerous samples. Direct determination of CO2 content in a rock sample has been made by coulometric titration for five main groups: Zanskar Tethyan Shelf-Panjal Volcanic basalts (Ba); Lesser Himalaya-Panjal Volcanic basalts (PJ); Higher Himalaya Second Cover-Panjal Volcanic amphibolites (A); Higher Himalayas Second Cover-Panjal Volcanic dolerites (D) and Higher Himalaya Second Cover-Panjal Volcanic eclogites (E). The main observation on the occurrence of % CO2 in the Panjal Volcanic with increasing metamorphic grade is that there is a decrease in CO2 that appears to be fairly gradual. This therefore suggest that with increasing metamorphism , CO2 is being driven off by decarbonation reactions. Estimation of the volatile content in a sample can be made by the simple weight loss on ignition, and used as a method of indirect determination of H2O. The loss on ignition (L.O.I) and the H2O (+FeO) in the Panjal Volcanics show that with an increasing metamorphism, volatiles are being removed by dehydration reactions. Comparison of the results of this work with the results of some published theoretical calculations are made for wt.% H2O of subducting, and therefore dehydrating, oceanic crust or tholeiitic basalt. Here, predictions were made by combining calculated pressure-temperature paths with a model of metabasalt phase equilibria, where a progression (for the upper parts of the oceanic crust) pass through greenschist to amphibolite to eclogite facies. The agreement between these two independently produced sets of data is clearly apparent.
Key words: Geochemistry, metamorphic facies, Panjal volcanics, Himalaya.

S/483. Spencer, D.A., 1995c. Continental collision in the northwest Himalayan Tethyan region. In: Ahmed, R. & Sheikh, A.M. (Eds.), Geology in South Asia-1. Proceedings, First South Asia Geological Congress Hydrocarbon Development Institute Pakistan, Islamabad, 185-202.

Consult Spencer (1994a).
Key words: Continental collision, Himalaya, Tethyan region.

S/484. Spencer, D.A., 1995d. The Indus suture zone (Northwest Himalaya, Pakistan): Problems of high pressure lithology interpretation. Abstracts, International Symposium on Himalayan Suture Zone of Pakistan. Pakistan Museum of Natural History, Islamabad, 5-8.

The nature (i.e. structure and lithology) of the Indus Suture in Pakistan is traced. The blueschists (yielding 100±20 to 67±12 Ma) in the suture mélange in Shangla (Swat) and adjacent areas is described, as are 49±6 to 43±1 Ma eclogites from Kaghan valley. The Himalayan deformation play an important role with the evolution of the high pressure rocks, yet these ages are interpreted as resulting from a pre-Himalayan event.
Key words: Indus Suture Zone, blueschists, eclogites, Shangla, Kaghan, Himalaya.

S/485. Spencer, D.A., 1996a. “Collapse folding” as a mechanism of explaining the early ductile extension along the Indus Suture and the subsequent exhumation of the Himalayan eclogites (Upper Kaghan, Pakistan). Abstract volume, 11th Himalaya-Karakoram-Tibet Workshop, Flagstaff, Arizona, 141-142.

The structural evolution of the Higher Himalayan and Tethyan units of Upper Kaghan has been suggested to show a remarkable similarity to the “Pennine style of nappe formation” and deformation in the Alps: i.e., complex large-scale folding subsequent to fold nappe emplacement (Spencer, 1991, 1993). However, one of the major problems that exist in the interpretation of the “Penninic folding” model for the Upper Kaghan Nappe, is the Indus Suture. Whilst no evidence for extensional movement on the Indus Suture was found in the brittle structures, extensional movement during ductile deformation could have occurred. The Indus Suture may have had, in its early stage of deformational history, a significant effect on the eclogite facies metamorphism because the pressure-temperature-time data show that a significant amount of early exhumation had taken place during the first 15 m.y. since peak

metamorphism. Erosion alone is probably not fast enough to achieve the exhumation and the suggestion of an early phase of extensional tectonics along the suture is likely.
Froitzheim (1992), describing the D2 folds of the Swiss Austroalpine nappes, suggested that the footwall folding during extensional tectonics is not only possible, but exists to depths of several kilometers even with only moderate shear deformation. He shows the D2 folds in the Ela and Err-Carungas nappes are related to ductile crustal stretching and thinning contemporaneous with normal faulting in the Silvretta nappe. High competence contrasts and the fact that the folds are not restricted to mylonite zones, are used to suggest that a sheath fold model does not apply. A pure or simple shear extension model is suggested where both would result in footwall folding. In simple shear extension, it is suggested that the most intense folding is likely to occur in layers that dip in the same direction as the shear plane, but at a slightly steeper angle. The model is termed “Collapse Folding”.
The “Collapse Folding” model provides a solution for the formation of recumbent folds in a simple shear environment (thrusting at the base and extensional tectonics at the top). It also allows for the vertical thinning (and, therefore, exhumation) of footwall lithologies. A combination of the deformation with a thrust fault at the structurally lowest level (Main Central Thrust), recumbent nappe folding between the structurally lowest and highest levels and extensional movement at the structurally highest level (Indus Suture) is described and can explain how footwall folding (eclogite uplift in the core of the Upper Kaghan Nappe) can occur from extensional movements. The effect of uplifting the footwall with folding and lowering the hanging wall (essential for eclogite exhumation) is relatively unknown. Moreover, the timing of these features is important. If the extensional sense of movement had occurred along the Indus Suture, this would have had to develop at the same time as the footwall deformation, which produced the recumbent folds.
The following listed evidence suggests that the Upper Kaghan Nappe may be associated with the first (and subsequent second) major phase of deformation (50-35 Ma):
Rapid cooling rates within the Upper Kaghan Nappe from 50-35 Ma
Change in cooling paths within the Upper Kaghan Nappe at 32 Ma
Rapid exhumation rates within the Upper Kaghan Nappe from 50-35 Ma
Change in exhumation paths within the Upper Kaghan Nappe at 35 Ma
Convergence of cooling paths from the footwall and hanging wall of the Indus Suture after 20 Ma, suggesting that the movement that had caused their separation was now complete and underwent a common thermal history. The localized nature of the eclogite facies metamorphism which is interpreted as being controlled by the first phase of folding in that it only occurs in the core of the Upper Kaghan Nappe
Thrusting on the Main Central Thrust, which forms the lower boundary plane of the nappe, is shown by the large mylonite zone that marks its delineation with all sense of shears showing a “top-to-the-southwest” sense of movement
Early thrusting on the Main Central Thrust is shown by the fact that leucogranites, which are suggested to be formed by movements along the shear zone, give ages of ≈ Ma (Zeitler and Chamberlain, 1991).
The “Collapse Folding” model relies on the fact that ductile deformation can occur in an extending crust below a certain depth, which is in turn dependent on the magnitude of the least principals stress, geothermal gradient, fluid pressure and deformation mechanisms, amongst other factors. For the model to be applied in mountain-forming orogens, a steep initial orientation of the layering and then a phase of lateral extension is then required for footwall ductile folding to occur. Extension can be caused by any mechanism (gravitational spreading, pull-apart extension, lateral, etc.) and the results are suggested to be the same.
An interpretation of the above evidence explains the rapid exhumation of the Upper Kaghan Nappe whilst the early D1 folding was occurring (Spencer, 1993). The “Collapse Folding” is interpreted to occur coeval with the thrusting along the Main Central Thrust and extension along the Indus Suture. The fact that the “Collapse Folding” occurred so early in the deformational history allows for the conditions of ductile folding to occur in the footwall whilst the extension is still occurring. Most importantly however, unroofing and uplift that would not be present if the Indus Suture maintained its thrust sense of shear. Discussion on the reasons for the change from thrusting to extensional movement at or around 50 Ma and a model to show the formation of recumbent folds in a simple shear, “Collapse Folding” regime will be shown.
Key words: Structural evolution, collision, Kaghan valley, Himalaya.

S/486. Spencer, D.A., 1996b. The Upper Kaghan Nappe (NW Himalaya, Pakistan): Regional Synopsis. Abstract volume, 11th Himalaya-Karakoram-Tibet Workshop, Flagstaff, Arizona, 145-146.

The tectonic evolution of the Upper region involves two simple considerations: the mechanism of subducting the Indian Plate to depths within a specific time that is constrained by the large-scale plate tectonic forces and, secondly, it's subsequent exhumation to the surface where it is found today. The relation between the timing of peak metamorphism and the timing of collision of the Indian Plate shows that Himalayan metamorphism in the Upper Kaghan region was well under way by 50 Ma and that peak metamorphic conditions were reached very soon after collision. It is important to ascertain whether the Upper Kaghan eclogites can be subducted to the appropriate depths in the given time available and whether the lithologies will heat up to produce the suggested 650ºC suggested for the peak metamorphic temperatures. Theoretical thermal observations suggest that Himalayan metamorphism is the result of thermal relaxation after crustal thickening and has been used by previous researchers as a type example in the continental collisional models. Predictions necessitate that at least 20-25 m.y. is needed for thermal equilibrium to heat the Indian Plate to 650ºC, unless an alternative heat source is found. If the Himalayan metamorphism is not related to crustal thickening, then its relationship to the actual processes of subduction of the Indian Plate beneath the Kohistan Island Arc is the most viable alternative. Plate models rely on a rather simplistic set of parameters: plate velocity, depth of subduction, distance of subduction, angle of subduction and finally the time needed for subduction.

The results for the rates of subduction, with variations in the angles of subduction range from 5º to 45º which subsequently alters the distance to subduct (to eclogite forming depths of 60 km) form 42 km to 688 km. This is coupled with the velocity of the plate movement, which is varied from between 15cm/year to 1cm year. If the most generally accepted velocity of Indian Plate movement (15cm/year) and angle of subduction (30º) are considered, then only a minimum time interval of less than 1 m.y. is needed to produce the depth sufficient to attain eclogite facies metamorphism in the Upper Kaghan region. With virtually any angle of subduction from 5º-45º, the subducting slab will reach depths of eclogite formation in less than 5 m.y. This suggest that collision can have occurred at any time from 0.8-4.6 m.y. before the peak metamorphism, and any estimate that can therefore range from 50-56 Ma for the timing of collision is acceptable for the depths achieved for eclogite formation. The time needed to reach the temperature of formation of the eclogite is calculated by solving the one-dimensional conduction equation. Here, temperature of eclogite formation can be obtained by heating as a result of subduction as the depth of penetration of a given isotherm increases with plate velocity. Therefore, the depth of the slab temperature inversion within the slab decreases with increasing plate velocity, easily resulting in the necessary temperature recorded by the Upper Kaghan eclogites. The fundamental key to achieving this result is the temperature recorded by the Upper Kaghan eclogites. The fundamental key to achieving this result is the velocity of the Indian Plate at the initiation of collision. If it is fast, subduction will be rapid and eclogite depths of formation easily achieved with corresponding medium (600ºC) temperatures.

Exhumation consists of the amount of material that has been removed by erosion or tectonic thinning (i.e., relative uplift combined with erosion). The exhumation rate is the rate at which a rock rises from depth of burial towards the earth's surface. Time-averaged rates of exhumation can be obtained from depth-time averages. Maximum pressure estimates of the eclogite path give 16-18 Kbar, which equates to depths of formation at 60-65 km with peak metamorphism at 49 ma. The average exhumation rate is, therefore, 1.2-1.3 mm/year. By contrast, maximum pressure estimates for the amphibolite path give 8-9 Kbar which equate to depths of formation at 30-35km with peak metamorphism around 40 (?) Ma. The exhumation rate is, therefore, 0.7-0.9 mm/year. These exhumation rates are more or less consistent with previous authors, interpretations of exhumation rates for the areas to the west of Upper Kaghan e.g., for Nanga Parbat at 1 mm/year and for the Suru region at 1.4-2.1 mm/year. Nevertheless, whilst these exhumation rates are comparable for the Northwest Himalaya, they bring rocks in the core of the upper Kaghan nappe to the present surface from depths of almost double those exposed in Nanga Parbat. This is simply due to the timing of peak metamorphism and the depths from which they originated. Exhumation rates can also be derived from pressure-temperature paths (i.e., the appropriate depth at which the cooling age occurred). The amphibolite facies area plots with an early stage of rapid exhumation and then a slowing down at 35 Ma. For the eclogite nappe core, the results again show an early stage of rapid exhumation and then a slowing down at 35 Ma. This shows that the exhumation was much greater in the early part of the Himalayan orogeny than in the later. Perhaps as much as two thirds of the exhumation took place in the first 15 m.y. with a noticeable change in the exhumation rates at around 37 Ma. This exhumation is suggested to be related to two main tectonic processes: early extension along the Indus Suture with associate "Collapse Folding" and late fold superposition combined with erosion. The evidence shows a fast exhumation history in the first 15 m.y., that is, in the early stages of the nappe emplacement combined with extension. This is suggestive of exhumation during convergence. Other evidence, however, does come from the pressure-temperature path which changes from the perturbed/stable to the relaxed state (i.e., heating begins signifying that the subduction is over). The underplating of the Indian Plate below the nappe is considered to be of crucial importance in driving the exhumation as it is this that creates the normal faulting along the Indus Suture that appears to thin the crust and exhume the nappe.

In summary, the exhumation history and exhumation rates all point to the fact that Upper Kaghan appears to be the most far traveled nappe known so far in the Northwest Himalayas and possibly in the Himalayas. This may assert that, during the collision of the Indian Plate, the Upper Kaghan nappe was the first impinging part of the Indian Plate to collide due to the Indian Plate promontory and again suggests that the Indian Plate collision was not simply one of head-on collision, but one that varied from west to east across the Himalayan belt. For an overview of some of the features associated with the Upper Kaghan Nappe, a time chart for the structural, metamorphic and cooling history, related to the Indian Plate motion, is given. Its aim is to show how many aspects of the tectonic history of Upper Kaghan show some remarkable interactions with each other. A summery model of the collision and subsequent exhumation of the Upper Kaghan Nappe is also presented.

Key words: Structural evolution, continental collision, Kaghan valley, Himalaya.

S/487. Spencer, D.A., 1996c. Structural geology of the upper Kaghan nappe, NW Himalayas, Pakistan. Abstract volume, 11th Himalaya-Karakoram-Tibet Workshop, Flagstaff, Arizona, 151-152.

The structural geology of the Upper Kaghan area shows a complex history of Himalayan-aged deformation which r3esulted in the formation of many small-scale and large-scale features. Many observations of small-scale structure were made at the micro-, macro- and megascale.

Planar Structures

Planar structures, such as the preservation of original sedimentary bedding surfaces, which are surfaces of primary accumulation, are only preserved in the Higher Himalayan First and Second Covers. No evidence was found for bedding in the Higher Himalayan Basement. A schistosity is often parallel to a gneissic foliation or banding consisting of impersistent laminae and segregations of mineral grains. All evidence suggests that the schistosity that is observed in the Upper Kaghan region is of Himalayan age. This is based on the fact that the mineral grains show a preferred orientation (such as mica, flattened quartz and amphibole) that form as a result of the imposed tectonic strain field have been dated as Himalayan. No evidence has been found that suggests that the schistosity cuts a pre-existing penetrative fabric. The orientation of the schistosity in the Upper Kaghan area is extremely varied, explained by subsequent refolding of the S1 schistosity by a later F2 folding event. An axial planar crenulation cleavage occurs that is approximately parallel to the axial planes of the folds of the deformation, which produced the schsitosity. The axial planar crenulation cleavage generally has a northeast-southwest or north-south orientation and are parallel (or subparallel) to the F2 folds. The position of the limbs and hinges of the fold cause a striping known as the crenulation cleavage fold axes to occur. This banding forms due to the relative enrichment or depletion of insoluble and soluble minerals such as quartz and mica. The calculated crenulation cleavage fold axes lies close to the great circle of the F2 fold axes and the F2 fold axis congregate around this position. The mean vector of all the data shows a consistent northeast-southwest orientation. A plot of the crenulation cleavage traces joins the axial surfaces of the small-scale crenulation cleavage folds. These directions can generally not be extended over very large areas as the folds are often impersistent. Nevertheless, they provide further indication of the strain ellipse XY plane orientation of the second phase of deformation. All crenulation cleavage traces indicate a ubiquitous northeast-southwest orientation, apparently parallel to the crenulation cleavage fold axes and the L1 mineral-stretching lineation.

Planar-linear and linear structures

Four lineations were measured. An intersection lineation is either aligned parallel to the axes of the F1 folds showing a low to moderately dipping, northeast-southwest orientation or sub-parallel to the mineral-stretching lineation. A mineral-stretching lineation is defined by mica, amphiboles and phyllosilicates and is low to moderately plunging, with a southwest-northeast orientation. The lineation is far less common around the Besal area due to the fact that the Besal area comprises of the structural core of the Upper Kaghan nappe where the metamorphism appears to predate the main deformational period. A few observations of a crenulation cleavage intersection lineation are found in regions where the F2 folds form a fold hinge. Variations in orientations ranged from plunges of north to northeast, although always at moderately dipping angles.

Folds

Folds form an important structural component of the Upper Kaghan area. The large, nappe scale F1 fold axes were never directly measured in the field (as no hinges to these major folds were directly observed). The existence of the F1 folds through smaller scale folds however possibly relate to the major fold axes. In general, the fold axes strike form northwest-southeast, plunging at low to high angles. The F1 fold axes are sub-perpendicular to the mineral-stretching lineation. The folds are generally recumbent (tight to isoclinal). F1 fold axial planes were generally oriented at low dips, although the values were often quite variable due to subsequent refolding by F2. F1 fold axial traces varied throughout the Upper Kaghan nappe due to the refolding of F2. In the Besal area, this probably had an initial strike east-west, but this direction was subsequently changed orientation to north-south. The F2 fold axes are found to be associated with the crenulation cleavage folds and crenulation cleavage and were probably formed synchronously. The F2 fold axes show a northeast-southwest trend and plunge at moderate to very steep angles. The dimensions of the F2 fold are regional in scale. They are open to tight folds. The axial planes have a northeast-southwest orientation with dips to the southeast and, occasionally, to the northwest. The F2 fold axial planes are almost vertical-moderately dipping tectonic features that could be fairly continuously traced through the Upper Kaghan Nappe in a northeast-southwest orientation. The F2 fold axial trace structures continue across the whole region and roughly trend with the present outcrop of the Indus Suture suggests that there is a common link between them. A structural domain calculated F2 fold axial plane is virtually vertical-dipping 87ºC to the southeast. The folds are tight due to the wide spread of the poles to bedding over the great circle. Other minor structures that were found in the Upper Kaghan are syn-sedimentary extension faults, veins and joints.

Strain Analysis

Strain analysis was attempted on strain markers such as xenoliths, schlieren, marble lenses, amygdales, folded veins, stretched feldspar in augen gneiss and a stretched amphibole dyke. Two main types of strain ellipse were found in the Upper Kaghan Nappe: one of uniaxial flattened ellipsoids and the other of uniaxial constricted ellipsoids. Amounts of extension in stretched grains varies to a maximum of 32%. All strain analysis indicates that the strain values are very high, typical for the internal zones of mountain belts where ductile deformation is the main style for deformation. Sense of shear of the movement along the suture zone, such as imbrications, ramping, rotated boudins, overfolds, slickensides, kink bands, crenulation cleavage fold axes, crenulation cleavage and mineral-stretching lineation relations, fold intersection lineation, orientations of the fibres and overstepping fibres all give a “top-to-the-south” sense of shear. No evidence for brittle extensional movement was found along the Indus Suture at Babusar Pass.

Regional Tectonics

The geometric relationships of the mesoscopic structures can be used in the Upper Kaghan region to infer what is happening on a more regional scale. The delineations of the geometric relationships suggest that two/three? major phases of deformation will account for what is observed. The superposition observed does not seem to fall under a simple classification. It appears to be a series of domes or basins of the type 1 classification, which, due to the high ductility environment in which they were found, resulted in the rotation of the first formed fold axis sub-parallel to the second tectonic transport direction, especially noted in the Naran area. In the Besal area, the interference pattern that occurs is possibly a type 1 to 3, where 1 is the dome itself and 3 is the convergence and divergence pattern of the first formed fold axis. The two main phases of deformation are: a First phase of deformation (D1) and Second phase of deformation (D2) although locally there are indications of a Third phase of deformation (D3) and a Pre-Himalayan deformation. D1 consists of the development of the Indus Suture followed by the Main Central Thrust with deformation continuing throughout early stages of fold formation; extension along the Indus Suture and southwest-northeast transport movement producing major folds, schistosity and mineral-stretching lineation. D2 is fold formation with southeast-northwest regional fold superposition, crenulation cleavage formation, although it may be a progression (i.e., anticlockwise rotation transport direction) of D1. This is followed by a late regional fold compression leading to the basin and dome formation, possibly east-west.

Comparison of the suggested structural evolution of the Upper Kaghan nappe to the other regions of the Higher Himalaya which lie to the east (Nanga Parbat Syntaxis and Zanskar area) and the west (Besham area and Swat region) show that similarities exist with the Zanskar and Swat regions for the overall regional deformation. However, the thrust imbrication of nappe pile by late stage tectonic movements is not seen and correlations with the tectonic history of Besham are difficult. Except for the timing of the tectonic events, broad correlation can be made with the Nanga Parbat area, in terms of the structural style of deformation, although the latter formed in a time period by which the deformation in the Upper Kaghan area was virtually complete.

Key words: Structural geology, Kaghan valley, Himalaya.

S/488. Spencer, D.A., 1997. Reactivation of early collisional structures-the long and varied geological history of the Indus suture (NW Himalaya Pakistan). Abstract volume, 12th Himalaya-Karakorum-Tibet International Workshop, Rome, Italy, 223.

Suture zones are boundaries between crustal blocks carried on two different tectonic plates that were subsequently juxtaposed by plate motions. As such, they are sites of former oceans that play an important role in our interpretation of the geodynamic evolution of orogenic belts. Almost by definition, a suture zone marks one of the earliest events in any collisional cycle. Paradoxically, these early zones of deformation are often reactivated at later stages in their tectonic history, to such an extent that even neotectonic activity can be seen along these older structures. These late stage deformational events can, in many cases, completely wipe out any evidence of the typical suture zone lithologies (such as ophiolites).

Although suture zones are often characterized by the presence of ophiolites, their subsequent obduction and preservation is inevitably a question of their structural evolution throughout the subsequent collisional processes. As continental collisions themselves are generally not simple head-on processes, it is inevitable that the along-strike development and preservation of suture zones vary. For example, there is a marked difference along the strike of the Indus Suture, which separates the Indian Plate and the Asian Plate. This is especially so in the western part of the Himalayan chain (i.e., Northwestern India and Northern Pakistan) where the suture between the Indian Plate and the Asian Plate is located at the base of the Kohistan-Ladakh complex.

Why are suture zones targets for fault reactivation? What do they inherit that allows them to be subsequently deformed by later tectonic movements? It is known that documented ophiolite remnants in the Himalayas of Pakistan are restricted to a few regions (e.g., Shang-La, Dargai). Intervening areas have been strongly affected by post collisional deformation that has now removed most of the evidence that this tectonic boundary was once a former site where oceanic subduction had taken place. Intriguing questions therefore remain about what controls these post-collisional movements? In particular, why is it that across the border from Pakistan into India, the Suture Zone is preserved almost relatively free from any of the severe deformation associated with the Himalayan Orogeny? In this context, it is necessary to examine the reasons why (in Pakistan) one of the earliest structures associated with the oceanic subduction/continental collision cycle seems to play such an important role in the late stage deformational (and therefore exhumation) history of the footwall plate.

Key words: Collisional structure, Indus Suture, Himalaya.

S/489. Spencer, D.A., Chaudhry, M.N., Ghazanfar, M. & Hubbart, M.S., 1995. The role of the Indus suture in the exhumation of the Indian plate (NW Himalaya, Pakistan). Terra Abstracts, European Union of Geologists Meetings, Strasbourg, 7, p.118.

Key words: Exhumation, Indian Plate, Indus Suture, Himalaya.

S/490. Spencer, D.A. & Gebauer, D., 1996. Shrimp evidence for a Permian Protolith age and a 44 Ma metamorphic age for the Himalayan eclogites (Upper Kaghan, Pakistan): Implications for the subduction of Tethys and the subdivision terminology of the NW Himalaya. Abstract volume, 11th Himalaya-Karakoram-Tibet Workshop, Flagstaff, Arizona, 147-150.

Since the discovery of the High Pressure Metamorphism in the Upper Kaghan region (Pakistan), a number of questions were raised that needed to be answered for a better understanding of the geodynamic evolution of the eclogites and their country-rocks. Some of these questions have now been answered and the results published (summary give below). New results are presented here to solve another question, which is related to the eclogite protolith age and a more age of HP-metamorphism.

Proof of eclogite existence

Microprobe analysis showed the presence of omphacite + garnet (no plagioclase was found), confirming the discovery of high-pressure eclogite facies metamorphism in the Himalayan belt. A typical high-pressure assemblage found in the Upper Kaghan consists of omphacite-garnet-quartz-rutile (Spencer et al., 1990, 1991; Pognante and Spencer, 1991; Spencer, 1993).

Pressure-temperature conditions of formation

The analysis of the eclogites has given calculated depths of formation, based on mineral geobarometry, of around 60 km (Spencer et al., 1990; Pognante and Spencer, 1991; Spencer 1993) and are the deepest known rocks to have been exhumed form the Indian Plate. Geothermometry calculations of the suggested peak metamorphism by the garnet-clinopyroxene geothermometer gives T=650º ± 50ºC.

Geochronology of eclogites

Tonarini et al. (1993) showed that the eclogite facies metamorphism of Upper Kaghan was of Himalayan age. Specifically, a peak metamorphic age of 49 ± 6 Ma was obtained by the Sm/Nd method in garnet-clinopyroxene. Cooling ages were obtained with the Rb/Sr radiometric dating in phengite at 43 ± 1 Ma and U/Pb in rutile at 39-40 Ma, both of which are interpreted to constrain the thermal evolution of the eclogite down to ≈500ºC. Tonarini et al. (1993) and Spencer (1993) also showed that Ar/Ar and K/Ar analysis of phengite and hornblende can give meaningless results when compared to the Sm/Nd, Rb/Sr and U/Pb ages obtained in the same sample. This is almost certainly due to excess argon.

Mechanism of exhumation

The fact that the high pressure rocks are located within the NW Himalayan syntaxial region suggests that, in part, their late-stage erosion-dominated exhumation was also controlled by the large-scale late-stage folding associated with the syntaxial formation. However, evidence exists that the majority of the exhumation was achieved by a reactivation of the Indus Suture from initial thrust tectonics (associated with the subduction of the Indian Plate beneath the Kohistan Island Arc) to ductile extensional tectonics, a “collapse folding” scenario which is driven by the movements on the Main Central Thrust (Spencer, 1993).

Geochemical characteristics

Bulk rock geochemistry and Sr-Nd isotopic composition were made and results were compared to lower grade metamorphic equivalents of rocks of the same as well as to unmetamorphosed basalt. Major and trace element diagrams indicate tholeitic to alkalic magma compositions, which evolved by fractional crystallization. 87Sr/86Sr initial values 270 Ma for the eclogite are 0.7053-0.7073 with values increasing for metabasites of lower metamorphic grade. 147Sm/144Nd values range form 0.1397-0.2096. Nd(270) from +4.9-10. The lowest initial values occur in the least metamorphosed rocks. Based on their bulk geochemistry and isotopic data, the eclogites could be the equivalents of the Permian Panjal Traps (Spencer et al., 1995).

Protolith age

In the Higher Himalaya of Kaghan Valley (and in the areas further to the west), a basement-cover sequence was recognized that is clearly different from the last known occurrence of the basement-only lithologies to the east in Zanskar (Greco et al., 1989). The basement consists of the Higher Himalayan Crystalline (sensu stricto) with granitoids and metagranites. This is overlain by a cover unit of metagrawackes of suggested Lower Paleozoic age with a clear sedimentary origin. This is then diachronously and unconformably overlain by a distinctively mappable unit consisting of some 30-40 extensive amphibolite layers at the base of the cover. It is associated with syn-volcanic marine deposits (marble). This sequence then develops into an extensive dolomite-rich shelf sequence with minor mica-schist horizons.

Two main ideas exist on the age of the cover units and the associated eclogites:

The metasedimentary units were thought to be part of the Precambrian Salkhala Formation proposed by Wadia 1931. This interpretation has been incorporated into numerous works since.

Greco et al. (1989) and Papritz and Rey (1989) first made the suggestion that the cover sequence was not Precambrian, but suggested a correlation and comparison between adjacent regions. To the east, for example, the Permian Panjal Traps and overlying Triassic series have a distinct similarity to the Cover units found in Upper Kaghan. Subsequently, numerous lines of evidence link the metamorphosed (eclogite/amphibolite facies) cover to the unmetamorphosed(with up to greenschist facies transition) equivalent (Greco et al., 1989; Papritz and Rey, 1989; Spencer et al., 1991; Spencer, 1993). This is based on field, petrographic, geochemical, stratigraphic, structural, fossil, stable isotope and regional correlations.

Accurate determination of protolith and metamorphic peak ages of mafic rocks is a difficult geochronological task (for a summary, see Gebauer, 1990). This fact is also illustrated with the Upper Kaghan eclogites as Sm-Nd whole-rock data (Spencer, 1993, Spencer et al., 1995) yielded an unpublished errorchron ‘age’ of 337±434 Ma. SHRIMP-dating, especially when combined with cathodoluminescence information of the zircon to be dated, is the most promising technique available today to obtain this required information (e.g., Gebauer et al., 1988; Gebauer, 1990, in press; Schafer et al., 1993; Vavra et al., in press). Thus, zircons from the eclogites of Upper Kaghan (Sample 90/80 used in Tonarini et al., 1993) were analyzed to help solve the problem of the disputed and geochronologically poorly constrained protolith ages of the Higher Himalayan Cover and hopefully get a precise as possible age of high pressure metamorphism. Within the oscillatory-zoned zircon domains that were formed during precipitation of zircon in the mafic protolith, a Permian protolith age of about 269 Ma was found. It is important to note that, based on the size of the magmatic zircons, the protolith was not effusive (basaltic) but intrusive (e.g. gabbroic). This is in accordance with the outcrop locality-a basement feeder (Tonarini et al., 1993; Spencer, 1993); this data confirms a Tethyan affinity and, therefore, the stratigraphic correlations that were first suggested by Greco et al. (1989). Apart from a number of clearly discordant ages, a metamorphic rim age of 44±3 Ma was found, in accordance with the Sm-Nd mineral data of Tonarini et al. (1993) which gave 49±3 Ma. However, due to the smaller error of the

SHRIMP-data, the pressure peak, coinciding closely with the temperature peak, is now better constrained. One spot age giving ca. 470 Ma in a magmatic domain proves the presence of inherited zircon components of very probably early Paleozoic age. This may therefore indicate that the Higher Himalayan Basement can be correlated with the ≈500 Ma Lesser Himalayan "Mansehra" Granites of the "Pan-African" event. This contamination is probably one reason for the scattered Sm-Nd WR-data and subsequent errorchron 'age'.

Implications for the Subduction of Tethys

Not only do these new results provide for a modified extension of the Tethyan Himalaya into Pakistan, they more importantly give geologists a unique metamorphic record of a continental collision. The Panjal Traps, which consist of basalts with interlayered carbonates, can be stratigraphically mapped in Upper Kaghan (Pakistan), where they are found in eclogite, amphibolite-eclogite facies and amphibolite facies, along-strike to their lower grade equivalent (greenschist facies and unmetamorphosed) in the Tethyan Himalaya of Zanskar (India). This complete record of vertical (dominantly depth-controlled) progressive metamorphism for a colliding and subducting continent has been differentially exhumed to its now relatively horizontal position. One stratigraphic unit can therefore be traced in five metamorphic grades to provide a unique record of a colliding continent. Each metamorphic grade will show the effects of the prevalent pressure-temperature conditions and provides a progressive record of the subducting continent on the same stratigraphic protolith.

Implications for the Subdivision Terminology of the NW Himalaya

The arcuate curvature of the Himalayan mountain belt becomes more complex in the northwest (Pakistan and India) and northeast (Tibet and India) syntaxial regions. The northwest Himalayan syntaxial region is dominated by the structural anomalies of the Nanga Parbat, Kaghan, Hazara-Kashmir and Besham syntaxes (Spencer, 1994). Here, the linearity of the Himalayan topography changes in direction from a general northwest-southeast orientation to a more southwest-northeast orientation. The structural reorientations of lithologies that resulted from syntaxial formation give evidence for some of the fastest exhuming metamorphic regions in the world. Subsequently, the interpretations of the tectonic setup to the Himalayas changed from one of relatively simplicity to a complicated terminology with numerous indications suggesting that the Lesser-, Higher- and Tethyan Himalaya terminology should be totally abandoned in these areas. Only recently have both the separation, terminology and definitions of the Lesser- and Higher Himalaya become apparent (Chaudhry et al., 1994; Greco and Spencer, 1993). The new SHRIMP evidence anow shows that the Higher Himalaya and Tethyan Himalaya can also be clearly distinguished in the NW Himalayan region. However, the Tethyan Himalaya is clearly modified in this region and, for the sake of consistency and conformity, we suggest that the term "Higher Himalaya" be kept in the Pakistan Region, even though it is now shown that this Higher Himalayan unit act as a basement to its cover of the "Tethyan Himalaya".

Key words: Permian protolith, Eocene metamorphism, eclogites, Kaghan, Himalaya.

S/491. Spencer, D.A., Ghazanfar, M. & Chaudhry, M.N., 1988. Deformation on the Main Mantle Thrust zone at BabusSar Pass Karakoram Highway Pakistan. Geological Bulletin, Punjab University 24, 44-60.

The Main Mantle Thrust Zone passes through the Babusar Pass area as a complex zone of, not just one, but three thrust faults that enclose a complex assemblage of two tectonic mélanges. This Indus Suture Mélange Group includes an earlier subduction-related ultramafic mélange and a later metavolcanic mélange. Deformation on the suture zone results in the formation of various structures that give a six phase deformation history, dividing the area into four structural domains. This leads to a four stage tectonic evolution, comprising of a subduction stage, obduction stage, lateral movement stage and a neotectonic stage.

Key words: Deformation, MMT, Babusar, KKH.

S/492. Spencer, D.A., Ghazanfar, M. & Chaudhry, M.N., 1990a. Structural of the Higher Himalaya, upper Kaghan valley, NW Himalaya, Pakistan. Abstracts, 2nd Pakistan Geological Congress, University of Peshawar, 1-2.

The Higher Himalaya of the NW Himalaya is a complex sequence of granites, gneisses, metapelites, marbles, amphibolites, quartzites and in situ ultramafics. It is bound by two major thrusts: the Main Central Thrust (MCT) to the south and the Main Mantle Thrust (MMT) to the north, which have subsequently led to the exposure of some of the deepest level rocks of the Indian plate during collision with the Asian plate. A complex deformational history of pre-, syn-, and post-"Himalayan" age is associated with a pre- to syn- deformational upper amphibolite (kyanite to

sillimanite) facies metamorphism which reached in places over 6500C, as evidenced by in situ migmitisation and granitisation.
The Higher Himalaya of Kaghan Valley is structurally positioned between three major syntaxes: the Hazara-Kashmir syntaxis (HKS), the Kaghan Syntaxis (KS) and the Nanga Parbat Syntaxis (NPS) which are interpreted as forming due to a change in transport direction. Between the Kaghan Syntaxis and the Nanga Parbat Syntaxis, the Higher Himalaya consists of a polyphase, superposed folded domain which produces the Burawai synform, the Besal antiform and other large-scale features located to the south in Neelum Valley. The fold interference patterns are affected by the extreme ductility of the rocks and caused the rotation of, not only the first fold axis, but also the whole interference structure itself, as seen by the asymmetrical shape of the Besal antiform.
A provisional tectonic analysis of the features observed suggest that the first southwestwards-directed phase of nappe transport led to a thickening of the tectonic pile, and that thickening was followed by a northeast-southwest directed deformation. This is in accordance with movements suggested for the formation of the Hazara-Kashmir and the Kaghan syntaxis and leads to the suggestion of a similar model, with a further increment of anticlockwise transport direction change, for the formation of the Nanga Parbat Syntaxis.
Key words: Structure, Kaghan Valley, Himalaya.

S/493. Spencer, D.A., Ghazanfar, M. & Chaudhry, M.N., 1990b. Fold interference patterns in the higher Himalayan crystalline unit, upper Kaghan valley, NW Himalaya, Pakistan. Abstract volume, 5th Himalaya-Karakoram-Tibet Workshop, Milano, p.58.

The Higher Himalayan Crystalline Unite (HHCU) of the NW Himalaya is complex sequence of granites, gneisses, metapelites, marbles, amphibolites, quartzites and insitu ultramafics. It is bound by two major thrust: the Main Central Thrust (MCT) to the south and the Main Mantle Thrust (MMT) to the north, which have subsequently led to the exposure of some of the deepest level rocks of the Indian plate during its collision with the Asian plate. A complex deformational history of pre-, syn-, and post "Himalayan" age is associated with a pre- to syn-deformational upper amphibolite (kyanite to sillimanite) facies metamorphism which reached in places over 650oC, as evidenced by insitu migmatization and granitization.
The HHCU of Kaghan Valley is structurally positioned between three major syntaxis: the Hazara-Kashmir Syntaxis (HKS), the Kaghan Syntaxis (KS) and the Nanga Parbat Syntaxis (NPS) which are interpreted as forming due to change in transport direction. Between the Kaghan Syntaxis and the Nanga Parbat Syntaxis, the HHCU consists of a polyphase, superposed folded domain which produc3es the Burawai synform, the Besal antiform and other large-scale features located to the south in Neelum Valley. The fold interference patterns are affected by the extreme ductility of the rocks and caused the rotation of, not only first fold axis, but also the whole interference structure itself, as seen by the asymmetric shape of the Besal antiform.
A provisional tectonic analysis of the features observed suggest that the first southwestward-directed phase of nappe transport led to a thickening of the tectonic pile, and that thickening was followed by a northeast-southwest directed deformation. This is in accordance with movements suggested for the formation of the Hazara-Kashmir and the Kaghan syntaxis and leads to the suggestion of a similar model, with a further increment of anticlockwise transport direction change, for the formation of the Nanga Parbat Syntaxis.
Key words: Structure, HHC, MMT, MCT, Hazara Kashmir syntaxis, Kaghan Valley, Himalaya.

S/494. Spencer, D.A., Ghazanfar, M. & Chaudhry, M.N., 1990c. Eclogite in the Indian plate of NW Himalaya, Pakistan. Abstract volume, 5th Himalaya-Karakoram-Tibet Workshop, Milano, p.76.

Key words: Eclogite, Kaghan Valley, Himalaya.

S/495. Spencer, D.A., Ghazanfar, M. & Chaudhry, M.N., 1990d. Structure of the higher Himalaya, upper Kaghan valley, NW Himalaya, Pakistan. Second Pakistan Geological Congress, Peshawar, 2p.

Key words: Structure, Kaghan Valley, Himalaya.

S/496. Spencer, D.A., Ghazanfar, M. & Chaudhry, M.N., 1991a. Eclogite in the Indian plate of NW Himalaya, Pakistan. Abstracts of Meeting, European Union of Geologist, Strasbourg.

Key words: Eclogite, Kaghan Valley, Himalaya.

S/497. Spencer, D.A., Ghazanfar, M. & Chaudhry, M.N., 1991b. The higher Himalaya crystalline unit, upper Kaghan valley, NW Himalaya, Pakistan. Geological Bulletin, University of Peshawar 24, 109-125.

Kaghan valley, in north Pakistan, provides an unparalleled cross-section of the Indian Plate in the Himalaya, with all of the tectonic units, structural features and metamorphic grades of the Indian Plate exposed in one valley. The Higher Himalaya Crystalline of the NW Himalaya, which exposed in one valley. The Higher Himalaya Crystalline of the NW Himalaya, which crops out in the upper reaches of the valley, is a complex sequence of granites, gneisses, Calc-pelites, metapelites, marbles, amphibolites, quartzites and eclogites. It is bound by two major thrust: The Main Central Thrust (MCT) to the south and the Main Mantle Thrust (MMT) to the north, which have subsequently led to the exposure of some of the deepest level rocks of the Indian plate during its collision with the Asian plate. A complex deformational history of pre-, syn-, and post- “Himalayan” age is associated with a pre- to syn- deformational upper amphibolite (kyanite to sillimanite) to eclogite facies metamorphism, which reached in places over 6500C, as evidenced by minor insitu granitization.
Key words: Indian plate, tectonics, HHC, Kaghan Valley, Himalaya.

S/498. Spencer, D.A. & Herren, E., 1992. Geochemistry of higher Himalayan leucogranites: Comparison between upper Kaghan, Zanskar, Manaslu and Bhutan. Abstract Volume, 7th Himalaya-Karakoram Workshop, Department of Earth Sciences, Oxford University, England, 128.

Late stage leucogranite Intrusions In the Higher Himalaya and Tethyan covers are well known all along the length of the Himalayas, although they are far more prolific in the central parts of the Himalayas than the NW Himalaya. A few exposures of these Intrusions have been recorded in Kaghan In the NW Himalaya. They are of special Interest for Himalayan evolution as they are one of the rare magmatic products of the Himalayan collision zone. Geochemical analysis of leucogranites has been previously carried out by workers at the Swiss Federal Institute of Technology with leucogranites from two other areas (Zanskar and Bhutan) from the Himalayan belt. Similar methods of preparation and measurement have been made on the Kaghan rocks and allows direct comparisons between the major and trace element analysis with a higher degree of certainty. The analysis of the Zanskar leucogranite were carried out by Herren (1987) and of the Bhutan leucogranite by Dietrich and Gansser (1981). Reference is also made the Manaslu Leucogranites (Le Fort et al., 1987).
Analyses are presented in three chemical mineralogical diagrams (Debon and Le Fort, 1983). In a Q-P Diagram, the Manaslu leucogranites center on the adamellite sector; Zanskar leucogranites range from granites to granodiorites, whilst the Kaghan leucogranites range from adamellite to granodiorite. Characteristic mineral (A/B) plots show all samples In the leucocratic field (B<38.8), with the exception of one sample. In the O-B-F diagram, all samples plot In the leucogranites field, with most plotting below the critical quartz-poor field line. Kaghan. Manaslu and Zanskar leucogranites show a negative correlation between Na2O and K2O with (Na2O+K2O) varying from 8-8.5 for Manaslu, 7.9-8.6 for Zanskar and 7.2-8.9 1 for Kaghan.
Major and trace element spider diagrams for Kaghan and Zanskar were normalised to a Bhutan mean standard deviation. Discrimination Is made for the tourmaline-, garnet-biotite and garnet-varieties in the Zanskar region, but only tourmaline leucogranites are found in the Kaghan region. The Kaghan leucogranites, compared to Bhutan normalizations, are enriched In Ba. Sr. Y, Zr, Ti, Sc and Zn but are depleted In Rb, K, P. Na, K. Pb and Co. The actual values more or less mirror the Zanskar tourmaline leucogranite, except that the Kaghan samples are far more enriched or depleted In the respective minerals with the notable exceptions of Sr. Zr, Ti and Zn. A-F-M plots of the Kaghan leucogranite compared to a typical calc-alkaline differentiation trend, for example in granitoid rocks from the Trans-Himalayan Batholith, are unusual In that they seem to be the only leucogranites that show any differentiation. Selected trace element variation diagrams (Zr, Y, Ba and Rb) with increasing SiO2 also show a magmatic differentiation trend.

These results show that there is a variation along the Himalaya of the leucogranites In terms of selective major and trace element geochemistry. Previous workers (e.g. Villa, 1988 and Pognante, 1991) have also noted changes in leucogranites In terms of cooling ages (20-19 Ma In the NW Himalayas to 16-14 Ma in the eastern Himalayas) and PT evolution (kyanite ± sillimanite bearing In the NW Himalayas and cordierite - andalusite bearing in the eastern Himalayas). The main reason for this variation is due to the timing of collision and the state of development of the MCT for the liberation of large quantities of fluid and anatectic melting of the crust. The MCT was mature enough for this process in the central Himalayas, but not in the Kaghan region. Furthermore, PT paths and cooling histories of the Upper Kaghan nappe suggest that the relaxation of the geotherm was very rapid, with a decrease of temperature below the level where anatectic melting is possible. As such, inverse prograde metamorphism below the MCT In Kaghan was probably too fast to liberate large quantities of fluid necessary to produce the melting temperature of this crustal source and therefore only produce a limited number, and rather differentiated suite, of leucogranite. Zeitler and Chamberlain (1991) also notes SHRIMP ion microprobe analysis to obtain U-Pb dates on zircon In leucogranites In Upper Kaghan of about 50 Ma, which would again support the notion of rapid metamorphism and exhumation after collision.
Key words: Geochemistry, leucogranites, Kaghan Valley, Zanskar, Manaslu, Bhutan, Himalaya.

S/499. Spencer, D.A., Hubbard, M.S. & West, D., 1995. The role of the Indus suture in the exhumation of the Nanga Parbat massif (Indian Plate, NW Himalayas). Abstracts, International Symposium on Himalayan Suture Zone of Pakistan. Pakistan Museum of Natural History, Islamabad, 8-9.

Whilst there is no doubt that the initial sense of movement along the Indus Suture has to be a bulk 'top-to-the- south' thrust sense of shear associated with the subduction and underthrusting of the Indian Plate underneath the Kohistan Island Arc it is obvious that, if this sense of movement, continued from the time of collision until the present day a very active type of exhumation process would be needed to explain how the Higher Himalayan Crystalline in the footwall of the suture is exhumed. In the Central Himalaya, the effective means of exhuming the Higher Himalayan Crystallines has been achieved by extensional tectonics (accompanied by erosion), occurring along the boundary that separates the Higher Himalayan Crystalline and the Tethyan Sedimentary Series. In Pakistan, these Tethyan sediments were subducted with the Indian Plate and arc now overlying the Higher Himalaya Crystalline.
Recent fieldwork results from locations along the Suture Zone show that extensional deformation has been, in part, responsible for the exhumation of the Indian plate. However, this clearly varies in timing duration and the amount of exhumation that has occurred and was, in most locations, subsequently overprinted by brittle, top-to-the-south thrust sense of shear. This is interpreted as the end of the extensional 1novcnicnts and the welding together of the plates.
Hubbard and Spencer (1990; Geol. Bull. Univ. Peshawar, Vol. 23.pp.101-110) and Hubbard, Spencer and West (1995, Earth and Planetary Science Letters), also investigate the Indus Suture around parts of tl1e Nanga Parbat Syntaxis. Numerous studios have documented the recent uplift of this massif as one of the fastest rising metamorphic terrains in the world. New structural and kinematic analysis of the Nanga Parbat region shows that extensional deformation has been, in part , responsible for the exhumation of the gneissic rocks of the Indian Plate basement complex that dominates the Nanga Parbat Massif Fieldwork along the Suture Zone and within the Indian plate rocks in the area between Babusar Pass and Toshe Gali, southwest of the peak of Nanga Parbat, provides evidence from shear fabrics and a shallowly-plunging stretching lineation for a dominant phase of extensional deformation that moved rocks of the Kohistan sequence and the Indian Plate Cover sequence to the west-southwest relative to the rocks of the Indian plate basement, including the Nanga Parbat gneissic rocks. This ductile fabric is pervasive at the Suture Zone contact and within the Indian plate cover sequence below the suture, but decreases in the Indian Plate basement rocks and the Nanga Parbat gneisses. The fabric is post metamorphic and, with $^{39}Ar/^{40}Ar$ geoehronology of hornblendes, the age of pre-deformational, amphibolite facies metamorphism has been constrained to 40-56 Ma. Published cooling ages from the Babusar Pass region further document that the extensional deformational was completed by 20 Ma. This ductile, extensional shear is interpreted as being the mechanism responsible for significant tectonic exhumation of the gneissic and granitic rocks of the Nanga Parbat Massif which may have then been followed by flexural, surface uplift and accompanying erosion which continues to thepresent.
Key words: Exhumation, Indian Plate, Indus Suture, Himalaya.

S/500. Spencer, D.A. & Mullis, J., 1994. Fluid inclusion analysis in eclogites and associated high pressure rocks, Upper Kaghan, NW Himalaya, Pakistan. Journal of Nepal Geological Society 10 (Abstract Volume, 9th Himalaya-Karakoram-Tibet Workshop, Kathmandu), 135-136.

Fluid inclusions are small quantities of liquid (or glass) and/or vapour trapped in cavities, a "sample" of the fluid phase present in the rock at some time during its evolution. They provide information on one ox~ more intervals in the history of a metamorphic rock between peak temperatures of the metamorphism and arrival of the rock at the surface. The vast majority of fluid inclusions in metamorphic rocks are secondary, the Fluids being trapped along fractures of various sizes. Most fluid inclusions in metamorphic rocks originate by devolatization reactions in the immediately surrounding rock and are in equilibrium with the host mineral assemblage at the time of the formation of the inclusion. Inclusions are most commonly found in quartz due to the fact that it is stable at all metamorphic conditions within the crust. Studies in high-pressure lithologies (such as blueschist and eclogite facies metamorphism) are relatively rare and to date, the maximum-recorded depth of fluid inclusion formation is around 45 km. In general, most densities observed were much lower than inferred peak metamorphic pressure-temperature conditions and the synmetamorphic fluids were not present.

Fluid inclusions were analyzed in Upper Kaghan by the non-destructive microthermometry technique using an optical microscope combined with a heating and freezing stage. In all the samples studied, some primary (?) but mainly secondary fluid inclusions were found. The host minerals of the fluid inclusions were obviously dependent on the rock lithology. Results were obtained for five samples. Sample 89/55.A is a quartz host in quartzite, which shows one population of fluid inclusions and one cluster of inclusions. The single phase system suggests that the inclusion consists essentially of CO2 and that other gasses than may be present (e.g. N2 or CH4 } are very minor. Sample 89/55.B is a quartz host in quartzite, which shows a population of secondary inclusions consisting of aqueous H2O rich solutions of intermediate density. Sample 89/56.B.2 also shows another Population of inclusions, which are not found in trails, but clusters. The inclusion cluster is a higher density aqueous H2O rich solution inclusion showing no bubble before heating. After heating the bubble was one of a different size, indicating that stretching and decrepitation had taken place. Sample 89/86 is a quartzite showing secondary inclusions consisting of gaseous CO2- rich solution of low density. Sample 89/178.A is a garnet host in eclogite, which shows one population of fluid inclusions consisting of gaseous CO2-rich solution of high density.

Based on the melting and homogenization temperatures, as well as the estimated gas water volumes, the composition of the fluid and the density of the fluid inclusions were determined. Isochores were then calculated using a Redlich-Kwong form for the equation of state, which are modified for the relevant system of H2O-CO2-NaCl (89/55.B and 89156.B), H2O-CO2-CH4 (89/55.B and 89/56.B) and CO2 (89/55.A and 89/56.B, 89/86 and 90/178.A). From the isochore calculations, the secondary conclusions show that they were all produced in the late stages of metamorphic retrogression, and subsequently can be interpreted as forming as a result of retrogressive reactions that lead to the liberation of H2O and CO2.

There are two main phases of fluid inclusions: early and late. The early fluid inclusions are characterized by low fluid pressures whereas the late inclusions are characterised by higher fluid pressures suggesting a younger retrograde fluid evolution event. The relationship. between these early and late inclusions is somewhat contradictory to what is normally expected in metamorphic rocks. The maximum densities are commonly assumed to characterize the fluid closest to the peak metamorphism. However, other recordings of the exceptions where there is a density increase for later inclusions (generally related to conditions where the isochores pass above or below the peak metamorphic temperatures and pressures and do not represent a syn-metamorphic fluid phase) are published. Timing relationships also help confirm the observations of the two phases of fluids: the earlier lower density fluid inclusions are cut by the later higher density fluid inclusions. Subsequently, as a result of this renewed activity, the earlier inclusions are evacuated and filled with the later more dense fluid along the same trail. The main evidence that supports this hypothesis is the occurrence of trails of several inclusions in the same direction. An alternative explanation is that the two separate fluid densities reflect a true metastability or that one is a late filling of the other, although no observational evidence, for this was found. One of the most obvious questions that result from the observations made on the fluid inclusions is the source of the CO2 and H2O. The most likely and accepted source of H2O in inclusions in deep-seated metamorphic belts is by dehydration and devolatization. The most reasonable source for the CO2 is decarbonation, a well-known result of regional metamorphism.

Key words: High pressure rocks, eclogites, fluid inclusions, Kaghan, Himalaya.

S/501. Spencer, D.A., Pognante, U. & Tonarini, S., 1995. Geochemical and Sr-Nd isotopic characterisation of higher Himalayan eclogites (and associated metabasites). European Journal of Mineralogy 7, 89-102.

Key words: Geochemistry, isotopes, eclogites, Himalaya.

S/502. Spencer, D.A., Ramsay, J.G., Cervato, C.S., Pognante, U., Chaudhry, M.N. & Ghazanfar, M., 1990. High pressure (ecologite facies) metamorphism in the Indian plate, N.W. Himalaya, Pakistan. Geological Bulletin, University of Peshawar 23, 87-100.

A zone of high pressure (eclogite facies) metamorphism, characterized by eclogites with an assemblage of omphacite - garnet - quartz - rutile -+ yhengite, has been recognized in the higher Himalaya in the Indian Plate of NE Pakistan. This suggests that the Upper Kaghan nappe is the deepest derived part of the Indian Plate to have been subducted and subsequently uplifted along the whole length of the Himalaya. Mineral chemistry by microprobe analysis suggests that the eclogites formed at temperatures of 650~50 OC and pressures of 13-18 kbar, suggesting depth of eclogite formation at 60 km. The eclogites show an incipient decompressional re-equilibration which probably occurred at decreasing temperatures.
Key words: Eclogite, high pressure rocks, Indian Plate, Himalaya.

S/503. Spencer, D.A, Ramsay, J.G., Ghazanfar, M. & Chaudhry, M.N., 1991a. A revised stratigraphy for the higher and Tethyan Himalaya in North Pakistan. Abstract Volume, 6th Himalaya-Karakoram-Tibet workshop, Grenoble, France, 81.

Recent investigations into the stratigraphy of the Higher Himalaya in Upper Kaghan valley, north Pakistan has led to a complete revision for the tectono-stratigraphy for this region of the Himalayas. The whole of the region south of the suture was always correlated with Salkhala unit until workers located the Main Central Thrust and divided the area into the Lesser and Higher Himalaya. The later unit was again all classified under one group, the Sharda Group (Ghazanfar et al., 1989), until recently when another reclassification (Greco et al., 19989) was made. Modifications to this are now proposed:
Basement: The oldest pre-Cambrian unit consists of granitoids that have intruded into an even older meta-pelite.
First cove: Unconformably overlying the basement is a lower Paleozoic metagraywacke unit. The unconformity is only recognized on a regional scale with a transgression gently cutting out the underlying granite. Excellent metamorphically-reversed graded bedding is found in the unit showing the original way-up structure. Its composition suggest a turbidite environment.
Second cover: Unconformably above these two units is a Tethyan sedimentary sequence. Recognition of this unit is difficult and controversial, as it was metamorphosed and deformed during the nappe formation to eclogite and amphibole grade, which is not seen in the rest of the Himalaya where they are unmetamorphosed. It unconformably lies over the first cover and then eventually the basement, again showing the transgressive nature of the unit. They begin with the Permian Panjal Traps, which are subaerial basaltic lavas with intercalated limestone, now marble, horizons, before a Triassic sequence of marbles, dolomites and garnet-mica schists.
Himalayan leucogranites: All the units are cut by Himalayan age tourmaline-bearing leucogranites with some minor in situ anatexis found.
The Higher- and Tethyan Himalayan units are bound to the south by the Main Central Thrust mylonites which separate it from the Lesser Himalayan Salkalah Unit and to the north by the Indus Suture Mélange Group which separates it from the Kohistan Island Arc Group. This revised stratigraphy has already been used in the recognition of the controversial Main Central Thrust in the Swat area of the western Himalaya.
Key words: Stratigraphy, Kaghan valley, Himalaya.

S/504. Spencer, D.A., Ramsay, J.G., Ghazanfar, M. & Chaudhry, M.N., 1991a. Penninic style of nappe deformation in the NW Himalaya. Abstracts, Tectonic Studies Group Meeting, University of Liverpool, p.67.

Consult the Spencer et al. 1991 for further information.
Key words: Deformation, orogeny, Himalaya.

S/505. Spencer, D.A., Ramsay, J.G., Ghazanfar, M. & Chaudhry, M.N., 1991b. Penninic style of nappe deformation in the NW Himalaya. Abstracts, Swiss Tectonic Studies Group Meeting, p.35.

Consult the Spencer et al. 1991 for further information.
Key words: Deformation, orogeny, Himalaya.

S/506. Spencer, D.A., Ramsay, J.G., Ghazanfar, M. & Chaudhry, M.N., 1991c. Penninic style of nappe deformation in the NW Himalaya. Abstract Volume, 6th Himalaya-Karakoram-Tibet workshop, Grenoble, France, 83-84.

The Upper Kaghan nappe of the NW Himalaya is of crucial importance in the understanding of deep seated orogenic processes associated with the Himalayan collision. Bounded by the Main Central Thrust to the south and the Indus Suture to the north, this Higher Himalayan and Tethyan tectonic unit thus represent the deepest exposed part of the Indian plate. Evidence of the deep subduction and subsequent erosion of the tectonic unit is shown by the presence of eclogites- the only eclogites so far recorded in the whole of the Himalayan belt –from which recent analysis suggest formation at temperatures of 650ºC±50ºC and pressures of 14 kbar (Pognante and Spencer, in prep.). The exhumation rate for his unit is very rapid.
Stratigraphically, the basement consists of granites that have intrude into a garnet-mica schist: its first cover (a metagraywacke unit showing excellent metamorphically reversed graded bedding) and a second cover o Permian Panjal Trap volcanics with associated syn-sedimentary marine deposits, which give carbon and oxygen stable isotope ratios of a high temperature, deep marine water environment (Spencer and Spencer-Cervato, in prep.). All units have a very unusual metamorphic history of progressive eclogite facies metamorphism and retrogressive amphibolite facies metamorphism.
The structural evolution of the High Himalayan and Tethyan units in Pakistan show a remarkable similarity to the Pennine style of nappe formation and deformation in the Alps: i.e. complex large scale folding subsequent to nappe emplacement. Previous research suggests that, in general, the large-scale crustal nappes in the NW Himalaya are each internally imbricated and separated from each other by late thrusts.
However, in the Higher Himalaya of Kaghan, where ductile deformation was the main process of deformation, this is certainly not the case, as no internal thrusts or shear zones were recognized. Evidence suggests that polyphase ductile- penetrative overprinting occurred after the original nappe forming movement. This led to the development of a system of major post nappe folds, which deformed a pre-Himalayan history of deformation.
As with the Pennine nappes of the European Alps, the post-nappe folds can be subdivided into two groups: main Himalayan folds and late Himalayan folds. The main Himalayan folds are large, isoclinal and recumbent fold structures, which produce a series of sheets that are associated with a penetrative foliation, which is either a newly form daxial planar schistosity or a rotated and modified earlier foliation on the limbs of folds. The late Himalayan folds, which affect an already developed penetrative foliation and, when present, lineations show a minor crenulation cleavage. They are superimposed on the main Himalayan folds with type 1 or 3 interference patterns giving very large scale domes, which are found in the Hazara-Kashmir, Kaghan and Nanga Parbat syntaxis, as well as basins and domes in the areas between the syntaxes, such as that in Upper Kaghan.
Key words: Deformation, orogeny, Himalaya.

S/507. Spencer, D.A., Ramsay, J.G., Ghazanfar, M. & Chaudhry, M.N., 1992a. Nappe deformation the NW Himalaya. Abstracts First South Asia Geological Congress, Islamabad, p.65.

Key words: Deformation, orogeny, Himalaya.

S/508. Spencer, D.A., Ramsay, J.G., Ghazanfar, M. & Chaudhry, M.N., 1992b. Stratigraphic boundaries for the higher and Tethyan Himalaya in North Pakistan. Abstracts First South Asia Geological Congress, Islamabad, 64-65.

Key words: Stratigraphy, orogeny, Himalaya.

S/509. Spencer, D.A., Ramsay, J.G., Pognante, U., Ghazanfar, M. & Chaudhry, M.N., 1991a. High pressure (eclogite facies) metamorphism in the Himalayan belt. Abstracts of Meeting, European Union of Geologists, Strasbourg 3, p.88.

Key words: Eclogite, high pressure rocks, Indian Plate, Himalaya.

S/510. Spencer, D.A., Ramsay, J.G., Pognante, U., Ghazanfar, M. & Chaudhry, M.N., 1991b. The significance of eclogites in the Indian plate, NW Himalaya. Abstract Volume, 6th Himalaya-Karakoram-Tibet workshop, Grenoble, France, 85.

High-pressure assemblages are widespread in the Alpine belt with blueschist and eclogite facies rocks occurring both in ophiolitic and in continental rocks. However, in the Himalayan belt, only blueschist rocks have been recognized in the ophiolites associated with the suture and, to date, true high-pressure assemblages were never recognized in the continental rocks. A new discovery of eclogite facies metamorphism in the Higher- and Tethyan Himalaya of the Indian plate in north Pakistan leads to the suggestion that the Upper Kaghan nappe represents the deepest derived rocks of the Indian shield known.

The medium grained, granoblastic and metamorphically foliated eclogites consist of: sodian augite and omphacites with Xjd<0.42, almandine garnets (Xalm=0.46-0.60) with low grossular and pyrope contents. Only slight zoning with almandine and spessartine rims occur and minor simpletic reaction rims are seen, consisting of diopside and albite. Preliminary temperatures estimates, based on the CPX-GRT geothermometer, give T=650±50oC, while pressure estimates, based on the stability of the omphacite (Xjd<0.42) and quartz, give P>13-14 Kbar. These pressure estimates are significantly greater than any other estimates concerning the Higher Himalaya of Indian plate. The eclogite faces assemblage shows an incipient recrystallization producing amphibole, epidote, diopside and albite. This recrystallization registers a decompressional path at decreasing temperatures, which probably reflects high uplift rates. This was achieved initially by thrusting along the Main Central Thrust and then by post-nappe folding, resulting in the doming of the structure to its present elevation.

The significance of this only true high pressure assemblage to be discovered so far in the Indian plate Himalaya raises many questions as to why it only occurs in one particular area (total area approx. 700-km2) of the orogenic belt. A relationship to the Indian plate promontory and the syntaxes of the western Himalaya is suggested which account for some of the most unusual tectonic features of the Himalaya. A comparison is also made to the Central parts of the Himalaya where none of these features are seen.

Key words: Eclogite, ultra-high pressure rocks, Indian Plate, Kaghan, Himalaya.

S/511. Spencer, D.A., Ramsay, J.G., Pognante, U., Ghazanfar, M. & Chaudhry, M.N., 1992. Higher pressure assemblages in the Himalayan collision belt: Significance of Indian plate eclogite. Abstracts, First South Asia Geological Congress, Islamabad, p.65.

Key words: High pressure rocks, eclogites, Indian Plate, Himalaya.

S/512. Spencer, D.A. & Spencer-Cervato, C., 1992a. Stable isotope analysis of Tethyan carbonates in the Higher and Lesser Himalayan, North Pakistan. Abstracts, First South Asia Geological Congress, Islamabad, p.42.

Key words: Isotopes, Tethyan carbonates, Himalaya.

S/513. Spencer, D.A. & Spencer-Cervato, C., 1992b. Exhumation and cooling history of eclogite and amphibolite facies rocks in the Upper Kaghan Nappe. NW Himalaya. Pakistan. Abstract Volume, 7th Himalaya-Karakoram Workshop, Department of Earth Sciences, Oxford University, England, 85.

The Upper Kaghan Nappe in the NW Himalayas appears to have gone through a tectonic history that involved differential subduction and differential exhumation. The nappe does not show constant metamorphic, deformational, cooling or exhumation histories, but rather a gradual gradient between the structurally deeper Inner core and the more outer shallower sheet structures. This has been described as a ‘Penninic style of nappe deformation’. A traverse, from southwest (Type area: Safu Maluk) to northeast (Type area: Besal) across the nappe, most strikingly shows these differences in the metamorphic grade: from amphibolite facies in the southwest to lithologies that contain a high pressure eclogite facies mineral assemblage of omphacite - almandine garnet - quartz - rutile at Besal (formation at 650±500C at 15 kbar). Detailed structural mapping has shown that there are no tectonic imbrications of any type, as documented in the nappes to the west of Upper Kaghan (e.g. Besham, Hazara). Furthermore, the deformation Is pre- to syn-metamorphic In the Besal area and syn-metamorphic In the Safu Maluk area. Pressure-temperature paths show a characteristic anticlockwise rotation, as expected for continental collision belts.
Further Insights into the cooling history of the Upper Kaghan Nappe can be made with multisystem radiometric dating. Ten different systems have been used on lithologies from the Upper Kaghan Nappe (Sm/Nd - garnet and clinopyroxene: U/Pb - rutile; Rb/Sr - phengite, garnet and clinopyroxene: Rb/Sr - biotite: K/Ar - hornblende; K/Ar - muscovite; K/Ar - biotite; Ar/Ar -muscovite; Fission Track - zircon and Fission Track - apatite). These ages have been obtained by Tonarini et al. (Submitted), Zeitler (1985) and Treloar et al. (1989). The ages suggest that the cooling history vary with locality with cooling rates differing between the two type areas, although the trends are similar. The eclogite nappe core Initially cools rapidly at 19.30C Ma-1 for 15 Ma until 35 Ma: It then slows to 7.20C Ma-1for 33 Ma until 2 Ma and then rapidly cools again at 600C Ma-1in the last 2 Ma. A similar trend (le. rapid - slow - rapid), but with different rates, is found for the amphibolite path (outer sheet at Safu Maluk). This sheet Initially cools rapidly at 400C Ma-1for 7 Ma until 33 Ma; It then slows to 7.50C Ma-1for 36 Ma until 4 Ma; and then rapidly cools at 250C Ma-1 In the last 4 Ma. It is difficult to envisage such a cooling history, where the eclogite and amphibolite cooling paths cross each other during their exhumation in any other environment other than a nappe. In comparison, cooling paths of the adjacent regions of Besham and Nanga Parbat, are very different. Nanga Parbat shows progressively increasing cooling rates from 20 Ma onwards to present, whilst the Besham area shows the complete reverse of the Upper Kaghan area (slow - rapid - slow) in a much shorter time span. The cooling history Is also significantly different from the East Central Kohistan Island Arc, with the notable exception of the last 15-17 Ma, where a time averaged cooling was simultaneously 110C Ma-1.
Exhumation rates can be obtained from depth-time averages. Maximum pressure estimates of the eclogite path give 15-16 kbar, which equates to depths of formation at 60 km with peak metamorphism at 49.7 Ma. The average exhumation rate is therefore 1.2-1.3 mm/yr. Maximum pressure estimates for the amphibolite path give 8-9 kbar which equate to depths of formation at 30-35 km with peak metamorphism around 40 Ma. The exhumation rate is therefore 0.7-0.9 mm/yr. These rates provide supportive evidence for the exhumation model of fold superposition, which predict that exhumation rates cannot be constant (higher relative uplift by folding in the core of the nappe produces greater relative erosion rates). Searle (1991) calculated the exhumation rates for Nanga Parbat (1 mm/yr.) and for the Sum region (1.4-2.1 mm/yr.). These exhumation rates axe comparable for the NW Himalaya, but bring rocks in the core of the Upper Kaghan nappe to the present surface from depths of almost double those exposed in Nanga Parbat. This is simply due to the timing of peak metamorphism and the depths from which they originated. The Upper Kaghan Nappe was the first part of the Indian Plate to collide in Eocene times: it was the deepest part of the Indian plate to subduct and began its exhumation long before the ‘Main’ Central Himalayan Collision. This could only have been due to a promontory on the Indian plate that had a major influence on the deformational history of the NW Himalaya.
Key words: Exhumation, cooling history, eclogite, amphibolite facies, Kaghan Nappe, Himalaya.

S/514. Spengler, W.H., 1985. The Katlang pink topaz mine, North West Frontier Province, Pakistan. Journal of Gemmology 19, 664-671.

This is a description of the location, mining, and other information of the unique pink topaz of Mardan. Some properties of gemstones are given along with 12 photographs of the area and the gemstone.

Key words: Gemology, topaz, Mardan.

S/515. Staley, J.F., 1963. Hunza-Nagar and the Minapin Glacier. Explorers Journal 41, 12-18.

Key words: Glaciers, Minapin, Hunza.

S/516. Stanin, S.A., 1966. Laterite and other aluminous deposits of West Pakistan. US Geological Survey/Geological Survey of Pakistan, Information Release, PK-11, 25p.

Laterite and other aluminous deposits in West Pakistan are briefly described, and their locations are shown on accompanying base sheets of West Pakistan, scale 1:2,000,000. Localities in Muzaffarabad, kotli tehsil, and Sangar Marg, Azad Kashmir, and in the margalla Hills, Rawalpindi District, may contain bauxite that could be mines profitably. These deposits may extend into the Garhi Habibullah area of Hazara district. The laterite rocks near surg and Campbellpore, Attock District, might be valuable for alumina production. The laterite in the Ziarat area, Sibi and Loralai districts, are rich in $Fe2O3$; these deposits may contain iron resources. Small production of laterite for several year at one locality in Loralai District furnished material for the manufacture of cement.
Detailed stratigraphic, structural, lithologic, mineralogic and economic studies are required to evaluate the resources and potential of these and other deposits in West Pakistan and to appreciate their value as raw materials for aluminum, abrasive, refractory, chemical and other industrial uses.
Key words: Minerals, laterite, West Pakistan.

S/517. Stanin, S.A. & Hasan, M.S., 1966. Reconnaissance for phosphate in West Pakistan. Geological Survey of Pakistan, Information Release 32, 7-11.

Low-grade phosphatic nodules have been found in (1) the lower argillaceous sections of the Jakkher group in the Pab Range; (2) strata of the Mughal Kot formation, Drazinda Shale Member, Domanda Shale Member, and the lowermost beds of the Ghazij Shale in the Sulaiman Range; (3) the Patala Formation and the basal shale member of the Chhidru Formation in the Salt Range; and (4) the basal glauconitic beds of the Chichali Formation in the Kohat Range. The phosphatic nodules seem to be original constituents of the containing rocks. X-Ray diffraction data show that the phosphate in nodules form the Chichali Formation derives from apatite. The Habib Rahi limestone member along the eastern flank of the Sulaiman Range contains beds of slightly phosphatized, dark-coloured, cherty limestone that suggests these rocks may have been deposited under upwelling marine conditions. None of the formations in the areas investigated seem to contain sufficient reserves to be of economic importance. Encouraging indications, however, of phosphate in the Habib Rahi limestone member, Ghazij Shale, and Chichali Formation warrant detailed investigations of these formations in adjacent areas.
Key words: Reconnaissance, phosphates.

S/518. Stauffer, K.W., 1963. Reconnaissance map of the Khyber Pass, West Pakistan. GSP

Consult Stauffer (1968b) for further information.
Key words: Reconnaissance, mapping, Khyber pass.

S/519. Stauffer, K.W., 1964a. Geology of the Gilgit Hispar area, Gilgit Agency, Pakistan. U.S. Geological Survey, PK–19, 41p.

Key words: Mapping, geology, Gilgit.

S/520. Stauffer, K.W., 1964b. Stratigraphy of Northwestern Pakistan and Northwestern Kashmir. 22nd International Congress, New Delhi, Proceedings, 8, 99–111.

Key words: Stratigraphy, Kashmir.

S/521. Stauffer, K.W., 1967. Devonian of India and Pakistan. In: Oswald, D.H. (ed.), Proceedings, International Symposium on Devonian System. Alberta Petrological Society, Calgary, 1, 545-556.

Key words: Palaeontology, Devonian, stratigraphy, India, Pakistan.

S/522. Stauffer, K.W., 1968a. Silurian-Devonian reef complex near Nowshera, West Pakistan. Bulletin of the Geological Survey of America 79, 1331-1350.

The first Paleozoic reef belt on the Indo-Pakistan subcontinent has recently been recognized near the town of Nowshera (lat 34°00′ N., long 72°00′ E.) in northern West Pakistan. It consists of nine separate hills aligned in a 15-mile-long, east-west band rising out of the Peshawar alluvial plain. Each hill is composed of one or more reef cores whose thicknesses range from less than 100 feet to more than 700 feet. The reef cores are separated by relatively unfossiliferous carbonate rocks thinner than the reefs.
The reef belt contains a fauna entirely new to Pakistan that has been dated as Early Devonian to Late Silurian (Ludlovian to Gedinnian). The reef carbonates are the first sediments of possible Silurian age found anywhere in the country and the southernmost Devonian deposits in West Pakistan. Individual reef cores consist of faunal zones or layers that indicate a gradual growth of the reef mass from relatively quiet water upward into rough water.
The presence of these reefs and correlative fossiliferous carbonate sediments in the Peshawar area suggests that in Silurian and Devonian times much of northern West Pakistan was covered by warm, shallow seas bordered by reefs or containing reef platforms. The association of these Paleozoic reefs with extensive deposits of fetid black limestones and porous dolomites may indicate economic potential for the accumulation of oil.
Key words: Palaeontology, Devonian, stratigraphy, reef complex, Nowshera.

S/523. Stauffer, K.W., 1968b. Geology of Khyber Pass, Khyber Agency, West Pakistan. US Geological Survey/Geological Survey of Pakistan, Information Release, PK-22, 42p.

The defile of the Khyber Pass is cut in massive gray recrystallized Limestone whose thickness exceeds 3000 feet. Although no fossils have been found in the immediate vicinity of the pass, assemblages collected at the end of the last century from 5 miles south of the pass, and recently collected fossils from Afghanistan suggest strongly that the limestone is Carboniferous to Permian and perhaps Jurassic in age. The basal contact of Khyber Limestone in places appears to be conformable upon the quartzites and tuffs of Ali Masjid Formation; elsewhere it is probably an unconformity or a fault, especially where the limestone lies directly on the Ordovician to Carboniferous Landi Kotal Slates. The Ali Masjid Formation overlies the shagai Limestone, which, in turn, rests in fault contact on the Landi Kotal slates. A sodic granite intrusion 10 miles northeast of the Khyber Pass on the Kabul River has altered nearby parts of the Khyber Limestone to a fine-quality marble that is today the only mineral resource of commercial importance in the Khyber area.
Structurally the area is characterized by at least four major, roughly east-west trending thrust or reverse fault, along which relatively older rocks have moved southward over younger rocks. A north-northeast-trending system of alternating anticlines and synclines has been superimposed on the earlier structures. Elevated terraces and alluvial valleys suggest a very recent uplift of about 600 to 1000 feet.
Key words: Stratigraphy, structure, Khyber pass, NWFP.

S/524. Stauffer, K.W., 1968c. Heavy minerals in the stream sands of the southern Hazara, West Pakistan. Geological Survey of Pakistan, and U.S. Geological Survey, Information Release, PK – 18, 42p.

The real distribution of heavy minerals in 99 samples from stream sands in the southern Hazara District, West Pakistan, indicate that the metamorphic grade of the rocks in the area increase towards the northwest. Minerals of potential economic value in the heavy-mineral samples include scheelite from the Oghi-Batgram-Battal area and hematite from the Galdanian area. The total weight of magnetite sand grains transported down the Indus Rive past

Darband is calculated to be about 200,000 tons per year, a quantity which may be of economic value. Radioactive minerals are not present in any of the samples in sufficient quantity to be of economic importance.
Key words: Heavy minerals, panning, stream sand, Hazara.

S/525. Stauffer, K.W., 1968d. Geology of the Gilgit-Hispar area, Gilgit Agency, West Pakistan. United States Geological Survey, Information Release PK-10, 42p.

This is an account of the geology of the lower Hunza river valley. The transect from Gilgit to Matum Das is occupied by granitic rocks (now called the Kohistan Batholith). Further north is a wide terrain of pillowed volcanic rocks stretching up to Chalt. Then on is a mixture of low grade pelitic to calcareous metasedimentary rocks and some talcosic rocks. Onward of Hini is a sequence of higher grade metasedimentary rocks followed by granitic rocks of the Karakoram Batholith. In the present day terminology the rocks between Chalt and Hini are considered to be Suture zone mélange, whereas those to the north are put in the Karakoram plate.
Key words: Geology, Hispar, Gilgit

S/526. Stauffer, K.W., 1969. Devonian laterite in Chitral State, West Pakistan. Economic Geology 64, 252-254.

A Devonian laterite has recently been discovered near Reshun in the Mastuj valley of Chitral State, West Pakistan. It is believed to be the fourth recorded Paleozoic laterite in the world. The laterite is entirely within a thick carbonate of the Shogram Formation of Upper Devonian (Frasnian) age. A chemical analysis of the laterite shows the principal constituents to be: $Al_2 O_3$ 35.5%, SiO_2 21.7% Fe_2O_3 16.0%, FeO 10.3%, TiO_2 3.5% CaO 0.97%, and MgO 0.70%. Minerals determined by X-ray analysis include hematite, boehmite, diaspore, anatase, rutile, kaolinite, pyrophyllite and what is probably chamosite.
Key words: Metallic minerals, laterite, Chitral.

S/527. Stauffer, K.W., 1971. Geology of the Reshun area, Chitral State, West Pakistan. U.S. Geological Survey, Information Release, PK–24, 44p.

Key words: Maps, geology, Chitral.

S/528. Stauffer, K.W., 1975. Reconnaissance geology of the central Mastuj valley, Chitral State, West Pakistan. US Geological Survey/Geological Survey of Pakistan, (IR) PK-24, 51p.

The Mastuj Valley in Chitral state is a part of the Hindu Kush Range, and is one of the structurally most complicated areas in northern Pakistan. Sedimentary rocks ranging from at least Middle Devonian to Cretaceous, and perhaps Early Tertiary age lie between ridge-forming granodiorite intrusion and are cut by thrust faults. The thrust planes dip 10 to 40 degrees to the northwest. Movement of upper thrust plates has been towards the southeast relative to lower blocks.
If this area is structurally typical of the Hindu-Kush and Karakoram ranges, then these mountains are much more tectonically disturbed than previously recorded, and suggest compression on a scale compatible with the hypothesis that the Himalaya, Karakoram, and HinduKush Ranges form part of a continental collision zone.
The thrust faults outline two plates consisting of distinctive sedimentary rocks. The lower thrust plate is about 3000 feet thick and consist of the isoclinally folded Upper Cretaceous to perhaps Lower Tertiary Reshun Formation. It has overridden the Paleozoic metasedimentary rocks of the Chitral Slate unit. This thrust plate is, in turn, overridden by an 8000 foot thick sequence containing largely of Devonian to Carboniferous limestones and quartzite.
Key words: Maps, reconnaissance geology, Mastuj, Chitral.

S/529. Stauffer, K.W. & Calkins, J.A., 1966. Heavy mineral prospecting. US Geological Survey/Geological Survey of Pakistan, (IR) Pk-16, 35p.

Heavy mineral prospecting is a method of tracing potential ore minerals to their source by systematically examining the heavy minerals of stream sand. The heavy minerals are partially concentrated in the field by panning. In the laboratory the heavy minerals are further concentrated by floating off the quartz and feldspar in a heavy liquid, such as boroform, having a specific gravity of 2.89. Magnetite is separated magnetically and scheelite is identified under short-wave ultraviolet light. To obtain quantitative results on the minerals present, the sample is reduced by coning and quartering, mounting on a slide in oil, and a count of a minimum of 250 rains made. The chisquare test applied to the splitting and counting techniques shows them to be statistically valid. The properties of some heavy minerals most useful for their rapid identification is listed. Methods here described are those utilizing a minimum of field and laboratory equipment and may be appropriate for application in many areas of the world.
Key words: Prospecting, heavy minerals.

S/530. Stefanini, G., 1917a. Echinidi Mesozoici del Caracorum raccolti dalla Spedizione Italiana nell'Asia Centrale (1913-1914). Rendiconti della Reale Accademia Nazionale dei Lincei, Series 2(26), 49-50.

Key words: Italian expedition, palaeontology, Mesozoic echinide, Karakoram.

S/531. Stefanini, G., 1917b. Su l'esistenza de depositi cenomaniani e di altri livelli mesozoici nel Caracorum (Asia Centrale). Rendiconti della Reale Accademia Nazionale dei Lincei, Series 2(26), 190-195.

Key words: Italian expedition, Mesozoic, Karakoram.

S/532. Stefanini, G., 1928a. Echinidi mesozoici del Caracorum. In: Relazioni Scientifiche della Spediozione Italiana de Filippi nell'Himalaia, Caracorum e Turchestan, Cinese (1913-1914), Series 2(6), 41-100. Zanichelli, Bologna.

Key words: Italian expedition, Mesozoic echinide, Karakoram.

S/533. Stefanini, G., 1928b. Moluschi e Brachiopodi calloviani del Caracorum. Relat. Scient. Spediz. De Filippi etc., II, 6, 41-100.

Key words: Palaeontology, moluscs, brachiopods, Karakoram.

S/534. Stellrecht, I., 1992a. Environmental perception and vertical classification in Hunza valley (North Pakistan). In: Shams, F.A. (ed.), Culture Area Karakorum Research Project in the Northern Areas, Pakistan. Proceedings of the Pak-German joint Workshop, December 1991, Lahore, 104-116.

Key words: Environment, Hunza valley, Karakoram.

S/535. Stellrecht, I., 1992b. Perception of environment in a high mountain area: Vertical classification in the Karakorum (Hunza valley/Pakistan). Abstracts, International Symposium on the Karakorum and Kunlung Mountains, June 5-9, 1992, Kashi.

Key words: Environment, classification, Hunza valley, Karakoram.

S/536. Stellrecht, I., 1992.c Umweltwahrnehmung und vertikale klassifikation im Hunza-Tal (Karakorum). Geographische Rundschau 44, 426-434.

Key words: Environment, classification, Hunza valley, Karakoram.

S/537. Stern, L.A., Johnson, G.D. & Chamberlain, C.P., 1993. Carbon isotope signature of environmental change found in fossil ratite eggshells from a South Asian Neogene sequence. Geology, 22, 419-122.

A > 10-my.-long sequence of ratite (e-g., ostrich) eggshells from Siwalik Group sedimentary deposits of northern Pakistan and India shows a dramatic (~8%0) increase in the δ13C in biomineralogic calcite by ~4 Ma. Values of δ13C from ratite eggshell carbonate older than 7 Ma are about the same as those from carbonate from contemporaneous fossil mammal tooth enamel and paleosols. However, after 4 Ma, the ratite eggshell carbonate δ13C values are ~5%0 less than these coexisting materials. These findings are evidence of the development of a C3-C4 vegetative mosaic probably mirroring the sedimentologic-edaphic mosaic of the aggrading alluvial plain of the Siwalik depositional system.
Key words: Carbon isotope, neogene sequence, Siwaliks, northern Pakistan.

S/538. Stewart, A.G., 1990. For debate: Drifting continents and endemic goiter in northern Pakistan. British Medical Journal 300, 1507-1512.

Although Baltistan, north East Pakistan, is in a region of iodine deficiency disorders, the distribution of goiter within the district, according to age and sex, has not been clearly defined. To establish the prevalence of the condition and to measure the reported difference in prevalence in the north and south of the district thyroid size was assessed in new patients attending the Aman clinic, Khapalu, and outlying areas between April and September from 1981-1986. Samples of potable water collected from villages were analysed for iodine (as iodide) concentrations in Britain. Population weighted prevalences were: in the north in males 28.1% and in the south in males 13.9%, in females 21.2%. There was an overall deficiency of iodine in the water (mean iodine (as iodide) concentrations (north) 11.0 nmol/l (1.4 µg/l), (south) 11.8 nmol/l (1.5 µg/l) (95% confidence interval –0.7 to 0.9). The differences followed the Main Karakoram Thrust, suggesting a geological goitrogen in the north, which might be minerals containing ions such as BF4 and SO3F, and molybdenite and calcium which are present in rock in Baltistan.
A new hypothesis for the genesis of endemic goiter is proposed—that is, that continents on crustal plates drift across the earth and collide, one plate sliding under the other and melting, fiving rise to characteristic mineral assemblages in the overlying rocks. As the minerals weather out they enter the diet of the local population, where in the presence of iodine deficiency they produce or enhance iodine deficiency disorders. Despite the current iodised oil compaign by the Pakistani government with UNICEF a long term working iodisation programme is still urgently needed.
Key words: Medical geology, goiter, iodine deficiency, MKT, Baltistan.

S/539. Stewart, J.L., 1860. Notes on the geology of the Wazeeree Country. Journal of the Asiatic Society of Bengal 29, 314-318.

Key words: Geology, Waziristan.

S/540. Stuart, M., 1919a. Suggestions regarding the origin and history of the rock salt deposit of the Punjab and Kohat. Geological Survey of India, Records, 51 (1), 57-97, pls 9-25.

Key words: Rock salt deposits, Punjab, Kohat.

S/541. Stuart, M., 1919b.The potash salts of the Punjab Salt Range and Kohat. Geological Survey of India, Records 50(1), 28-56.

Key words: Potash salt, Punjab, Kohat.

S/542. Stuart, M., 1919c. Natural gas bituminous salt from Kohat. Geological Survey of India, Records 50(4), 263-267.

Key words: Natural gas, Kohat, India.

S/543. Stuart, M., 1922. The geology of the Takki Zam valley, and the Kaniguram-Makin area. Waziristan. Geological Survey of India, Records 54(1), 87-102.

Key words: Geology, Waziristan.

S/544. Stump, E. & Sorkhabi, R.B., 1993. Syntaxial tectonics at Nanga Parbat and Denali. Abstracts with Program, Annual Meeting of the Geological Society of America, p.A-123.

NangaParbat (NP) and Denali (Mt McKinley), two of the loftiest and most rapidly exhuming massifs on earth occur at syntaxies of major fault systems from FT analysis. The average rate of exhumation for Denali is more than 1 mm/yr for the last 6 my; for NP exhumation has increased for the past 7 ma from 0.5 mm/yr to over 7 mm/yr. the differences in tectonic settings of the two areas include: 1. NP sits at the corner of two obliquely opposed thrust systems; denali occurs at the apex of and orcuate right-lateral strike – slip fault, 2. In map view, NP is a tightly appressed structure; Denali is open, 3. NP results from continent-continent collision; Denali occurs in a continental margin orogenic belt, 4. The current pulse of exhumation of NP follows a long history of uplift of the Himalaya (at least 20 ma), whereas that of Denali had no precursors prior to 6 ma.
The tectonic feature of that both denali and NP share is that they have formed in large-scale plan view, convergent stress systems.
Key words: Tectonics, Nanga Parbat, Himalaya.

S/545. Su, Z., Zhang, X. & Gu, Z., 1980. The thickness and the quality of ice of the Batura Glacier. In: Shi, F. (ed.), Professional Papers on the Batura Glacier in the Karakoram Mountains. Science Press, Beijing.

Key words: Glaciers, geomorphology, Batura.

S/546. Sulaiman, M. & Iqbal, S., 1972. Geology of the northern part of Jandul, District Dir, N.W.F.P., M.Sc. Thesis, University of Peshawar, 51p.

The northern part of the Jandul valley is underlain by the Palaeozoic rocks of the amphibolite facies. These metamorphic rocks were intruded by the igneous rocks in the Mesozoic times. The early phase of intrusive activity is represented fey diorites, granodiorites, granite and apparently later phase by morite. During the Tertiary period these intrusives were followed by the volcanic rocks of andesitic and dacitic composition. The volcanic rocks also include porphyritic volcanic dykes which are abundant in both palaeozoic and Mesosoic rocks. The porphyritic rocks have suffered a low grade metamorphism. This phase was followed by a granite intrusion. Quartz and pegmatitic veins represent the last phase of igneous activity.
Structurally the area is very complex. Shearing and local folding is very prominent. Repeated tectonic activities seem to have occurred in the area as is evident from deformation. Copper mineralization and vein quartz, which occur in the area, are not of any economic value at present.
Key words: Structure, metamorphic rocks, igneous rocks, Jandul, Dir

S/547. Sullivan, M., 1990. The roof zone of the Kohistan batholith, Pakistan. In Abstract volume, 5th Himalaya-Karakoram-Tibet Workshop, Milano, 59.

The final stages in the evolution of the Kohistan terrane are represented by the eruption of volcanic material onto a continental margin, formed after the Cretaceous collision of Kohistan with the Asian plate.

Recent fieldwork during 1988-1989 has shown that the sub-volcanic basement lithologies of this area include meta-pelitic schists and metaquartzites of the Kamila amphibolite belt, which were intruded into by Cretaceous hornblende-biotite-pyroxene diorite and granodiorites.
Uplift and erosion of this basement preceded volcanism, with the development of a basal unconformity in the tuffaceous material, stretching form Swat westwards into Dir. Volcanism was predominantly explosive with the development of between 700m-1000m of reworked ash and agglomerate/breccia. Lavas are more restricted (200m-500m) and these range in composition from andesite to rhyolite, often ignimbritic. These volcanics are dated as Paleocene/Lower Eocene by foraminifera assemblages (Discocylina, Elphidium and Ranikothalia bermudezi).
The volcanic pile was then intruded by later Paleocene/Middle Eocene calc-alkaline diorites, granodiorites and granites, with associated pegmatites. Finally, southeastward directed thrusts imbricated the roof zone and provided pathways for copper-rich fluids to develop strata-bound mineralization in the Dir area.
Key words: Tectonic evolution, volcanic, erosion, Kohistan batholith, Himalaya.

S/548. Sullivan, M.A., 1991. Continental margin volcanism along the leading edge of Eurasia: the Dir Volcanics. Abstract Volume, 6th Himalaya-Karakoram-Tibet workshop, Grenoble, France, 91.

In northwestern Pakistan (Kohistan) volcanic rocks associated with the northward subduction of Indian oceanic crust beneath Eurasia record two discrete episodes of activity:
1/Early tholeiitic and calc-alkaline basalts, andesites and rhyodacites, which make up part of the Kohistan, island-arc (early Cretaceous Chalt Volcanics).
2/ Later silicic lavas and tuffs (Dir Volcanics dated 55 Ma 40Ar-39Ar) which erupted subsequent to the accretion of the Kohistan are onto Eurasia, but prior to the collision of India.
Mineralogical and geochemical characteristics indicate that as a whole the Dir volcanics belong to an calc-alkaline continental margin series. They are L.I.L.E. enriched, depleted in H.F.S.E. (i.e. Nb) and show L.R.E.E. enrichment. The majority of material is rhyolitic in composition with few basalts. Such substantial amounts of silicic volcanism imply the existence of extensional tectonics. Limestone clasts in conglomerate at the base of the Dir Volcanics are dated at 58 Ma, and record a period of marine incursion onto the margin of Eurasia. Attenuation of the continental lithosphere may have resulted in the development of small marginal seas, in contact with the ocean, which later were subject to uplift and erosion at the onset of volcanism at 55 Ma.
Along the northern margin of Kohistan the Shamran Volcanics have yielded a radiometric age of 54 Ma (40Ar-39Ar). This implies that rather than being associated with the Chalt Volcanics they are more likely contemporaneous with the later Dir Volcanics. They have similar geochemical characteristics and indicate that the extent of continental margin volcanics in Kohistan is greater than was first thought, recording perhaps the migration of the magmatic-arc with time.
Key words: Volcanism, tectonics, Eurasia margin, Dir.

S/549. Sullivan, M.A., 1992. A palaeogeographic reconstruction of the Dir group: Evidence for magmatic arc migration in the N.W. Himalayas. Abstract Volume, 7th Himalaya-Karakoram Workshop, Department of Earth Sciences, Oxford University, England, 89.

The Dir Group records the resumption of volcanic activity along the southern margin of Eurasia after a prolonged period of uplift and erosion. Two contrasting depositional environments are identified; a distal deep-water marine fore-arc (Baraul Banda Slate Formation) and a proximal subaerial volcanic core facies (Utror Volcanic Fm. and Shamran Volcanics). Eruptive style was predominantly explosive, with poorly sorted polymict volcanic breccias and sandstones testifying to the importance of epiclastic processes. Sedimentary thicknesses and the abundance of rhyolite lavas and pyroclastic flows indicates extensional tectonic control (hinge roll-back) even though the arc developed at a convergent margin. Fore-arc sediments show provenance from a dissected arc source implying either blockage of volcanogenic detritus due to coastal topography or by-passing.by submarine canyons. Juxtaposition of the two different facies along the Dir Thrust excludes any record of shoreline or coastal processes from the volcanic stratigraphy. The inferred original geographical separation of the two environments (50-100 kin), coupled with their individual relationships to dated plutons reveals that between Upper Cretaceous (ca. 78 Ma) and early Eocene (ca. 48 Ma) times the locus of magmatic activity within the Kohistan-arc migrated northward. Furthermore this

palaeogeographic reconstruction also implies that considerable shortening has taken place within the Kohistan Terrane subsequent to the closure of Tethys.
Key words: Palaeogeography, magmatic arc, sedimentology, volcanics, Dir group, Kohistan.

S/550. Sullivan, M.A., 1993. The geology of the roof zone of the Kohistan batholith, northwestern Pakistan. Ph.D dissertation, University of Leicester.

Key words: Geology, tectonics, structure, Kohistan batholith, Himalaya.

S/551. Sullivan, M.A., Saunders, A.D. & Windley, B.F., 1996. The petrology and geochemistry of the Utror and Shamran volcanic Formations, Kohistan, NW Pakistan. Abstract volume, 11th Himalaya-Karakoram-Tibet Workshop, Flagstaff, Arizona, 155.

The Utror and Shamran Volcanic Formations represent the extrusive parts of the Dir Group, and are remnants of an elongate, dominantly subaerial volcanic arc that was active along the southern edge of Eurasia during the subduction of the Indian plate. They were erupted between ca. 55 Ma and 48 Ma, above an erosion surface cut deep into the Kohistan Batholith, during a brief period of caldera activity prior to continent-continent collision. They are broadly contemporaneous with the Dras II and Khardung Volcanic sequences of Ladakh and the Lingzizong Volcanics of Tibet.
Fragmental material dominates the volcanic record, and pyroclastic flows and ignimbrites testify to a highly explosive eruptive style. Coherent lava flows consist of a variably-altered suite of tholeiitic and calc-alkaline lavas, that range in composition from basalt to high-silica rhyolite. All lavas are holocrystalline, although there is textural evidence for the existence of originally glassy rhyolite. All lavas are holocrystalline, although there is textural evidence for the existence of originally glassy rhyolite flows. Lavas are strongly porphyritic throughout the compositional spectrum, containing between 5% and 45% (volume) of phenocrysts.
Secondary alteration effects, such as devitrification, polyphase hydrothermal alteration, and metamorphism influence the petrology of both lava suites. Augite, hornblende, titanomagnetite, and Ca-rich plagioclase dominate in the more basic compositions. Ferromagnesian minerals have Mg-rich compositions, with no tendency to show Fe enrichment, indicating that conditions were sufficiently oxidizing to prevent a tholeiitic evolutionary trend. Hornblende and pyroxene phenocrysts rarely coexist and probably reflect varying water contents of the magmas. Dacites and rhyolites are dominated by quartz and plagioclase feldspar. No primary ferromagnesian phases are observed and there is a notable absence of orthoclase feldspar. Textural evidence suggest that many of the rhyolites were originally obsidian with phenocryst contents indicating high viscosities.
Plagioclase, hornblende, clinopyroxene and titanomagnetite controlled early mineral fractionation with fO2 fluctuations resulting in two identifiable trends. LILE are enriched relative to HFSE (Ba/Nb=4.7-101) and LREE relative to HREE (Ce/Ybn=2.3-9.9). Unlike typical orogenic arcs, which are dominated by andesite/dacite volcanic rocks, much of what remains of the Utror and Shamran Volcanic fields consist of a bimodal suite of andesite and rhyolite lavas and ash-flow tuffs. Crustal anatexis although favored by volume considerations does not agree with observed fractionation trends and thin-section evidence. Unfortunately considerable petrological variability exists even within a restricted geographical location, and this, coupled with an intense and varied alteration state, make detailed petrogenetic modeling inappropriate. Much of the variability that does exist appears related to initial source characteristics, magma ascent paths, fluctuating oxidation conditions and fractionation crystallization processes. Geochemical characteristics confirm existing isotopic data indicating that the Shamran Volcanics are contemporaneous with the continental margin suite of rocks (Dir Group) rather than with the earlier Chalt Volcanic island-arc suite.
Key words: Petrology, geochemistry, Utror, Shamran, Kohistan, Himalaya.

S/552. Sullivan, M.A., Windley, N.F., Saunders, A.D., Haynes, J.R. & Rex, D.C., 1993. A paleogeographic reconstruction of the Dir group: Pakistan. In: Treloar, P.J. and Searle, M.P. (Eds), Himalayan Tectonics. Geological Society of London, Special Publication 74, 139-160.

The Late Palaeocene Dir Group records the resumption of volcanic activity along the southern margin of Eurasia after a prolonged period of uplift and erosion. The group forms an integral part of the Kohistan Batholith and is readily divisible into two distinctly contrasting volcanic successions.
The Baraul Banda Slate Formation comprises 2700 m of fore-arc sandstones and siltstones. The basin formed during the collapse of the Kohistan continental margin and was filled initially by subaerial debris and mass-flow deposits. Subsidence was rapid such that >900f the sedimentary record consists of thin-bedded sheet turbidites. These maintain a remarkable lateral continuity and indicate deposition in a restricted deep-water environment. Rare interbedded limestones have yielded a Thanetian (60.2–54.9 Ma) marine fauna of *Miscellanea miscella* and *Actinosiphon tibeticus*.
In direct contrast the Utror Volcanic Formation comprises 3000 m of volcaniclastic sedimentary material, lava flows and ignimbrites. Eruptive style was predominantly explosive with fragmental material dominating the volcanic record. Lavas range in composition from 53% to 79% SiO_2 with rhyolite the predominant rock type. A basaltic andesite has an ^{40}Ar-^{39}Ar age of 55 ± 2 Ma. Although the volcanic stratigraphy is complex preliminary investigations suggest accumulation in a predominantly subaerial ring-plain or flanking facies distal to the main focus of volcanic activity. Sedimentary thickness and the abundance of silicic lavas and pyroclastic flows imply extensional tectonic control even though the arc developed at a convergent margin.
Juxtaposition of the two facies along the Dir Thrust excludes any record of shore-line or coastal processes from the volcanic stratigraphy. The inferred original geographical separation of the two environments coupled with their relationships to isotopically dated plutonic suites reveals that between Late Cretaceous and Early Eocene times the locus of magmatic activity within the Kohistan arc migrated progressively northward.
The Shamran volcanic rocks although originally correlated with the island-arc Chalt Volcanic Group are now identified on the basis of a 58 ± 1 Ma (^{40}Ar-^{39}Ar) age as a northern continuation of the Late Palaeocene volcanic arc.
Key words: Palaeogeography, magnetic arc, sedimentology, volcanics, Dir group, Himalaya.

S/553. Sultan, M., 1970. Volcanic rocks from Kalam, Upper Swat. Geological Bulletin, University of Peshawar 5, 138-141.

Green and pink mottled volcanic rocks occur about three miles northwest of Kalam. A detailed investigation of these rocks has not been carried out so far, and the purpose of this paper is to give a preliminary report on the petrography of some of them. This report is based on the study of three thin-sections cut from rocks apparently different in hand specimen; one of these is a banded dacite, and two are pryoclastic dacite. The writer considers that the Kalam volcanics are a part of the Panjal Volcanics of Upper Carboniferous age.
Key words: Petrography, volcanics, Kalama, Swat.

S/554. Sultan, M., 1996. Heavy and trace metal abundance related to pollution in Peshawar Cantt, and along Jamrud Road, N.W.F.P., Pakistan. M.Phil. Thesis, University of Peshawar, 89p.

Polluted air, water and soil are considered to be the sources of several fatal diseases in human beings and animals. Among other pollutants, heavy metals are one which if incorporate with air, water and soil, could cause many diseases in human beings. The heavy metals incorporate with air, 'water and soil from different sources like mineral and ore processing industries, chemical industries, glass and paper industries, textiles, fertilisers, petroleum refining and vehicular emanations. Pakistan is one of the developing countries where the rapid growth of infrastructure including mad systems and vehicular traffic is in progress. One of the major sources of heavy metals along the roadsides, in the big cities of the Pakistan, is automobiles. Besides cocktail of toxic gases, exhaust from automobiles contain various heavy metals, which directly contaminate air, and when fall on ground, could enter into the surface and subsurface water systems. Such waters, if reach the aquifer and are utilised by the municipality, could he distributed in the city for both drinking and agricultural/ gardening purposes.
The present study has been conducted to analyse and determine the levels of heavy metals including Cr, Co, Cu, Ni, Zn, Fe and Ph in air, sewerage drains and subsoil samples from various parts of Peshawar cantonment and along .Jamrud road. Air dust samples (48) were taken from different busy chouks/intersections from the Peshawar cantonment and along Jamrud road In addition 30 sewage water and mud samples were taken from the sewerage system of Peshawar cantonment to determine the contamination levels in drains which ultimately join the Kabul river. Ten soil samples were taken along the Jamrud road and from the busy chouks in Peshawar cantonment at a

depth of two feet, and one foot away from the metalled roads to find the extent and effect of surface air pollution in the subsurface soils along the roads.
Results revealed that higher concentration of heavy metals especially Ph, Fe and Zn were present in air and sewage samples. In general the deposition and dispersion systematics of these metals are related to their atomic masses as well as to their availability in the surroundings. It was found that Pb is the most prevalent element in the air along the roads of Peshawar. Emission from automobiles is one of the major sources of lead in the atmosphere.
Analysis of all the sewage samples showed the presence of high levels of heavy metals. The heavy metals, being heavier than water, tend to settle at the base of the drains. The mud sewage samples contained more heavy metals than water sewage samples. Different shops, working in metals, printing presses and roads contiguous to the uncovered drains are the major sources of heavy metals in the drains of the Peshawar cantonment. These drains, containing heavy metals, ultimately fall into the Kabul river through Shahi kata and Budni canal. Soil samples show the levels of heavy metals with in the normal ranges and are, therefore, not bothersome from environmental point of views.
Key words: Heavy metals, trace elements, pollution, Peshawar, NWFP.

S/555. Sultan, M. & Ali, A.N., 1970. Sedimentology and petrography of Ghundai Sar reef complex, Jamrud, Khyber Agency. M.Sc. Thesis, University of Peshawar, 64p.

A belt of Silurian-Devonian. Coralline Limestone of pink, yellowish-pink, and greyish-white colour, is exposed in the hills of Ghundai Sar, near Jamrud; Khyber Agency. This belt, which unconformably overlies the Phyllitic rocks, (Kandar phyllite) intruded by dolerite and gabbroid intrusion, is divisible in two definite units, that is,
(1) the Reef Core and (2) Reef Breccia .the two collectively are known as the Nowshera formation. The entire formation represents deposition on a stable shelf, the environments were conducive for the development of coral reefs. The orthoquartzite associated with dolomite and limestone support this observation,
In this paper, petrography and sedimentology of the reef limestones is discussed in detail 101 Samples were collected and 30 sections were cut to describe the petrography. The Limestone and dolomite show variations in their mineralogical composition. All variations from arenaceous limestone to calcareous orthoquartzite occur.
It is observed that dolomite is both primary (originally secreated by organisms) and secondary, introduced by low grade regional metamorphism afterward. Early Tertiary and Late Cretaceous intrusions have caused silicification and introduction of crystalline Quarts and feldspar in limestone. Limonitization is most probably a recent phenomenon, and might have introduced by the leaching of iron from overlying arenaceous formation.
Key words: Sedimentology, petrography, reef complex, Khyber agency.

S/556. Sultan, S.A. & Arbab, K.U., 1985. The Geology and the structure of a part of southern flank of Attock-Cherat Range, West of Indus River, N.W.F.P. (Pakistan). M.Sc. Thesis, Department of Geology, University of Peshawar, 84p.

The area of investigation covers 25 square kilometres on the eastern side of Attock-Cherat Range which stands as a structural high between southern portion of Peshawar Plains and Nizampur valley.
Structural style of the area is controlled by two major thrust faults, i.e. Khairabad fault in the north, which separates Dakhner Formation of late Pre-Cambrian age from Utch Khattak Formation and Cherat fault towards southern end of Attock-Cherat Range, which separates Dakhner Formation from Palaeozoic rock sequence. The Tertiary sequence is represented by Lockhart limestone, lying in the form of isolated patches and bands in Dakhner Formation. Their contact is considered to be of tectonic origin. Some strike-slip faults are identified in the area which may have formed in response to southward movement of the sequence along Cherat thrust.
Economically, the area- holds a promise for setting up Cement Industry in future.
Key words: Structure, geology, Attock-Cherat Range, Indus River.

S/557. Suzuki, M. & Khan, S.R., 1992a. Geochemical exploration in Jijal area. Proceedings of Geoscience Colloquium, Geoscience Lab, Geological Survey of Pakistan, Islamabad 2, 79-109.

This report describes the results of a geochemical exploration targeting mainly precious metals (Gold and Platinum Group) in the Jijal Complex, north of Besham, which was carried out by Japan International Cooperation Agency

(JICA) and Geological Survey of Pakistan (GSP). The study area occupies the southern limit of the Kohistan island arc terrain and samples were collected mostly from the area between Indus River and Duber Khwar. From Jijal to the eastern foothill of Mt.Gabar, a jeepable metaled road is available. However the general topography of the area is quite steep, and accessibility is poor on the whole. The geological mapping and the sampling of stream sediments were carried out for 30 days during October, 1990 to February, 1991, and the check survey to the results of geochemical analyses was conducted for 5 days in May, 1991.
Key words: Geochemistry, exploration, ultramafics, Jijal, Kohistan, Himalaya.

S/558. Suzuki, M. & Khan, S.R., 1992b. Regional geochemical exploration in Gilgit area, Proceedings of Geoscience Colloquium, Geoscience Lab, Geological Survey of Pakistan, Islamabad, 2, 110-159.

The present report is to summarize the results of a geochemical exploration targeting gold in the Gilgit Agency.
The study area is divided into the northern and southern parts by the EW-trending Main Karakorum Thrust (MKT) in the central part. The Aslan Plate terrain on the northern side of the thrust is largely underlain by Paleozoic to Mesozoic sedimentary formations that have been intruded by Jurassic to Tertiary batholiths, whilst the Island Arc terrain on the southern side consists mainly of sedimentary and volcanic formations, which have been intruded by granitoids ranging from 102 to 25 Ma. Sampling for the geochemical exploration, which used stream sediments and panned concentrates as media, was conducted along the main streams of the Hunza and Gilgit Rivers and their major tributaries. Sampling denshy was slightly enhanced in the neighborhood of Gilgit, where a number of alteration zones have been found. One hundred and twenty samples of stream sediments were analyzed for gold, while 92 samples of panned concentrates underwent chemical assays of Au. Ag, As, Bi, Cu, Mo, Pb, Sb, and Zn in Chemex Laboratory.
Gold contents in the study area are generally higher than the average of the earth crust, implying a high probability of some gold mineralization in this area. A univariate analysis demonstrates that all elements except Cu and Mo show high concentrations along the MKT and on the northern side as a whole. Gold shows particularly high concentrations along the MKT. Factor analyses have led to the extraction of the following two factors related to gold mineralization: 1) a factor represented by a combination of Au-Ag-As-Sb (Factor 4) and 2) a factor represented by a combination of Bi-As-Ag-Au (Factor 2). High factor scores for the Factor 4 are found along the MKT. High-scored points for the Factor 2 are distributed mainly around the glacial areas.
A survey on the alteration zones was conducted in the northern area of Gilgit simultaneously with the geochemical exploration. Results of gold assays for prominent quartz-veins and highly silicified zones were disappointing. The results of the geochemical exploration and geologic survey on the alteration zones indicate a low potentiality of economically promising gold mineralization. The present survey leads to a conclusion that it is along the MKT, above all, the Chatorkhand area showing high contents of 11.0 ppm and 50.5 ppm Au as well as high scores for factor 4 that deserves a high priority to a follow-up survey.
Key words: Geochemistry, exploration, ultramafics, Gilgit, Himalaya.

S/559. Suzuki, M., Khan, S.R. & Khan, I.H., 1992. Lithogeochemical exploration in Mansehra area. Proceedings of Geoscience Colloquium, Geoscience Lab, Geological Survey of Pakistan, Islamabad, 3, 35-83.

The present report is to summarize the results of lithogeochemical exploration targeting tungsten and surveys of the mineralized zone. The study area is underlain by the Tanawal Formation consisting of schists and quartzites, the Mansehra Granite composed d granitic gneisses and schistose granites, and the Younger intrusions comprising porphyritic granites, aplites and diabases. Sampling for the exploration was implemented on the basis of a grid net with an interval of 200 m in a 4 km by 4 km area selected by the previous geochemical exploration by stream sediments. The following 25 elements were analyzed: Ag, Al, Ba, Be, Bi. Ca. Cu, Cr, Co, F, Fe. K. Mg, Mn, Mo, Na, Ni, P, Pb, Sr, Sn, Ti, V, W, and Zn. Analysed samples amount to 305.
Univariate analysis led to detection of a large anomaly of W, F, Al, and P and a small anomaly of Ba, Ca, K, Ti, and V. Above all, F has been found to be an effective index element, which forms strong geochemical anomalies around the porphyritic granites, a ore bringer. As a result of factor analysis, W, F, Al, Ca, P, Ti, and V were extracted as elements related with W- mineralization (Factor 5). The distribution map of this factor shows a widespread distribution of high-scored areas from the Khabbal primary school to the southeastern slope of the Mt. Manna

Danna, indicating that they are most promising in the study area. In addition, comparison with univariate analysis dem0nstrate the effectiveness of factor analysis for erasing anomalies derived from background fluctuations.
W-mineralization found in the vicinity of the Knabbal primary school is of greisen type, which occurred near the top of a sheet-shaped intrusion of pophyritic granites. Impermeable caprocks covering the porphyritic granites presumably prompted concentration of scheelite. Showings of the mineralization in this area are so small for the strong geochemical anomalies, that any more discovery of larger mineralizations seems impossible.
Key words: Lithology, geochemistry, exploration, Mansehra, Hazara.

S/560. Suzuki, M., Khan, S.R. & Khan, I.H., 1995. Lithogeochemical exploration for scheelite mineralization in Mansehra area, northern Pakistan. Geologica 1, 13-59.

Key words: Lithochemical, exploration, scheelite, Mansehra, Hazara.

S/561. Sweet, W.C., 1970. Uppermost Permian and Lower Triassic conodonts of the Salt Range and Trans-Indus Ranges, West Pakistan. In: Kummel, B. & Teichert, C. (Eds.), Stratigraphic Boundary Problem; Permian and Triassic of West Pakistan. University of Kansas, Special Publication 4, 207-276.

Key words: Palaeontology, conodonts, Permian, Triassic, Salt Range, Trans-Indus Range.

S/562. Syed, A.F. & Jabbar, M., 1984. Petrology of a part of Ambela granitic complex (Malandari area) district Mardan, NWFP. M.Sc. Thesis, University of Peshawar, 89p.

Key words: Petrography, Ambela granitic complex, Mardan.

S/563. Symes, R.F., Bevan, J.S. & Jan, M.Q., 1987. The nature and origin of orbicular rocks near Deshai, Swat Kohistan, Pakistan. Mineralogical Magazine 51, 635-647.

Orbicular dioritic-noritic rocks from an area of mixed metamorphic and igneous rocks in Swat Kohistan, northern Pakistan, have been examined petrographically and chemically in order to determine the nature and origin of the orbicular texture. Using textural and compositional sequences it has been possible to relate the apparently different orbs to one another, and obtain a sequence of orb formation. The majority of the orbs comprise a series of distinct layers (shells) surrounding a central zone (core). Plagioclase, clinopyroxene, orthopyroxene and hornblende form the bulk of the shells. The cores have been extensively recrystallized. The development of a ‘comb-layered’ texture in some orbs and in associated layered rocks is comparable to that commonly described from other occurrences. A dual igneous/metasomatic crystallization history is invoked to explain the features of the orbs in this locality, the oscillatory zoning of the orbicular structure being caused by the alteration of primary minerals, such as pyroxene to amphibole, due to fluctuations in the p_{H2O} of the magma.
Keywords: Orbicular rocks, diorite, norite, Swat Kohistan.