B/1. Babar, M., 1993-95. The application of electrical resistivity technique for the detection of buried stream channels and ground water exploration in Saidabad Area, District Malakand, NWFP, Pakistan. M.Sc. Thesis, Punjab University, Lahore, 190p.

Key words: Resistivity, groundwater, Malakand.

B/2. Baber, Z.A., 1981. Thesis on the geology and petrology with special emphasis on Calcareous quartzite and Chlorite and Biotite Schists of Sawani–Sheringal area, District Dir, NWFP. M.Sc. Thesis, Punjab University, Lahore.

Low grade metamorphosed Early Tertiary inter-arc sediments of the Kalam area appear to extend into Sheringal and Baraual area of Dir district. This thesis concerns the general geology and petrography of these rocks.

Key words: Petrology, metamorphism, Dir.

B/3. Badgley, C., 1984. Bibliography of the GSP-Yale Peabody Museum Research Project on the Miocene sediments, faunas, and hominoids of the Potwar Plateau, Pakistan, 1973-present. In: Shah, S.M.I. & Pilbeam, D. (Eds.), Contributions to the Siwalik of Pakistan. Geological Survey of Pakistan, Memoir 11, 19-42.

Key words: Bibiliography, Miocene, siwalik molasse, Potwar.

B/4. Badgley, C., Bartels, W.S., Morgan, M.E., Behrensmeyer, A.K. & Raza, S.M., 1995. Taphonomy of vertebrate assemblages from the Paleogene of northwestern Wyoming and the Neogene of northern Pakistan. Paleogeography, Paleoclimatology, Paleoecology, 155, 157-180.

We compare the taphonomy of vertebrate assemblages from two long continental records-the early Paleogene of the Bighorn Basin, Wyoming, and the Neogene Siwalik sequence of northern Pakistan. Both sequences contain a similar array of fluvial facies, and the abundance of these facies differs among formations. We document environments of preservation of vertebrate localities over time to determine comparability of fossil assemblages within and between sequences. Changes in sample size and species richness are noted to reveal potential sampling effects on patterns of faunal turnover. Preservational history determined the environment, sample size, quality of specimens, taxonomic composition, and spatial and temporal resolution of fossil assemblages and thereby the quality of the fossil record and its suitability for further analyses.

In both sequences, changes in prevailing taphonomic processes reflect changes in lithofacies and habitat distribution. Correlated changes are found in fossil productivity, species richness, and faunal composition. Both sequences contain some episodes of apparent faunal change in which appearances and disappearances of rare taxa can be attributed principally to changes in sample size. The Paleogene record has high taxonomic resolution (i.e., to genus or species) for most mammalian fossil remains. Temporal and spatial averaging of Paleogene fossil assemblages changes with lithofacies. The Neogene record has higher taxonomic resolution for remains of small mammals (<2 kg) than of large mammals. All formations have several fossiliferous facies, with moderate to high degrees of temporal averaging and low to high degrees of spatial averaging.

Different preservational circumstances impose different constraints on paleoecological and evolutionary analyses. The best opportunities for paleocommunity reconstruction are provided by high taxonomic resolution, large samples, and varied environments of preservation. These circumstances are found in limited portions of each record. The best opportunities for documenting evolution within lineages and species-replacement patterns are provided by high taxonomic resolution, high temporal resolution, and consistent preservational context. These taphonomic attributes pertain to the more common Paleogene mammals, particularly from the rich paleosol localities of the Willwood Formation, and to the more common Neogene small mammals from abandoned-channel fills of the Siwalik record.

Key word: Palaeontology, vertebrate, Wyoming, Siwalik Molasse, Himalaya.

B/5. Badgley, C. & Behrensmeyer, A.K., 1980. Paleoecology, middle Siwalik sediments and faunas of Northern Pakistan. Paleogeography, Paleoclimatology, Paleoecology 30, 133-155.

The Siwalik deposits of northern Pakistan are distinctive for their excellent sedimentary record and Neogene mammal faunas that include a family of homonoids, the Ramapithecidae. A 160-m interval was chosen from 3500 m of local section for study of lateral lithofacies variation, microstratigraphy and taphonomy of selected fossil localities. Field data consists of: (1) stratigraphic sections that span 30 km of lateral exposure, (2) microstratigraphic sections of fossil localities in presentative depositional environments, and (3) taphonomic sampling of a subset of these localities. These data form the basis for landscape, habitat, and community reconstruction. The physiography of the paleoenvironment was determined by braided and meandering river channels. Lateral distribution of channel and floodplain deposits suggests that a mosaic of vegetation types covered the entire drainage basin, including constantly renewed plant succession along channel margins and more stable associations on floodplains. Vertebrate fossils occur in three major depositional settings: channel-lags, channel-margin swales, and floodplain land surfaces. Most collected fossils come from channel-lag conglomerates. The predominant taphonomic influence on the overall fossil assemblage from this interval has been fluvial transport and sorting resulting in a sampling bias toward medium-sized taxa. However, rank abundances from the fossil samples may be valid for these taxa. Fluvial processes probably harvested bones from all habitats present, but no habitat associations of major taxa are detectable. A relatively high species richness of small to medium ungulate herbivores suggests the presence of diverse vegetation types that probably included forest, woodland, and grassland. The ramapithecids were uncommon, medium-sized members of this community.
Key word: Paleoecology, sediments, fauna, Siwaliks.

B/6. Badgley, C. & Behrensmeyer, A.K., 1995. Two long geological records of continental ecosystems. Palaeogeography, Palaeoclimatology, Palaeoecology 115, 1-11.

The early Paleogene continental sequence of northwestern Wyoming and south central Montana (USA) and the Neogene Siwalik sequence of northern Pakistan are exceptionally long, fossiliferous, and well studied in terms of geology, paleontology, mammalian evolution, paleoecology, and paleoclimatology. Each record spans about 15 myr of alluvial deposition in a foreland basin. The fluvial systems differed in size, drainage of floodplains, and change in alluvial architecture through time. Both sequences preserved abundant paleosols, which are a source of paleoclimatic signals in stable isotopes from soil carbonates. Fossil collections from both records are dominated by vertebrate remains and especially by mammals; the Paleogene sequence also preserved abundant floral remains. Patterns of vertebrate preservation differed markedly between the two sequences, placing inherent limitations on paleoecological reconstruction and on the scope of evolutionary studies of mammalian linkages.
In this introductory paper, we summarize the major similarities and differences in geologic setting, chronology and time resolution, and mammalian faunal composition of these two long sequences. Finally, we present a brief overview of the organization of papers in this special issue.
Key Words: Continental ecosystems, Montana, siwaliks, Himalaya.

B/7. Badgley, C. & Tauxe, L., 1990. Paleomagnetic stratigraphy and time in sediments: Studies in alluvial Siwalik rocks of Pakistan. Journal of Geology. 98(4), 457-477.

Sediments may acquire magnetic remanence upon deposition and shortly after deposition. Hence, the paleomagnetic record of sedimentary rocks may provide a chronostratigraphic framework for rates and patterns of depositional and post-depositional processes over time scales intermediate between those of modern observation and those of the dated geologic record. Two applications of high-resolution magneto- stratigraphy in Miocene, alluvial rocks of Pakistan illustrate this point. (1) Transition stratigraphy-the dense sampling of a magnetic reversal-of correlated sections in the Dhok Pathan Formation revealed high variability in sediment accumulation rates (over several thousand to 10,000 yr), time-transgressive strata representing a paleosol and a floodplain marsh, and a pervasive post-depositional record mainly from pedogenesis. (2) Lateral tracing of paleomagnetic reversal boundaries in the Chinji Formation revealed a secular change in sediment accumulation rate and evidence for increased accumulation rate associated with extensive sandstones and the time-transgressive nature of certain sandstone units. Both studies demonstrate the significant lateral component to accumulation of lithological units, indicating that individual strata

may embody considerably greater time spans in their lateral extent than in any vertical transect. Hence, stratigraphic completeness should be evaluated in the lateral as well as the vertical dimension.
Key words: Palaeomagnetism, stratigraphy, siwaliks, Potwar.

B/8. Badshah, M.S., 1975. Geology of lower Gandao with main emphasis on silica sand. FATA DC, Record, 1, 32p.

The geology and various sedimentary rocks of the Gandao area in Mohmand Agency are described. The main emphasis has been laid on promising silica sand deposits.
Key words: Mineral deposits, silica sand, Mohmand Agency.

B/9. Badshah, M.S., 1979a. Geology of Bajaur and northern part of Mohmand. Geological Bulletin, University of Peshawar 11, 163-179.

Geological investigation in about 1000 sq. km of area in Bajaur and Ambhar Utmankhel reveal that the area falls in the western tip of Kohistan with the Main Mantle thrust (MMT) running roughly east-west, following the course of Bajaur Khwar. The area is overlain by the tectonic slices, which moved from NW to SE.
The area exposes igneous and metamorphic rocks. Nawagai limestone of (?) Silurian-Devonian age lies to the south-west. The pelitic sediments include amphibolites, epidote chlorite schists, phyllitic schists, piemontite schists, talc carbonate schists, graphite schists and slates. Extensive distribution of garnet schists is observed in the Shamozai area, lying to the south-east.
The igneous masses comprise granites and diorites; ultrabasic and volcanic rocks. The granitic and dioritic rocks are not considered to be comagmatic. The intrusion of diorites started sometimes in the Late Cretaceous, while the whole magmatism ended with the last phase of granitic stocks and dykes in Middle Eocene. The late Upper Cretaceous to Eocene-Oligocene ultrabasic phases of serpentinite, peridotite and pyroxenite / hornblendite lie “interbedded” with the metasediments. Eocene to Oligocene rocks of andesitic, rhyolitic and tuffaceous composition are also present.
Poor mineralization of copper, promising mineralization of manganese, soapstone and chromite along with large deposits of marbles are the noteworthy prospects in the area.
Key words: Petrography, MMT, Bajaur, Mohmand, Kohistan Arc.

B/10. Badshah, M.S., 1979b. Soapstone deposits of Daradar Valley, Kurram Agency. Federally Administered Tribal Areas Development Corporation, Information Release 11, 17p.

For further information consult the following .
Key words: Economic geology, soapstone, Kurram Agency.

B/11. Badshah, M.S., 1983a. Soapstone deposits of Daradar valley, Kurram Agency. Second National Seminar on Development of Mineral Resources, Peshawar, 1, 13p.

Soapstone deposits were mapped and studied along with geology of the area. Kurram Agency here is a part of the Precambrian of the Indian plate. Detailed exploration (involving pitting, trenching, aditing, sampling and chemical analyses) was carried out for grade; the reserves are estimated at 1.5 million tons.
Key words: Economic geology, soapstone, Kurram Agency

B/12. Badshah, M.S., 1983b. Geology and breccia pipe primary and secondary copper mineralization in Waziristan. Second National Seminar on Development of Mineral Resources, Peshawar, 1, 16p.

Key words: Economic geology, copper, ophiolite, Waziristan.

B/13. Badshah, M.S., 1985. Development potential of Waziristan copper. Records of the FATA Development Corporation, Peshawar, Pakistan 3, 1-35.

Key words: Economic geology, copper, Waziristan.

B/14. Badshah, M.S., Gnos, E., Jan, M.Q. & Afridi, M.I., 2000. Stratigraphic and tectonic evolution of the northwestern Indian plate and Kabul Block. 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, 467-475.

A 1:500 000 scale geological map covering large parts of the northwest Pakistan-southeast Afghanistan borders region between 31-34ºN and 69-71ºE has been completed. The map covers the tribal area of Kurram and of North and Waziristan in Pakistan, where the map is base on unpublished data of the Federally Administered Tribal Areas Development Corporation. The map area comprises Precambrian crystalline rocks of the Indian and Kabul blocks, Permian to Quaternary sedimentary rocks, and the Late Cretaceous-Palaeocene Kabul-Altimur and Zhob-Waziristan-Khost ophiolite complexes. The Himalayan collision resulted in extrusion of the Kabul Block along the Chaman Fault system and formation of the Katawaz Basin which was filled with clastic deposits of the 'Early-Indus' fan. Ongoing contractional tectonics led to southward thrusting of the Spinghar Indian crystalline basement over the Miocene Murree Formation. New names and type sections are proposed for six units in the Spinghar and South Waziristan. These units are the Daradar Dolomite, Spinghar Quartzite, Sikaram Series, Makai Limestone, Wana Schist and Kaniguram Slates.
Key words: Stratigraphy, tectonic evolution, Indian plate, Kabul block, Waziristan.

B/15. Bai Zhongyuan & Zhang Jinhua, 1980. Some features of radiation and heat balance of the Batura Glacier. In: Shi Yafeng (Ed.), Professional Papers on the Batura Glacier in the Karakoram Mountains. Science Press, Beijing.

Further information not available.
Key words: Glaciology, Batura Glacier, Karakoram.

B/16. Baig, M.A. & Faruqi, F.A., 1984. Industrial minerals for whiteware industry. Abstract Volume, First Pakistan Geological Congress, Lahore, 32p.

There are several occurrence of raw material, e.g., china clay, feldspar, that can be used in the manufacture of ceramics. This account gives some details of the raw material for ceramic industry.
Key words: Economic geology, industrial minerals.

B/17. Baig, M.A.A., 1967. Important economic minerals of Pakistan. Geological Bulletin, Sindh University, Jamshoro 3 (4), 18–27.

This is one of several such compilations by different authors. It gives a summary of the more important economic minerals discovered by 1967 in Pakistan.
Key words: Economic geology, mineral deposits.

B/18. Baig, M.A.A., 1970. Geological bibliography of Salt Range, Sulaiman Range, Potwar and Hazara areas. Sindh University, Geology Department, Jamshoro, Pakistan, 40p.

This document lists many of the publications on the three area up to 1969. Those of Hazara and Siwaliks of the salt Range are included in the present work
Key words: Salt Range, Sulaiman Range, Potwar, Hazara.

B/19. Baig, M.A.S., 1984. Some observations about change of fluvial pattern in Cis-Indus and Trans-Indus exposures of Dhok-Patan Formation. Abstract volume, First Pakistan Geological Congress, Lahore, 46-47.

The paleocurrent measurements in the Dhok Pathan Formation at different parts of the Cis-Indus and Trans-Indus Siwalik exposures indicate different directions of paleoflow. The stream systems responsible for the deposition of Dhok-Pathan Formation in the Cis-Indus part of Potwar were flowing towards east while those which caused deposition of similar sediments in the Trans-Indus Potwar as well as in Sub-Suleman Ranges flew due south.
The Paleomagnetism data collected at Chinji and Khisor Range indicate a difference of about 5 million years in the depositional age of Chinji Formation sediments at both these places. This observation confirms the difference in depositional systems for Siwalik exposures in Cis-Indus and Trans-Indus areas. It is evident from this data that the fluvial systems responsible for the deposition of Dhok Pathan Formation were flowing due east similar to the present day Ganges and Yamuna river systems. Late, due to some structural disturbance, this flow changed and the river started flowing due south, parallel to the present day Indus river system, thus indicating two different depositional basins.
Key words: Sedimentology, siwaliks, Potwar, Salt Range.

B/20. Baig, M.A.S. & Pervaiz, K., 1995. Remobilized uranium mineralization: A record episodal uplift of frontal fold-thrust belt, NW Himalaya. Abstracts, International Symposium on Himalayan Suture Zone of Pakistan. Pakistan Museum of Natural History, Islamabad, 18-19.

Salt Range-Potwar and Bannu basin were developed during the last phase of the Himalayan orogeny which is still active. The mechanism of uranium ore formation in Bannu Basin and Salt Range potwar suggests leaching of the Siwalik Molasse rock and its subsequent reprecipitation along the water table due to change in physio chemical conditions. An analysis of the uranium ore formation process indicates presence of ghost (depleted) ore bodies in the oxidized zone. These radioactive haloes represent paleo water tables which were developed due to episodal uplift. At least four such upheaval episodes have been registered in the Siwalik rocks of Bannu separated by periods of relative stability. This process seems to be still active.
Key words: Uranium mineralization, structural geology, Himalayan fold-thrust belt.

B/21. Baig, M.G., 1992-94. Geology and structure of Barian area, Hazara, Northwest Himalaya and sedimentology of Early Cretaceous Lumshiwal Formation and Early Eocene Chorgali Formation. M.Sc. Thesis, Punjab University, Lahore, 251p.

It is a study of the geology and structure of the Barian area (50 sq. km) along with sedimentological study of the Early Eocene Chorgali Formation and Early Cretaceous Lumshiwal Formation.
A large-scale geologic map of Barian area as (1: 10,000) is presented. The area comprises sedimentary rocks from Middle Jurassic to Early Miocene age, tectonically forming a part of the Lesser Himalayan sequence in the Galiat Area Hazara. The Palaeogene and older sequence is mainly limestone and shales of shallow massive shelf facies. The overlying Neogene rocks are gypsiferous marls, limestone and shale of supratidal to sabkha facies in the lower sandstone, shale molasse of Murree Formation in the upper part. Structurally the area comprises NE-SW trending cylindrical to double plunging folds constituting anticlinoria and synclinoria. The folded sequence is disturbed by numerous reverse faults. However small number of normal faults also exist. Faults are either dip slip or oblique slip and except for the MBT involves a maximum displacement of a few hundred meters. MBT is the major tectonic discontinuity of regional significance. At Darya Gali the thrust is high angle feature dipping to the northwest with opposing dips in the rocks on the two sides. A fault-related escarpment accompanies the surface expression of M BT and much degradation accompanied by land sliding.
Chorgali Formation has been divided into 3 facies and 20 microfacies. Basic microrfacies, which repeat, are wackestone microfacies, shale microfacies, mudstone microfacies, and dolomite mudstone facies, calcareous shale microfacies and arenaceous dolomite microfacies.
XRD analysis shows that illitc is the predominant clay mineral of shale. Other essential minerals are chlorite, kaolinite, quartz and smectite. Chorgali Formation represents open shelf subtidal to lagoonal environment. In lower part deposition appears to be cyclic with periods of clastic influx alternating with little clastic influx. Fossils present

are mostly broken and probably transported from high energy environment. Shale horizons were deposited in quite subtidal zone but not below 70m due to paucity of pelagic fauna. In upper part of the section dolomites are interbedded with shale. They also show cyclic deposition. Dolomites were probably initially deposited as mudstones in deeper part of shelf. They lack of pelagic fauna and evaporites. Dolomitization appears secondary. Non-ferroan microcrystalline calcite appears biological in origin.

Key words: Structure, sedimentology, Hazara, Himalaya.

B/22. Baig, M.I., 1997. Utilizing geothermal waters. Abstracts, National Symposium on Economic Geology of Pakistan, Islamabad, 2p.

This review paper briefly describes geothermal manifestations in form of warm and hot water springs both in northern mountains and in southern regions of Pakistan. The basic data on the thermal springs in Pakistan mainly comes from second half of the last century. It was compiled later almost independently b Waring (1965) and Bakr 1965). Later isolated work has appeared since independence. Areas of potential geothermal resource identified are northern mountain regions of the country, northern Baluchistan and Dadu in Sind. There are large number of manifestations reported: to mention a few, a number of springs in Garam Chashma in Chitral. along Astore river. Tatta Pani in Azad Jammu & Kashmir, Kohlu in Baluchistan and a number of springs in Dadu including super heated stream Issuing at Lakhra in Sind. Reservoir temperature calculated by workers at Murtza Abad in Hunza range 114-296ºC, at Tatta Pani near Chilas. 130-239ºC. In south, the super heated stream at Lakhra and the other more than 15 springs in Dadu be studied to determine potential underground source of energy in that load center of' Pakistan.

This potential geothermal energy source is non-depleting and is non polluting. Its utilization can lessen the risk of depleting perishable source (oil. gas and coal) and to an extent we can avoid the danger of polluting our environment. While super heated steam is being utilized world over in production of electric power, the low enthalpy waters have been used for centuries for recreation, baths and as health spas for their curative effects (hydrotherapy), injuries, joint pains and cutaneous diseases. These waters are being used e1sewhere for warming houses, heating green houses for larger productively in agriculture, poultry farming and fish breading and even air conditioning. Natural reserves are generators of economic growth. A lot needs to be done to explore and harness this source of energy in the country. Plans need to he developed to collect reliable data to utilize this energy resource as a contribution to the development and in improving quality of life of those areas.

Key words: Energy, Himalaya, Hindukush.

B/23. Baig, M.S., 1980. Geology of Jurah-Doarbian area, Neelum valley, State of Azad Jammu and Kashmir. M.Sc. Thesis, Punjab University, Lahore.

Key words: Geology, Neelum valley, Azad Kashmir.

B/24. Baig, M.S., 1989. New occurrence of blueschist from Shin-Kamer and Marin areas of Allai-Kohistan, Northwest Himalaya, Pakistan. Kashmir Journal of Geology 6 & 7, 103-108.

In Allai-Kohistan, the Indus Suture Zone is represented by the Allai melanges. The Allai melanges constitute the Baleja ophiolitic melange, Shin-Kamer blueschist melange, and Matai greenschist melange. The Bela ophiolitic melange, Shin-Kamer blueschist melange, and Matai greenschist melange represents the Neotethys oceanic crust, Neothys trench, and island arc affinities respectively.

New in situ blueschist occurrence have been found from the Shin-Kamer blueschist melange, near the Shin-Kamer and Marin areas of Allai-Kohistan. The Shin-Kamer blueschist is composed of glaucophane, epidote, chlorite, quartz, white mica, with small amount of calcite and plagioclase. The mineral assemblage, suggest blueschist facies P-T conditions of about 380-450 ^{0}C and pressure of about 7-8 kbar.

In the blueschist melange, the high-pressure blueschist facie metamorphism is overprinted by the low-pressure greenschist facies metamorphism. During the greenschist facies metamorphism, the actinolite (rims around glaucophane), chlorite, and white mica overprinted the blueschist assemblages. Similar change from high-pressure to low-pressure metamorphic conditions also occurred in the Indus Suture Zone of Ladakh and Shangla areas of the Northwest Himalaya. The transition from blueschist to greenschist facies metamorphism in the Indus Suture Zone can be relate to tectonic decompression along the Neotethys trench zone or due to a separate tectonic event related to melange emplacement.

Key words: Blueshists, melange, Allai-Kohistan, Indus Suture, Himalaya.

B/25. Baig, M.S., 1990. Structure and geochronology of Pre-Himalayan and Himalayan orogenic events in the Northwest Himalaya, Pakistan, with special reference to the Besham area. Ph.D. Thesis. Oregon State University, Corvallis, U.S.A. 300p.

Details of structural studies, geochronology (including large number of ^{40}Ar-^{39}Ar dates) and tectonics of the Besham and neighbouring areas are presented in this thesis. The information has been published in a series of papers, including the following one and others listed here.

Key words: Geochronology, tectonics, Swat, Hazara, Himalaya.

B/26. Baig, M.S., 1991. Geochronology of pre-Himalayan and Himalayan Tectonic events, Northwest Himalaya, Pakistan. Kashmir Journal of Geology 8 & 9, 197.

In the northwest Himalaya of Pakistan, metamorphism, deformation and plutonism are the result of collision between the Indo-Pakistan and Asian plates. The timing of pre-Himalayan orogenic events remain uncertain, due to strong, pervasive Himalayan overprinting.

This study presents new field, structural and metamorphic date together with ^{40}Ar/^{39}Ar isotopic age data on hornblende, muscovite, biotite and K-feldspar for Besham, Mansehra, Swat and Hazara areas of northern Pakistan. These data provide the first detailed record of Early Proterozoic to Late Paleozoic events in the northwest Himalaya and combine with prior U/Pb, Rb/Sr, and fission track data record an orogenic history from the Early Proterozoic to Cenozoic. The Early Proterozoic orogenic events in the Besham basement complex occurred at (A) 2,031 ± 6 to 1,997, ± 8 Ma, (B) 1,950 ± 3 Ma, and (C) 1,887 ± 5 to 1,865 ± 3 Ma. These were followed by sodic granite intrusion at 1,517 ± 3 Ma.

Subsequently, flysch of the Kurmang, Gandaf, Manki, Hazara, Dakhner, Dogra and Simla formations was deposited unconformably on the basement rocks of the Indo-Pakistan plate. These units are unconformably overlain by the molasse of the Tanawal and Manglaur formations. The area underwent metamorphism and deformation at 664 to 625 Ma, and volcanism and plutonism at 850 to 600 Ma (Hazaran orogeny or Pan-African orogeny). Later metamorphism and deformation at > 466 ± Ma and plutonism at 550 to 450 Ma record an Early Paleozoic orogeny. This tectonic event is marked by the development of Cambro-Ordovician unconformity in the Himalaya. Alkaline magmatism (315 ± 15 to 297 ± 4 Ma), sodic granites (> 272 ± 1 Ma), mafic Panjal volcanism (284 ±4 to 262 ± 1 Ma) and metamorphism (333 ± 1 Ma), occurred during early rifting of the Cimmerian microcontinent from Gondwana. The early Himalayan metamorphism and deformation in northern Pakistan occurred between 70 to 64 Ma. The Late Cretaceous to Early Paleocene deformation and metamorphism is related to melange emplacement along the northwestern margin of the Indo-Pakistan plate. This tectonic event is marked by the widespread development of Paleocene unconformity in the Himalaya. ^{40}Ar/^{39}Ar dates of 51 to 36 Ma, 36 to 30 Ma, 30 to 24 Ma from shear zones, date successive shearing and thrusting and 24 to 5 Ma fission rack dates show unroofing and tectonic erosion, during the development of the Indus syntaxis. The presence of active faults, seismicity and newly recognized 1600 m of uplifted Indus River terrace, show that the Indus syntaxis is an active feature, which has an uplift rat of about 1 mm/year since 5.2 Ma.

Key words: Geochronology, tectonics, Swat, Hazara, Himalaya.

B/27. Baig, M.S., 1992. New occurrences of blueschist from Indus Suture Zone of Allai-Kohistan, Northwest Himalaya, Pakistan. Abstracts, First South Asia Geological Congress, Islamabad, p.6.

In northern Pakistan, the Indus suture zone marks the collision boundary between the Indo-Pakistan plate and the Kohistan island arc. The Late Cretaceous blueschists have been reported from the Topsin and Shangla areas of the Indus suture zone.

This paper reports new blueschists occurrences from the ShinKamer and Marin area of the Indus suture zone of Allai-Kohistan. The blueschist is composed of glaucophane, epidote, chlorite, quartz, white mica a minor plagioclase and calcite. The mineral assemblage suggests blueschist facies P-T conditions of about 7-8 kbars and 380-459 C. The new micropobe data on the blue amphibole show the rims of calcic amphibole (actinolite) around the cores of sodic amphibole (glaucophane). The presence of actinolite rims around the cores of glaucophane shows that the high-pressure blueschist facie metamorphism is overprinted by the low-pressure greenschist facies metamorphism. The change from the blueschist to greenschist facies metamorphism can be related to tectonic decompression or melange emplacement along the Indus suture zone of Allai-Kohistan.

Key words: Metamorphism, blueschist, Indus suture zone, Allai-Kohistan.

B/28. Baig, M.S., 2000. Precambrian polyphase pre-Himalayan deformation and metamorphism in the Indian plate, Indus syntaxis, North-West Himalaya Pakistan: Ar^{40}/Ar^{39} constraints. Abstracts, Third South Asia Geological Congress, Lahore, 53-54.

South of Indus suture zone in northern Pakistan near the village of Besham, the Precambrian Besham Block rocks of the Indian plate in the core of the Indus syntaxis preserve polyphase pre-Himalayan deformation and metamorphism through the Tertiary Himalayan metamorphism. The Indus syntaxis is the basement-cored antiformal hinterland syntaxis similar to the Nanga-Parbat syntaxis. The Besham Block is separated from lower greenschist to upper amphibolite facies Precambrian to Mesozoic metasedimentary and metaigneous rocks of the Mansehra Block to the East and Swat Block to the West by high-angle oblique slip Thakot and Puran Faults respectively. The Besham block consists of Late Archaean to Middle Proterozoic metasediments, amphibolites, sodic granite gneisses and tourmaline-bearing graphic sodic granites of the Besham Basement Complex (BBC) and Late Proterozoic lower greenschist facies cover metasediments of the Karora Group (KG). The BBC is unconformably overlain by the KG. The BBC and KG rocks are intruded by Palaeozoic peralumineous sodic granites. The polyphase pre-Himalayan deformation, metamorphism and plutonism in BBC occurred before the deposition of the KG. The field evidence for pre-Himalayan metamorphism and deformation includes the truncation of gneissic fabric of the BBC at the base of the KG, the presence of BBC metasedimentary and metaigneous gneissic clasts in the phyllitic fabric of the basal metaconglomerate of the KG and the major change in metamorphic grade from amphibolite facies to lower greenschist facies across the KG unconformity. The field, fabric, petrographic and AR^{40}/Ar^{39} studies show three phases of pre-Karora group deformation (Dl, D2 and D3), metamorphism (M_{B1}, M_{B2} and M_{B3}), fabric development (S_{B1}, S_{B2} and S_{B3}) and folding (F_{B1}, F_{B2} and F_{B3}). Early S_{B1} fabric related to M_{B1} upper amphibolite facies metamorphism is preserved as intrafolial fabric in sheath folds. S_{B1} fabric yields minimum age of 2031 - 1998 Ma (Hb Ar/Ar dates) for M_{Bl} metamorphism. S_{B2} upper amphibolite facies penetrative gneissic to schistose fabric is axial planner to NS-striking, small scale tight to isoclinal folds. S_{B2} fabric yields minimum age of 1950 Ma (Hb Ar/Ar dates) for M_{B2} metamorphism. The epidote amphibolite fakes S_{B3} spaced fabric is axial planner to N-S-striking tight to isoclinal folds, those deform S_{B2} fabric. S_{B3} fabric yields age of 1887-1865 Ma (Hb Ar/Ar dates) for M_{B3} metamorphism.

The Early Proterozoic polyphase deformation and metamorphism in BBC is postdated by 1500 Ma tourmaline-bearing graphic sodic granites. All of these deformational, metamorphic and plutonic events predated the unconformable deposition of the Late Proterozoic KG. The lower greenschist facies (up to biotite grade) D_{iv} deformation forms S_{K1} and S_{B4} fabrics in the KG and BBC respectively. S_{K1} occurs as relict fabric in intrafolial folds and microlithons and S_{B4} occurs as spaced fabric and actinolite rims around hornblendes. S_{K1} and S_{B4} fabrics predate the intrusions of 500 Ma and 272 Ma sodic granites. The Tertiary Himalayan deformation in the Besham block occurred at 66-64 Ma, 50-40 Ma and 36-26 Ma.

Key words: Metamorphism, deformation, Precambrian, Swat, Hazara, Himalaya.

B/29. Baig, M.S. & Lawrence, R.D., 1987. Precambrian to Early Paleozoic orogenesis in the Himalaya. Kashmir Journal of Geology 5, 1-22.

Precambrian to Paleozoic Himalayan rocks are metamorphosed from lower greenschsit facies in the south to amphibolite, and granulite facies in the north. Two or possibly three, metamorphic episodes are preserved in the Precambrian shelf and platform sediments of the northern margin of Gondwana in the Indo-Pakistan plate. At least one metamorphic episode appears to be Precambrian to early Cambrian in age and significantly predates Himalayan metamorphism.

The late Precambrian to early Cambrian tectonism is evidenced by the presence of an angular unconformity, between the late Precambrian and early Cambrian rocks in Hazara, Kotli Azad Kashmir, and the Nepal Himalaya.

The unconformity is marked, by a basal conglomerate, which is composed of clasts of metamorphic rocks that are derived from the underlying Precambrian basement rocks of the Indo-Pakistan plate. The late Precambrian to early Cambrian tectonism is here designated the Hazaran orogeny, because it is well evidenced in the Hazara Himalaya of Pakistan. In the Hazara area, the early Cambrian Tanakki basal conglomerate of the Abbottabad Group above the angular unconformity is unmetamorphosed, whereas the underlying Precambrian Hazara Formation is metamorphose to lower greenschist facies. The Tanakki conglomerate has cleaved metamorphic clast derived from the underlying Hazara Formation but the matrix of the unit is uncleaved. The Hazara Formation is deformed and has growth of new mica along, the axial plane cleavage, which is truncated by the Tanakki conglomerate. This confirms that the Precambrian metamorphism and tectonic occurred before the deposition of early Cambrian Tanakki conglomerate.

During the Hazaran orogeny, 600-900 Ma plutonic and volcanic rocks intruded into and extruded onto the Precambrian basement rocks of the Indo-Pakistan plate and predate the late Precambrian to early Cambrian unconformity. Somewhat after the Hazaran orogeny, 500-600 Ma peraluminous granites, with initial 87Sr/86Sr ratios of 0.7102-0.7190, intruded the Precambrian as well as earliest Paleozoic rocks. The high initial 87Sr/86Sr ratios suggest that these plutons were derived by antexis from the basement rocks of the Indo-Pakistan plate. The 500-600 Ma plutons of the Indo-Pakistan plate may be late Hazaran or post-Hazaran orogenic phase of the Hazaran orogeny. The Hazaran orogeny in the Himalaya occurred before the Permo-Triassic breakup of Gondwana and may correlate with the Pan-African, Batkalian, Cadomian, Katangan, and Assyntic orogenies of Africa and Europe.

Key words: Precambrian, Paleozoic, orogenies, Himalaya.

B/30. Baig, M.S., Lawrence, R.D. & Snee, L.W., 1988. Evidence for late Precambrian to early Cambrian orogeny in the northwest Himalaya, Pakistan. Geological Magazine, 125, 83-86.

An angular unconformity below Cambrian rocks is present in the northwest Himalaya in the Hazara district, Pakistan. Low-grade metamorphism and folding with axial planar cleavage present in Precambrian rocks below the unconformity, but not in those above it, confirm orogenic deformation at this time. This is the first clear evidence for such a deformation episode and it may be referred to locally as the Hazaran orogeny. Anatectic peraluminous granites of the Himalaya are of only slightly younger age and may be related to this orogenic episode.

Key words: Orogeny, Precambrian, Cambrian, Hazara, Himalaya.

B/31. Baig, M.S., Siddiqui, M.I., Zaman, Q., Khan, M.A. & Hussain, A., 1991. Structural events in the sub-Himalaya of Nikial Khuiratta area, district Kotli, Azad Kashmir. Kashmir Journal of Geology 8&9, 197-198.

This paper deals with structural events in sedimentary rocks of this sub-Himalayan area of the Himalayan fold-and-thrust belt

Key words: Structure, Kashmir, Sub-Himalaya .

B/32. Baig, M.S. & Snee, L.W., 1989. Pre-Himalayan dynamothermal and plutonic activity preserved in the Himalayan collision zone, NW Pakistan. Geological Society of America, Abstract Program, 21(6), A264.

Ar-Ar and K-Ar dates were determined for many rocks from Besham and adjacent areas of the western Himalaya of Pakistan. Many of the dates are pre-Himalayan. The history of the igneous activity and metamorphism and deformation extends into Early Proterozoic. For additional details, see B/34 and B/35.

Key words: Precambrian, tectonics, Indian Plate, Himalaya.

B/33. Baig, M.S. & Snee, L.W., 1991. A Discovery of Late Archean to Early Proterozoic Komatiite from the Northwestern Margin of the Indian Plate, Besham area, Northwest Himalaya Pakistan. Kashmir Journal of Geology 8 & 9, 19-24.

In northern Pakistan, near the village of Besham, the Besham block of Indian plate is exposed in the core of the Indus syntaxis. This basement block is separated from low-to high-grade Precambrian to Mesozoic metamorphic rocks to the east and west by high-angle ramp faults and from low-grade to unmetamorphosed sedimentary rocks to the south by thrust faults. The Besham block consists of epidote-amphibolite to upper amphibolite facies Late Archean to Middle Proterozoic cover sediments of the Karora group.

Precambrian komatiites are known from the basement rocks of the southern Indian plate. No komatiites have previously been reported from the Indian basement Early Proterozoic komatiites from the Besham basement complex of the Besham area, northwest Himalaya, Pakistan. It is the first report of komatiites from the northwest basement rocks of the Indian plate. An amphibolite from the Besham basement complex is herein characterized as a alumina depleted basaltic komatiites on the basis of high SiO_2 (55%), high MgO (15.94 %), <0.5% K_2O (0.24%), <0.9% TiO_2 (0.25 %), low Fe/Mg ratio (0.89) at given Al_2O_3 (3.77%) and >CaO/Al_2O_3 ratio (3.45).

Precambrian komatiites are commonly associated with the rift-related extensional environments. The presence of Late Archean to Early Proterozoic mafic komatiites in the Besham basement occurred during the rifting of Indian plate.

Key words: Komatiite, Precambrian, Late Archean, Besham, Indian Plate.

B/34. Baig, M.S. & Snee, L.W., 1997. Precambrian tectonics of the Indian plate, Indus syntaxis region, Northwest Himalaya, Pakistan: $Ar^{40}/^{39}Ar$. Abstract volume, 12th Himalaya-Karakorum-Tibet International Workshop, Rome, Italy, 117-118.

In the northwest Himalaya of Pakistan, metamorphism and deformation are the result of collision between the Indian and Asian plates. The presence, timing and significance of pre-Himalayan orogenic events have previously been uncertain, due to the pervasive high-grade Himalayan tectonic overprint which apparently obscures any prior record (Baig and Lawrence, 1987; Baig and others, 1988). The study of the Indus syntaxis of northern Pakistan has discovered earlier pre-Himalayan events, which are dateable due to weaker Himalayan metamorphic overprinting (Baig and Snee, 1989; Baig and others, 1989, 1992; Baig; Treloar and Rex, 1990). New field, structural, metamorphic and stratigraphic data together with 40Ar/39Ar isotopic age data on hornblende and muscovite are presented for the basement and cover rocks of the Indian plate near Besham and Hazara areas. These data reveal a lengthy pre-Himalayan orogenic history initiated at least in the Early Proterozoic and /or in the Late Archean.

The newly recognized Besham basement complex of the Indian plate, in the core of the Indus syntaxis, consists of multiply-intruded epidote-amphibolite- to upper amphibolite-facies metasediments of the Besham group. 40Ar/39Ar dating of Indian basement rocks (Baig, 1990) confirms the following Precambrian events:

Archean to Early Proterozoic Besham group shallow water pre-to syn-rift sedimentation and associated mafic and komatiitic volcanism, mafic dike intrusions, Darwaza Sar potassic and Lahor sodic granite intrusion, upper amphibolite-facies metamorphism at >2,000 Ma (40Ar/39Ar hornblende dates), upper amphibolite-facies metamorphism at >1,950±3 Ma (40Ar/39Ar hornblende dates), hornblende-biotite granodiorite and granite intrusions, mafic dike intrusions and epidote-amphibolite-facies metamorphism at 1,887±3 Ma (40Ar/39Ar hornblende dates). Proterozoic by tourmaline-bearing sodic graphic granites at 1,500 Ma (40Ar/39Ar hornblende dates). The 2,000-1,500 Ma orogenic events define the Early to Middle Proterozoic Besham orogeny.

The Late Proterozoic syn- to post-rift Karora group was deposited subsequently with a breakup unconformity on the Archean to Middle Proterozoic Besham basement complex. It is composed of Amlo conglomerate Formation, Kurmang Formation and Kandoana Formation (Baig, 1990). The shallow water turbidite Kurmang Formation and its facies equivalent Manki, Dakhner, Hazara, Landikotal, Simla, Dogra, Phe and Salt Range formations show syn-rift sedimentation and associated local mafic Dogra and Khewra volcanisms. The Amlo conglomerate Formation marks the breakup unconformity at the base of this widespread unit in the northwest Himalaya. The Kurmang and Manki formations are conformably succeeded by post-rift shallow water carbonates of the Kandoana and Shahkot formations respectively.

The Eocambrian or Latest Proterozoic Hazaran orogeny initiated at 650±25Ma (40Ar/39Ar sericite dates). The Hazaran orogeny uplifted and eroded the Precambrian basement and cover rocks of the southern Indian shield and deposited the Eocambrian Hazaran clastic molasse of the Tanawal and Manglaur formations north Panjal thrust in a pre-Himalayan subsiding Hazaran foreland basin. The Hazaran orogeny predated the unconformable deposition of the Early Cambrian fossil-bearing sedimentary strata in the northwest Himalaya of Pakistan. The Eocambrian Hazaran or Pan-African orogeny caused the amalgmation of Gondwana as a supper continent.

Key words: Precambrian, tectonics, geochronology, Indian Plate, Himalaya.

B/35. Baig, M.S., Snee, L.W., Fortune, R.J.L. & Lawrence, R.D., 1989. Timing of Pre-Himalayan orogenic event in the Northwest Himalaya: $^{40}Ar/^{39}Ar$ Constraints. Kashmir Journal of Geology 6 & 7, 29-40.

In the Northwest Himalaya, pre-Himalayan metamorphism and deformation is present, which is postulated by early Paleozoic peraluminous granites. The early Paleozoic granites and the Precambrian basement rocks of the Indo-Pakistan plate were metamorphosed and deformed, during the pervasive high-grade Himalayan metamorphism and deformation, which caused uncertainty in the recognition of the timing of the pre-Himalayan metamorphism and deformation.
Field criteria such as intrusive age relationship of meta-igneous plutons, relative ages of deformation phases, overprinting of gneissic fabric by weak younger fabric, and an angular unconformity, can provide relative ages for the pre-Himalayan and Himalayan metamorphism and deformation. However, such data do not constrain the absolute timing of metamorphism and deformation, which must be constrain by isotopic dates. The new 40Ar/39Ar dating of the Precambrian basement rocks of the northwest Himalaya of Pakistan, confirms five pre-Himalaya metamorphic events. These metamorphic events occurred at >2,000 ± 6 Ma, >1,950 ± 3 Ma, 1,865 ± 3 Ma to 1,887 ± 5 Ma, 650 ± 2 Ma, and > 466 ± 2 Ma. The 600-900 Ma plutonic, volcanic, metamorphic, and deformational events are related to the Hazara orogeny. The 550-450 Ma peraluminous granites and > 466 ± 2 Ma metamorphism in the Himalaya, record a separate Cambro-Ordovician orogenic event. This orogenic event correlates with the Pan-Paleozoic orogenic events on the Indo-Pakistan plate occurred before the Permo-Triassic breakup of Gondwana.
Key words: Precambrian, tectonics, geochronology, Indian Plate, Himalaya.

B/36. Baig, S., 1995. Structural study of the Main Boundary Thrust in North West Himalaya, Pakistan. M.Sc. Thesis, Quaid-i-Azam University, Islamabad, 76p.

It describes structures associated with the Main Boundary Thrust.
Key words: Structure, MBT, Himalaya.

B/37. Baig, Z.M., 1996. Environmental geochemistry of water, rock and soil of Gadoon and surrounding area, District Swabi, N.W.F.P., Pakistan. M.Phil. Thesis, University of Peshawar, 165p.

Elements like carbon, hydrogen and oxygen are considered as an essence for living organisms, while the trace elements have both benevolent and harmful effects to living organism upto certain limits. Environmental geochemistry is one of the science that deals with the interaction of the pollutants in our daily life. These pollutants may be either contributed by anthropogenic or natural processes or both. A wide range of industrialization throughout the country is flourishing on one side but poor management in this sector is polluting the water and soil with the toxic effluents that are coming from these industries. In Gadoon and surrounding areas natural and anthropogenic pollution is effecting the quality of water by adding pollutants such as SO_4, NO_3 and trace metals like Cd, Cu, and Pb.
In the present study thirty-five samples of water (both surface and groundwater) and twenty-six sample of soil, from Gadoon and surrounding areas, were analyzed for different parameters. The most alarming issue of the study area is the higher concentration of sulfate and nitrate contents in the drinking water of Gandaf, and Biasak, where the concentration of SO_4 in the drinking water exceeds 1700 and 1525 mg/l respectively. The US-EPA & WHO recommended a permissible limit of 250 mg/l in drinking water. The source of this high concentration in the drinking water of the area is the contamination through the rocks of the Salkhala Formation. The rocks of the Salkhala Formation are enriched in sulfide minerals like pyrite. Sulfate as a pollutant is causing diarrhea, dehydration and gastrointestinal problems in the people of the area. The concentrations of NO_3 in the Gandaf and Miani wells also exceed 946 and 286 mg/l respectively. The US-EPA's permissible limit for nitrate is considered to be 10 mg/l. The higher concentration of nitrates in water is due to agricultural pollution (i.e. fertilizers and human feces. etc.). This enormous increase of nitrate in drinking water is due to the mixing of animal manure in the soil. Ultimately, this manure makes its way to water, due to the run-off from cultivated and fertilized field. In infants, nitrate contaminated water cause a disease called methemoglobinemia, a type of blood disorder in which red blood cells cannot carry oxygen.

Key words: Environmental geochemistry, Gadoon, Swabi.

B/38. Baig, Z.M. & Shah, M.T., 1997. Nitrate as an anthropogenic pollutant in the ground water of Gadoon area (N.W.F.P), Pakistan. Environmental Pollution 3rd National Symposium Abstract 106.

Key words: Groundwater, pollution, Gadoon, Swabi.

B/39. Baird-Smith, R., 1842. Notes on the recent earthquakes in the North-Western Frontier. Journal of the Asiatic Society of Bengal, N.S. 11, 242-255.

This is one of the early accounts of the earthquakes that occurred in the northwestern part of the subcontinental British India.
Key words: Earthquakes, NW Frontier, India.

B/40. Baird-Smith, R., 1843, Memoir on Indian Earthquakes, Pt. II, Journal of the Asiatic Society of Bengal, 12(2), New Series, 136, 1029-1056 .

This compilation , and the one following, also refer to earthquakes that occurred in the northwestern part of the subcontinental India.
Key words: Earthquakes, NW India.

B/41. Baird-Smith, R., 1844, Memoir on Indian Earthquakes, Pt. III, J, Journal of the Asiatic Society of Bengal, 156, 964-983.

This compilation , and the preceding one, refer to earthquakes that occurred in the northwestern part of the subcontinental India.
Key words: Earthquakes, India.

B/42. Bajwa, M.A., 1995. Shallow seismic reflection surveying for mapping the weathered layer velocity and lithology correlation in Attock District. M.Sc. Thesis, Quaid-i-Azam University, Islamabad, 35p.

Shallow Seismic Refraction Survey was carried out to map the low velocity weathered zone in Attock District for the completion of M.Sc. dissertation. For this purpose five parallel profiles were laid. Overall 52 Seismic spread were shot using reverse shooting technique. After plotting the observed refraction travel times, in the travel time versus distance graph, velocities V0, V1 and depth Ho were calculated.
The values thus obtained have been used to prepare isovelocity (Vo) map, isovelocity, (V1) map and isopach (Ho) map. Hawkin's method was also used for comparative study. Integrating the available geological information along with interpreted velocity depth picture, a relationship between velocity and lithology has been established. The low velocity of weathered layer ranging from 400 m/sec to 1100 m/sec, which shows unconsolidated material of alluvial deposits comprising of sand and clay. The high velocity of sub-weathered layer ranging from 1400m/sec to 3200 m/sec indicates the combination of sandstone, shale, clay and wet sand. The thickness of weathered layer varies from 2m to 8m in the project area.
Key words: Seismic reflection, Attock.

B/43. Bajwa, M.S., 1970. Geology and petrology of Swat Hornblendic Complex in the Chargah–Khawza Khela Area, Swat. M.Sc. Thesis, Punjab University, Lahore.

The geology and petrography of this area of the Kohistan magmatic arc is described. The principal rocks include amphibolites, metagabbros and their associates.
Key words: Petrology, amphibolites, Swat.

B/44. Bajwa, M.S., 1984. Petrology of Siwalik rocks of Chakri-Chauntra area, Attock and Rawalpindi Districts, Punjab, Pakistan. Kashmir Journal of Geology 2, 93-102.

A sequence nearly 3000 meters thick of the Siwalik Group of Late Cenozoic age is exposed in the Chauntra quadrangle, in Attock and Rawalpindi Districts. For the purpose of petrological studies, the sequence has been differentiated in to Lower, Middle and Upper Siwaliks. The sandstones and clays of these sub groups have been studied lithologically, petrographically and chemically. The petrographically evidences suggest that sediments of the Siwalik Group were derived from igneous, metamorphic and sedimentary rocks of the adjacent Himalayan region and were deposited in a shallow fast sinking basin, after their short and rapid transportations.
Key words: Petrology, siwaliks, Attock, Rawalpindi.

B/45. Bajwa, M.S., 1997. Geochemical study of the detrital almandites of Murree and Siwalik Formations from Potwar, Pakistan. Abstracts, 3rd GEOSAS Workshop on Siwaliks of South Asia, Islamabad. Geological Survey of Pakistan, Records 109, p.139.

The detrital almandites (garnets) of Murree and Siwalik formations of Miocene to Pleistocene ages, from Rawalpindi and Jhelum areas, eastern Potwar, Pakistan, were chemically analysed with the help of EPMA (Electron Probe Micro Analyser), at Kyoto, University, Japan. The data of more than three hundred almandites were plotted on Mg-Fe-Mn and Mg-(Fe+Mn)-Ca triangles. The distribution of the data points, based on Mg, Fe, Mn and Ca molecular percentage ratios in both the triangles showed a marked difference between Murree and the Siwalik strata. Some differences in the chemical trends of the garnets from the Lower, Middle and Upper Siwalik formations can also be seen in Mg-Fe-Mn triangles, but no such difference could be noted in the second type. It is evident that most of the garnets of Murree Formation have been concentrated in the high Fe, high Mn zones as compared to that of Middle and Upper Siwaliks, which have taken positions in the high Fe and high Mg areas. Whereas, the data of Lower Siwaliks are distributed almost equally in the zones of high Fe, low Mg and low Mn, but the trend towards Mn is a little higher. However, some evidences suggest that the almandite garnet s of Murree Formation have been derived from low grade metamorphic rocks, those of Lower Siwaliks from medium and high grade, and Middle and Upper Siwaliks from high grade rocks from a source area situated in northern Pakistan.
Key words: Geochemistry, Murree Formation, siwaliks, Potwar.

B/46. Bajwa, M.S. & Akhtar, M., 1988. Preliminary bibliography of Siwalik rocks of Pakistan. Geological Survey of Pakistan, Information Release 343.

This bibliography lists available references on the Siwaliks up to 1987.
Key words: Bibliography, siwaliks.

B/47. Bajwa, M.S., Shams, F.A. & Shiki, T., 1987. Geochemistry of garnet grains from Murree and Siwalik Formation, Rawalpindi and Jhelum Districts, Punjab, Pakistan. Geological Bulletin, Punjab University 22, 1-12.

The Siwalik molasse heavy mineral assemblages also include garnet. There are many places in the north-west Himalaya where metamorphic and igneous rocks contain garnet, the source of for the Siwaliks. The analyzed garnets range from Fe-rich compositions to those having substantial amounts of Ca and/or Mg.
Key words: Geochemistry, garnet, Murree Formation, Siwalik Formation.

B/48. Bajwa, Z.A., 1991-93. Geology of Dubran Area District Haripur with microfacies study of Langrial Algal limestone. M.Sc. Thesis, Punjab University, Lahore, 127p.

Geological mapping of some 64-km2 area around Dubran in District Haripur has been carried out at the scale 1: 12500. The geomorphology, soils, stratigraphy and structure have been described. Stratigraphically a Mesozoic-Tertiary sedimentary cover is overlying a Precambrian to Eo-Cambrian basement of Hazara Group now

metamorphosed in the lower greenschist facies. Numerous faults, high angle north dipping Nathiagali Thrust is the main fault that passes through the area and has thrusted the Precambrian Hazara Slates over the younger sedimentary sequence. Dubran syncline lying on top of a major anticlinorium makes an interesting structure.
Key words: Stratigraphy, geomorphology, microfacies, Langrial limestone, Hazara.

B/49. Baker, D.M., 1987. Balanced structural cross-section of the central Salt Range and Potwar Plateau of Pakistan: Shortening and overthrust deformation associated with a salt decollement. M.S. Thesis, Oregon State University, Corvallis.

This thesis concerns structures associated with salt décollement. Crustal shortening and overthrust deformation are described. A balanced cross-section of the central Salt Range to Potwar Plateau is presented.
Key words: Structure, deformation, Potwar Plateau, Salt Range.

B/50. Bakr, M.A., 1965a. Geology of parts of Trans–Himalayan Region in Gilgit and Baltistan, West Pakistan. Geological Survey of Pakistan Records, 11(3), 17p.

The Gilgit-Lower Hunza area comprises a range of volcanic rocks (Chalt Formation), some sediments, and major batholiths. This paper presents details of geology and petrography of the rocks. According to recent studies this region comprises Kohistan arc in the south and Karakoram plate in the north.
Key words: Petrography, Kohistan, Karakoram Plate, Gilgit, Hunza.

B/51. Bakr, M.A., 1965b. Vermiculite deposits of Pakistan. Geological Survey of Pakistan. Records, 16(1), 9p.

Key words: Mineral deposits, vermiculite.

B/52. Bakr, M.A., 1965c. Fluorspar deposits of Pakistan. Geological Survey of Pakistan. Records, 16(2), 6p.

Key words: Mineral deposits, fluorspar.

B/53. Bakr, M.A., 1965d. Thermal springs of Pakistan. Geological Survey of Pakistan. Records, 16(3), 4p.

This description includes the thermal spring of northern Pakistan, such as Garam Chashma in Chitral and Thatta Pani near Rakhiot on the west flank of the Nanga Parbat.
Key words: Thermal springs, Chitral, Gilgit.

B/54. Bakr, M.A. & Jackson, R.O., 1964. Geological map of Pakistan, Scale 1:2,000,000. Geological Survey of Pakistan, Quetta.

This is geological map of West Pakistan, East Pakistan (now Bangladesh) and Kashmir on a scale of 1:2,000,000. The compilation is based on whatever data were available by that time, a large area of the Kohistan terrene in Himalaya-Karakoram region is shown unmapped.
Key words: Geological map, Pakistan.

B/55. Bakhtiar, K. & Ahmad, W., 1979. Geology of Shewa Shahbaz Garhi Area, Mardan. M.Sc. Thesis, University of Peshawar, 79p.

Shewa Shahbaz Garhi area is occupied by silicic alkaline rocks ranging from tuffs to shallow intrusions. These rocks constitute a part of the Peshawar Plain Alkaline Igneous Province of Late Paleozoic – Early Mesozoic age. The thesis provides geological and petrographic data of the rocks.
Key words: Alkaline rocks, granitic rocks, Mardan.

B/56. Baldi, P., 1976. Magnetism of Karakorum and surrounding regions. In: Geotectonics of the Kashmir Himalaya-Karakorum-Hindu Kush-Pamir orogenic belts. Accademia Nazionale dei Lincei, 139-142.

Key words: Magnetism, Karakoram.

B/57. Balka, M.S., 1994. Delineation of surface trace of MBT along G.T. Road near Nicholson Monument by electrical resistivity, gravity, and magnetic methods. M.Sc. Thesis, Quaid-i-Azam University, Islamabad, 41p.

Geophysical methods have been applied to trace the Main Boundary Thrust of the Margalla hills near Nicholson monument.
Key words: Geophysics, Main Boundary Thrust, Margalla, Rawalpindi.

B/58. Balme, B.E., 1970. Palynology of Permian and Triassic Strata in the Salt Range and Surghar Range, West Pakistan. In: Kummel, B. & Teichert, C. (Eds.), Stratigraphic Boundary Problems: Permian and Triassic of West Pakistan. Geology Department University of Kansas, Special Publication 4, 305-454.

This paper deals with the palynological examination of 57 samples of sediments, six of which came from a single locality in the Surghar Range, and the remainder from eight localities in the Salt Range, West Pakistan. The material ranges in age from Lower Permian (Artinskian) to Middle Triassic, but most of the samples are from the uppermost Permian and Lower Triassic.
Seventy-nine species of spores and pollen grains, 23 of which are new, have been described and illustrated. Sirneonoshota (type species: S. khlonovae sp. nov.) and Paravittatina (type species: Decussatis!Jorites lucifer Bharadwaj and Salujha) have been instituted as new form genera.
Implications of the palynological data are discussed in relation to biostratigraphy and the plant geography of late Paleozoic and early Mesozoic times. They provide evidence for sweeping floral changes in the Salt Range area, coincident with the Permian-Triassic boundary, and for further extensive modifications during the late Scythian. Spore and pollen assemblages from the Late Permian Chhidru Formation appear to have derived from a transitional flora, but to have much in common with those from strata of similar age in Madagascar. Triassic assemblages both in their composition and succession closely resemble those from the Perth Basin, Western Australia.
Key words: Palynology, Permian, Triassic, Surghar Range, Salt range.

B/59. Baloch, I.H., 1986. A mineralogical study of the industrial utilization of bauxitic clays of Nawa area, Kala Chitta Range, Attock District, Pakistan. Acta Mineralogica Pakistanica 2, 144-152.

This paper gives a detailed account of the mineralogy of the Bauxite clays of Nawa area from the Datta formation of early Jurassic age exposed in the kala Chitta Range, Pakistan. The mineralogic studies show that the Kaolinite, diaspora and boehmite are the essential minerals, while chlorite, anatase, rutile, quartz and haematite are accessories. A brief account of the chemistry, phase transformation and detailed description of industrial utilization is also presented. Three grades of clays are found: one can be used as a high grade refractory, the second for ceramics and the third for common bricks.
Key words: Mineralogy, clays, economic geology, Kala Chitta Range, Attock.

B/60. Baloch, I.H., 1997. Petrogenesis of alkaline igneous province of Pakistan. Geological Bulletin, Punjab University 31 & 32, 169-176.

The Alkaline Igneous Province of Northwest Pakistan (AiPNP) extends from Loe-Shilman in the West to Tarbela in the East for a distance of about 150 Km. There are at least two distinct periods of magmatic / volcanic activity in the alkaline province. One is Permo- Carboniferous in age and is related to the break up of Gondwana land through Intra continental rifting.
The second activity is Tertiary in age. This is related to bending of Indian Plate during subduction. This bending caused tension and rifting. Tectonically the alkaline province falls in two Himalayan subdivisions: (a) Tarbela, Kogu, Utla, Babaji, Ambela and Loe Shilman falls in the Lesser Himalaya South of the Main Central Thrust and (b) Sillai Patti and Jambil fall in the Higher Himalaya North of the MCT. It may therefore be concluded that alkaline province is not restricted to the Lesser Himalaya alone.
Key words: Petrology, alkaline rocks.

B/61. Baloch, I.H., 2001. The age of the carbonate cover to the basement of higher Himalayan crystalline. Abstracts, 4th Pakistan Geological Congress, Islamabad, p.45.

The cover rocks of the Higher Himalayan Crystalline (HHC) in Swat are composed of a basal pelitic-psammitic unit overlain by a thick sequence of carbonates and calc-pelites. This cover has variously been considered as Pre-Cambrian or Triassic. Most of the workers have correlated this cover with Lesser Himalayan carbonates variously known as Bampokha group, Tursak marbles, Khasala Formation etc. The Lesser Himalayan carbonates have in turn been considered as Triassic/Jurassic to Siluro-Devonian.
The units equated with HHC cover rocks have been intruded at various places by Babaji syenite, Sills, dykes and minor apophyses of Babaji syenite intrude the rocks of Tursak/Bampokha/Khasala formations. Clear-cut hornfelsing in pelitic horizons has been identified at a number of places. Babaji Syenite has been dated as Carboniferous by U/Pb, Ar/Ar and Rb/Sr methods. The country rocks are therefore Pre-Carboniferous. If these rocks are correlated with HHC pelite/carbonate cover, then the HHC cover is older than Carboniferous.
Key words: Alkaline rocks, carbonates, stratigraphy, Swat.

B/62. Baloch, I.H., Ahmed, N., Mateen, A., Chaudhry, M.N. & Ghazanfar, M., 1999. K-Rb relations in the Koga Ijolite-feldspathoidal syenite complex, Buner Swat, Pakistan: Their bearing on the petrogenesis and comparison with similar alkaline undersaturated magma series of the world. Pakistan Journal of Geology 10 & 11, 20-33.

The Ambela granitic complex contains a range of alkaline rocks, including syenite, ijolite and carbonatite. This paper describes thee alkaline rocks and uses geochemistry in drawing conclusions regarding their origin and comparison with other such rocks from other parts of the world.
Key words: Petrogenesis, alkaline rocks, Buner, Swat.

B/63. Baloch, I.H. & Chaudhry, M.N., 1991. Occurrence, geology, petrology and industrial applications of More Khun barite deposits of Northern Areas of Pakistan. Geological Bulletin, Punjab University 26, 71-73.

The Mor Khun barite deposit is a hydrothermal replacement deposit which occurs within Gujhal Dolomite close to the contact of Gircha Formation. It is exposed intermittently for hundreds of metres. The deposit is snow white and very pure with a specific gravity between 4.3 and 4.4. Chemical and physical characteristics of this deposit indicate a number of industrial applications.
Key words: Economic geology, barite, Northern Areas.

B/64. Baloch, I.H., Chaudhry, M.N. & Mateen, A., 2000. The mineral chemistry of the Koga undersaturated alkaline complex, Buner, Swat, North Pakistan. Abstracts, Third South Asia Geological Congress, Lahore, 130-131.

Mineral Chemistry of feldspathoids, feldspars, sodium pyroxenes and biotite-annite-siderophyllite series coupled with petrochemistry of the Koga Alkaline igneous complex has been studied and interpreted to understand the crystallization history of the undersaturated magma in the region.

The Koga feldspathoidal complex is comprised of feldspathoidal syenites, foyaites, melanite nepheline syenite, alkali syenites and sodalitecancrinite rich pegmatites. The pegmatites are minor. The feldspathoidal synenites formed at pressure of < 5 kbar. These rocks comprised essentially of feldspar and feldspathoids. Pyroxene, biotite magnetite, garnet, sphene, apatite and zircon are minor to accessory minerals. The mafics along with sphene, apatite and zircon occur as tiny enclaves or microxenoliths. Cancrinite and sodalite generally occur as accessory minerals; however, in some pegmatites they assume the status of essential minerals.

The feldspar is a single phase highly exsolved feldspar with a K-feldspar host. The composition of nepheline is restricted to the MorozewiczBuerger convergent field in the system Ne-Ks-Qz. Such a composition is characteristic of subsolvous nepheline syenites. Cancrinite and sodalite show constant composition with relatively high $SiO_2$and Al_2O_3. However, CaO is comparatively low. The sodium pyroxenes fall within the narrow field of aegirine-Jadeite. Hedenbergite is lacking. The aegirine composition ranges from Ae_{80} Jd_{20} to Ae_{75} Jd_{25}. The fractionation trend of pyroxenes in this complex is rather unique and does not duplicate other complexes of the world.

Within the Biotite-Annite-Siderophyllite series in the Koga undersaturated rocks, four compositional groups may be recognized. 1. An90Sd10 to An73Sd27 with as much as 30 to 50% phlogopite, 2. An_{95} Sd_5 with 15 to 30% phlogopite. 3. $An_{80}Sd_{20}$ to An_{65} Sd_{35} with 5 to 15% phlogopite. 4. An_{70} Sd_{30} to An_{60} Sd_{40} with 0 to 5% phlogopite.

Key words: Alkaline rocks, mineralogy, Buner.

B/65. Baloch, I.H., Dunham, A.C. & Chaudhry, M.N., 1994. Mineral processing of the Koga feldspathoidal syenite complex, Northwestern Pakistan: Use in glass and ceramics. Pakistan Journal of Geology 2 & 3, 91-99.

Key words: Industrial mineralogy, alkali syenite, glass, Buner.

B/66. Baloch, I.H., Dunham, A.C. & Ghazanfar, M., 1996. Geology of the Koga feldspathoidal syenite complex, Northwestern Pakistan. Pakistan Journal of Geology 2(2) & 3(1), 1-8.

Key words: Alkali syenite, Buner.

B/67. Baloch, I.H., Ghazanfar, M., Dunham, A.C. & Chaudhry, M.N., 1997. First account of deep chemical weathering and its implications on the reserve and mining potential of Koga feldspathoidal syenite complex of north western Pakistan. Abstracts, National Symposium on Economic Geology of Pakistan, Islamabad, 1p.

It is the first report and systematic study of deep chemical weathering affecting a plutonic igneous complex in Pakistan. Discovery that the patchy outcrop of Koga feldspathoidal syenite is not a result of separate intrusions but a result of the deep chemical weathering which has led to the isolation of the still intact patches which has been taken as separate intrusion in the past. Downwards below the zone of weathering the Koga feldspathoidal syenite must he fresh everywhere. This has a direct implication on reserve calculation. It throws light and invites further research on the nature and operation of deep-seated chemical weathering on feldspathoidal syenites. The new minerals found in the altered rock comprise kaolinite, illitc, pyrophanite and siderite. It would be interesting to trace the exact sources of the ions required for these alterations. It is here suggested that aegirine, orthoclase and sphene have suffered partial breakdown. The CO_2 for the CO_3 had come from the rainwater and the soil.

It is interesting to note in the field that the weathered rock shows increase of volume and decrease of hardness which has resulted from the broad process of hydrolysis, carbonation and oxidation. The rock has become soft and swollen even though the broad textural fabric has been more or less maintained at many places. It is also significant that the total alkali content of even the highly weathered and altered rock does not fall below 10.84% from an average of 15%. This deficiency of alkali can be overcome by blending with high alkali foyoites which make it possible to utilize even the weathered material. This shows that the process of weathering though important from the mining, processing and academic point of view has not substantively affected the ore potential of the complex. Although

hydrothermal alteration of a small part of the Koga feldspathoidal syenite is known. However, implication of weathering for the mineability and reserve potential of this very important industrial rock deposit are profound. The deposit is composite in nature and composed of a number of plugs and dykes. But weathering gives a very wrong impression of the configuration of the internal structure of this complex. In the past composite outcrops. rising out of the weathered envelope were regarded as discrete intrusive bodies. Such an assumption fails to take into consideration the facts of weathering on the reserve and mineability.
Key words: Weathering, alkaline rocks, economic geology, Buner.

B/68. Baloch, I.H., Ghazanfar, M., Dunham, A.C. & Chaudhry, M.N., 1997. First account of deep chemical weathering and its implications on the reserve and mining potential of Koga feldspathoidal syenite complex of north western Pakistan. In: Hussain, S.S. & Akbar, H.D. (Eds.), Proceedings, National Symposium on Economic Geology of Pakistan, 1997, Islamabad, 149-159.

Consult preceding account for further information.
Key words: Weathering, alkaline rocks, economic geology, Buner.

B/69. Baloch, I.H., Mateen, A. & Chaudhry, M.N., 1998. Feldspars of the Koga feldspathoidal syenite-carbonatite complex, Buner, Swat, NW Pakistan. Pakistan Journal of Geology 7, 1-5.

Key words: Feldspar, Koga, alkaline complex, Buner.

B/70. Baloch, I.H., Mateen, A. & Chaudhry, M.N., 1999. Biotite-annite-siderophyllite series in feldspathoidal syenite of the Koga Alkaline Igneous Complex, Swat, NW, Pakistan. Geological Bulletin, Punjab University 33 & 34, 83-90.

The mineral chemistry of biotites has been investigated by the electron microprobe analysis performed on various rock units from the Koga feldspathoidal syenite complex. Four distinct groups- biotite-annite-siderophyllite series have been recognized; (1) An_{70} Sd_{30} to An_{60} Sd_{40} with 0 to 5% phlogopite (2) An_{80} Sd_{20} to An_{65} Sd_{35} with 5 to 15% phlogopite (3) An_{95} Sd_{5} to An_{73} Sd_{27} with 15 to 30% phlogopite (4) An_{90} Sd_{10} to An_{73} Sd_{27} with 30 to 50% phlogopite.
Key words: Mineralogy, Koga, alkaline complex, Buner.

B/71. Baloch, I.H., Mateen, A. & Chaudhry, M.N., 1999. Rare earth elements geochemistry of the Koga feldspathoidal syenites, Chamla–Buner valley, NW Pakistan. Pakistan Journal of Geology, 8(1), 1–5.

Key words: Geochemistry, REE, Koga, Buner.

B/72. Baloch, I.H., Mateen, A., Chaudhry, M.N. & Dunham, A.C., 1999. Petrography and petrochemistry of the Koga feldspathoidal syenites, Northwestern Pakistan. Pakistan Journal of Geology, 8 (1) 11–33.

Key words: Petrography, petrochemistry, syenite, Koga, alkaline complex, Swat.

B/73. Baloch, I.H., Mateen, A., Chaudhry, M.N. & Ghazanfar, M., 1998. K-Rb relations in the Koga feldspathoidal syenite complex, Buner, Swat, Pakistan: Their bearing on the petrogenessis and comparison with similar alkaline undersaturated magma series of the world. Pakistan Journal of Geology 7, 88-89.

Key words: Petrogenesis, alkaline complex, Koga, Buner.

B/74. Baluch, A.Q., 1981-83. Geological mapping and site investigations of dam site and reservoir area of Basha Dam (Chilas Diamer). M.Sc. Thesis, Punjab University, Lahore. 99p.

The electric power demand of Pakistan is very high and the present generation capabilities of the country are insufficient to cope with the increasing load created by industry, agriculture and domestic consumers. In order to tide over the situation water and power development of Pakistan initially identify thirteen sites on the Indus River upstream of Tarbela upto Skardu, because the drop along Indus plains show attractive locations for hydro power development.

To study the potential/plan the development of 13 identified sites and feasibility of one best site, first Canadian Technical Assistant has been arranged. Basha damsite is the site selected by the Canadian Consultant for the feasibility purposes which is located on the Indus river near the village Basha about 45 km downstream of Chilas in Gilgit Agency.

Key words: Engineering geology, Basha, Chilas.

B/75. Baluch, S.Q., 1998. Geotechnical aspects of hydropower projects in Indus Kohistan, Northern Pakistan. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 27-29.

A number of high head hydropower projects are being planned on tile tributaries of the Indus River in Indus Kohistan. These projects, with locations as shown in Fig. 1, are at various levels of study and the first may come into operation around the year 2005. The estimated total installed capacity of 5,000 MW mostly in the form of peaking plants will significantly reduce the power deficit currently being faced by Pakistan. The main characteristics of these cascade schemes include storage dams at higher elevations with regulation facilities in the middle and lower catchment sections. As is the case with most high head hydropower projects, the planned schemes are in relatively remote areas and contain long waterways (tunnels) across areas of high overburden. High erosion rate in the Himalayan region will also result in deposition of sediments in the reservoirs requiring careful sedimentation management and provision of sediment handling facilities. Main geotechnical data available for the schemes is summarised and discussed ' in relevant detail. The Allai Khwar Hydropower Project is the most advanced and is a likely candidate for implementation ahead of others. The other cascade schemes on left bank of' the Indus river in the adjacent catchments of Chor Nala and Spat Gah have been studied to conceptual and reconnaissance level, respectively. Based on geological and tectonic setting of the area, the process of site selection and establishment of design parameters are also presented.

The continued subduction and Arc-Continental collision (thrusting) induced several phases of faulting and metamorphism, resulting in a wide spectrum of low to high grade metamorphic rocks. The projects areas are in close vicinity of the Main Mantle Thrust (MMT); a major orogenic feature which marks collision boundary of the Indian plate to the Eurasian plate with intervening Karakoram micro-plate and Kohistan Arc. The alignment of MMT and other major tectonic features have been mapped within the projects area. Based on the regional geological conditions, the geotechnical zoning has been attempted to define expected geotechnical and geomechanical characteristics of' rock mass along the long tunnel routes. Attempt has been made to predict tunnelling conditions and rock mass behaviour together with estimated rock support requirements.

Investigation techniques, including interpretation of satellite imagery, aerial photographs interpretation, engineering geological mapping, geophysical methods and core drilling is described together with their application from site selection to microlocation of the project structures. The paper describes the successful use of various geophysical investigation techniques and results obtained at the initial stage of site selection in these relatively remote and inaccessible areas. This allowed to replace expensive and time consuming drilling and other relevant rock mechanics testing. Systematic discontinuities surveys regionally and at selected sites were carried out to define characteristics of dominant discontinuities groups. Also presented is the use of this data in stability assessment of foundations, tunnels and slopes on various project sites. In the concluding section, recommendations are given for appropriate methodology and approach in obtaining geotechnical data and site selection for hydropower projects in northern areas of Pakistan.

Key words: Engineering geology, energy, Kohistan.

B/76. Baluch, S.Q. & Ali, I., 1998. Seismic risk assessment of hydropower projects with reference to the tectonic structure of northern Pakistan. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 29-32.

Seismic phenomenon has been responsible for the severe damage to water-retaining structures in the ' world. Examples from USA include Sheffield dam, Hebgen Lake dam, Upper San Fernando dam, and Lower San Fernando dam. Similarly, Koyna dam; a concrete gravity structure in India sustained severe earthquake damage in 1967. However, a complete failure of a dam due to earthquake impact is virtually unknown. The safe design of dams to withstand destructive earthquakes is, therefore, extremely important because failure of such a structure may have disastrous consequences both on life and property. The paper briefly describes seismo-tectonic environment in the Himalayan region and its impact on existing dams in tilts area such as Bakhara-Nangal dam in India, Mangla and Tarbela dams in Pakistan. In addition, earthquakes that may pose a multitude of hazards to dams either by direct loading of the structure or by initiating a sequence of events that may lead to the dam failure are discussed with a special reference to tile tectonic structure of Northern Pakistan. The geological and tectonic setting of the Northern Pakistan is an example of Continental collision characterised by the occurrence of an ancient island arc. The continuing subduction and Arc-Continental collision (thrusting) induced several phases of faulting and metamorphism, resulting in a wide spectrum of low to high grade z-metamorphic rocks. The tectonic processes in the area have produced a mixed and very complex geological situation. The collision tectonics have resulted in formation of thrust and strike slip faults. Most of the high head hydropower projects planned in the Indus Kohistan area are located in close vicinity of the Main Mantle Thrust (MMT) and other major tectonic features. The rocks are foliated to cataclastic and mylonized with high degree of shearing and folding in vicinity of the MMT. The MMT, Indus Kohistan seismic Zone (IKZS), Thakot Shear Zone (TSZ) and the Main Boundary Thrust (MBT) in the form of a detachment fault underlying the project area are the main seismogenic features in the area. Relationship between distribution of seismic events and main seismo-tectonic features in Indus Kohistan is given in Fig. 1. The Northern areas of Pakistan are considered highly seismic and in spite of the fact that all the future main hydropower projects are being planned in this region, this area has never been covered by any seismic instruments in the past. Recently, M/S Allai Khwar Consultants (AKC) have managed a microseismic network study in Indus Kohistan area. The instruments installed at locations shown in Fig. 2 recorded several hundred seismic events during six months study period. The study indicated that the level of micro-seismicity in this region is fairly frequent and probably greater than in other parts of the Himalayan region. Another important aspect identified by the study is the shallow depth of seismic events. It is observed that even small magnitude events can produce high accelerations in Northern Pakistan. For example, an earthquake of' April 17, 1970 with a body wave magnitude 4.9 produced 25% g and that of February 20, 1996 wave a magnitude 5.2 produced 27% g at the Tarbela site. Based updated geological information, historical earthquake data and preliminary results of the recent microseismic network study, design parameters such as Maximum Credible Earthquake (MCE), Operational Basis Earthquake (OBE) and acceleration (g) values are proposed. Relevance of various attenuation equations for this area are also discussed. Satellite imagery and aerial photographs to determine location and lengths of lineaments provided information on the probable extent of possible movement on major fault planes. Accurate geological and tectonic snapping allowed correlation of instrumental data with the known tectonic features. Based on the recommendations of the International Committee on Large Dams (IOCLD), the investigation methods used in site selection, classification of fault systems and identification of neo to recent tectonic activity are described. Relevant design features are proposed to minimise damage to dams avid appurtenant structures in case of extreme shaking during strong seismic events.

Key words: Seismology, engineering geology, energy, Kohistan.

B/77. Baluch, W.A., Begum, I., Aslam, M. & Shah, A., 1982. Geology of Shergarh-Sar Complex, Allai Kohistan, Hazara. M.Sc. Thesis, Peshawar University, 55p.

This report covers the Geology of an area located in the Allai Kohistan, Hazara division between 34^0 50’ to 34^0 60’ N latitudes and 73° 0’ to 73° 10’ E longitudes. A detailed petrographic study together with a geological map is presented in this manuscript. Broadly, the rocks types of the thesis area are divisible into two major groups, i.e. amphibolites and ultramafics. In the studied area the amphibolites are divided into three groups: 1) Epidote-Amphibolites, 2) Garnet-Epidote-Amphibolites, and 3) Garnet-Amphibolites.

The amphibolites may be inferred to be metamorphosed product of oceanic crust. Ultramafics are peridotites, pyroxenites, dunites, and serpentinites. These ultramafics represent the obducted ophiolites. The area is located along MMT, which is a vital tectonic element of the Himalayan geology. Due to the involvement of MMT, the area has undergone complex tectonic episodes in response to the collision of Indian plate and Eurasian continent.
Economic mineral chromite is found in ultramafics whereas gem quality garnet is expected to be found in arnphibolites. Vein deposits like Pb and Zn are also expected but no comprehensive work has been done.
Key words: Petrography, Shergarh-Sar, Allai Kohistan.

B/78. Banaras, M. & Ghani, A., 1982. Petrography of the Tora Tigga Complex, Munda area, Dir District. M.Sc. Thesis, University of Peshawar, 157p.

This work presents a detailed geological map (1:12,500), petrography and a discussion regarding the petrogenesis of the ultramafic rocks of the Tora Tigga complex in Dir district ($34^0$49' N, $71^0$44 'E). The complex, covering about 7sq. km. area, is situated in the Southern Amphibolitic Belt along the Main Mantle Thrust. The amphibolites, hosting the ultramafic rocks, are divisible into metagabbros/ metanorites, banded- amphibolites and garnet-amphibolites. The metagabbros/metanorites consist of prograde hornblende and plagioclase (An_{40-43}) with or without quartz, white mica, apatite, rutile and ore. Clinopyroxene and orthopyroxene occur as relics, and chlorite and epidote as retrograde alteration products. The banded-amphibolites are composed of quartz, plagioclase (An_{38}) hornblende, biotite, sphene, and ore. The garnet-amphibolites are similar in composition to metagabbros except for the presence of garnet porphyroblasts and a slightly more calcic plagioclase (An_{45}). All these rocks have been metamorphosed under Barrovian-type amphibolite facies conditions. The ultramafic rocks are broadly classified into olivine-pyroxene-ultramafites and hornblendites. The olivine-ultramafites include peridotites, amphibole-peridotites, serpentinites and dunites. The pyroxene-ultramafites include hornblende - websterites – hornblende - orthopyroxenites, hornblende clinopyroxenites, hornblende-olivine-websterites and olivine-clinopyroxenites. There is a complete range from hornblende-pyroxenites to pure hornblendites, plagioclase (An_{40-45}) occurs in only a few hornblendites.
Felsic dykes, dykelets and veins, as well as epidote veins crosscut the hornblendites. The mineralogy of the felsic dykes and veins (hornblende- plagioclase (An_{30-40}) Quartz, epidote with or without garnet-biotite and rutile) is suggestive of metamorphism in the amphibolite-facies. However, retrogressive alteration accompanying shearing has led to the development of greenschist facies minerals (tremolite-actinolite-chlorite and secondary epidote).
The petrography of the ultramafites as well as the composition of the olivine (FO_{89}) and orthopyroxene (En_{87}) remain inconclusive regarding their petrogenetic affinity to one of the standard categories, i.e. alpine-, layered- or ring-complexes. They may represent an obducted slab of oceanic crust/upper mantle or a part of ultramafic rocks differentiated from a calc-alkaline or a basaltic magma. Most of the field and textural features suggest a metasomatic origin for the hornblendites generally at the expense of pyroxenites. They appear to have formed by the addition of H_20, Al, Fe and (Ca) to the ultramafites. The metasomatism seems to have been synchronous with regional metamorphism and obduction of the ultramafites during the Early Tertiary.
Key words: Petrography, ultramafics, hornblendites, Tora Tigga, Dir.

B/79. Band, G., 1955. Road to Rakaposhi. 1st edition. Hodder and Stoughton, London.

Key words: Rakaposhi, Hunza.

B/80. Banerjee, D.M., 1992. Carbon isotopic excrustion along PC/C boundary-evidences from Soltanieh Range in Iran, Hazara in Pakistan, Mussoorie Hills in India and Urandush Mountain, Mongolia. Abstracts, First South Asia Geological Congress, Islamabad, 6-7.

Black shale, dolomitic limestone and chert are the predominant host rocks of the phosphorites occurring along Proterozoic Cambrian boundary in several parts of Asia. Detailed sampling along three stratigraphically measured sections in India, Iran and Mongolia and random samples from Hazara in Pakistan, provided the material for stable isotope analyses of carbon and oxygen in the carbonate, apatite and organic fractions of the phosphorite. A marked negative inflexion of data points at the base of Cambrian succession is coupled with an abrupt change to a positive excursion. Markedly light carbon isotopic shift can be related to the methanogenesis in the black-shale rich phosphorites. Carbonate hosted phosphorites are associated with bacterial degradation products and therefore are

heavier in their isotopic composition. This phenomenon is more or less consistent through all the sections in 4 different countries and show conformity with the results obtained from Greenland, Newfoundland and China.
Key words: Geochemistry, isotope geology, phosphorites, Hazara.

B/81. Bangash, I.H., 1991. Petrology and geochemistry of the Southern Amphibolite Belt rocks from Mahak and surrounding area, Swat, Pakistan. M.Phil. Thesis, University of Peshawar.

The Mahak and surrounding area is located in the southern amphibolite belt of North, Pakistan. A detailed petrography and geochemistry of the Mahak area is presented. Rocks of the area are distinguished into amphibolite, Hornblendite, hornblende-pegmatite, diorites, metagabbros, metapyroxenites, and quartzo-felspathic veins and dykes. Amphibolites are the most abundant rocks of the area, and are distinguished into epidote-amphibolites, plagioclase-amphibolites, and epidote-plagioclase amphibolites. These are generally medium to coarse grained and consist of hornblende, plagioclase, epidote, clinopyroxene, orthopyroxene, sphene, quartz, ore, rutile, and chlorite. Hornblendites are usually monomineralic, but have a variable grain size. They are mainly composed of hornblende, cloudy plagioclase, epidote, chlorite, quartz, rutile and ore. Hornblende-pegmatites are coarse grained containing hornblende and plagioclase as dominant minerals, epidote, quartz, sphene, rutile and opaque minerals as accessories.
Key words: Petrology, geochemistry, amphibolites, Swat.

B/82. Banks, M.P., 1958. Rakaposhi climbed. Himalayan Journal, 21(6), 55p.

This is an account of the successful ascent of the Rakaposhi Range in the central Karakoram of Hunza. The expedition was conceived as a small but exacting experiment in international and inter-service co-operation. All the members were service officers and were drawn fairly equally from the Pakistan Army and the British Navy, Marines, Army and Air Force, making a total of nine climbers. Field-Marshal Sir Gerald W. R. Templer, G.C.B., G.C.M.G., K.B.E., D.S.O., Chief of the Imperial General Staff, and General Mohammad Ayub Khan, Commander-in-Chief of the Pakistan Army, lent their powerful support as joint Patrons; and the expedition committee was, appropriately, presided over by Major-General J. L. Moulton, C.B., D.S.O., O.B.E., Chief of Amphibious Warfare, and an officer of the Royal Marines.
The objective was the ascent of Rakaposhi, one of the unclimbed giants of the Karakoram Range. Rakaposhi has a long mountaineering history, closely associated with British climbers. In the dawn of Himalayan mountaineering, in 1892, Martin Conway (later Lord Conway of Allington) penetrated the Bagrot nulla to the south of the peak. The lower ramparts deterred him but he pronounced the upper mountain climbable. The peak lay unmolested until 1938 when two British climbers, Secord and Vyvyan, approached Rakaposhi from the West. They investigated the peak via the N.W. ridge but only attained a height of about 19,700 ft. The first determined attempt, which had some chance of success, was spearheaded by the celebrated 'Everester' H. W. Tilman in 1947. He was eventually turned back at about 19,000 ft. both on the N.W. ridge and on the S.W. spur. He regarded neither route as promising. In 1954, two expeditions had designs on Rakaposhi. An Austro-German expedition under Rebitsch approached from the South but came to much the same conclusion as Conway had done sixty years earlier and they left the peak, dubbing it unclimbable from that direction as it most probably is. In the same season a Cambridge University expedition, under Tissi6res, and including Band who was on Everest in 1953 and was later to climb Kangchenjunga, again tried TilmanVs routes, They discovered that the S.W. spur was the most hopeful line of approach and they reached about 20,800 ft. before their assault petered out through lack of impetus, The final 2,000 ft. of climbing had been up a great face of snow and ice called the Monk's Head. This was a most formidable obstacle, particularly for porters.
Key words: Rakaposhi, Hunza.

B/83. Bank, H., 1976a. Farblose topase aus Pakistan mit hoher lichtbrechung. Z. Deutsche Gemmologischen Gesell 25, 157-158.

Describe a topaz from northern Pakistan. Refractive index was measured at between 1.630 and 1.640 with a birefringence of 0.010.
Key words: Gemstones, topaz.

B/84. Bank, H., 1976b. Rosafarbige durchsichtige topase aus Pakistan. Zeits. Deutschen Gemmologischen Gesell 25, p.41.

This material, found in the Mardan District, Hill-Top pegmatite [probably Katlang], has α=1.632, β=1.636, γ=1.641; and specific gravity of 3.53.
Key words: Gemstones, topaz, Mardan.

B/85. Bank, H. & Berdesinski, W., 1975. Durchscheinender fast durchsichtiger antigorit (serpentin) aus Pakistan. Zeits. Deutschen Gemmologischen Gesell 24, 157-159.

This antigorite serpentine has α=1.559 γ=1.561, and birefringence of 0.002. The specific gravity is 2.57.
Key words: Gemstones, topaz.

B/86. Bank, H. & Okrusch, M., 1976. Uber rubin-vorkommen in marmoren von Hunza, Pakistan. Z. Deutsche Gemmologischen Gesell 25, 67-85.

This is a report on the occurrence and properties of the ruby in marbles near Hunza.
Key words: Ruby, marbles, Hunza.

B/87. Bannert, D., Cheema, A., Ahmed, A. & Schaffer, U., 1992. The structure development of the western fold belt, Pakistan. Geologisches Jahrbuch, Reihe B 80, 3-60.

Key words: Structure, fold belt.

B/88. Bannert, D. & Raza, H.A., 1992. The segmentation of the Indo-Pakistan plate. Abstracts, First South Asia Geological Congress, Islamabad, p.7.

The Kirthar and Sulaiman ranges of western Pakistan and the Kohat and Potwar area adjacent to the northeast have been structurally analyzed using LANDSAT·MSS colour and black and white images at a scale of 1:250.000, literature studies, and a limited field survey. The pattern of tectonic deformation caused by the collision of the lndo-Pakistan Plate with the Eurasian plate have been analyzed. Tethyan oceanic crust covered by Triassic through Early Tertiary sediments, are preserved between the Eurasian Plate and the Indo-Pakistan Plate and called the Bela-Waziristan Ophiolite Zone. The oblique collision of the Indo-Pakistan Plate with the Eurasian Plate forced the Indo-Pakistan Plate to rotate in an anticlockwise mode. The collision further opened a number of basement faults that segmented the western part of the Indo-Pakistan Plate mostly on Pakistan territory -into several basement blocks, which were involved en-echelon in the collision. They are the Kirthar Basement Fault in the southwest, the Sulaiman Basement Fault, and the Jhelum Basement Fault in the northeast. The deformation of the sediments of the Indo-Pakistan Plate during the collision resulted in different tectonic patterns on the individual basement blocks.
Key words: Plate tectonics, collision, structural geology.

B/89. Baqri, S.R.H., 1984. The Correlation of Khewra Sandstone (Salt Range) with a Cambrian Sandstone, exposed near Abbottabad, Hazara Division, North West Frontier Province, Pakistan. Kashmir Journal of Geology 2, 75-78.

The detailed lithological units of the Khewra Sandstone (Salt Range) and Tanakki-Sanghargali members have been compared for their probable correlation. The probable correlation of the Khewra Sandstone with the Tanakki-Sangharghali member indicates that the Khewra Sandstone extends as north as Riwat Rawalpindi in the subsurface. It is also inferred that the Khewra Sandstone is not localized in Salt Range only but extends regionally towards Abbottabad.
Key words: Stratigraphy, sandstone, Cambrian, Khewra, Hazara.

B/90. Baqri, S.R.H. & Dawood, H., 1995. The stratigraphic importance of Pasu Slates and Gujhal dolomite and their stratigraphic relations with the Baltit Group. Abstracts, International Symposium on Himalayan Suture Zone of Pakistan. Pakistan Museum of Natural History, Islamabad, 22-23.

The south western flank of the Sost anticline displays the exposures of the Pasu Slates and Gujhal Dolomite in the Upper Hunza Valley which form the most prominent and distinct lithological features, representing rugged topography and high cliffs. The Pasu Slates and Gujhal Dolomite represent the same lithological units as Misgar Slates and Kilk formation, respectively, exposed on the north eastern flank of the Sost anticline. The basal and upper contacts of the Pasu Slates and Gujhal Dolomite were studied at several places such as Pasu, Dih, Sost etc. as it is very difficult to observe these contacts at one place due to sever tectonic activity in the area.
The Pasu Slates unconformably lie over the Pak China Friendship Formation (mainly quartzites with lenticular pebbles and gravels) and arc conformably overlain by the Gl1jhal Dolomite. The Pasu Slates are dark grey to grey, flaggy, thin to medium bedded, thinly laminated. sandy, silty, more arenaceous towards base and more calcareous/marly with lenticular limestone beds towards its top. The slates display the random distribution of the perfect diagenetic crystals of pyrite, the size of which increases towards the base. The slates arc about 2000m thick and have been assigned a Permian age due to the discovery of the products fossils in the Gircha Formation. The Gujhal Dolomite overlies conformably on the Pasu Slates and is unconformably overlain by the Shanoz Conglomerate. The Gujhal Dolomite is dirty yellowish grey to grey, lenticular bedded, massive bedded, occasionally argillaceous and display two beds of lenticular intraformational conglomerates, near the base and the middle of the formation. The dolomite is about 750 m thick at Pasu and has been assigned a Permian age.
The Pasu Slates and Gujhal Dolomite arc severely folded, faulted, intruded mostly by acid igneous rocks and display generally faulted contacts. They occupy stratigraphically same position as the Baltit Group exposed in the lower Hunza Valley. These studies revealed that the Pasu Slates and the Gujhal Dolomites were comparatively highly metamorphosed into schists gneisses and marbles (Baltit Group) around the older original intrusive backed contacts with the Karakoran1 batholith (Cretaceous) in the southern areas at lower Hunza Valley as compared to the younger thrusted contacts of the Karakoram batholith with these formations in the northern side in the upper Hunza Valley (north west of Husaini Village).
Key words: Stratigraphy, Pasu slates, Gujhal dolomite, Baltit Group, Hunza.

B/91. Baqri, S.R.H., Javed, M., Ahmed, Z. & Haq, A., 1995. The X-ray diffraction and geochemical studies of the Hunza ruby and associated rocks. Abstracts, International Symposium on Himalayan Suture Zone of Pakistan. Pakistan Museum of Natural History, Islamabad, 21-22.

The sample of the dark pinkish red ruby and its associated carbonate rocks (marbles) were collected from the ruby mine of Hunza, located on Karakoram Highway, near Aliabad. The X-ray diffraction and geochemical studies on the Hunza ruby and associated rocks were conducted to understand the influence of the mother solutions during the mineralization of Hunza rubies and the nature of the lattice parameters. The Hunza ruby displays perfect X-ray diffraction pattern giving all the important reflections and may be called a well crystallized precious gem variety. The mother solutions originated during the intrusion of the Karakoram batholith into the country rocks.
Key words: Geochemistry, XRD, gemstone, ruby, Hunza.

B/92. Baqui, M.A., 1963. Geology of Palsala Bir, Haripur, Hazara, M.Sc. Thesis, Punjab University, 30p.

Details not available.
Key words: Geology, Haripur, Hazara.

B/93. Baranowski, J., Armbruster, J., Seeber, L. & Molnar, P., 1984. Focal depths and fault plain solutions of earthquakes and active tectonics of the Himalaya. Journal of Geophysical Research 89, 6918-6928.

We have compared synthetic seismograms with long-period body waves for nine earthquakes with epicenters in the Himalayan arc to determine depths of foci and to improve fault plane solutions. Focal depths are shallow (10–20 km). Inferred slip vectors are locally perpendicular to the mountain range; they plunge very gently (□10° (in the eastern sections of the range and more steeply (□25°) in western sections. Assuming India to be a rigid plate, the radially oriented slip vectors imply that southern Tibet extends at about half the rate of underthrusting in the Himalaya and therefore probably at about 5–10 mm/yr. The shallow depths and gentle dips of the fault planes, at least for the events in the eastern half of the range, are consistent with coherent underthrusting of the Indian plate beneath, at least, the Lesser Himalaya. The steeper dips of fault planes in the western part of the arc might reflect deformation of the overriding thrust plate or simply a steepening of the main underthrusting zone beneath the Greater Himalaya.
Key words: Seismology, neotectonics, earthquakes, Himalaya.

B/94. Barbieri, M., Caggianelli, A., Di Florio, M.R. & Lorenzoni, S., 1994. Plagiogranites and gabbroic rocks from the Mingora ophiolitic melange, Swat valley, NW Frontier Province, Pakistan. Mineralogical Magazine, 58, 553-566.

Major, trace element composition and Sr isotopic data were collected for gabbroic rocks, plagiogranites and albitites in the ophiolite assemblage from Swat Valley (NW Frontier Province, Pakistan). Petrographic study revealed that these rocks were subjected to important structural and mineralogical modifications due to greenschist-epidote-amphibolite facies sub-sea-floor metamorphism and to brecciation. On the other hand, the examination of whole rock chemical composition and of chemical trends showed that these rocks were affected by some chemical modifications, concerning especially Na20, K20 and Rb. The very low contents of HFS (high field strength) and RE elements found in gabbroic rocks and plagiogranites were considered to be a primary magmatic feature pointing in part to their cumulitic nature and in part to an origin from a refractory parental magma. The Sr isotopic data indicate that gabbroic rocks and plagiogranites were subjected to exchange-with sea water. The particular chemical features shared by gabbroic rocks and plagiogranites suggested that fractional crystallization was a possible evolution process. In contrast, albitites are characterized by anomalously high contents in HFSE and LREE and by values of the 87Sr/86Sr ratio very close to sea water. These features suggest a more complex origin with respect to gabbroic rocks and plagiogranites.
Key words: Ophiolites, melange, petrology, Shangla, Swat.

B/95. Bard, J.P., 1978. Initiation of intra–continental subduction in the Himalayas. Journal of Geophysical Research, 83(310), 4975–4987.

Independent arguments based on topographic stress and crustal strength give upper limits of 200 bars and 300 bars, respectively, for the average shear stress on the intracontinental thrust fault that formed the Himalaya. According to either a one-dimensional or a two-dimensional fault model, such stresses could not have produced the Himalayan granites by friction, unless overthrusting velocity exceeded 30 cm/yr. More probably, Himalayan metamorphism was caused by exposure of continental crust to hot asthenosphere prior to the formation of the intracontinental thrust. Crust was exposed by peeling away of Indian subcrustal lithosphere in response to the force and moment exerted by the Tethyan slab. This detachment of buoyant crust from dense lithosphere better explains the metamorphic pattern and also explains why the distributed crustal shortening at the beginning of the collision orogeny was replaced by localized thrusting or intracontinental subduction.
Key words: Intracontinental, subduction, Himalaya.

B/96. Bard, J.P., 1983a. Metamorphic evolution of an obducted island arc: example of the Kohistan sequence (Pakistan) in the Himalayan collided Range. Geological Bulletin, University of Peshawar 16, 105-184.

In the northern Pakistan, the extraordinary 40km thick Kohistan sequence of mafic, ultramafic and calc-alkaline layered plutonic and volcanic (mainly andesitic and rhyodacitic) rocks has been interpreted as the only complete vertical section of an intraoceanic island arc presently exposed anywhere in the world. Plate-scale models have been suggested to explain the origin and the tectonic evolution of this arc in the Himalayan collided range. Despite some noticeable differences in the models, there is a general agreement that the Kohistan sequence represents the crust of an arc obducted onto the Indian plate before the Oligocene collision of India against Asia.

The purpose of the present paper is to give new data on the tectono-metamorphic evolution of the Kohistan sequence and to try to estimate its changing metamorphic conditions on petrological, mineralogical and crystal chemistry grounds. The structural, textural and mineralogical data suggest two main tectono-metamorphic events that have affected the Kohistan arc before late lower grade overprints. From various geothermometry estimates as well as from field zonations, it is concluded that the major (D1) phase developed with a thermal structure strongly controlled by thermal anomalies in the metamorphic pile. These anomalies seem centered around isolated bodies of two-pyroxenes and cpx-garnet granulites. Because the petrographical evidences indicate the latter are derived from large pre-tectonic layered calc-alkaline intrusion(s), the former anomalies are interpreted as remnant magmatic heat source(s) within the arc. This interpretation fits nicely with theoretical thermal models. Assuming D1 is contemporaneous with obduction of the arc and together with the geochronological data, it is suggested that the tectonic emplacement of the Kohistan arc was 20 ± 5 m.y. after the intrusion of enormous calc-alkaline pluton(s) within the arc crust. Such a relatively short elapsed time between a strong magmatic activity and a tectono-metamorphic event may explain why the T-P paths during D1 produced sinous geotherms in the petrogenetic grid, i.e., the dT/dp are varying from 35oC ± 5oC /km upto 100oC /km in the 40 km thick pile.

The second (D2) phase is contemporaneous with syn-kinematic low- to mid-grade retrogression upto the epidote-amphibolite facies conditions. The T – P curve during this phase is a classical one and the D2 geotherm approached 25oC ± 5oC /km within a re-equilibrated thermal structure. Scarce geochronological data suggest the D2 was contemporaneous with the Oligocene collision of India against Asia and possibly synchronous with the Oligocene Barrovian metamorphism which has affected the Indian plate south of Kohistan. The origin of the rocks of the Kohistan granulites as well as the significance of a blueschist belt under the Kohistan metamorphic pile are briefly discussed.

Key words: Metamorphism, petrology, Kohistan.

B/97. Bard, J.P., 1983b. Metamorphism of an obducted island arc: example of the Kohistan sequence (Pakistan) in the Himalayan collided range. Earth and Planetary Science Letters 65, 133-144.

In northern Pakistan, the extraordinary 40-km-thick Kohistan sequence of metamorphosed mafic, ultramafic and calc-alkaline layered plutonic and volcanic (mainly andesitic to rhyodacitic) rocks has been recently reinterpreted as the only complete vertical section of an intra-oceanic island arc presently exposed anywhere in the world. Plate scale-models have been suggested to explain the origin and the tectonic evolution of this arc in the Himalayan collision range. Despite some noticeable differences in the models, there is general agreement that the Kohistan sequence represents the crust of an arc obducted onto the northern edge of the Indian plate before the Oligocene collision of India against Asia. New data on the tectonometamorphic evolution of the Kohistan sequence have led to the conclusion that a first major D1 event developed with increasing metamorphic grades oriented downward the Kohistan pile but also toward "ensandwiched" basic-ultrabasic granulitic rocks. Rare geochronological data and petrological evidence indicate that the latter granulites (pyriclasites and various plagiopyrigarnites, pyrigranites, metatroctolites, metawebsterites, metadunites, etc.) were parts of enormous Lower to Middle Cretaceous layered calc-alkaline plutons emplaced during the arc-building stages. As the D1 metamorphic event is correlated with the Upper Cretaceous obduction process of the Kohistan onto India, it is proposed that the D1 thermal structure was strongly controlled by remnant magmatic heat source(s) within the obducted arc. This interpretation fits nicely with recent theoretical thermal models since the obduction of the arc was probably shortly after (10–20 Ma) the emplacement of the former plutonic arc rocks. A blueschist "tectonic mélange" underlying the obducted arc was possibly synchronous to the obduction and not clearly linked to the older subductive process. The Oligocene collision of India against Asia was associated with a Barrovian overprinting metamorphism in the Kohistan arc. During this second event the dynamo-thermal structure was much more classical and not controlled by the occurrence of the Cretaceous metaplutonic rocks. A tentative model of the thermal structures during the major events which affected the Kohistan arc is proposed.

Key words: Metamorphism, petrology, Kohistan.

B/98. Bard, J.P., Jan, M.Q., Maluski, H., Matte, P. & Proust, F., 1979. Position et extension de la "ceinture" metamorphique a facies schistes blues dans 1'Haimalaya du Pakistan, Nord. 7e R. Ann. Terre Lyon, 29p.

This account describes the Indus suture mélange stretching from Kaghan to Shangla. It contains blueschists locally, such as those near Shangla. The high-pressure metamorphism is related to the suturing of the Indian plate and Kohistan island arc during the Late Cretaceous.
Key words: High-P metamorphism, blueschist, Indus suture, Himalaya.

B/99. Bard, J.P., Maluski, H., Matte, P. & Proust, F., 1980. The Kohistan sequence: crust and mantle of an obducted island arc. Geological Bulletin, University of Peshawar 13, 87-94.

The Kohistan sequence outcrops in the western part of the western Himalayan syntaxis. It is a thick pile (30-40km) of metamorphosed magmatic, volcanic and sedimentary rocks. It is composed of six main units i.e. from bottom to top: the southern amphibolite belt with basal ultramafics, the "pyroxene granulite" belt (10-15 km thick), the northern amphibolite belt, intruded by various dioritic bodies, a metasedimentary oceanic series (Kalam series), a volcanic calc-alkaline series (Utror Volcanics), up to 6-8 km thick, an upper detrital series (Yasin group, Lower Cretaceous). This sequence is interpreted as a complete cross-section of a mature island arc formed by subduction during Mesozoic in the southern part of the Neotethys and obducted onto the Indian plate in Upper Cretaceous time.
Key words: Petrology, tectonics, Kohistan.

B/100. Barndt, J., Johnson, N.M., Johnson, G.D., Opdyke, N.D., Lindsay, E.H., Pilbeam, D. & Tahirkheli, R.A.K., 1978. The magnetic polarity stratigraphy and age of the Siwalik Group near Dhok Pathan village, Potwar Plateau, Pakistan. Earth and Planetary Science Letters 41 (3), 355-364.

The magnetic polarity zonation of the terrestrial strata exposed in the Dhok Pathan area of Pakistan has been established utilizing data from 204 paleomagnetic sites. Individual magnetic transitions are traced laterally over 15 km and provide convenient time lines for correlating the fluvial facies of the middle Siwalik Group. A pervasive, normal polarity zone dominates throughout the region and has been interpreted as Magnetic Polarity Epoch 9. Based on this interpretation and using the absolute ages from the published magnetic time scales the average sedimentation rate in the area is calculated at 0.8 m/1000 years, and the average elapsed time between fluvial cycles is 56,000 years. Major sandstone units are minimally time transgressive in an east-west direction. The Nagri Formation in the Dhok Pathan area spans the time from 10.0 to 8.6 m.y. B.P. Ramapithecus and other hominoid primates are found in Epoch 9 at about 9 m.y.
Key words: Magnetostratigraphy, siwaliks, Potwar.

B/101. Barndt, D.E., 1977. The magnetostratigraphy of the type locality of the Dhok Pathan faunal stage, Potwar Plateau, Pakistan. M. A. thesis, Dartmouth College, Hanover, New Hampshire, U. S. A.

Consult the preceding for further information.
Key words: Magnetostratigraphy, Dhok Pathan, siwaliks, Potwar.

B/102. Barnett, D.E., Chamberlain, C.P. & Zeitler, P.K., 1991. Oxygen isotope constraints on the geneses of young (<5 Ma) leucogranites from the Nanga Parbat-Haramosh Massif. EOS 72, p.525.

The Nanga Parbat massif contains some of the youngest granitic intrusions in the world, less than 5Ma. This paper provides oxygen isotope constrains for the genesis of these young leucogranites.
Key words: Geochemistry, leaucogranites, oxygen isotopes, Nanga Parbat-Haramosh.

B/103. Barnett, S.G., Kohut, J.J., Rust, C.C. & Sweet, W.C., 1966. Conodonts from Nowshera reef limestones (uppermost Silurian or lowermost Devonian), West Pakistan. Journal of Paleontology 40, 435-438.

Eighteen previously described conodont species distributed among 11 genera are described from the Nowshera reef limestones of the northern part of West Pakistan. The identified species are lowermost Devonian and are equivalent in part to the western European Spathognathodus oesteinhornensis and Icriodus woschmidti zones.
Key words: Palaeontology, limestone, reef, Siluro-Devonian, Nowshera.

B/104. Barnicoat, A.C. & Treloar, P.J., 1989. Himalayan metamorphism-an introduction. Journal of Metamorphic Geology 7, 3-8.

This is an introduction to a special issue of the Journal of Metamorphic Geology edited by the two authors. Following introductory comments on geological evolution of the Himalayas, very brief account of metamorphism and the contained papers is given. Two papers (Treloar et al. and Chamberlain et al.) dealing with Pakistan Himalaya are summarized elsewhere.
Key words: Metamorphism, Himalaya.

B/105. Barry, J.C., 1980. Occurrence of a Hyaenodontine Creodont (Mammalia) in the Late Miocene of Pakistan. Journal of Paleontology 54, 1128-1131.

A recently discovered hyaenodontine mandible from the Nagri Formation of northeast-ern Pakistan extends the stratigraphic range of the Creodonta into a considerably younger geological period than previously known. An estimated age of eight to nine million years (N. M. Johnson, pers. comm.) makes this specimen two or three million years younger than the proviverrine Dissopsalis carnifex Pilgrim, previously the youngest known hyaenodontid (Pilbeam et al., 1977). By comparison hyaenodontids apparently became extinct in North America during the early Arikareean Land Mammal Age at approximately 27 million years (Macdonald, 1970; Mellet, 1977); in Europe during the middle Miocene (Helbing, 1925); and in Central Asia in the middle or late Oligocene (Mellet, 1968, 1977). In East Africa creodonts were still present in the middle Miocene, approximately 14 million years ago (Savage, 1965, 1978), while in North Africa a specimen was found in beds that may be as young as 12 million years (Savage, 1978; Cooke, 1978). By contrast in Pakistan there were at least four genera of hyaenodontids as recently as 12 million years ago. The recently discovered mandible was found in situ by Grant Meyer (then of the Yale A recently discovered hyaenodontine mandible from the Nagri Formation of northeast- ern Pakistan extends the stratigraphic range of the Creodonta into a considerably younger geological period than previously known. An estimated age of eight to nine million years (N. M. Johnson, pers. comm.) makes this specimen two or three million years younger than the proviverrine Dissopsalis carnifex Pilgrim, previously the youngest known hyaenodontid (Pilbeam et al., 1977). By comparison hyaenodontids apparently became extinct in North America during the early Arikareean Land Mammal Age at approximately 27 million years (Macdonald, 1970; Mellet, 1977); in Eu- rope during the middle Miocene (Helbing, 1925); and in Central Asia in the middle or late Oligocene (Mellet, 1968, 1977). In East Africa creodonts were still present in the middle Miocene, approximately 14 million years ago (Savage, 1965, 1978), while in North Africa a specimen was found in beds that may be as young as 12 million years (Savage, 1978; Cooke, 1978). By contrast in Pakistan there were at least four genera of hyaenodontids as recently as 12 million years ago. The recently discovered mandible was found in situ by Grant Meyer (then of the Yale Peabody Museum) at Yale-Geological Survey of Pakistan locality Y311. Judging from the preservation of a delicate predepositional fracture on the ascending ramus there is little possibility the mandible has been reworked. Locality Y311 is one of the richest localities yet found by the Yale-GSP group and is undoubtedly the same locality from which many fossils of Pilgrim's "Nagri Stage" fauna came (Pilgrim, 1939). This locality has also been worked by Dehm and von Koenigswald (Pilbeam et al., 1977). Locality Y311 is located in the type section of the Nagri Formation near the village Sethi Nagri. The locality has been dated by paleomagnetic methods at between 9.7 and 8.3 million years (N. M. Johnson, pers. comm.). The fauna is highly varied and includes among the mammals Sivapithecus indicus, Gigantopithecus cf. G. bilaspurensis, Percrocuta carnifex, the small bovid Elachistoceras khauristanensis (Thomas, 1977), and Hipparion (s.l.), as well as a probable para- doxurine carnivore. Other mammal

groups still being studied include several suids and bovids, giraffes, anthracotheres, tragulids, rodents, rhinoceroses, and a deinothere. At least one bird has also been recovered. The ecological affinities of this fauna are not clear.
Key words: Palaeontology, vertebrates, Miocene, siwaliks.

B/106. Barry, J.C., 1983a. Biostratigraphic problems of the Siwaliks of the Potwar Plateau of Pakistan. Geological Bulletin, University of Punjab 18, 68-73.

Pilgrim's faunal zones of Neogene terrestrial sediments of Potwar are rejected. Instead biostratigraphic interval-zones are proposed, based on extinction of fauna. Four interval-zones, each of 2 m.y. duration, are characterized.
Key words: Biostratigraphy, siwaliks, Potwar Plateau.

B/107. Barry, J.C., 1983b. Herpestes (Viverridae, Carnivora) from the Miocene of Pakistan. Journal of Palaeontology 57, 150-156.

Fossil remains of small canivores from Pakistan are referred to as Herpestes, the common mangoose of Asia and Africa. The material belongs to three separate, but indeterminate species. The oldest species may be as old as 10 million years, while the youngest is 7 million years. These specimens are the first fossil records of Herpestes in Asia and may be the earliest record of the genus.
Key words: Palaeontology, vertebrate, siwaliks, Potwar.

B/108. Barry, J.C., 1984a. A summary of data file structure and data standards for the Yale-GSP Project-Siwalik fossil collections. In: Shah, S.M.I. & Pilbeam, D. (Eds.), Contributions to the Siwalik of Pakistan. Geological Survey of Pakistan, Memoir 11, 71-77.

Key words: Palaeontology, fossil collection, siwaliks.

B/109. Barry, J.C., 1984b. Middle Siwalik biostratigraphy of the Khaur region in northern Pakistan. Geological Survey of Pakistan, Memoirs, 11, 9-13.

Biostratigraphy of the middle siwalik of the Khaur area of Potwar is described. For comparison see Barry et al. 1980.
Key words: Biostratigraphy, siwaliks, Potwar.

B/110. Barry, J.C., Behrensmeyer, A.K. & Monaghan, M., 1980. A geologic and biostratigraphic framework for Miocene sediments near Khaur village, Northern Pakistan. Peabody Museum Natural History, Yale University, Postilla 183, 1-19.

This is a summary of the biostratigraphy of Miocene Siwalik molasse sediments near Khaur. The text is accompanied by three figures and three tables.
Key words: Biostratigraphy, Miocene, siwaliks, Potwar.

B/111. Barry, J.C. & Cheema, I.U., 1984. Notes on a small fossil collection near Gali Jagir on the Potwar Plateau of Pakistan. In: Shah, S.M.I. & Pilbeam, D. (Eds.), Contributions to the Siwalik of Pakistan. Geological Survey of Pakistan, Memoir 11, 15-18.

Key words: Palaeontology, siwaliks, Potwar.

B/112. Barry, J.C., Jacobs, L.L. & Kelley, J., 1986. An early middle Miocene catarrhine from Pakistan with comments on the dispersal of catarrhines into Eurasia. Journal of Human Evolution, 15 (6) 501-508.

An isolated catarrhine primate molar from the Kamlial Formation of northern Pakistan is shown by magnetic polarity stratigraphy to be 16.1 My old, making it the oldest securely dated catarrhine in Eurasia. It is most similar to small catarrhines from East Africa and China, particularly Micropithecus Fleagle and Simons, 1978, and Dionysopithecus Li, 1978. It is distinctly different from European pliopithecids, suggesting that the dispersal of catarrhines into Europe and Asia, while broadly contemporaneous, took place in the context of at least partly independent immigration events. In terms of morphology, the specimen sheds no more light on the ancestry of gibbons than do other small early Miocene catarrhines with a phenetic resemblance to gibbons. However, as part of the Siwalik Miocene provincial fauna which has clear affinities with the modern fauna of Southeast Asia, it is perhaps a more likely candidate for gibbon ancestry than other purported gibbon ancestors.
Key words: Magnetostratigraphy, palaeontology, siwaliks, Potwar.

B/113. Barry, J.C., Johnson, N.M., Raza, S.M. & Jacobs, L.L., 1985. Neogene mammalian faunal change in southern Asia: correlations with climatic, tectonic and eustatic events. Geology, 13, 637-640.

The fluvial Neogene Siwalik formations of northern Pakistan span long time intervals with only minor hiatuses and, being highly fossiliferous, are uniquely suited for studies of change in mammalian faunas. Magnetostratigraphic correlations of a critical stratigraphic section give dates for 45 middle and late Miocene biostratigraphic events. These mark either first appearances or extinctions in the mammal fauna and show that in the Siwaliks there were major fauna turnovers at between 20 and 16 Ma and at 9.5 and 7.4 Ma. Two minor faunal events are dated at 13.2 and about 12 Ma. Many species making their first appearance were immigrants from Europe or Africa and indicate when connections to those regions existed. Immigration and extinction were the dominant modes of faunal change; in situ evolution was much less important. The Siwalik biostratigraphic record correlates closely to climatic, oceanographic, and tectonic events, which probably controlled immigration into southern Asia. Abiotic events were therefore important factors affecting evolution of the mammal communities.
Key words: Palaeontology, tectonics, biostratigraphy.

B/114. Barry, J.C., Lindsay, E.H. & Jacobs, L.L., 1982. A Biostratigraphic zonation of the Middle and Upper Siwaliks of the Potwar Plateau of northern Pakistan. Palaeogeography, Palaeoclimatology, Palaeoecology 37, 95-130.

Two biostratigraphic reference sections are designated for the middle and upper Siwalik formations of northern Pakistan. The stratigraphic ranges of 41 mammalian taxa are established in the reference sections and the two sections are correlated to each other and to the standard Magnetic Polarity Time Scale by the magnetic-polarity stratigraphy. The resulting stratigraphic and magnetostratigraphic framework is used to define four contiguous biostratigraphic interval-zones. The proposed interval-zones are bounded by five important faunal events which are identified in the reference sections. The four proposed interval-zones and the approximate ages in the reference sections of their lower and upper boundaries are: (1) the “Hipparion s.l.” Interval-Zone 7.4–9.5 m.y. B.P.; (2) the Selenoportax lydekkeri Interval-Zone 5.3–7.4 m.y. B.P.; (3) the Hexaprotodon sivalensis Interval-Zone 5.3-2.9 m.y. B.P.; and (4) the Elephas planifrons Interval-Zone 2.9-1.5 m.y. B.P. The paleomagnetic and biostratigraphic evidence indicates that the Tatrot Beds, from which Pilgrim developed his “Tatrot Faunal Zone”, are between 2.5 and 3.4 m.y. B.P., with a preferred maximum age of 2.9 m.y. B.P. The biostratigraphic evidence indicates the Sethi Nagri locality (Y311)—the primary source of Pilgrim's “Nagri Faunal Zone”— is in the “Hipparion s.l.” Interval-Zone. The paleomagnetic evidence suggests an approximate age of 9 m.y. B.P. A major faunal event at 9.5 m.y. B.P. introduced equids, suids, and large giraffes from Eurasia into the Indian subcontinent. A second, more diffuse faunal event between 5.3 and 2.9 m.y. B.P. introduced several African taxa as well as Eques and cervids from Eurasia.
Key words: Biostratigraphy, magnetostratigraphy, siwaliks, Potwar.

B/115. Barry, J.C., Morgan, M.E., Flynn, L.J., Pilbeam, D., Jacobs, L.L., Lindsay, E.H., Raza, S.M. & Solouniass, N., 1995. Patterns of faunal turnover and diversity in the Neogene Siwaliks of northern Pakistan. Palaeogeography, Palaeoclimatology, Palaeoecology 115, 209-226.

The fluvial Neogene Siwalik formations of northern Pakistan contain a long and richly fossiliferous sequence of terrestrial vertebrate faunas in which patterns of faunal turnover and changes in diversity can be documented and analyzed for intervals having durations of 0.5 m.y. The complete sequence extends from circa 18.5 to 1 Ma, but the part between 18.5 and 5.5 Ma is best sampled, and most intervals within it are well represented.
Thirteen orders of Siwalik mammals have been identified, with well-sampled intervals having 50 or more species. Most Siwalik mammals, however, are either rodents or artiodactyls. Bovids are the most common and most speciose of the larger mammals, while murid and "cricetid" rodents dominate the small mammal assemblages.
Between 18.5 and 5.5 Ma species diversity varied considerably. Among artiodactyls and rodents the number of species first increased between 15 and 13 Ma and then fell. Data on stratigraphic ranges of rodents and artiodactyls show that faunal change in the Siwaliks was episodic, occurring during short intervals with high turnover followed by longer periods with considerably less change. Maxima of first appearances occurred at approximately 13.5 and 8.5 Ma, while maxima of last occurrences were at 12.5 and 8.0 Ma.
Some of the observed faunal events can be correlated to climatic and environmental changes. The Middle Miocene diversification occurred during a period of global cooling, while the latest Miocene decline in diversity and increased turnover accompanied oxygen and carbon isotopic changes that correlate to globally increasing seasonality and aridity. Other correlations are ambiguous. The marked decrease in diversity and the major turnover events between 13 and 8 Ma do not correspond to known local or global events.
The Neogene Siwaliks and Paleogene Bighorn-Crazy Mountains sequence in Wyoming and Montana share many similarities. They have equivalent levels of temporal resolution and similar levels of completeness of their fossil records. Siwalik ordinal abundance and diversity patterns differ markedly from those of the Paleogene, but generic, and probably species, diversity was approximately the same, although the Siwalik faunas may have been slightly less diverse. Over time, changes in diversity were of comparable magnitude, with monotonic trends persisting for more than 5 million years. The magnitude of faunal turnover was also similar, ranging from less than half to 3.5 times that expected. In both sequences faunal change appears to have been episodic, with strong pulses between intervals of low turnover. The Siwaliks, in contrast to the Paleogene sequence, may have had more distinct pulses and longer intervals between pulses. Neither sequence has peaks of first occurrences coinciding with peaks of last occurrences.
Key words: Palaeontology, biostratigraphy, siwaliks, Potwar.

B/116. Barry, J.C., Morgan, M.E., Winkler, A.J., Flynn, L.J., Lindsay, E.H., Jacobs, L.L. & Pilbeam, D., 1991. Faunal interchange and Miocene terrestrial vertebrates of southern Asia. Paleobiology, 17, 231-245.

Problems of stratigraphic completeness and poor temporal resolution make analysis of faunal change in terrestrial sequences difficult. The fluvial Neogene Siwalik formations of India and Pakistan are an exception. They contain a long vertebrate record and have good chronostratigraphic control, making it possible to assess the influence of biotic interchange on Siwalik fossil communities. In Pakistan, the interval between 18 and 7 Ma has been most intensively studied and changes in diversity and relative abundance of ruminant artiodactyls and muroid rodents are documented with temporal resolution of 200,000 years. Within this interval, diversity varies considerably, including an abrupt rise in species number between 15 and 13 Ma, followed by a decline in ruminant diversity after 12 Ma and a decline in muroid diversity in two steps at 13 and 10 Ma. Significant changes in relative abundance of taxa include an increase in bovids between 16.5 and 15 Ma, a decrease in tragulids after 9 Ma, and a very abrupt increase in murids at 12 Ma. Megacricetodontine rodents also decrease significantly at 12 Ma, and smaller declines -re recorded among myocricetodontine and copemyine rodents after 16 Ma. An increase of dendromurine rodents at 15.5 Ma is also observed. There is also a trend of progressive size increase among giraffoids and bovids throughout the sequence. We have also investigated relationships between biotic interchange and diversity, body size, and relative abundance, concluding that (1) the rapid increase in ruminant and muroid diversity was largely due to immigration, whereas in situ speciation had only a secondary role; (2) during intervals of increasing diversity, resident lineages did not have higher than average rates of in situ speciation; (3) during intervals with rising diversity, greater extinction did not accompany increased immigration; (4) during intervals with falling diversity, there may have been greater extinction in recently invading lineages; and (5) change in diversity was independent of changes in relative abundance and body size.
Key words: Palaeontology, magnetostratigraphy, biostratigraphy, siwaliks, Potwar.

B/117. Bartole, R., 1978. Structural lineaments of the Central Asian orogenic syntaxis from LANDSAT imageries. Atti Rend Accademy Nazionnale di Lincei, series VIII. 64(5), 485-489.

Key words: Structure, orogeny, syntaxis, GIS.

B/118. Bashir, M., 1992-93. Structure, stratigraphy, micropalaeontology and petrography of Jabri-Bodla areas Districts Haripur & Abbottabad, Hazara (NWFP), Pakistan. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 78p.

The Jabri-Bodla area lies in the Attock-Hazara fold-and-thrust belt of the northwestern Himalaya of Pakistan. Precambrian to Cenozoic sedimentary rocks are folded and imbricated during the Tertiary-Himalayan collision. The oldest exposed stratigraphic unit is the Precambrian Hazara Formation. The formation is composed of slates, shales and phyllites. The presence of ripple marks and graded bedding shows that the Formation is deposited in shallow water turbidity environments. The Middle Jurassic Samana Suk Formation, Late Jurassic to Early Cretaceous Chichali Formation and Early Cretaceous Lumshiwal Formation were deposited in shallow marine conditions. The late Cretaceous Kawagarh Formation was deposited in deep to shallow water shelf environment. The late Cretaceous to Early Paleocene uplift in the area caused the regression of the Tethyan Sea. The Tethyan regression initiated the deposition of ferruginous sandstone of the Hangu Formation. The lower Tertiary sequence of Early to Late Paleocene Lockhart limestone, Late Paleocene Patala Formation, Early Eocene Margalla Hill Limestone and Early to Middle Eocene Chorgali formation mark the complete cycle of transgression and regression of the Tethyan Ocean. The presence of early Paleocene to Late Eocene foraminiferal assemblage like globorotalia, globogorina, lockharia, assilina and nummulites in the limestones and shales of the Lower Tertiary sequence show the tropical sub-tropical open sea upper slope to outer shelf environments. The Paleocene-Eocene boundary cannot be marked on the basis of microfossils in the area because the Patala Formation lacks microfossils. However, the tentative Paleocene-Eocene boundary between the Patala Formation and the Margala Hill Limestone can be marked at the base of Margala Hill Limestone on the basis of first appearance of Early Eocene microfossils.

The structural analysis of the investigated area shows that the Precambrian to Eocene rocks record at least two major events of deformations i.e D1 and D1 deformation phases. The D1 deformation is divided into D1a and D1b deformation phases. The D1a is associated with the southeast-directed thrusts and southeast vergent F1 folds. The second phase of D1b deformation is related with the backsteeping of the major thrusts and northwest overturning of the major F1 folds. The northwest plunging F2 cross-folds are recognized as D2 deformation phase in the project area. These F2 cross-folds are related with the development of the Hazara-Kashmir syntaxis.

Key words: Structure, stratigraphy, palaeontology, petrography, Hazara.

B/119. Bashir, R.M. & Ahmed, Z., 1966. Report on Ambela area (Swat). M.Sc. Thesis, Punjab University, 89p.

The Ambela medium- to coarse grained granite covers a large area in Buner, which constituted the southern part of the former Swat State. Preliminary geology and petrography of the granitic and related rocks is given in this thesis.

Key words: Petrography, granites, Buner.

B/120. Basit, M.A., Hasan, S.K., Fazil, M. & Ahmed, Z., 1990. Total chlorine in Pakistan coal. Proceedings, First SEGMITE Conference on Industrial Minerals, Peshawar, 88-91.

The contents of chlorine, moisture, ash, volatile matter, fixed carbon, total sulphur and calorific values (BTU/Lb) are determined in coals in various parts of Pakistan, and the chlorine content is compared with averages of the coals from USA (Illinois Basin, eastern USA and western USA) and worldwide average. Total chlorine content as chloride in Makerwal is 155 ppm and in Kotli 1936.6 ppm, which are much much higher than those of the USA and the world.

Key words: Coal analysis, Makerwal, Salt Range, Kotli, AJK

B/121. Basra, M.A., 1994-96. Geotechnical studies for land slide problems along Karakoram Highway from Danyor to Aliabad. M.Sc. Thesis, Punjab University, Lahore, 124p.

This thesis mainly composed of the study of about land sliding along Karakoram Highway from Danyor to Aliabad. A brief description of other Geotechnical features is also included in the thesis. The Geological map shows the different types of socks present in the project area.
Detailed study has been made in the project area to collect the data about discontinuities as joints, which play the dominant role in case of sliding in hard rocks. This data has been plotted on equal-area stereonet to check the stability of the slopes. In case of sliding in soft material like alluvial fan, samples were collected and tested for detailed analysis. Finally, on the basis of this analysis, the road is classified into stable, potentially unstable and unstable regions.
Key Words: Engineering geology, landslides, Hunza, KKH.

B/122. Bassoulet, J.P., Boulin, J., Colchen, M., Marcoux, J., Mascle, G. & Montenat, C., 1980. L'evolution des domains tethysiens au pourtour du bouclier indien du Carbonifere au Cretace. BRGM memoirs, 115, 180-198.

This is not a Pakistan specific paper. It deals with the evolution of the Carboniferous to Cretaceous rocks of the Tethyan domains along the periphery of the Indian shield.
Key words: Tectonics, Tethys, Carboniferous, Cretaceous, Indian shield.

B/123. Bates, R.H., 1986. The Ulugh Muztagh. American Alpine Journal 28, 27-38.

For me the long quest began in 1966 on the slopes of Mount Russell in the Alaska Range, where I shared a two-man tent with Eric Shipton. Adams Carter had invited me to join him on an expedition and now we were sheltering from a week-long storm that drove in from the coast. Finally, we looked at each other and yawned.
"Eric," I said, "if you were doing everything all over again, what would you change?"
"Well, I certainly wouldn't spend six years trying to climb Mount Everest. That's too long for any mountain."
"What would you have done instead?"
"Somehow I would have got to the Ulugh Muztagh."
"The Ulugh Muztagh? What's that?"
"It's a big mountain in Central Asia—nobody knows how high—reached in the 1890s by an Englishman who surveyed it as being well over 25,000 feet. It's probably the hardest place in the world to get to, harder than the Antarctic, because the land around it is so high and nobody lives near it. Bill Tilman and I had hoped to get there but it is too far in."
That was all I knew about the mountain for years, but in 1973 I found that Nick Clinch had also talked to Eric. In no time, Nick and I decided to become partners in a quest: to get to the mountain, find its height and climb it—and together we began to push ahead. First Betsy Clinch, Nick's wife, found an article by an Englishman, St. George Littledale, in an 1896 issue of the Geographical Journal of the Royal Geographical Society. Littledale, his wife, his terrier and his nephew ("of Oxford University boating renown") in 1895 had passed the Ulugh Muztagh and surveyed it while attempting to reach Lhasa from the north. The article had a map showing his route from the Southern Silk Road into Tibet, and told how after three weeks on horseback they had reached the "Great Ice Mountain" (Ulugh Muztagh in Turki). Our next success was securing publicly available satellite photos of the mountain, showing great glaciers flowing out from it, but what we could not secure was permission from the Chinese to let us go there. In the days before ping-pong diplomacy we even tried to get permission for a joint China-Pakistan-U.S.A. expedition, under Pakistan leadership, but the Chinese turned that down too.
In February, 1979 in Beijing, I again applied, this time in person to Mr. Shi Zhan Zhun of the Chinese Mountaineering Association, but learned that "the area is not yet open to foreigners"; and annually thereafter we continued to apply until late January, 1985 when we learned that our mountain had suddenly been made available to somebody else. At this, Nick Clinch rose from a sick bed, flew to Beijing and discussed our previous negotiations. To our delight the Chinese agreed that the permission should be ours, but the agreement was not finally signed until May 30, and that only after Nick had made two more visits to China.
During the three months that followed, Nick Clinch, an old pro at organizing expeditions, showed his usual skill. By September 11, when the eight members of the expedition left by air from San Francisco, we were what we called a

“geriatric expedition.” I had told Nick I was by now too old to be any use, but he insisted on my going. The real climbers, in addition to Nick, starting with the oldest, were Pete Schoening (in charge of equipment), Tom Hornbein (also our doctor), Jeff Foott and Dennis Hennek. Peter Molnar and Clark Burchfiel, distinguished geologists from M.I.T, both with wide experience in China and Tibet, completed the party. The Chinese were supposed to have twelve climbers, but by the time we had flown to Beijing and on to Urumchi (Woolamoochi) the number had grown to 16, with 27 support personnel, including 12 drivers, a cook, 4 geologists, a doctor, a radioman, photographers, reporters, and so forth. This joint mountaineering expedition was to be the first the Chinese shared with Americans. (They had had only one previous joint expedition, one with the Japanese a few months before.) Also, as our Chinese hosts kept telling us, we were the first foreigners to be allowed into the southern part of the Xinjiang since Chinese Turkestan became part of the People’s Republic 30 years ago. Celebration of that event explained the size of our Chinese team, for ascent of the Ulugh Muztagh was to be a major part of the celebration activities. Chinese climbers are all paid professionals, and naturally success on the mountain was to be of the greatest professional importance to our partners.

Burchfiel and Molnar were already in China when the other six of us took off from San Francisco on September 11. We had 87 bags or boxes with us, including identical personal equipment items for eight Americans and twelve Chinese. In Beijing we were warmly greeted by old friends of the Chinese Mountaineering Association, who gave us a splendid banquet. It was here that we met Governor Tehmer of the Xinjiang; Lu Ming, head of the All China Sports Federation of the Xinjiang and our expedition’s overall leader (though she would not go to the mountain); and Wang Zheng Hua, in charge of transportation to and from the mountain, and of all Chinese on the mountain. He had led the recent attempt on Namcha Barwa.

In Urumchi, which we reached by air, we were generously welcomed again. It was here that we agreed on the purposes of the expedition: to climb the mountain, find its height, and whether or not it is a volcano. If it were, it would be the world’s highest. At Urumchi too, we checked the condition of our survey instruments. These consisted of a satellite surveyor (a computer that uses the Doppler effect to establish latitude, longitude and altitude), a Uniranger electronic distance measuring device (borrowed from Bradford Washburn of the Boston Museum of Science), a 7-crystal cluster to use with it (loaned by Cubic Precision), and a Kern T-2 theodolite and tripod loaned by the Thompson School, University of New Hampshire. All were in good shape, but when we opened the box whose bill of lading declared it held the antenna for the satellite surveyor, we found only spare parts. Someone had goofed. We were to leave at dawn two days later on our 1,100-mile safari to the mountain. We were shocked. It looked as if it would now be impossible to find the height of our mountain, a major responsibility of the expedition.

I won’t go into detail about what happened, but some brilliant work on the part of someone in the company, and by the Chinese Mountaineering Association in Beijing and Urumchi, ended with a jeep chasing us, three men taking turns driving night and day, and catching us near the point where they could no longer follow.

The 1100-mile drive to the mountain in seven huge army trucks, three land- rovers and two jeeps was in many ways the most interesting part of the expedition, but hard travelling. It took ten days, including two days off to work on the vehicles. At Korla, where we expected to find a small town, we instead found a city of 120,000, with ten hospitals, a tire factory, a washing machine factory, and so on. Beyond it a yellow brick road led us to Rojeng, formerly Charklik, where Marco Polo had stopped many centuries ago and Sven Hedin had wintered at the turn of the last century. From here we continued along the north side of the Altyn Tagh Range, finally crossing it on a beautifully engineered road. We also crossed the great Altyn Tagh fault before reaching a big asbestos mine, our jumping-off point. Now we headed out across the roadless desert, finding hard going for the trucks. After a night in a game warden’s house, the last habitation, we pushed on to Acchikul Lake, 40 miles long, where we saw brown-headed seagulls, Orongo antelope, wild asses, a number of yaks, bears, a wolf and a fox. On the second of October, long after the first view of our handsome peak, we crossed an arid valley, forced our way up a canyon and set up our Base Camp tents on the east side of the mountain at what we later learned was over 17,400 feet. Burchfiel and Molnar learned that the Ulugh Muztagh strictly speaking is not a volcano, though it is a result of volcanic processes*.

Our plan at Urumchi had been to hold a sort of short training camp at Base, testing one another’s skills, learning to work together despite language difficulties and becoming acclimatized, but Wang Zheng Hua was anxious to get to work on the mountain. After a flag raising ceremony involving the entire group, with Pete Schoening carrying the American flag, three Chinese went off to reconnoiter. The Chinese had been on the mountain for the first time a year before, when they had made a brief attempt to climb it. Accordingly we followed their choice of route, though a more thorough reconnaissance would have improved it. Soon all climbers began packing to Camp I, with every man responsible for carrying his sleeping bag, personal gear and a good load of expedition equipment, for there were no porters. At age 74, I was no longer good at load carrying and I determined to focus entirely on the survey and try to be useful at Base Camp thereafter.

By October 9 Camp I was well established at the snout of a glacier, reached by a climb over a rounded foothill and a descent of several hundred feet; and shortly afterward loads began to be cached five or six miles up the glacier at what was to be Camp II. Peter Molnar and Clark Burchfiel now showed the advantage of their acclimatization, built up during the past summer's geological expedition. They began to help the other load carriers. Hennek, Foott and Tom Hornbein were carrying big loads but Pete Schoening was getting over some sort of flu (which Nick caught later) and Nick is slow to acclimatize. Tom, as our climbing leader, was also working out routes and the logistics of where food and equipment would be needed, and how much.

Meanwhile our survey was moving along. All equipment had survived the rough bouncing around, and the Doppler Satellite Surveyor had by now been moved to a site on the great outwash plain below our canyon and left running. From there, despite a furious wind, Molnar, Burchfiel, Schoening and I completed our theodolite work. Peter Molnar's final computations from observations at three points on our seven-mile baseline, allowing for curvature of the earth and the difference between geoid height and sea level height, gave us at a much later date a final figure of 6,987 meters ± 10 meters for the higher peak—roughly a disappointing 23,000 feet.

On the 12th, Pete Schoening felt better and left Base Camp for Camp I. From then on he and Tom Hornbein spearheaded the route above Camp II, which by now had been occupied. Next day Nick Clinch returned to Base Camp with a bad cold that had settled in his chest and seemed more like pneumonia. He was utterly exhausted when he arrived and looked very ill. On the 13th Tom, Pete Schoening and Clark Burchfiel began putting in ice screws to fix the route to Camp III, but the wind was very bad. Weather continued bad with some snow on the 14th and wind and cloud on the 15th, but Pete and Tom moved higher and established a cache at 6,200 meters. At Camp II the next morning there was nearly a meter depth of blown snow and no possibility of climbing. On the 17th several Chinese and Jeff and Dennis returned to Base to conserve food packed to Camp II. They told of big drifts at II and development of potential windslab danger. We woke to light snow on the 18th, but the weather cleared and Foott, Hennek and several Chinese took loads to Camp II.

All of us by now were worrying about whether the mountain would be climbed in the time left to us. On the morning of the 19th I went with Zhou Zheng and the Chinese geologists to see where two continents had met long, long ago. We saw a mass of serpentine rock that had been sea bottom at the time Gondwanaland had pushed into southern Asia millions of years ago and formed India. The sea bottom had been thrust northward over the region of the Himalayas and even over the Kun Lun to reach its present position. On our return, to our great surprise, Foott and Hennek appeared at Base Camp. They were to have been our summit team, but a major misunderstanding had developed about the number of Chinese climbers they could safely lead to Camp III and higher. Original plans had been changed. At this point Foott and Hennek came down to Base. Nick, now feeling stronger, pushed back up to Camp II the same day, and Tom Hornbein and Pete Schoening came down to II to try to sort out the confusion. This put them out of position for an immediate summit climb. Tom had been pushing himself very hard and was not feeling well, and so after a discussion at II he continued on down to Base Camp to recuperate. Next day, October 20, the weather was perfect and so the Chinese at Camp III moved up to Camp IV within easy striking distance of the summit. Since bad weather was still likely any day and we had such a short time left, we urged Wang Zeng Hua to tell his man at IV not to wait for Pete Schoening, who was returning to III with Burchfiel and Molnar, intending to go for the summit on the 22nd. The night of the 20th-21 st two Chinese photographers lost the route near Camp IV, and were not found and brought in—too cold to speak—until three A.M. The members of the assault party were searchers, and the effort took a good deal out of them. They did not leave Camp IV until after lunch and did not reach the summit until 7:28. When they radioed the good news to Base Camp there was pandemonium, but we were all concerned about their getting down. They were Hu Fengling, Zhang Baohua, Ardaxi, Mamuti and Wu Qiangxing.

Pete Schoening and his companions at Camp III did not get the news that evening. They went to bed early, planning an early start so as to climb the peak and return the same day. When they waked at dawn on a clear, cold morning, however, they saw that there had been an accident. A figure was lying unmoving on a snowfield far below, while another, who seemed hurt too, was trying to pull him. That changed everything. You can't go for a summit when injured men you can help may be dying. They went down.

They reached the injured men at about the same time Nick Clinch did, for three members of the five who climbed the mountain had arrived in Camp II late the night before, but two were missing, and he had gone out to look for them. All had come down by a different route from the one they had used to go up—and after sunset! Both injured climbers had had a 500-meter fall. One of them, Hu, looked so badly hurt that Clinch and Schoening thought he might not live until they reached Camp II, but later it was determined that despite multiple bruises his worst injury was having badly frozen feet. His companion was badly bruised too, but somewhat better. Hu's friend Guo, our interpreter, had reached Hu before anyone else, and soon four Chinese and four Americans combined efforts and were able to get the injured ones across the ice and up to Camp II.

There was now no chance for a second climb of the mountain and the following morning (the 23rd) everyone on the mountain began moving to Base. Hu had to be carried, a process painful for him and for his carriers, while his companion and a third Chinese who had also had a fall were able to limp down on their own. It took a long time to get everyone down. Some arrived after midnight and Hu and his carriers did not get in until nearly seven on the morning of the 24th. Dennis Hennek and Tom Hornbein did marvelous work caring for them as they came in. Our interpreter at this point was so moved by the care the Americans were taking of the Chinese that he remarked, “Americans must be the kindest people in the world.”

On the 24th there was a great sorting and breaking camp, and next day after the Base Camp area was in large measure policed the long journey back began. It was far colder than when we had arrived, we were low on food and everyone was eager to get back. We drove straight to Acchikul Lake, stopping only to pick up a fuel cache, but stayed only long enough to gulp some quick-cooking noodles. It was dark now, but we all wanted to go on. Tom Hornbein and I, who rode in truck number six, will never forget that bumpy drive across the endless, snow-covered, deserted land, shining in the moonlight. Siberia can not be more desolate. At dawn we stopped for an hour or more at the warden’s cabin, then continued our hard driving to Mangyai Chen, which we reached 27 hours after leaving Base Camp. We were here a day, then drove on to Ro-jeng, where eight pretty dancing girls cavorted ahead of us as we marched two or three hundred yards through streets lined with people. Banners crossed the street exhorting people to “follow the example of the jaint (sic) expedition.” If they followed our example at the huge banquet that followed, the price of melons, pear-apples and all sorts of their delicacies must have soared, for we were very hungry. That day we continued on to Army Camp 34, where we were welcomed by another delicious banquet, which ended at one o’clock in the morning. Then on again towards Korla. Some 20 or 30 kilometers before we reached the city we found Lu Ming, the marvelous Chinese woman who was the joint leader, waiting for us. She hugged us all, with tears running down her cheeks, saying again and again, “Oh, I was so worried about you.” She told us of a celebration in Korla and she was right. Welcoming banners flew across the street and several thousand people lined the sides. Flashbulbs popped, firecrackers went rat-a-tat, big drums boomed, school children squealed, hollered or tootled horns, and pretty girls came up to pin rosettes on us and give us big bunches of artificial flowers. Heady stuff.

Then there was a further welcome at Urumchi, with Governor Tehmer, and the Party Secretary and others standing in the snow to greet us. Two days later came the big celebration. We put on the black suits and knitted red ties especially made for a magnificent victory banquet in the newly built Great Hall of the People. A whole roast sheep was wheeled in as a special expression of friendship, and Chinese and Americans ate, drank and danced together with a warmth and enthusiasm none of us will ever forget.

A few days later, after warm send-offs in Urumchi and Beijing, and still wearing our hats from Korla, we were on the way home. Long before our arrival, however, there had been a moment when Nick and I looked at each other, raised a glass and murmured, “To ERIC SHIPTON.”

Measurement of the Altitude of Ulugh Muztagh

The altitude and position of the Ulugh Muztagh were much easier to determine in 1985 than they were in 1895 because of the extraordinary array of new surveying equipment that has been developed in recent years. The Magnavox Company leased the party its latest position-finding Geoceiver, the University of New Hampshire loaned one of its light but precise Kern T-2 theodolites, and Boston’s Museum of Science loaned its Keuffel & Esser Uniranger electronic distance-measuring instrument.

Bob Bates, who was in charge of these observations, working closely with Bradford Washburn, made detailed surveying plans long in advance of the actual expedition, knowing with certainty that the peak was surrounded with a treeless desert which would make intervisibility of many survey stations extremely simple. Also the high desert atmosphere seemed to assure virtually perfect visibility (given good weather, which was rarely the case!).

Because the peak was too far from Base Camp to make a single direct electronic distance-measurement from there to its summit, it was planned to have three valley-survey-stations, arranged so as to have a precise baseline almost twice as long as the Uniranger’s 5-mile limit. The summit of the peak was also definite enough so that it could be clearly identified from all three stations without the need for installing a target on top-extremely lucky in view of the problems later encountered by the climbers who actually got there.

Using the theodolite and the Uniranger, a basic triangle was established with all three points intervisible and with both of the summits of the Ulugh Muztagh also visible from all three. The composite baseline was 10,460 meters (6.5 miles) long, giving excellent strength to this little survey network. The distances to the summit from these stations were 22, 18 and 14 km. (13.6, 11.2 and 8.7 miles).

The Magnavox Geoceiver was used to determine the geographical location of this base network, observing Doppler signals resulting from scores of passes by five navigation satellites. Unremitting cold, wind and cloudiness, as well as the 18,000-foot altitude, made this otherwise relatively simple work both miserable and difficult.

The results of the Doppler observations were computed for the expedition by the Defense Mapping Agency in Washington and the triangulation network computed and balanced by Prof. Peter Molnar.
This field work determined the altitude of the highest peak of Ulugh Muztagh to be 6987 meters (22,923 feet) with an estimated possible error of ± 6 to 10 meters. This is compared with the Chinese determination of the peak's altitude to be 6970 meters (22,867 feet)—and Littledale's 1895 estimate of 7723 meters (25,338 feet). The geographical coordinates of the Base Camp are now considered to be North Latitude: 36° 25' 09.235'7East Longitude 87° 29' 47.264".
Although the long-fabled Ulugh Muztagh did not turn out to be nearly as high as everyone had hoped it would be, it is still indeed a fascinating mountain massif in the midst of some of the world's most exciting geology.
A detailed account of these observations may be found in the full report of the expedition which is on file at the Library of the American Alpine Club in New York City.
Key words: Geography, Muztagh, Karakoram.

B/124. Baticci, G. & Poretti, G., 1988. Gravity models of the deep structures of the Karakorum Range. Abstracts, 4th Himalayan- Karakoram-Tibet Workshop, Lausanne, Switzerland, p. 8.

A gravimetric modeling of the Karakoram Range has been carried out taking into account all the geophysical data available. The regional behavior of the Bouger anomaly has been computed interpolating with 2nd order polynomial surface gravity data available in the area along the Hindu Kush and Karakoram mountain ranges.
Four two-dimensional orders have been considered along profiles crossing the Kohistan-Kashmir areas. The first along the 1978 DSS profile, runs from Nanga Parbat to Karakul in the USSR and takes into account the results of the seismic processing, establishing the possible average values of thickness and density for the upper crust underneath. The second model fits the residuals on the same profile and the remaining two on the profiles crossing the Kohistan island arc region. The modeling of the residual has been planned considering the geophysical and geological data available from surface observations and the surface measured and tabulated densities existing in recent literature.
These models fit reasonably well the field results for a discontinuity at 10-15 km depth. In order to get an acceptable regional model along the DSS profile, according to the data of seismic survey, it appears that the density of the upper crust must be higher than the standard 2.67 g/cm^3 value. The trend of the seismic layers fits the regional gravity anomalies with a density contrast of 2.25 gcm^3 between the upper and lower crust and 0.7 g/cm^3 between the lower and the upper mantle.
Key words: Gravity, structure, Karakoram.

B/125. Batool, A., 1996. Application of geoelectrical and hydrogeological parameters for groundwater investigation studies in the proposed area for Quaid-I-Azam University Housing Scheme Islamabad. M.Sc. Thesis, Quaid-i-Azam University, Islamabad.

As the title indicates, this is a geophysical and hydrological investigation for groundwater in the university housing scheme.
Key words: Geophysics, groundwater, Islamabad.

B/126. Beaux (De) O., 1935. Spedizione Italiana al Karakorum Comandata da S.A.R. il Duca di Spoleto (1929). Mammiferi. Atti Soc. Ligustica Sc. Lett. Genova, 14, 61-84.

Key words: Italian expedition, Karakoram.

B/127. Baud, A., Atudorei, V. & Sharp, Z.D., 1996. Late Permian and Early Triassic evolution of the northern Indian margin carbon isotope and sequence stratigraphy. Geodinamica Acta, 9, 57-77.

The Northern part of Great-India underwent an early rifting phase in the late Paleozoic, just at the end of the large scale Gondwanian glaciation. The beginning of the rifting processes is marked by large hiatus and discontinuities (paraconformities) between the early or middle Paleozoic sedimentary succession and the discontinuous middle-late

Permian Traps and transgressive sediments. The Northern Indian passive margin consists of the present High and Lower Himalaya and a small part of the Indian craton and their sedimentary cover. The Permian rift shoulder is located in the Higher Himalaya, with part being in the underthrusted Lower Himalaya. The rim basin landward of the shoulder) is well developed in the Pottawar -Salt Range area. From the rifting to the beginning of the drifting stages (early late Permian to late early Triassic time), the sedimentary evolution is characterized by three transgressive-regressive (T-R) second order cycles, two in the late Permian and one in the early Triassic. The break-up of the rift occurred during the second cycle (late Dzhulfian).

In the Salt Range area, these three T-R cycles have been subdivided in eight third order sequences, five sequences for the upper Permian and three for the lower Triassic.

At the end of Permian, hiatuses, gaps and local erosion of part of the margin are direct consequences of a first order relative sea-level fall; this is also the time of the largest extinction event of the Phanerozoic that deeply affected the carbonate productivity and the stratal patterns. With the following worldwide sea-level rise, a rapid and large scale transgression occurred in the early Triassic, well dated and recorded on the whole margin. High rate thermal subsidence gave way to generalized pelagic deposits about 2 My after the transgression.

Profiles of whole rock inorganic carbon and oxygen isotopes from Guryul Ravine and Palgham sections in Kashmir, Nammal Gorge and Landu sections in Trans Indus Ranges (Pakistan), Thini Chu section in Kali Gandaki Valley, Central Nepal are presented in connection with the sequence stratigraphic analysis. The upper Permian record of high positive δ^{13} C values are closely correlated with the second order T -R cycles and the third order sequences. The results presented in this study confirm the drastic drop of δ^{13} C from the high positive values that characterized the upper Permian to lower values in the lower Triassic time. Stratigraphic correlation problems in the lower Triassic using carbon isotope geochemistry are briefly discussed. A positive a 13 c excursion of 4-5%0 near the Smithian-Spathian substages boundary is observed for the first time.

The δ^{18}O values of samples from all the sections display major variations suggesting that the oxygen isotope record has been significantly affected by meteoric diagenesis, deep burial diagenesis or land monsoon signature.

Key words: Sedimentary, glaciation, Permian, Triassic, isotopes, sequence stratigraphy, Himalaya.

B/128. Beck, R.A., 1995. Late Cretaceous ophiolite obduction and Paleocene India-Asia collision in the westernmost Himalaya. Ph.D. Thesis, University of Southern California, Los Angles.

Some information from the thesis is extracted in the following two descriptions

Key words: Cretaceous, ophiolite obduction, collision, Himalaya.

B/129. Beck, R.A., Burbank, D.W. & Sercombe, W.J., 1995. Evidence for a very Late Cretaceous to Paleocene Collision between India and Asia: Paleogeographic, isotopic and climatic implications. Abstract Volume, 10th Himalaya-Karakoram-Tibet Workshop, (ETH Zurich) Switzerland.

The collision of India and Asia strongly influenced Cenozoic earth history. Decades ago it was argued that the Indian-Eurasian collision instigated not only the formation of the Himalaya, Karakoram and Tibet, but the wider deformation of Asia (Argand, 1924; Molnar and Tapponnier, 1975). Others have boldly suggested that the collision drove global plate reorganization (Patriat and Achache, 1984). Regardless of disagreements on the details, many would argue that the Indian-Eurasian collision was the most important tectonic event of the Cenozoic or even the latest Cretaceous (see Burchfiel and Royden (1991) for summary).

More recent research has suggested additional fundamental links between the Indian-Eurasian collision and the Earth’s oceanic circulation patterns (Stille, 1992), global biogeochemical cycles and the isotopic record (Raymo and Ruddiman, 1992; Edmond, 1992); Paleogene global warming (Kerrick and Caldeira, 1993; Beck, et al., 1994), Neogene global cooling, (Selverstone and Gutzler, 1993; Raymo and Ruddimari, 1992) and evolution (Jaeger et al., 1989). However, knowledge of the kinematics and timing of collision at several points along the Indian-Eurasian suture zone is necessary before hypothetical links between the collision and global change may be evaluated. A growing body of evidence from terrestrial paleomagnetism and sea-floor magnetic anomaly studies (Besse et al., 1984; Chen et al., 1993; Besse and Courtillot, 1988; Klootwijk et al., 1992), paleontology (Jaeger et al., 1989), stratigraphy (Cassaigneau, 1979; Tapponnier et al., 1981; Burg and Chen, 1984; Beck et al., 1995; Einsele et al., in press), radioisotope chronologies of metamorphism (Chamberlain et al., 1995; Searle et al., 1988; Spencer, 1993;

Tonarini et al., 1993), marine oxygen isotopes (Kerrick and Caldeira, 1993) and marine carbon isotopes (Beck et al., 1994) indicates that the Neo-Tethys was at least locally closed (our definition of collision) before the end of the Paleocene.

Evidence from several areas along the Indian-Eurasian suture zone suggests that the collision may have been relatively synchronous (i.e. latest Cretaceous to Paleocene) from NW Pakistan to Tibet (Bossart and Ottiger, 1989; Searle et al., 1987; Searle et al., 1988; Gaetani and Garzanti, 1991; Gaetani et al., 1983; Garzanti and Critelli, 1993). Some diachrony is likely, but its magnitude is unknown along the lndus-Tsangpo suture north of the Higher Himalaya. Diagnostic evidence regarding the timing of collision is difficult to find (Beck et al., 1995). Therefore further research regarding the kinematics and timing of collision is needed along the entire length of the suture.

We summarize the broad paleogeographic, kinematic, isotopic, and climatic implications of a Paleocene collision for Paleogene earth history in the context of recent research in the Waziristan and Kurram tribal areas of Pakistan's Northwest Frontier Province (Figure 1) (Beck et al., 1995). A graphic summary of our provisional, composite, tectono-stratigraphy for the NW Indian-Eurasian suture zone is shown in Figure 2. It is remarkably similar to that of the lndus-Tsangpo suture zone north of the Higher Himalaya (Gansser, 1964; Thakur, 1981; Sinha and Upadhyay, 1990; Searle et al., 1988, Gaetani and Garzanti, 1991; Gaetani et al., 1983).

The most important paleogeographic implication of an early collision is that pre-collisional India extended farther to the north and/or pre-collisional Asia extended farther to the south (Powell and Conaghan, 1973; Besse, et al., 1984; Besse and Couttillot, 1988; Achache, et al., 1983; Chen et al., 1993; Klootwijk and Bingham, 1980; Treloar and Coward, 1991) (Figure 3). Because our data are from the westernmost Himalaya, we cannot preclude the existence of early Eocene back-arc basins or small remnant oceans similar to the modern Mediterranean in areas to the east or south of our study area. Regardless, closure of the Neo-Tethys at any point would stop deep, through going, Neo-Tethyan ocean circulation between India and Asia. Loss of this component of circulation influenced the eastern Atlantic Ocean as recorded by an increase in marine $^{143}Nd/^{143}Nd$ values (Stille, 1992).

While the deep Neo-Tethys was at least locally closed by collision during the latest Cretaceous and Paleocene, a flexural marine foreland basin (Wells, 1984) formed via tectonic loading in front of the arc fragment/prism/trench complex as it was thrust onto the NW Indian craton (Yeats and Hussain, 1987; Gaetani and Garzanti, 1991; Bossart and Ottiger, 1989; Beck et al., 1998). At least one during the Late Paleocene, erosion regionally beveled the allochthonous Asian rocks before upper Paleocene shallow marine limestones were deposited above them (Davies, 1926, 1940b, 1950). The marine foreland basin gradually filled during the latter early Eocene with lacustrine, evaporitic and fluvial sediments (Wells, 1984, Pivnik and Sercombe, 1993) before a late middle Eocene transgression drowned the foreland and resulted in the deposition of regionally extensive shallow marine limestones (Davies, 1 926b, 1 937b; Wells, 1984; Meissner et al., 1974, 1975).

We reanalyzed the stratigraphic and paleontological work of Davies (1926,1940) in the light of plate tectonic theory and new biostratigraphic, lithologic and structural data from the Waziristan and Kurram tribal areas to provide a more rigorous chronology for the collision. Upper Paleocene and upper lower Eocene shallow marine limestones separate and date two discrete and significant phases of thrusting which transported parts of Eurasia onto India during the Paleogene (Beck et al., 1995). Our scenario is summarized in Figure 4. The unconformable upper Paleocene shallow marine limestones overlap deformed and eroded remnants of the prism/trench complex and Indian outer shelf/slope. Similar upper lower Eocene limestones higher in the sequence unequivocally tie the Asian rocks to the Indian craton before 49 Ma (Davies, 1926; Beck et al., 1995).

This refined timing for two major phases of collision (66-55.5 and 55.5-49 Ma), along the westernmost Indian-Eurasian suture, has larger implications regarding the Paleogene marine isotopic record and global climate change (Beck et al., 1994). The revised timing for collision is consistent with hypothetical mechanisms for well substantiated early Eocene global warming. One of the most provocative hypotheses is that of Kerrick and Caldeira (1992, 1993), which invokes the volatilization of carbonates during early Eocene Himalayan metamorphism. This hypothesis, in its purest form, might satisfy the marine oxygen isotopic record (δ^{18}Ocarb) (Douglas and Woodruff, 1981; Zachos, et al., 1992) via an increase in pCO_2 and sea surface temperature but would tend to shift marine carbon isotope values (δ^{13}Ccarb) in the wrong direction relative to what is observed (Beck et al., 1994) (Figure 5). Although the Kerrick and Caldeira hypothesis is not precluded by this observation it must be part of a larger system in which very large fluxes of ^{12}C-rich carbon entered the biosphere during the early Eocene (≈58-54 Ma) (Shackleton, 1987).

In view of the constraints imposed by the marine stable carbon isotopic record (Shackleton, 1987) and what little is presently known about the timing of collision, we have formulated an alternative hypothesis which links the Indian-Eurasian collision, the δ^{13}Ccarb and δ^{18}Ocarb records, pCO_2, and early Eocene global warming (Beck et al., 1994) (Figure 6). We suggest that ^{12}Cnch organic carbon exhumed from the active and passive margins during the collision was oxidized to CO_2, which entered the biosphere. New data regarding the organic carbon content of the largely eroded continental margins (Table 1) has allowed us to construct organic carbon budgets, reduced by the amount reburied in Paleogene Himalayan flysch (Table 2), which satisfy published mass balances based on δ^{13}Ccarb values for the interval (Shackleton, 1987). These imbalances in the late Paleocene/early Eocene carbon cycle exceed some published thresholds considered necessary for climate change by up to three orders of magnitude (Selverstone and Gutzler, 1993). Thus, our collisional organic carbon exhumation hypothesis might explain the rapid Paleocene-Eocene decline in S^{13}Ccarb values, contemporaneous global warming (Wolfe, 1990) arid decreasing δ^{18}Ocarb values.

If one considers the carbon and oxygen isotopic record of benthic foraminifera (δ^{18}Obenforam and δ^{13}Cbenforam) (Zachos et al., 1993) rather than bulk carbonates values (δ^{18}Ocarb and δ^{13}Ccarb) (Shackleton, 1987), it might be argued that δ^{18}Obenforam values began to decline up to a million years before δ^{13}Obenforam values. This relationship implies that organic carbon exhumation was not the only mechanism involved Paleogene global warming. Given the complex network of feedbacks within the Earth's biogeochemical system, this is not surprising. The net climate signal is the sum of many processes (Raymo and Ruddiman, 1992). Some of these processes may have had little or nothing to do with the Indian-Eurasian collision.

Nevertheless, in view of the new evidence, which indicates at least part of the collision occurred between 66 and 55.5 Ma, it is tempting to consider other tectonic-climatic mechanisms. The first, which comes to mind is a decline of (rather than an end to) Trans-Himalayan volcanism and the production of sulfate aerosols. Sulfate aerosols are powerful cooling agents (Rampino and Self, 1991): one volcanic eruption can cool the Earth's atmosphere by 3-5ºC for several years by reflecting a portion of incoming solar radiation (the "Pinatubo effect").

This hypothetical late Paleocene increase in global temperature due to a decrease in the "Pinatubo effect" is supported by existing geochronologic data. For example, volcanism in the Baluchistan-Afghan sector of the Trans-Himalayan arc declined markedly at 66 Ma with a few areas experiencing volcanism until 55 Ma (Debon et al., 1987; Wolfart and Wittekindt, 1980). Isotopic cooling ages indicate that magmatism in the Trans-Himalayan Batholith and Arc of what is now northern India and Tibet slowed between 60-50 Ma (Searle et al., 1988).

Deposition of the wide spread upper lower and lower middle Eocene "nummulitic" Tethyan limestones may have damped contemporaneous global temperatures through the storage of CO_2 as carbonate (Kerrick and Caldeira, 1993). Large quantities of organic carbon were contemporaneously sequestered in the Laramide basins of western North America and elsewhere, drawing down pCO_2, and driving δ^{13}Ccarb values upward. This phase of Rocky Mountain deformation may have been due in part to a global plate reorganization triggered by the Indian-Eurasian collision (Patriat and Achache, 1984). Further cooling of the Cenozoic Earth during the late Paleogene and Neogene could have proceeded due to deep subduction of carbon in the Alpine-Himalayan orogen (Selverstone and Gutzler, 1993) and/or the weathering of calcium silicates in the metamorphic core of the Himalaya and fertilization of the oceans during the Neogene according to the "Raymo hypothesis" (Raymo et al., 1988).

We hypothesize that the Indian-Eurasian collision may have been the dominant driver of the Earth's long-term (>1 My) climate throughout the entire Cenozoic by the following means: 1) Between as61 and as58 Ma the collision may have passively warmed the earth by extinguishing at least some explosive arc volcanism thus decreasing the "Pinatubo effect"; 2) From ≈58 to ≈54 Ma δ^{18}Obenforam and δ^{13}Cbenforam values decreased and imply that the rate of net organic carbon burial decreased (Shackleton, 1987; Zachos et al., 1993) which suggests that the collision may have actively warmed the earth further by exhuming organic carbon from the colliding continental margins and increased the greenhouse effect (Beck et al., 1994); 3) From ≈54 to ≈52 Ma δ^{18}Obenforam and δ^{13}Cbenforam values increased and imply that the rate of net organic carbon burial increased (Shackleton, 1987; Zachos et al., 1993) possibly due to deposition in the Himalayan foreland (Wells, 1984; Bossart and Ottiger, 1989; Burbank, et al., 1995) or other basins created by the collision; 4) From ≈52 to ≈48 Ma δ^{18}Obenforam and δ^{13}Cbenforam values were relatively stable and suggest that carbon storage in upper lower and middle Eocene Tethyan "nummulitic" carbonates and shales (Kerrick and Caldeira, 1993) and to a lesser degree subducted eclogitic rocks (Selverstone and Gutzler, 1993) may have set the stage for Neogene global cooling; 5) From≈48 Ma to ≈38 Ma δ^{18}Obenforam values steadily increased while δ^{13}Cbenforam values remained relatively constant and suggest that cooling was driven by modest rates of calcsilicate weathering rather than organic carbon burial (e.g. Raymo, 1994); 6) From ≈38 Ma to <20 Ma δ^{18}Obenforam values generally exceeded δ^{13}Cbentoram values and suggest that carbon was sequestered as carbonate because of high rates of calcsilicate weathering in the core of the Himalaya ("Raymo hypothesis") (see Edmond, 1992; Raymo, 1994), and to a lesser degree, as organic carbon (the "Monterey hypothesis" of Vincent and Berger, 1985; see Raymo, 1994).

Obviously some of these mechanisms overlapped in time and some acted in opposite directions with respect to the Earth's isotopic record and climate. However, it is the relative size of the associated chemical fluxes, which is important with respect to the Earth's long-term biogeochemistry (Berner, 1991; Edmond, in press; Edmond, 1992;

Raymo and Ruddiman, 1992; Raymo, 1994). Although the Indian-Eurasian collision was not the only event of the Cenozoic, its timing, magnitude and numerous interactions with the rest of the present lithosphere and biosphere, indicate that the hypotheses recounted above must be explored further in order to understand the long-term global context of the Himalaya, Karakoram, and Tibet.
Key words: Cretaceous, Paleocene, isotopic, climate.

B/130. Beck, R.A., Burbank, D.W., Sercombe, W.J., Khan, A.M. & Lawrence, R.D., 1996. Late Cretaceous ophiolitic obduction and Paleocene India–Asia Collision in the westernmost Himalaya. Geodynamica Acta, 9, 114–144.

Collision of the Kohistan island are with Asia at similar to 100 Ma resulted in N-S compression within the NeoTethys at a spreading center north of the Indo-Pakistani craton. Subsequent India-Asia convergence converted the Neo-Tethyan spreading center into a short-lived subduction zone. The hanging wall of the subduction zone became the Waziristan, Khost and Jalalabad igneous complexes. During the Santonian-Campanian (late Cretaceous), thrusting of the NW Indo-Pakistani craton beneath Albian oceanic crust and Cenomanian volcano-sedimentary complex, generated an ophiolite-radiolarite belt. Ophiolite obduction resulted in tectonic loading and flexural subsidence of the NW Indian margin and sub-CCD deposition of shelf-derived olistostromes and turbidites in the foredeep. Campanian-Maastrichtian calciclastic and siliciclastic sediment gravity flows derived from both margins filled the foredeep as a huge allochthon of Triassic-Jurassic rise and slope strata was thrust ahead of the ophiolites onto the Indo-Pakistani craton. Shallow to intermediate marine strata covered the foredeep during the late Maastrichtian. As ophiolite obduction neared completion during the Maastrichtian, the majority of India-Asia convergence was accommodated along the southern margin of Asia. During the Paleocene, India was thrust beneath a second allochthon that included open marine middle Maastrichtian colored melange which represents the Asian Makran-Indus-Tsangpo accretionary prism. Laterites that formed on the eroded ophiolites and structurally higher colored melange during the Paleocene were unconformably overlapped by upper Paleocene and Middle Eocene shallow marine limestone and shale that delineate distinct episodes of Paleocene collisional and Early Eocene post-collisional deformation.
Key words: Cretaceous, ophiolite, obduction, collision, Himalaya.

B/131. Beck, R.A., Burbank, D.W., Sercombe, W.J., Riley, G.W., Barndt, J.K., Berry, J.R., Afzal, J., Khan, A.M., Jurgen, H., Metje, J., Cheema, A., Shafique, N.A., Lawrence, R.D. & Khan, M.A., 1995. Stratigraphic evidence for an early collision between northwest India and Asia. Nature 373, 55-58.

The collision of India with Asia had a profound influence on late Cretaceous and Cenozoic oceanography, climate, fauna extinctions and the motion of at least some of the Earth's lithospheric plates. As the collision ended a period of rapid Indo-Asian convergence, a precise knowledge of its timing (when the crust of the neo-Tethys ocean was completely subducted, at some point along the plate boundary) is important for understanding its wider consequences. But current estimates of the collision age range from 65 to 38 Myr before present6, 8–11. Here we report the results of extensive biostratigraphic analyses from Waziristan and Kurram in northwest Pakistan, which show that accretionary-prism and trench strata were first thrust onto the northwest Indian passive margin after 66 Myr but before 55.5 Myr. After this time, volcanic-arc fragments, the accretionary prism, trench material and imbricates of the north Indian slope were raised to shallow water depths and overlapped by upper Palaeocene shallow-water carbonates and shales12–14, indicative of post-collision thrusting in this region. Finally, both the suture and the Indian craton were overlapped by continuous unconformable upper Lower Eocene shallow-marine strata, demonstrating that suturing was complete by 49 Myr.
Key words: Stratigraphy, collision, India, Asia.

B/132. Beck, R.A., Burbank, D.W., Shah, S.M.I. & Khan, I.A., 1987. Basin-scale isochronous paleocurrent study of chron 9 polarity interval, middle Siwaliks, Potwar Plateau, northern Pakistan. Abstracts, Mid-year Meeting, Society of Economic Paleontologists and Mineralogists, Austin, 6-7.

Key words: Paleocurrent, magnetic polarity, siwaliks, Potwar.

B/133. Beck, R.A., Sercombe, W.J. & Burbank, D.W., 1993. Structure, stratigraphy & geochronology of the Himalayan Indus-Tsangpo suture zone in NW Pakistan and E Afghanistan. Geological Society of America, Abstract Program, A-122.

Key words: Structure, stratigraphy, geochronology, Indus-Tsangpo suture, Himalaya.

B/134. Beck, R.A., Sercombe, W.J., Burbank, D.W., Khan, A.M. & Lawrence, R.D., 1995. Late Cretaceous ophiolite obduction and Paleocene India-Asia collision in the westernmost Himalaya. Abstracts, International Symposium on Himalayan Suture Zone of Pakistan. Pakistan Museum of Natural History, Islamabad, p. 3.

The northwestern edge of the Indian plate collided with the Kohistan and Asian blocks during the Paleocene. The closure of the intervening ocean and obduction of the ophiolites onto the Indian plate during the Late Cretaceous provide a supporting evidence.

Key words: Ophiolites obduction, collision, Himalaya.

B/135. Beer, E.J., 1923. Report on Swabi Marble, made for Frontier Marble Syndicate. (Reference from Coulson, A.L. 1973), Geological Survey of India, Record 71(3), 342p.

Key words: Marbles, Swabi.

B/136. Beg, I.R. & Samad, A., 1966. Thermometric analyses of some samples of Potwar area. Pakistan Journal of Scientific and Industrial Research 9, 150-155.

Key words: Thermometry, Potwar.

B/137. Beg, M.I., 1978. Geothermal energy, an inexhaustible sources of energy. National Seminar on Development of Mineral Resources, Lahore March 6-9, 1978, 174-182.

Key words: Energy, geothermal.

B/138. Beg, M.I. & Awan, A.Q., 1971. Statistical properties and petrography of the Misri Banda quartzite, Nowshera Tehsil, NWFP Geological Bulletin University of Peshawar 6, 82-89.

This paper presents the statistical properties and petrography of the Devonian and Carboniferous Misri Banda Quartzite. It occurs interbedded and overlying the Nowshera Formation of Siluro-Devonian reef complex. The statistical analyses show that most of the quartzite samples fall in the well-sorted range and are unimodal in their distribution. The size frequency curves show maximum sorting towards the coarse grades and skewness towards finer grades. Kurtosis values of size distribution range between 0.27 and 0.24.

Microscopic examination of several slides reveals that quartz grains, embedded in a carbonate matrix, are elongated with their longer axis being parallel to each other and to the longer dimensions of calcite/dolomite grains. Well-rounded grains of zircon, tourmaline, and other heavy minerals are present in lesser amounts. The high degree of textural and mineralogical maturity of the Misri Banda Quartzite and its association with the reef carbonates indicate a long history of transportation, reworking, and winnowing in shallow waters dominated by stable shelf environments. Statistical data, heavy mineral distribution, and field observations indicate that the Misri Banda Quartzite conformably overlying the Nowshera Formation and beds and stringers of quartzite, occurring interbedded with the reef carbonates are one and the same derived from a common source.

Key words: Sedimentary petrography, Misri Banda Quartzite, Nowshera Reef.

B/139. Behrensmeyer, A.K., 1979. Stratigraphy and environments of early hominoids. Abstracts with Programs, Geological Society of America 11(7), p.386.

Key words: Stratigraphy, hominoids, siwaliks.

B/140. Behrensmeyer, A.K., Quade, J., Khan, I.A., Roe, L. & Littore, C., 1997. Lateral variations in stable isotopes in paleosols of the Miocene Siwalik sequence, Pakistan. Abstracts with programs, Geological Society of America, Annual Meeting, p. A34.

Key words: Geochemistry, Miocene, siwaliks.

B/141. Behrensmeyer, A.K. & Raza, S.M., 1984. Procedure for documenting fossil localities in Siwalik deposit of Northern Pakistan. In: Shah, S.M.I & Pilbeam, D. (eds), Contribution to the Geology of Siwaliks of Pakistan. Geological Survey of Pakistan, Memoir 11, 65-70.

Key words: Palaeontology, siwaliks.

B/142. Behrensmeyer, A.K. & Tauxe, L., 1982. Isochronous fluvial systems in Miocene deposits of northern Pakistan. Sedimentology 29, 331-352

A Palaeomagnetic isochron dated at about 8.1 Myr BP and detailed lithostratigraph of a 40 m interval exposed along strike for 40 km establish the depositional patterns of two contemporaneous, interfingering fluvial systems in the upper part of the Meddle Siwalik sequence.

The two systems, referred to as the buff and blue-grey, differ in unit shape, lithofacies, bedding sequence, palaeocurrent direction and sand composition. Interfingering occurs along the south-west-north-east strike of the outcrops, with the palaeodrainage directions of the two systems generally perpendicular to this line. The axis of the blue-grey system, which deposited widespread sheet sands and silts, lay toward the south west end of the study area. The more complex axis of the buff system, which deposited shoe-string sand bodies and large volumes of silt and clay, lay toward the north-east. The source area for both systems was the rising Himalayan belt to the north and north-east of the study area. At maximum extent the blue-grey system occupied a channel belt at least 25 km wide. Channel belt widths and depths for the buff system are 1–3 km and 3–7 m, respectively. Current directions average 94° for blue-grey sands and 136° for buff sands. Blue-grey sands contain 20% more rock fragments and are otherwise less mature than buff sands.

The buff system shows a vertical pattern of avulsion, palaeosol formation and floodplain aggradation which we attribute to autocyclic processes of parallel rivers. The blue-grey system shows phases of erosion accompanied laterally by plaeosol formation, followed by valley fill and overflowing of interfluve surfaces. This pattern may be caused by allocyclic presses affecting the source area. We interpret the blue-grey system as a major drainage from the interior Himalayas (perhaps the ancestral Indus) and the buff system as a complex of smaller drainages along the mountain front which were probably tributaries to the bluegrey system.

Vertebrate fossils including hominoid primates from the area are almost exclusively associated with lithofacies of the buff system, and this probably reflects both taphonomic and palaeoecological differences between the two systems.

Key words: Paleomagnetism, stratigraphy, fluvial systems, siwaliks.

B/143. Behrensmeyer, A.K., Willis, B.J. & Quade, J., 1995. Flood plains and paleosols of Pakistan Neogene and Wyoming Paleogene deposits - A comparative study.
Palaeogeography, Palaeoclimatology, Paleoecology 115, 37-60.

Comparative study of fossil-bearing fluvial deposits in the Eocene Willwood Formation of northern Wyoming and the Miocene Chinji Formation of northern Pakistan indicate how tectonic and climatic processes operating at different scales controlled physical and chemical features of floodplain environments and affected preservation of the paleontological record.

The architecture of Willwood Fm. floodplain deposits represents a combination of avulsion-belt sediment packages and overbank sediments that formed alluvial ridges. The architecture of the Chinji Fm. floodplain deposits was controlled by widely distributed crevasse-splay deposition and floodplain topography. Similarities in individual paleosol-bounded overbank sequences from the two formations indicates that the internal structure of such deposits can be independent of channel belt proximity to areas of aggradation. Chinji Fm. paleosols have little vertical zonation and show no consistent pattern of lateral change in relation to major channels, while overbank paleosols in the Willwood Fm, exhibit considerable soil horizon development and a pattern of increasing maturity from alluvial ridge to distal floodplain. The "pedofacies model" of Bown and Kraus (1987) based on such lateral trends in the Willwood paleosols is not applicable to the Chinji Fm.

Plant and animal fossils are abundant in the Willwood overbank deposits, with vertebrate remains concentrated in paleosol A horizons. Plant remains are rare in the Chinji Fm. and vertebrate fossils occur primarily in channel fills rather than in paleosols. These differences relate to contrasting patterns of floodplain deposition and to levels of oxidation that controlled penecontemporaneous recycling of organic material, particularly in paleosols. Different large-scale climatic and tectonic controls on temperature and rainfall, water table fluctuations, and soil biota are proposed to account for the differences in organic preservation. Large and small-scale environmental processes also affected spatial and temporal resolution of the organic record, resulting in important differences in the paleoecological and evolutionary information that can be reconstructed from the two sequences.

Key words: Sedimentology, fluvial deposits, Miocene, siwaliks, Wyoming.

B/144. Beiersdore, H., 1972. Schwermineraluntersuchungen an sedimenten aus West-Pakistan sowie vom angrenzenden Schelf. "Meteor"-Forsch. Ergebnisse C9, 74-83.

The paper describes heavy minerals in the sediments from former West Pakistan as well as from the adjacent shelf.

Key words: Heavy minerals, sediments.

B/145. Beinat, A., Eckart, M., Kettling, B., Marchesini, C., Marchesini, A., Palmieri, F., Poretti, G. & Puruckherr, R., 1997. Geodetic Surveys in the Pakistan Baltistan and new measurement of the height of Mount K-2. Abstract volume, 12th Himalaya-Karakorum-Tibet International Workshop, Rome, Italy, p.11.

In July-August 1996 GPS measurements along the profile from Skardu to Askole and to the K-2 Base Camp were performed. Along the route gravity and deflections of the vertical were measured. In the K-2 Base Camp Area, across the Godwin Austen glacier a topographic network was established with points on bedrock and on the moving glacier surface. A tripod with a sight target and two reflecting primes was installed at the top of K-2 in order to measure angles and distances from the points of the base network to the summit. Metereologic observations were performed to determine the atmospheric refraction coefficient. Taking into account the movements of the glacier it was possible to link the summit of Mount K-2 to the trigonometric network of Pakistan improving the accuracy of the height of the mountain compared with the past measurements.

Key words: Geodesy, Baltistan, K-2.

B/146. Beljaewski, N.A., 1947. On the geology of KaraKorum. Izvestija Akademii Nauk SSSR, Geological Series 3, 100-116.

Key words: Geology, Karakoram.

B/147. Bell, I., Gardner, J. & De Scally, F., 1990. An estimate of snow avalanche debris transport, Kaghan valley, Himalaya, Pakistan. Arctic and Alpine Research 22, 317-321.

Debris transport by snow avalanches in the front ranges of the Himalaya in northern Pakistan is described using estimates of sediment concentration in avalanche snow deposits. Data were collected from two end-of-season avalanche deposits in Kaghan Valley. Sediment concentration estimates and measurements of avalanche deposit volumes are used to produce estimates of total sediment load. From these, deposit area accretion values of 0.74 and 0.21 mm for the two deposits representing the 1986/87 avalanche season are derived

Key words: Glaciers, debris flow, sediment transport, Kaghan, Himalaya.

B/148. Beloussov, V.V., Belyaevsky, N.A., Borsive, A.A., Volvovsky, B.S., Volvosky, I.S., Resvoy, D.R., Tal-Virsky, B.B., Khamarabaev, I.K., Kaila, K.L., Narian, H., Marussi, A. & Finetti, J., 1980. Structure of the lithosphere along the deep seismic sounding profile: Tien Shan-Pamirs-Karakoram-Himalayas. Tectonophysics 70, 193-221.

During 1973–1977, as part of the International Geodynamic Project, some seismic investigations of the Earth's crust have been carried out by geotraverses of the Tien Shan-Pamirs-Karakorum-Himalayas. The seismic data obtained together with other geophysical information, allow the construction and interpretation of the lithospheric section through the Pamirs-Himalayas structure. This section includes thick crust with complex layering, supra-asthenospheric and asthenospheric layers of the upper mantle. The thickness of the Earth's crust increases from 50–55 km in the north, in the Ferghana depression (Tien Shan), to 70–75 km in the south, near the Karakul Lake (Northern Pamir). It varies within 60–65 km for the Central and Southern Pamir, Karakorum and the Inner Himalayas. Its thickness is least (35–37 km) in the south, under the outer margin of the Himalayan foredeep. Extreme gravity minima and depressions on the geoid surface correspond to the regions with maximum thickness of the Earth's crust. The centers of the disturbing masses on the geoid surface are located in the vicinity of the asthenosphere's upper layer; this determines the effect of the whole lithospheric layer, including its asthenospheric layer, at intense changes of gravity anomalies. The asthenospheric upper layer is recorded at a depth of about 120 km, its base at a depth of 200 km, in the northern and southern regions, and 300 km in its central part (Southern Pamir, Karakorum). In the middle asthenospheric layer, wave velocities decrease to 7.5 km/sec, under the base they increase to 8.4 km/sec and reach 9.4 km/sec at a depth of about 400 km. In the supra-asthenospheric layer of the upper mantle, longitudinal and shear wave-velocities slightly increase (by less than 0.1 km/sec) towards its base.

Key words: Structure, seismic profile, Tien Shan-Pamirs-Karakoram-Himalayas.

B/149. Beloussov, V.V. & Volvovsky, B.S., 1983. Geodynamics of the lithosphere of the Pamir-Himalaya region. Bollettino di Geofisica Teorica ed Applicata (Pamir-Himalaya Volume) 25, 147-149.

Key words: Geodynamics, Pamir, Himalaya.

B/150. Beloussov, V.V., Volvovsky, B.S., Volvovsky, I.S., Kaila, K.L., Marussi, A., Narain, H., Tal-Virsky, B.B., Finetti, I. & Khamrabaev, I.Kh., 1983. General features of the lithospheric structures of the southern Tien Shan, the Pamirs, Karakorum and the Himalayas. Bollettino di Geofisica Teorica ed Applicata (Pamir-Himalaya Volume) 25, 151-161.

Key words: Structure, lithosphere, Tien Shan-Pamirs-Karakoram-Himalayas.

B/151. Beloussov, V.V., Volvovsky, B.S., Volvovsky, I.S., Khamrabaeve, I.Kh., Kaila, K.L. & Marussi, A., 1984. Deep structure of Central Asia along the Tien-Shan- Himalayas Geotraverse. 27th International Geological Congress, Moscow, 1984, Reports, volume 15, Tectonics of Asia, 29-51.

This region comprises very high mountains, adjacent to which are depressions where crustal blocks have sunk to great depth. The region is characterized by very high heat flow negative gravity anomaly, and high seismic activity. The gravity field of the traverse reflects the zoning of the geological structure of the upper crust. The principal role in the development of deep gravity anomalies is played by the Moho interface, and only to a small degree by the upper mantle inhomogeneity. The seismicity of the lithosphere in the region is controlled by geodynamic processes

that are manifested in its upper part by crustal block movements, and in the lower lithosphere by displacement of steeply dipping mantle blocks. The region has high seismicity originating in the intermediate part of the Earth's crust.
All these facts show that geodynamic processes that occur at depth under the Pamir-Himalaya are complicated. The upper mantle has a low density. In the Pamirs, considerable upwelling of the anomalously heated material from the Earth's deep parts is quite possible. This heated material might move NW-ward to the Pamirs and Tien Shan along the "weak zones" asthenospheric channels. It is along this direction that tensile stresses in the earthquake source show a horizontal alignment. Fields of intensive stresses of mechanical and thermal origin may concentrate above such regions and particularly along their periphery, and their release may result in intensification of seismic activity.
Key words: Geophysics, structure, lithosphere, Tien Shan, Pamirs, Karakoram, Himalaya.

B/152. Belyaevsky, N.A., 1965a. Main feature of the geology of Karakorum (translated from Russian). International Geological Review 8, 127-143.

There have been several publications in Russian literature on the transect from Tien Shan and Pamir to Himalaya, through the Karakoram – Hindukush ranges. This paper gives a summary of the geological contributions on the geology of the Karakorum range.
Key words: Geology, Karakoram.

B/153. Belyaevsky, N.A., 1965b. Major Geological features of Karakorum. Soviet Geology 1, 54–75 (in Russian).

This document is not very different from Russian version of Belyaesky 1965a.
Key words: Geology, Karakoram.

B/154. Belyaevsky, N.A., 1976. Tectonics of the northern part of the Pamirs-Himalaya-Karakoram-Hindu Kush-Pamir. Atti. Convengni. Lincei 21, 29-42.

Key words: Tectonics, Pamirs, Himalaya, Karakoram, Hindu Kush

B/155. Bender, F.K. & Kazmi, A.H., 1995. Non-metallic raw materials. In: Bender, F.K., & Raza, H.A. (Eds.), Geology of Pakistan. Gebrcider Borntraeger, Berlin, 258-281.

The book, Geology of Pakistan, comprises papers on various aspects of geology of Pakistan. This particular paper deals with non-metallic minerals of the country. As can be seen, Pakistan is endowed with a fair number of non-metallic mineral occurrences.
Key words: Mineral deposits, raw meterial, non-metallic.

B/156. Bender, F.K. & Raza, H.A. (Eds.), 1995. The geology of Pakistan. Bietrage zur regionalen geologie der Erdd. Band 25, Berlin, Stuttgart: Gebruder Borntraeger, 414p.

This wonderfully done book is the first of its kind on the geology of Pakistan. It contains chapters by ten different authors. Following General introduction (Chapter 1: Raza and Bender); it covers Geological framework (Chapter 2: Bender, D. Bannert, Raza & F.A. Shams); Sedimentary sequence (Chapter 3: A.H. Kazmi); Igneous and metamorphic rocks (Chapter 4: Shams); Tectonics and structure (Chpater 5: Bender, Shams and Bannert); Palaeogeographic and geodynamics evolution (Chapter 6: Bender and Bannert); Energy resources (Chapter 7: Raza, Bender, H. Porth, Kazmi, Shams, F. Barthel and H. Fohse); Metallic raw materials (Chapter 8: Shams): Non-metallic raw materials (Chapter 9: Bender and Kazmi); Water (Chapter 10: Bender): Soils (Chapter 11: F.H. Gurneberg). There is an extensive bibliography spread over 53 pages, and includes papers published up to 1992. The volume is accompanied by three sheets of a wonderfully drafted geological map on a scale of 1:500,000 covering the western fold belt. The book is nicely illustrated with 140 figures, 38 tables and ten foldouts (some colored).
Key words: Bibliography, tectonics, palegeography, mineral resources, water, hydrocarbons.

B/157. Benn, D.I. & Owen, L.A., 1998. The role of the Indian summer monsoon and the mid-latitude westerlies in Himalayan glaciation: review and speculative discussion. Journal of the Geological Society, London 155, 353-363.

New dates for late Quaternary glaciations in the Himalayas show that, during the last glacial cycle, glaciations were not synchronous throughout the region. Rather, in some areas glaciers reached their maxima at the global glacial maximum of c. 18–20 ka bp, whereas in others glaciers were most extensive at c. 60–30 ka bp. Comparison of these data with palaeoclimatic records from adjacent regions suggest that, on millennial timescales, Himalayan glacier fluctuations are controlled by variations in both the South Asian monsoon and the mid-latitude westerlies.
Key words: Quaternary, glaciation, Himalaya.

B/158. Benson-Cooke, G., 1930. Oil occurrences in the north west Punjab. Petroleum Times 24, 613-615.

This is one of the earliest accounts on occurrence of oil in the Punjab province of the present day Pakistan.
Key words: Oil, Punjab.

B/159. Berthelsen, A., 1951. A geological section through the Himalayas. Meddelanden fra Dansk Geologiske Forendlingen 12, 102-104.

Key words: Geology, structure, Himalaya.

B/160. Bertrand, J.M. & Debon, F., 1986. Evolution tectonique polyphase de la chain du Karakoram (Baltoro, Nord Pakistan). Comptes Rendus Hebdomadaires de Seances de l'Academie des Sciences Naturelles 303, 1611-1614.

The paper describes polyphase tectonic evolution of the Baltoro region in central Karakoram.
Key words: Tectonics, Baltoro, Karakoram.

B/161. Bertrand, J.M., Kienast, J. & Pinardon, J., 1988. Structure and metamorphism of the Karakoram gneisses in the Braldu-Baltoro valley, North Pakistan. Geodynamica Acta 2, 135-150.

The structure and metamorphism of the Braldu-Baltoro area in the Karakoram is described.
Key words: Tectonics, metamorphism, Braldu, Baltoro, Karakoram.

B/162. Best, F., Gruber, G. & Kick, W., 1981. Das ende des Chogo-Lungma Gletschers 1979. Beobachtungen zu Veranderungen an einem der grossen Eisstrome des Karakorums mittels photogrammetrie (1902-1954-1970-1979). Zeitschrift fur Gletscherkunde und Glazia Geologie 17, 177-189.

The paper deals with major changes in the eastern Karakoram glaciation, notably that of Chogo-Lungma, using photogrammetry for the period 1902-1954-1970-1979.
Key words: Photogrammetry, Karakoram.

B/163. Bhatti, A.R., 1978. Geology, petrology and economic geology of Shangla Par-Alpurai area, Swat, with special emphasis on Basi granits. M.Sc. Thesis, Punjab University, 77p.

This area comprises low-grade sedimentary rocks. They contain a large body of ultramafic rocks which have been serpentinized.
Key words: Petrology, economic geology, Shangla, Swat.

B/164. Bhatti, K.J.A., 1981-82. Geology and petrology of Tangir Valley (District Diamer) with special emphasis on the mineralogy/petrology of the intrusives. M.Sc. Thesis, Punjab University, Lahore, 144p.

Tangir covers 351-km2 area located between Kohistan in the South and Yasin in the North. According to plate tectonic concept it lies in between Indo-Pakistan and Eurasian plates comprising a part of Kohistan Island Arc. The particular project area is mapped on a scale of 1:62500. In the thesis, an attempt is made to introduce the detailed Geology of the above area. Bulk geological sequence of the area is consisted of Norite, Diorite, Amphibolite, Granodiorite and Granite which is obducted on to the Paleozoic rocks of Indo-Pakistan plate in the south and subducted under the Eurasian plate towards the North. The Northern part of the area is in contact with Yasin Group, which is volcanic. So Tangir area constitutes the lower sequence of Kohistan Complex.
Key words: Petrology, Tangir, Diamir.

B/165. Bhatti, M.A., 1949. Orography and drainage of the Potwar Plataeu. Pakistan Geological Review 14(1), 2-16.

Bhatti has described in this paper, the geographical and geomorphological aspects of the Potwar plateau. Details of Orography and drainage pattern of the area are elucidated.
Key words: Geomorphology, drainage, Potwar.

B/166. Bhatti, M.A., Bajwa, M.S., Kausar, A.B. & Khan, A.A., 1985a. Geological map of Fateh Jhang (7 (43C/10)). Geological Survey of Pakistan.

Key words: Geological map, Fateh Jhang, Attock.

B/167. Bhatti, M.A., Bajwa, M.S., Kausar, A.B. & Khan, A.A., 1985b. Geological map of Kot Fateh Jhang (15 (43C/11)). Geological Survey of Pakistan.

Key words: Geological map, Kot Fateh Jhang, Attock.

B/168. Bhatti, M.A., Jafferi, S.E.H. & Majeed, S., 1980. Geology and petrology of Usheri Darra, District Dir, Pakistan. M.Sc. Thesis. Punjab University, Lahore.

The Usheri area is a part of the Kohistan magmatic arc which comprises mafic to silicis igneous and some sedimentary rocks. This paper deals with such rocks in the Usheri area.
Key words: Petrology, Usheri, Dir, Kohistan.

B/169. Bhatti, M.M., 1981-83. Micropaleontology and stratigraphy of the Jhalar-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: Palaeontology, stratigraphy, Kala Chitta, Attock.

B/170. Bhatti, M.T. & Khan, A., 1966. A survey of potash deposits in West Pakistan. Pakistan Journal of Scientific and Industrial Research 4 (1), 21-24.

Key words: Economic geology, potash deposits.

B/171. Bhatti, N.A., 1972. Phosporite deposits of Kakul-Mirpur area, Hazara district, NWFP. Pakistan. Geological Survey of Pakistan. Information Release, 51, 33p.

Key words: Mineral deposits, phosphorite, Abbottabad, Hazara.

B/172. Bhatti, N.A., 1983a. Chronostratigraphic position of Panjal Formation in Azad Kashmir: A stratigraphic discrepancy. Kashmir Journal of Geology 1, 117-118.

Reported occurrence of Permo-Carboniferous fauna from the Panjal Formation and an interbedded nature of the Panjal Formation within Sirban Formation of Cambrian age in Azad Kashmir is in discrepancy. This is only explainable in the event of two isolated phases of volcanic activity. However, re-examination of the contact relationship between the two units-the Panjal Formation and Sirban Formation may finally clarify this discrepancy.
Key words: Stratigraphy, Panjal Formation, Azad Kashmir.

B/173. Bhatti, N.A., 1983b. Cathodoluminescence study of the dolomitized phosphate of Hazara. Kashmir Journal of Geology 1, 122.

Petrological examination of some of the Mg bearing phosphate rock of Hazara exhibits an illustrative relationship of the Phosphate deposition and the dolomitization process. MgO is an undesirable impurity in the phosphate ore and its higher values than the permissible limitations render the ore uneconomical.
Cathodoluminescene refers to the emission of light during electron bambardment. Energy levels of the light thus emitted are characteristics of the individual material and correspond with the chemical compositional and textural changes. These changes within a material itself, which are not otherwise discernable, become distinguishable under cahtodoluminescence and are seen as variation in the intensities of the luminescence.
Different concentrations of Mg produce different colors and intensities in the phosphate rock. These colors and intensities are helpful in tracing the flow direction of the Mg bearing ions which in turn can be utilized in delineating the phosphate ore bodies of the low Mg content.
Cathodoluminescence can be an useful tool in locating the phosphate ore bodies of the desirable composition.
Key words: Phosphate, cathodoluminescence, Hazara.

B/174. Bhatti, N.A., 1983c. Deposition of phosphate in the Hazara Himalayas and the Precambrian glaciation. Geological Bulletin, University of Punjab 18, 18-21.

Tanakki Conglomerate in Hazara is located at the base of formation, which lies below the phosphate-bearing unit of Cambrian age. Though some diagnostic characteristics of mudflow as well as of aquatic preluvial sediments are evident in some parts of the outcrop but dominant compositional and textural features indicate this unit to be of glacial origin.
Regional stratigraphic location of Tanakki Conglomerate fits well into the global picture when viewed in the context of Late Precambrian glaciation. A broad correlation of Tanakki Conglomerate with Late Precambrian Tillites based on the comparison of dates from other continents and particularly from Tien Shan, China is proposed.
Considering various views on water cooling effects on the phosphate deposits, it is likely that Late Precambrian glaciation in this region could have contributed, though indirectly, towards deposition of phosphate in Hazara by raising the phosphorous concentration in the sea.

Key words: Phosphate, Hazara, Precambrian glaciation, Himalaya,

B/175. Bhatti, N.A., 1984. Deposition of phosphate in Hazara and its implication on the collision boundary. Abstract Volume, First Pakistan Geological Congress, Lahore, p.76.

The descriptive similarities of Hazara phosphate deposits with those of Tien Shan geosyncline of neighbouring Russia and China are remarkable. The Hazara phosphate as well as lien Shan geosynclinal phosphate deposition both are associated with Late Precambrian glacial tillites, manganifereous and volcanic sediments, and occupy an identical distribution with the same rock types in their regional stratigraphic column. They were effected by the same tectonic event-the Baikalian orogeny. All these similarities in the environment and the tectonics and their present-day proximity point out that Hazara phosphate as well as lien Shan geosynclinal phosphate were deposited in one and the same geosynclinal basin. It is most logical that these deposits have continuously occupied their position unchanged. As unchanged position of Hazara deposits with respect to contemporaneous phosphate deposits of lien Shan imply that Hazara is part of Eurasia continent rather than of the Indian subcontinent.
Key words: Phosphate, Hazara, tectonics, Himalayan collision,

B/176. Bhatti, N.A. & Alam, A., 1989. Heavy mineral analysis of stream sand samples from Gilgit Agency. Geological Survey of Pakistan. Information Release, 336, 11p.

Stream sand sampling was carried out in the report area of Gilgit Agency under the Mineral Exploration program of the Geological Survey of Pakistan. 34 samples were collected by panning the detrital sands from the tributaries of the Gilgit River covering a drainage area of about 2,500 sq .miles. Heavy mineral concentrates from these samples were examined for the identification of their mineral constituents and their percentage composition. This report provides the locations of these samples and their percentage of mineral constituents. Some anomalous values of certain minerals have been noted and as such, their pertinent areas of occurrence are recommended to be of consideration for further exploration work in the area .
Key words: Heavy minerals, Gilgit.

B/177. Bhatti, N.A. & Ghaznavi, M.I., 1984. A modification of Precambrian phosphogenic model. Abstract Volume, First Pakistan Geological Congress, Lahore, 76-77.

The study concerns regional deposition of phosphates and draws inferences regarding Precambrian plate tectonics.
Key words: Phosphates, tectonics, Precambrian.

B/178. Bhatti, N.A., Hasan, M.T. & Hussain, M., 1972. Phosphate deposits of Kakul Mirpur area, Hazara District, North West Froniter Province, Pakistan. Geological Survey of Pakistan, Information Release 51, 31p.

The phosphate deposits of the Hazara area have been studied by many workers because of their economic potential. This stud gives details of the occurrence and reserve evaluation of the deposits of Kakul-Mirpur area near Abbottabad.
Key words: Phosphates, Abbottabad, Hazara.

B/179. Bhatti, N.A. & Khan, A.M., 1992. Status of gemstone in North-West Frontier Province, Pakistan. Abstracts, First South Asia Geological Congress, Islamabad, 7-8.

The gem resources of North West Frontier Province of Pakistan comprises of variety of gemstones that are being processed and sold worldwide as Pakistani gems. These include exquisite deep green to bluish green emeralds from district Swat, rare variety of topaz in natural pink color from district Mardan and sky blue color of aquamarine from district Chitral. All form highly prized rough and cut gemstones as well as mineral specimen.
Detailed exploration in the remote areas of the province has also revealed occurrences of emerald or green beryl, garnet, jade and epidote from Mohmand and Bajaur agencies, rosy quartz, bicolor tourmaline, garnet and baryl from

Chitral and Corundum, and aquamarine and garnet from Dir area. These gem deposits could not be mined or developed either due to their poor quality and grade or due to their hostile location in the tribal agencies.
All the above mentioned gemstones are the result of the processes that were generated due to complex tectonic activities and are associated with pegmatites, hydrothermal veins and ophiolitic mélange.
Key words: Gemstone, NWFP.

B/180. Bhatti, N.A., Rashid, A.Z. & Quraishi, I.H., 1967. Beneficiation of low grade lead ore. Pakistan Journal of Scientific and Industrial Research 10, 112-115.

Key words: Lead, beneficiation.

B/181. Bhatti, T.H., 2000. Seismic reflection data interpretation of Mianwali East, Pakistan. M.Sc. Thesis, Quaid-i-Azam University, Islamabad, 34p.

A Seismic line oriented in SE-NW direction covering 32.35 km area was provided for interpretation by OGDCL. The seismic line 904 -MwI-009 is acquired in Mianwali (East) area (Pakistan). Out of total length, 15.3 km VP-1.1.0- to-VP 450 is studied in this dissertation. The average velocity contour map of the study area shows the lateral as well as vertical velocity variations where the lateral velocity variations are due to structural changes and vertical variations are due to change in lithology. Three reflectors have been marked and their depth is calculated using Dix average velocity and mean average line velocity method by using given RMS and interval velocity.
Key words: Seismic reflection, Mianwali.

B/182. Bhatty, M.J., Khan, J., Ahmed, J. & Karimullah, 1966. A survey of potash resources in West Pakistan. Science and Industry, Karachi 4(1), 21-24.

Key words: Mineral deposits, potash, West Pakistan.

B/183. Bhuiyan, K., Sualeheen, M. & Qurashi, M.M., 1963. A brief report on the current status of the collaborative investigation on some important iron ore deposits of Pakistan. Pakistan Journal of Scientific and Industrial Research 1, p. 87.

Key words: Economic geology, iron ore.

B/184. Bhutta, A.A., Siddiqui, S. & Butt, M.Q., 1987. Fossils of Leguminaeceae from Nagri of Salt Range, Punjab. Palaeobotany, Palynology Club, Pakistan, Bulletin. 1, 49-54.

The fossils of Leguminaeceae are described from the Nagri Formation of the Siwalik Mollase in the Salt Range.
Key words: Palaeontology, siwaliks, Salt Range.

B/185. Bignold, S.M. & Treloar, P.J., 1998. The Kohistan island arc, N. Pakistan: A geochemical perspective on arc stratigraphy. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 38-39.

The Kohistan terrane represents a Cretaceous arc initiated offshore of Asia as an intraoceanic arc. At ca 100Ma it was accreted to the southern margin of Asia, and subsequently behaved as a continental margin volcanic arc until being underplated by continental India at the initiation of the India-Asia collision.
Three main volcanic sequences have now been recognized in the arc: from the south, these are the Kamila Amphibolites, the Jaglot Group and the Chalt Volcanic Group. On geochemical criteria, Treloar et al., (1996) argued that the Kamila Amphibolites can be divided into two suites: one which predated the arc and has a chemistry typical of ocean plateaux, and one which relates to the erection of a supra-subduction fore-arc on the ocean plateau sequence. They argued that subduction was to the north, and that the bimodal Chalt Volcanic Group, which contains

deformed, pillowed lavas, some of which have basaltic komatiite-high Mg basalt to high-Mg andesite and boninite chemistry, was extruded into a back-arc basin. In contrast, (Khan et al., 1997) proposed that the direction of subduction was southwards, and that the Chalt Volcanic Group represents a fore-arc sequence, the Kamila Amphibolites forming a back-arc basin. In an attempt to resolve this difference, we present new geochemical data from both the Chalt Volcanic Group and Kamila Amphibolite sequences, as well as the first full data set for the Jaglot Group. Preliminary interpretation of these data shows a clear geochemical transition from the rocks of the Kamila Amphibolites to those of the Jaglot Group. This is consistent with the field evidence that the Jaglot Group rocks overlie the Kamila Amphibolites with a consistent northward dip.

Although all rock units have clear subduction-related chemical signatures, those of the Chalt Volcanic Group are distinctly different from the others. The boninitic geochemistry of some of these rocks, and in particular the rare earth element pattern, bears a close similarity to the boninites from the Eocene Zambales Ophiolite in the Philippines (Yumul, 1996) and the Group III lavas from the Limassol Forest Complex, Cyprus (Rogers, et al., 1989), which are characteristic of a supra-subduction zone setting in a primitive intraoceanic arc or incipient back-arc or marginal basin. Ongoing geochemical, isotope and modeling programmes should enable the erection of a model for the initiation of subduction, the evolution of magma source regions and the role of crustal contamination in magma evolution.

Key words: Geochemistry, stratigraphy, Kohistan arc.

B/186. Bignold, S.M., Treloar, P.J. & Petford, N., 1999. The Kohistan island arc, N. Pakistan: Identification of changing magma sources during intra-oceanic evolution. Terra Nostra 99, Abstract Volume, 14th Himalaya-Karakoram-Tibet Workshop Kloster Ettal, Germany, 15.

The Kohistan arc terrane was initiated offshore of Asia during the mid-Cretaceous as an intraoceanic island during the mid-Cretaceous as an intraoceanic island arc above the subducting Tethyan oceanic slab. At ca. 100 Ma it was accreted to the south margin of Asia, and subsequent behaved as a continental margin volcanic arc until being underplated by continental India in the early Tertiary.

Three main volcanic and volcano-sedimentary sequences are recognised from the intraoceanic stage if arc evolution. Modelling of geochemical differences from basaltic rocks from these sequences illustrates significant changes in magma source regions during arc evolution. The oldest sequence, the Kamila Amphibolites, are tholeiitic to calc-alkali basalts, erupted on to thickened, plateau-like oceanic crust. Trace element and REE chemistry have clear arc signatures. Modelling shows the basalts were derived by up to 16% melting of spinel lherzolite at between 30 and 80 km. Field and geochemical data demonstrate an apparent upward transition from this sequence into the Jaglot Group. Jaglot Group basalts are also tholeiitic to calc-alkali, but are interbedded with turbiditic volcaniclastic sediments, the proportion of sediment to volcanic rocks increasing eastward. Basalts in the west are chemically similar to those in the Kamila sequence. Those from the eastern part of the sequence are more enriched in the REE than in the west although both have similar patterns. Modelling shows these basalts were derived by high (>80-km) pressure melting of garnet lherzolite, differences in REE chemistries being consistent with lower percent melting in the west (8%) than in the east (12%). Basalts from the Chalt Volcanic Group in the north of the arc, which include tholeiitic, pillowed, high-Mg basalts and high-Mg andesites and boninites, have signicantly different geochemical signatures from basalts of the other sequences. In contrast to those, the Chalt basalts are H, REE-enriched relative to the LREE. Modelling suggests derivation through 10% melting of a cpx-depleted spinel-rich mantle at shallow depths, probably during back-arc rifting, above a north-dipping subduction zone.

On the basis of geochemistry and modelling there is no evidence for significant metasomatism of the mantle wedge in the source region. It is hence likely that differences in basalt chemistry reflect differences in depth of melting and of melt percentage, both of which can be related to either magmatic thickening of the arc or to extensional thinning.

Key words: Mid-Cretaceous, Kohistan arc.

B/187. Bignold, S.M., Treloar, P.J. & Petterson, M.G., 2001. The Chalt Volcanic Group, Kohistan, N. Pakistan: Formation of a small back-arc basin. Journal of Asian Earth Sciences 19, p.4.

The Chalt volcanic have passed through low-grade metamorphism and commonly display pillow structure. They are a prominent feature of the northern part of the Kohistan magmatic arc. They have been variously interpreted in term

of tectonic locale. This paper gives geochemical details in support of a small back-arc basin in which the Chalt volcanic originated.
Key words: Volcanics, Kohistan, Chalt.

B/188. Bilgrami, S.A., 1982. Mineral Industry of Pakistan. Resources for the Twenty-first Century, Resource Development Corporation, Karachi1, 68-178. US GS professional Paper 1193, 168-180.

Key words: Mineral resources.

B/189. Bilgrami, S.A., 1989. Far East: Pakistan, a review of mineral deposits; exploration, production and commercial aspects. Mining Journal Annual Review 103.

This account deals with the exploration, production and commercial aspects of the mineral deposits of Pakistan. Most of the commercially exploited minerals have been discussed.
Key words: Mineral deposits, exploration.

B/190. Bilgrami, S.A. & Farah, A., 1986. Plate tectonics and mineral potential of Pakistan. Die Naturwissenschaften in Pakistan, Deutsch-Pakistanisches Forum, 239-257.

It has now been agreed that plate tectonics have a bearing on the mineral deposits. In this document, with two figures and two tables, the authors describe in detail plate tectonics and mineral potential of Pakistan.
Key words: Tectonics, mineral deposits.

B/191. Bilham, R., Panth, G.B. & Jacoby, G.C., 1984. A preliminary study of ancient trees in the Hunza valley, and their dendroclimatic potential. In: Miller, K.J., The International Karakoram Project, Volume 2. Cambridge University Press.

Trees of great age are found on the high mountain slopes bordering the Hunza Valley and tributary valleys in the Karakoram Mountains. The survival of ancient trees is partly attributable to the enlightened local practice of culling branches for fuel rather than felling entire trees. We have subjected two specimens of juniper found at elevations of 3,800 m and 4,150m to ring analysis and determined maximum ring counts of 1200 and 479, respectively. The detection of incomplete rings in different radial sections from both specimens suggests that some rings may be missing and that the age of the trees may be more than their ring counts indicate. The lower and older of the two specimens consisted of a dead stump of unknown absolute age and an attempt to crossdate the specimen with the higher, living specimen was unsuccessful.
The two specimens are unlikely to be the oldest or most climatically sensitive trees in the region. We conclude that there is a strong possibility for deriving climatic information for the last several centuries from the ancient trees of the region. A knowledge of past climate has Important consequences in the study of glacial movements, erosion, and agriculture in the Hunza Valley.
Key words: Paleobotany, climate, Hunza valley.

B/192. Bilham, R. & Simpson, D., 1984. Indo-Asian convergence and the 1913 survey line connecting the Indian and Russian triangular surveys. In: Miller, K.J., The International Karakoram Project, Volume 1. Cambridge University Press.

In 1913 a 480-km long north-south triangulation survey was conducted across the Karakoram and Pamirs near the 73rd meridian. It spans more than one third of the zone of convergence characterizing the collision of the Eurasian and Indo-Australian plates and its remeasurement after more than 65 years is expected to reveal considerable crustal deformation.

This article discusses the errors associated with the 1913 survey and attempts to predict the magnitude and style of deformation that may have occurred since then. It is know that the original survey accuracy is associated with errors greater than $\pm 10^{-6}$ strain and that, unless a convergence rate of more than 6 cm/year has occurred, uniform compression of the survey line will be undetectable. At 73º E the Indo-Asia convergence is expected to be 4 cm/year. However, it is clear from historical and continuing seismicity that the convergence is not uniform and that locally large deformations may have occurred. Two areas appear particularly promising. These are the area just north of Gilgit and the area north of Lake Karakul in the Soviet Pamirs.
Key words: Neotectonics, geodetic survey, Karakoram

B/193. Billington, S., Isacks, B. & Barazangi, M., 1977. Spatial distribution and focal mechanisms of mantle earthquakes in the Hindu Kush-Pamir region: a contorted Benioff Zone. Geology 5, 699-704.

Seismological evidence based on the spatial distribution and focal mechanism solutions of mantle earthquakes in the Hindu Kush–Pamir region supports a model in which suboceanic lithosphere that existed between the converging Eurasian and Indian continents is subducted into the upper mantle. Two lines of evidence support this model. First, a careful selection of well-defined hypocenters in the region from 1950 through 1973 defines a thin (about 25 km thick) contorted Benioff zone within the upper mantle. The zone dips steeply (about 70°) toward the north in the western part of the region and has a shallower dip (about 50°) toward the southeast in the eastern part of the region. Second, focal mechanism solutions of intermediate-depth earthquakes have extensional (T) axes oriented parallel to the dip of the Benioff zone. The thin slab-like distribution of hypocenters and the downdip extensional stress are similar to features found in many other more typical regions of active lithospheric subduction. In addition, comparison of the focal mechanism solutions and the spatial distribution of earthquakes demonstrates the presence of a fault plane at about 200 km depth within the western part of the subducted lithosphere. Similar fault planes have also been observed in other areas of subduction. Comparison of the seismicity of the Hindu Kush–Pamir region with the apparent lack of mantle earthquakes along the main Himalayan arc suggests that the region is the site of the final stage of subduction of suboceanic lithosphere along the collision boundary between the Indian and Eurasian plates.
Key words: Earthquakes, seismology, Hindukush, Pamir.

B/194. Bilqees, R., 1995. Petrological studies of some phosphorite deposits of Hazara, Pakistan and their Economic importance. M.Phil. Thesis, University of Peshawar, 65p.

For details see the following account.
Key words: Petrology, phosphorite, Hazara.

B/195. Bilqees, R., Tanoli, S.K. & Hussain, V., 1995. Petrological studies of some phosphorite deposits of Hazara, Pakistan and their Economic importance. Abstracts, International Symposium and Field Workshop on Phosphorites and other Industrial Minerals, Abbottabad, 35-36.

Phosphorites occurring in Hazara are the only commercially workable deposits in Pakistan. These phosphorites are of sedimentary origin belonging to Cambrian age occurring in a number of localities in the area. The rock phosphate in Kakul area occurs in a folded and faulted sequence of Cambrian to Jurassic sediments. The geology of the area has been complicated by thrusts which have divided the phosphate bearing strata into a number of discrete thrust sheets. There are two phosphatic horizons in this area. The main occurrence is in the Abbottabad Formation where it is associated with chert and dolomite while, in Hazira it is associated with siltstone. Present studies are based on the phosphorite deposits of Kakul and Lambidogi belonging to Abbottabad Formation. Field and laboratory studies reveal that these phosphorites were formed» by the upwelling currents in the shelf environments. Later, when high energy conditions prevailed, this authegenically formed phosphate mud was reworked and pellets were formed. The associated dolomite is of secondary origin which probably was formed by the alteration of limestone, whereas chert was formed by the incorporation of silica. Hazara phosphorites are of good quality and the estimated reserves are about 20 million tones which are sufficient to fulfil the requirements of our phosphatic fertilizers in Pakistan. Despite known large resources of phosphorite in Hazara, its annual production is about 40,000 tones. The selective mining of rock phosphate is being done at Kakul thus leaving huge quantities of low grade ore as dump. There is a

need to undertake beneficiation and direct application studies for utilizing rock phosphate resources of the country more judiciously. Further, these deposits should be exploited at a faster pace and efforts should also be made to explore the new ones in this district. Encouraging results in these directions can be obtained when the provincial and federal governments provide or facilitate the necessary technical and financial Inputs to this phosphorite project, as has been done in case of Saindak metallic project in Balochistan.
Key words: Petrology, phosphorite, Hazara.

B/196. Bird, P., 1978. Initiation of intracontinental subduction in the Himalaya. Journal of Geophysical Research 83, 4975-4987.

Independent arguments based on topographic stress and crustal strength give upper limits of 200 bars and 300 bars, respectively, for the average shear stress on the intracontinental thrust fault that formed the Himalaya. According to either a one-dimensional or a two-dimensional fault model, such stresses could not have produced the Himalayan granites by friction, unless overthrusting velocity exceeded 30 cm/yr. More probably, Himalayan metamorphism was caused by exposure of continental crust to hot asthenosphere prior to the formation of the intracontinental thrust. Crust was exposed by peeling away of Indian subcrustal lithosphere in response to the force and moment exerted by the Tethyan slab. This detachment of buoyant crust from dense lithosphere better explains the metamorphic pattern and also explains why the distributed crustal shortening at the beginning of the collision orogeny was replaced by localized thrusting or intracontinental subduction.
Key words: Tectonics, subduction, Himalaya.

B/197. Bishop, M.P. & Shroder, J.F.Jr., 2000. Remote sensing and geomorphometric assessment of topographic complexity and erosion dynamics in the Nanga Parbat massif. 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, 181-200.

The dynamic mountains of the western Himalaya are the result of complex interactions involving tectonic, structural, lithological, climatic and surface processes. The multi-scale dynamics of surface processes in this region are largely unknown. This paper assesses the spatial complexities of the topography at Nanga Parbat, as we seek to understand erosion dynamics, differential denudation and the geodynamics of uplift and denudation. Spatial analysis of a high resolution digital elevation model and three-dimensional terrain simulation using satellite imagery indicate that the topographic complexity of Nanga Parbat is highly scale-dependent and exhibits a hierarchical order that is reflective of erosion dynamics. Observations and analyses reinforce prior understandings of rapid rates of uplift and high rates of surficial denudation. Results indicate that climate controls the topographic complexity of the massif although a tectonic influence is present and is largely masked by the overprinting of surface processes with time. Consequently, Nanga Parbat is seen to owe its origin to erosionally induced tectonic uplift and rapid surficial denudation. Rapid uplift altered erosion dynamics and further accelerated erosion resulting in extreme relief. Nonetheless, the differential denudation resulting from erosion dynamics does not appear to be in spatial balance with the regional scale tectonic mass flux. Systematic integration of dynamic models that account for the scale-dependencies of subsurface and surface processes are required to study the nature of this complex system and explain topographic evolution.
Key words: Remote sensing, geomorphology, Nanga Parbat.

B/198. Bishop, M.P., Shroder, J.F.Jr., Hickman, B.L. & Copland, L., 1998a. Scale-dependent analysis of satellite imagery for characterization of glacier surfaces in Karakoram Himalaya. Geomorphology, 21, 217–232.

Information regarding process-structure relationships and change in the Karakoram Himalaya is of great importance in studying glacier hydrology, mass balance, and dynamic environmental change. Such information is not readily available. Detailed spatio-temporal assessment requires field investigation coupled with quantitative remote sensing studies. We conducted an investigation of the large Batura Glacier in Pakistan to determine if spectral variability can be quantified and used to characterize glacier surfaces. Specifically, SPOT Panchromatic satellite data were evaluated for differentiating features of glacier structure resulting from ice movement, ablation, and supraglacial

fluvial action. Image semivariogram analysis was conducted for assessing spectral variability patterns and fractal analysis was used to examine scale-dependent variation in the data. Results indicate that spectral variability from fields of ice seracs can exhibit fractal characteristics, although most surface features on the glacier exhibit a change in the fractal dimension over different ranges in scale. The fractal dimension was found to be useful for differentiating between glacier surfaces such as white ice and debris-covered ice. Characteristics of the debris-load and the scale-dependent nature of calculating the fractal dimension ultimately determined the potential of class separability.
Key words: Remote sensing, geomorphology, glaciology, Karakoram, Himalaya.

B/199. Bishop, M.P., Shroder, J.F.Jr., Sloan, V.F., Copland, L. & Colby, J.D., 1998b. Remote sensing and GIS technology for studying lithospheric processes in a mountain environment. Geocarto International 13, 75-87.

Analysis of relationships between uplift and denudation in complex mountain environments requires integrated approaches using remote sensing and geographic information systems (GIS) analyses in combination with field investigations. We present multidisciplinary research focusing on the Nanga Parbat Himalaya of northern Pakistan. Remote sensing of the subsurface includes radio-echo sounding to investigate glaciers, magnetotelluric sounding, and seismic tomography to investigate shallow to deep aspects of the lithosphere. Remote sensing of the landscape includes satellite image acquisition, multispectral analysis, geomorphometric analysis of a satellite-derived digital elevation model (DEM), and the application of GIS and pattern recognition procedures to analyze topographic complexity and the geomorphology of the mountain massif. Detailed mapping requires topographic normalization of satellite imagery using the non-Lambertian model. Radar measurement of thicknesses of glacier ice, coupled with assessment of satellite imagery and field data, have enabled calculation of ice and sediment discharge. Collectively, scientific observations reinforce prior understandings of rapid rates of uplift and high rates of surficial denudation. The integration of data has thus enabled a systematic approach to study localized coupling between tectonic and surface processes. In future studies of this kind, it will become ever more important for geoscientists to integrate quantitative remote sensing and GIS into a standard analytical framework in order to solve complex problems.
Key words: Remote sensing, GIS, Nanga Parbat, Himalaya.

B/200. Bishop, M.P., Shroder, J.F.Jr. & Ward, J.L., 1995. SPOT multispectral analysis for producing supraglacial debris-load estimates for Batura Glacier. Geocarto International, 10, 81-90.

SPOT multispectral and panchromatic data were evaluated to determine their utility to detect debris-load characteristics of the Batura Glacier located in the Karakoram Himalaya. Debris-depth measurements, surface samples, and ground photography were obtained and used with satellite-derived information to produce supraglacial debris-load and discharge estimates. Visual analysis of panchromatic data indicated that structural characteristics of the glacier exhibited unique textures associated with surface structure characteristics. Multispectral analysis revealed that stratified unsupervised classification of principal components can be used to produce classifications depicting supraglacial lithology and shallow debris-load variability. Debris-load discharge estimates ranged from 48-97 x 103 m3 yr1. These results indicate that SPOT multispectral data may be used to produce reasonable quantitative estimates of debris-load characteristics for glacier mass balance and regional denudation studies.
Key words: Remote sensing, glaciology, Batura, Himalaya.

B/201. Blandel, F. & Marivier, L., 1952. Note on iron ores in Pakistan. 9th International Geological Congress, Algeria. Symposium on Iron Ore 1, p. 381.

The iron ores of Pakistan, including those from the Northern part, are described.
Key words: Iron ore.

B/202. Blasi, A., Brajkovic, A., De Pol Blasi, C., Forcella, F. & Martin, R.F., 1980. Contrasting feldspar mineralogy, textures and composition of Tertiary anorogenic and orogenic granites, Gilgit area, northwestern Pakistan. Neues Jahrbuch fur Mineralogie, Abhandlungen 140, 1-16.

Key words: Mineralogy, texture, granites, feldspar, Gilgit.

B/203. Blauwet, D., Smith, B. & Smith, C., 1997. A guide to the mineral localities of the northern areas, Pakistan. Mineralogical Record 28, 183-200.

Key words: Mineral guide.

B/204. Blisniuk, P.M., 1996. Tectonic evolution of the NW-Himalayan thrust front: Implications from sediment characteristics in the Trans-Indus Ranges, Northern Pakistan. Abstract volume, 12th Himalaya-Karakorum-Tibet International Workshop, Rome, Italy 13-14.

This paper presents the results of sedimentological, magnetostratigraphic and structural work constraining the latest Miocene to recent tectonic evolution in the area of the present-day NW-Himalayan thrust front. In the Trans-Indus Ranges of northern Pakistan, forming the western part of the NW-Himalayan thrust front, unconformities, changes in paleocurrent directions and locally derived conglomerates contained in syn-orogenic foreland basin deposits provide evidence for local deformation between ≥3.5 and ≥3 Ma. The tectonic history of the Trans-Indus Ranges has previously been described in terms of a well-documented single episode of major thrusting starting at ~1 Ma [e.g., Khan et al., 1998], thus the work presented here implies, instead, that there were two distinct phases of local deformation, at ~6 to 5 Ma and ≤2.5 Ma to present [e.g., Burbank and Beck, 1989], this study demonstrates that the presence of two phases of deformation during latest Miocene to recent time is a regional-scale phenomenon, and these two phases are probably correlative along the present-day NW-Himalayan thrust front.

In the Salt Range, the earlier deformation can variously be interpreted as either initial thrusting along the Salt Range Thrust [e.g., Burbank and Beck, 1989], or normal faulting in the foreland basin [e.g., Lillie et al., 1987]. However, in the Trans-Indus Ranges, the reconstruction of possible source areas for the locally derived conglomerates shows that the earlier deformation is much more likely related to normal faulting than to thrusting. In combination with other workers' flexural and gravity modeling [Duroy et al., 1989], the results present here suggest that the tectonic evolution in the area of the present-day thrust front is characterized by: 1) latest Miocene to early Pliocene north-dipping normal faulting in the footwall of the frontal thrust system related to flexure of the Indian plate in response to topographic loads emplaced to the north on older NW-Himalayan thrust, and 2) subsequent south-directed thrusting along the present-day thrust front, related to outward growth of the NW-Himalayan thrust wedge since the latest Pliocene. The geometry of the present-day thrust front appears to be largely controlled by normal faults and monoclines formed during the earlier deformation and acting as thrust ramps during the still active younger deformation.

This mechanism may not only be responsible for the basement offsets observed in the subsurface of the thrust front, but also for others that appears to have controlled the location of several other major structures underneath the NW-Himalayan foreland fold-and-thrust belt, e.g. the Northern Potwar Deformed Zone [Leathers, 1987], and structures on the Kohat Plateau [Pivnik and Sercombe, 1994]. Basement normal faults acting as structural ramps have also been observed in other areas along the Himalayan thrust front [Talkudar and Sudhakar, 1972] as well as in other orogens such as the Western Alps [Butler, 1989] and Ouachita Mountains in Arkansas and Oklahoma [e.g., Briggs and Roeder, 1975]. Therefore, the interplay between thrust stacking above basal detachment of fold-and-thrust belts and syn-orogenic flexural deformation beneath the detachment may be a more significant component of collision-related deformation than previously recognized.

Key words: Tectonics, sedimentology, Trans-Indus Ranges, Himalaya.

B/205. Blisniuk, P.M. & Saheed, G., 1993. The Tectonic evolution of fault systems with strong lateral variations in tectonic style: The Trans-Indus Ranges (Northern Pakistan). Abstract, Volume, 8th Himalaya-Karakoram-Tibet Workshop, Vienna, 62-63.

The main focus of this ongoing study is the structural evolution of fault systems with lateral variations in tectonic style between compression and transpression. Such fault systems have been recognized in many mountain belts. However, due to the complex pattern of deformation their formation is still poorly understood, and the tectonic interpretation of regions affected by this kind of deformation is difficult The Trans-lndus Ranges are part of the young and still active frontal thrust system of the NW-Himalayan foreland fold-and-thrust belt which is characterized by the occurrence of several pronounced structural re-entrants and promontories. Studies of such structurally complex fault systems in actively deforming regions are important because they can provide information that is usually not available in older mountain belts but necessary to understand the mechanics of their formation. A particularly attractive aspect of the ongoing project is the young age of deformation in the study area (< 1 Ma ?), which allows a very precise quantitative assessment of the rates of deformation. Furthermore, thermal and tectonic overprinting which has occurred in many older mountain belts is absent, and exposure is excellent in most of the region.

Preliminary results of a first field season in the Trans-Indus region (11/91 to 1/92) indicate that the emergence of the Trans-Indus Ranges was controlled by a system of frontal ramps that form the centers of re-entrants and promontories, and lateral or oblique ramps that form their edges. The Construction of balanced cross-sections shows that the total shortening along the frontal ramp segment represented by the western Khisor Range is on the order of at least 10 km. This suggests that the deformation along the lateral and oblique ramps is characterized by a strike-slip Component of similar magnitude. Pronounced bends of structures in the Khisor Range near the transition zones to adjacent regions of transpressive deformation suggest that vertical axis rotations occur in these areas. Structures show an apparent clockwise rotation near the western end of the Khisor Range, which is truncated by a right-lateral strike-slip fault, and an apparent counterclockwise rotation near its eastern end, which seems to be truncated by a left-lateral strike-slip fault. The sense of the apparent rotations is therefore compatible with the assumed relative motions along the lateral terminations of the Khisor Range. Alternatively, the observed bends could simply reflect a complex ramping geometry, in which case vertical axis rotations would not have occurred at all. Present fieldwork (12/92 to 3/93) therefore includes sampling for a paleomagnetic investigation to test these hypotheses.

With the exception of the results of our previous investigations in the Trans-Indus Ranges, quantitative data on the deformation in that region are not yet available. The main goal of our study therefore is a qualitative analysis of the structural style of deformation, and a quantitative assessment of the total deformation.

The area presently represented by the Trans-Indus Ranges was part of the Himalayan foreland basin and received synorogenic deposits during Late Neogene folding and thrusting further north, and was subsequently deformed as part of the hanging wall of the younger frontal thrust system in the south. The onset of deformation in the Trans-Indus region should be reflected by decreasing sedimentation rates of the more distal facies with a source area further north, and subsequent nondeposition and erosion, or deposition of proximal deposits that have the Trans-Indus Ranges as source area. Ongoing research therefore integrates sedimentological and chronostratigraphic studies of the synorogenic deposits with structural investigations in this area.

The structural portion of this work includes detailed field mapping to provide constraints on the style of deformation. This mapping also is the basis for the construction of balanced cross-sections that are needed to quantify the total amount of shortening along the Trans-Indus Ranges. The chronostratigraphic studies will include paleomagnetic age determinations of young synorogenic molasse deposits, and fission track dating of volcanic ashes within that sequence. These studies will provide information on the age ranges and deposition rates of syntectonic sediments. Together with sedimentological mapping of syndeformational unconformities, facies changes and paleocurrent analyses these results will constrain the temporal and spatial character of deformation in the NW-Himalayan foreland.

Key words: Tectonics, structural geology, Trans-Indus Ranges, Himalaya.

B/206. Bloemendaal, S. (Ed.)., 1983. Technical report on ground water resources in Kohat Plain, Kohat District, North West Frontier Province. Pak-Dutch Programme for Water Investigation in North West Frontier Province. Hydrogeology Directorate, Water and Power Development Authority, Report No. III-1, 57p.

Key words: Groundwater, Kohat.

B/207. Bloemendaal, S. & Vanenk, D., 1982. A computer model for safe yield assessment of the Talash Valley, North West Frontier Province, Pakistan. Hydrogeology Directorate Water and Power Development Authority.

Key words: Hydrogeology, Dir.

B/208. Bloemendaal, S. & Sadiq, M. (Eds.)., 1985. Technical report on groundwater resources in Maira area, Mardan and Peshawar districts-NWFP. Report IX-I. Hydrogeology Directorate, WAPDA-Peshawar, Pakistan & Institute of Applied Geoscience, TNO-DGV, DELFT-The Netherlands.

The report comprises nine chapters, 11 tables, nine figures, five plates and five appendices.
Key words: Hydrogeology, Groundwater, Mardan.

B/209. Blum, J.D., Gazis, C.A., Jacobson, A.D. & Chamberlain, C.P., 1998. Carbonate versus silicate weathering in the Raikhot watershed within the High Himalayan Crystalline Series. Geology 26, 411-414.

The major element and Sr isotope geochemistry of surface waters, bedrock, and river sands was investigated in the Raikhot watershed within the Himalayan Crystalline Series (HHCS) in northern Pakistan. Mass-balance calculations of mineral-weathering contributions to the dissolved flux of ions from the watershed indicate that 82% of the HCO3- flux is derived from the weathering of carbonate minerals and only 18% is derived from silicate weathering, even though the bedrock is predominantly quartzofeldspathic gneiss and granite with only 1% carbonate in the watershed. This study demonstrates the importance of rare amounts of bedrock carbonate in controlling the water chemistry of glacial watersheds. We suggest that the flux of Sr with a high 87Sr/86Sr ratio in the major Himalayan river may be derived in large part from weathering of trace amounts of clacite within the largely silicate HHCS. Models that use the flux of radiogenic Sr from the Himalayas as a proxy for silicate weathering rates may, therefore, overestimate the amount of CO2 consumption due to silicate weathering in the Himalaya.
Key word: Isotope geochemistry, weathering, Raikhot, Himalaya.

B/210. Blume, H., 1962. Pakistan, a geographical summary. Zeitschrift für Kulturaustausch 18; Stuttgart.

Key words: Geography.

B/211. Bogue, R.G., 1962. Chromite deposits near Hari Chand, Peshawar Division, West Pakistan. Geological Survey of Pakistan, Mineral Information Circular 20.

Key words: Chromite, Hari Chand, ultramafic rocks, Peshawar.

B/212. Bogue, R.G. & Schmidt, R.G., 1961. Bentonite deposits near Padhrar, Rawalpindi Division, West Pakistan. Geological Survey of Pakistan, Mineral Information Circular 3, 24p.

Key words: Bentonite, Rawalpindi.

B/213. Bohlin, B. & Norin, E., 1960. Zentralasiatische gebirgszusammenhange. Geologische Rundschau 50, 325-334.

This account summarizes the orogenic relationship of the central Asian mountain ranges.
Key words: Tectonics, Central Asia.

B/214. Bokhari, S.A.A., 1999. Potential of export of gems & jewelry from Pakistan. In: Brochure "Pakistan Gems & Mineral Show ′99". Export Promotion Bureau, Government of Pakistan, 31-39.

This article gives a brief account of the commercial data on gem stones of Pakistan with information on occurrence and other aspects of jade, fluorite, tourmaline, ruby, lapis-lazoli, kunzite, garnet, emerald, topaz, aquamarine and peridot.
Key words: Gems, jewelry.

B/215. Bonis, N.R., 1985. Paleocurrent analysis of Siwalik strata in the Trans-Indus region, north-western Pakistan. B.Sc. thesis, Dartmouth College.

Key words: Paleocurrents, siwaliks, Trans-Indus region.

B/216. Bonney, T.G. & Raisin, C.A., 1894a. On rocks and minerals collected by Mr. W.M. Conway in the Karakorum-Himalayas. Proceedings of the Royal Society 55, 468-487.

During his journey in the Karakoram Himalayas, Mr. W. M. Conway collected more than 300 specimens of rocks and minerals,, which, however, were generally rather small. These were sent to us for examination at University College, London. Thin slices have been prepared of the specimens which promised to be the more interesting. Of the rest, the mineral composition was verified in cases of doubt by examining pulverised fragments under the microscope. Since the detailed results of our examination, which practically form an annotated catalogue of the specimens, will be printed as an appendix to Mr. Conway's forthcoming volume, we restrict ourselves in this paper to a summary of our work, and to a notice of a few specimens which appear to be of more than local interest.
Key words: Rocks, minerals, Karakoram, Himalaya.

B/217. Bonney, T.G. & Raisin, C.A., 1894b. Notes on Mr. W.M. Conway's collection of rock specimens from the Karakoram Himalayas. In: Conway, II: 41-73.

Some details are given in the preceding account.
Key words: Rocks, minerals, Karakoram, Himalaya.

B/218. Boota, M., 1978-80. Geology, Petrology and Geochemistry of Chalt-Hini Area, Gilgit Agency. M.Sc. Thesis, Punjab University, Lahore, 179p.

The project area (Chalt-Hini) lies in the Hunza Valley District Gilgit at (E) 74^0 35' to 74^0 18' latitude (N) 36^0 19' to 36^0 13' and has been mapped on tectonically. The area is located in the center of the Karakoram Mountain and represent a part of a cross section through this mighty range. Area is intensely disturbed tectonically being involved in Himalayan Orogeny, which is evident from the strained, crushed and deformed lamellae of the minerals in the rock.
Structures found in the area are orthotectonic; the most important are Sikandarabad anticline, Chalt Fault, Boudalus Fault and Hini Fault. The project area is composed mainly of metamorphic and igneous rocks.
The metamorphic rocks are sedimentary in origin. Rocks were originally deposited in eugeosynclinal conditions as argillaceous sediments and afterward these were regionally metamorphosed and uplifted due to stress during Himalayan Orogeny. These are of Permo-Carboniferous or Cretaceous to Eocene in age, and grade from chlorite to garnet. Lithologically metasediments units include Khizarabad Slate, Calcareous Quartzite, Chlorite Mica Schist, Biotite Schist and Garnet Mica Schists. Igneous rocks in the area are, Karakoram Axial Granodiorite which is acidic plutonic rock of Tertiary age Greenstone which is a basic volcanic rock of Pre-Carboniferous age. Mineralogical description and petrographic analysis of these rock units are reported in detail. An attempt is made to interpret the petrogenesis of rock type. Detailed geochemical study of rocks has been described. Study also covers the ore microscopic deposits, which show the presence of ore minerals such as magnetite, hematite, pyrite etc. Orogenesis is discussed in detail. Economic mineral found in area is also described.
Key words: Petrology, geochemistry, Chalt-Hini, Gilgit.

B/219. Bordet, P., 1978. The Western border of the Indian Plate; Implication for Himalayan geology. Tectonophysics 51, 171-176.

The study of regions situated beyond the western margin of the present-day Indian plate (Afghanistan principally) point to the following facts:
(1) During the Late Precambrian—Early Paleozoic, stratigraphical continuity existed between western and central Iran, Central Afghanistan, Salt Range and western Pakistan. (2) During the Paleozoic a similar epicontinental cover existed in central Afghanistan, Kashmir and Tibet, with Gondwana tillites and associated cold fauna, such as in India (Umaria); however, a so-called Hercynian zone exists also in northern Iran—Hindu Kush and northern Pamir: it exibits a Middle Paleozoic unconformity (Upper Devonian Carboniferous) on metamorphic Early Paleozoic. (3) The end of the Paleozoic, is marked by: a fracturation of the basement of the Hercynian zone, with powerful volcanic eruptions at the northern part of Hindu Kush, Kashmir (Panjal trap) and also Nepal (Nar valley) the formation of a geosynclinal zone at the southern part of Hercynian zone (Turkman, Penjaw). (4) During the Jurassic: the geosynclinal evolution of the Turkman—Penjaw furrow accelerated, with the accumulation of flysch, radiolarites, ophiolites, olistolites and incipient HP metamorphism. A general subduction took place followed by a Neocimmerian orogenic phase with overthrusting of the central Afghanistan ranges on the scar of the geosynclinal furrows. (5) During the Cretaceous: the geosynclinal evolution ended: Lower Cretaceous lies unconformably on the folded Jurassic flysch. In eastern Afghanistan and northern Pakistan, during the Middle (?) or Upper Cretaceous, a new geosynclinal zone was created. (6) During the Cenozoic, central Afghanistan was emerged; northwards, sedimentary basins were created along the Herat fault, with volcanic and magmatic activity. A southeastern geosynclinal furrow evolved with accumulation of flysch, ophiolites and finally molasse deposits (Katawas—Soleimans). Its western border began overthrusting, but this movement changed into a left lateral fault i.e., the presentday Chaman Arghandeh fault.
Conclusion: Two major phases of dislocation took place during the geological history of Gondwana: the first one began during the Permian and ended in the Jurassic; the second one began during the Cretaceous and is still active. The important Eocimmerian orogenic phenomena, existing in the Central Afghanistan and northern Pakistan, took place at the edge of a Gondwana continental fragment, which was larger than the presentday Indian plate. Coeval phenomena may exist in the Himalayan region and perhaps in one of the ophiolitic sutures of Tibet.
Key words: Indian Plate, tectonic history, Himalaya.

B/220. Bose, S.C., 1968. Lacustrine basins in the Himalaya. Geological Review, India 30(4), 25-32.

Deals with the formation and sediments of lacustrine basins of the Himalaya. Details not available, but might have descriptions covering northern Pakistan.
Key words: Lacustrine basin, Himalaya.

B/221. Bossart, P., 1986. Fine neue interpretation der tectonic der Hazara-Kashmir syntaxis (Pakistan). Doctoral Dissertation, ETH, Zurich.

The contents of this thesis have been reproduced in the following papers by Bossart and others.
Key words: Tectonics, structural geology, Hazara-Kashmir Syntaxis.

B/222. Bossart, P., Chaudhry, M.N., Dietrich, D., Ghazanfar, M., Greco, A., Meier, A., Ottiger, R., Papriz, K., Ramsay, J.G., Rey, R., Spencer, D.A. & Wahrenberger, Ch., 1992. A review of the geology of the northern Indian plate, Kaghan valley, NE Pakistan. Abstract Volume, 7th Himalaya-Karakoram Workshop, Department of Earth Sciences, Oxford University, England, 6-7.

A review is presented of the regional significance of the tectonic and metamorphic structure of the northern part of the Indian plate lying beneath the Main Mantle Thrust (MMT) of the Himalayas. The region in and around the Kaghan Valley is especially relevant in that it displays what is probably the best exposed and most easily accessible cross section of the overthrust nappes of the Himalayas in Pakistan.
From south to north the section passes from the northern Foreland of the Indian plate, with its sedimentary cover of Cambrian, Paleocene and Eocene (Murree) formations, which is overthrust along the Main Boundary Thrust (MBT)

by Precambrian rocks of the Lesser Himalayas and which are themselves overthrust along the Main Central Thrust (MCT) by the metamorphic rocks of the Higher Himalayan units. All these structural thrust slices lie beneath the Kohistan Island arc volcanics and their basement of granulite facies basic rocks and separated by the Main Mantle Thrust (MMT) from these overlying units.

Much of the displacement along the main thrust planes which demarcate the main structural units was accomplished after the main Himalayan high temperature (and high pressure) metamorphism. There is always a metamorphic jump across the major thrust surfaces such that higher grade (pressure P and temperature T) rocks always lie structurally above units with lower P-T conditions. However, within each overthrust slice there is a general systematic increase in P and T from south to north. Beneath the MBT the rocks show little or no metamorphism. In the units between the MBT and MCT metamorphic grades range from greenschist to low amphibolite facies and in the Higher Himalayan structural unit between the MCT and MMT the dominant metamorphism is of middle to high amphibolite facies. However, in the Higher Himalayas the Himalayan metamorphism is complicated in that there appears to have been an early high pressure-medium temperature phase, with local production of eclogites, followed by an overprint of amphibolite grade and later greenschist facies minerals. We have found no evidence to suggest the existence of abrupt metamorphic discontinuities of Himalayan age within the main structural units. However, within the formations making up the Higher Himalayan unit, there are preserved certain lithological and metamorphic characteristics which appear to predate the Himalayan overprint and which suggest that pre-Himalayan metamorphic and structural features are preserved: features which can be used to separate rock groups into 1) a pre-Himalayan metamorphic "crystalline" basement (Precambrian ?) and two overlying sequences of cover rocks predominantly of sedimentary aspect, a lower 2) Naran Formation of pelitic and greywacke-like sediments of late Precambrian or early Paleozoic age (?) and an upper 3) Burawai Formation of calc-pelites and interbedded basic lavas (Panjal Traps?) of Tethyan aspect possibly of late Paleozoic and Mesozoic age (?). Although all these rocks have suffered a strong Himalayan metamorphic overprint, there are locally preserved sedimentation structures (graded bedding in the Naran Formation and syn-sedimentary extensional faults and stromatolitic fossils in the Burawai Formation).

The structural styles seen in the various thrust slices are complex and are interpreted as being the result of superposed deformations with differing regional shortening directions. In the Foreland region and Lesser Himalayan Unit markers are available to determine local

and regional variations in the finite strain states and to give some indication of the progressive strain history. In the Higher Himalayas such markers are rarely identifiable but, where present, indicate that the strain states are often lower than that seen at the unit contacts. Strain markers along the locations of the MBT, MCT and MMT indicate extremely high deformations with the formation of shear zones and ductile mylonites. In the Lesser and Higher Himalayan Units the earliest deformations of Himalayan age appear to be broadly syn-metamorphic and appear to have developed large scale fold nappes, with isoclinal anticlinal folds cored with pre-Himalayan basement gneisses and granitoids. These structures were later refolded and now the geometry appears to be the result of complex fold interference patterns. In the Lesser Himalayas an early low amphibolite or greenschist fades (syn-nappe formation) shows late developed retrogression associated with the late fold superposition. In the Higher Himalayas an early eclogite facies (early subduction effect?) is locally very well preserved but, in general, the high pressure mineralogy is overprinted by amphibolite or greenschist metamorphic minerals and fabrics. In many regions this overprint is more or less complete and only traces of symplectite textures and abundance of rutile fingerprint, albeit imperfectly, the earlier high-pressure metamorphism.

The Kaghan cross-section appears to record the earliest subduction of the Indian plate beneath the Asian plate and the development of high pressure-medium temperature metamorphism (Eclogite facies). The stacking of large fold (and thrust?) nappes was followed by a thermal rise, development of further shortening and superposed folding and thrusting of individual regional units, uplift and erosion. The sediment debris was eroded from the uplifted collision zone and transported southwards to be deposited in an embryonic, low topographic, shallow marine foreland basin (the Murree Formation of the Foreland) in Paleocene to early Eocene time, and these foreland sediments were themselves involved in the late stage compressions, and overthrust by the more internal tectonic units along the Main Boundary Thrust.

Key words: Structural geology, tectonics, Kaghan, Indian Plate.

B/223. Bossart, P., Dietrich, D., Greco, A., Ottiger, R. & Ramsay, J.G., 1984. A New structural interpretation of the Hazara Kashmir Syntaxis southern Himalayas, Pakistan. Kashmir Journal of Geology 2, 19-36.

The stratigraphic and structural features of the Hazara Syntaxis are described. The principal lithological features of the geological formations are reviewed and special type of rhythmic sedimentation which characterises the structurally lowest Murree formation is described in detail. The region is one of overthrust and shear zone tectonics associated with the development of at least two superimposed sets of major folds and associated minor structures (Microfolds, cleavage, vein systems and various types of lineations related to rock strain or intersection of planar structures). It is concluded that the syntaxis results from an early set of nappe units developed by southwestward overthrusting of a previously metamorphosed (Himalayan) rocks followed by the formation of a large shear zone structure and finally by the transport of overthrust units from northwest to southeast.
Key words: Structural geology, Hazara-Kashmir Syntaxis, Himalaya.

B/224. Bossart, P., Dietrich, D., Greco, A., Ottiger, R. & Ramsay, J.G., 1985. A new structural interpretation of the Hazara Syntaxis, NE Pakistan. Abstract Volume, 1st Himalayan Workshop, Department of Geology, University of Leicester.

The stratigraphic and structural features of the Hazara Syntaxis have been remapped by a research team from the ETH. The region has been shown to contain overthrust and shear zone tectonics associated with the development of two sets of major folds and their attendant small scale structures (microfolds, cleavages, vein systems and various types of lineations related to total rock strain or to the intersection of differently oriented planar structures). Evidence will be presented that the syntaxis has been developed first by southwestward overthrusting of a series of metamorphic nappes over the Murree (Tertiary age) Formation. This thrusting event was followed by the formation of a large, steeply inclined shear zone structure and finally by the transport of overthrust nappes from the northwest to the southeast.
Key words: Structural geology, Hazara-Kashmir Syntaxis, Himalaya.

B/225. Bossart, P., Dietrich, D., Greco, A., Ottiger, R. & Ramsay, J.G., 1988. The tectonic structure of the Hazara-Kashmir syntaxis, southern Himalayas, Pakistan. Tectonics 7, 273-297.

The stratigraphic and structural features of the Hazara syntaxis are described. A special aim of this work was to integrate modern approaches to rock deformation with the regional tectonics. The region is one of overthrust and shear zone tectonics associated with the development of at least two superimposed sets of major folds and associated minor structures (microfolds, cleavage, vein systems and various types of lineations related to rock strain or intersections of planar structures). It is concluded that the syntaxis results from an early set of nappe units developed by southwestward overthrusting of previously metamorphosed (Himalayan) rocks followed by the formation of a large shear zone structure and finally by the transport of overthrust units from northwest to southeast.
Key words: Structure, Hazara-Kashmir Syntaxis, Himalaya.

B/226. Bossart, P. & Ottiger, R., 1989. Rocks of the Murree Formation in northern Pakistan: indicators of a descending foreland basin of Late Paleocene to Middle Eocene age. Eclogae Geologicae Helvetiae 82, 133-165.

The red clastic sand and shale deposits of the Murree formation have been regarded as continental deposits of Miocene age. A new and more detailed sedimentological and micropaleontological survey on a profile of about eight kilometers in length, in the apex region of the Hazara-Kashmir Syntaxis in Northern Pakistan, has shown that these rocks were deposited in a very shallow marine, tidally influenced environment. This hypothesis is based on the recognition and interpretation of the cyclic sedimentation seen in these rocks. One can interpret a single cycle as the product of meandering tidal channels in a continuously subsiding foreland basin. Each cycle starts with typical channel fill deposits (microconglomerates, crossbedded sandstones) and passes upwards into tidal flat deposits (laminated and strongly bioturbated sand and siltstones). The uppermost part of a cycle is composed of red clayey silt with local horizons containing calcareous concretions which are interpreted as a type of fossil Caliche. Chrome-spinels out of coarse grained sandstones from the base of the Murree formation, near Balakot, indicate the Kohistan complex as a possible source area. It therefore seems likely that the Murrees are derived from the North and not from the South as previously presumed. Age determination based on syndepositional nummulities and assilines indicate an age of late Iberan (latest Paleocene) at the base of the Murree formation and late middle Lutetian at a

position some into thirds from the base of the profile. In the North, the Murree formation is therefore much older than it is in the South (Kohat, Potwar) where data suggests an early Miocene age. This age discrepancy is explained by a southwestward migration of the Himalayan thrust front that led to a southwestward migration of the Himalayan foreland basin and the Murree facies belt. As a consequence the Murree deposits prograded on to progressively younger shallow marine deposits. The introduction of a new formation for the marine part of the Murree formation is recommended to the Stratigraphical Committee of Pakistan.
Key words: Foreland basin, Murree Formation, Paleocene, Eocene.

B/227. Bossart, P., Ottiger, R. & Heller, F., 1988. Paleomagnetism in the Hazara-Kashmir syntaxis, Northern Pakistan. Abstracts, 4th Himalayan-Karakoram-Tibet Workshop, Lausanne, Switzerland, p.9.

Consult the following, essentially similar, account.
Key words: Paleomagnetism, Hazara-Kashmir Syntaxis.

B/228. Bossart, P., Ottiger, R. & Heller, F., 1990. Rock magnetic properties and structural development in the core of the Hazara-Kashmir syntaxis, NE Pakistan. Tectonics 9, 103-121.

Paleomagnetic and structural analyses have been conducted on three well-exposed sections through a 6–8 km thick pile of molassic red beds (Murree formation) in the lowermost tectonic unit of the Hazara-Kashmir Syntaxis. Micropaleontological age determinations of the lowermost Murree sediments indicate Late Paleocene deposition (55 m.y.). From south to north, the sections are situated in the Jhelum, Neelum (both in Azad Kashmir), and Kaghan (northeastern Pakistan) valleys. Thermal demagnetization experiments suggest that haematite with high unblocking temperatures carries stable characteristic remanence directions. The relationship between finite strain and magnetic fabric was established by mapping deformed reduction spot strain markers and by measuring the anisotropy of magnetic susceptibility (AMS). For the Jhelum valley the weakly tectonized Murree beds are characterized by flattened AMS ellipsoids resulting from diagenetic compaction. Inclination values suggest that the Murree foreland basin started to develop at about 8°N during the early suturing of India and the development of island arcs to the north. India has moved northward by at least 2600 km since collision with Eurasia in the Paleocene. Declination values suggest 45° of clockwise rotation of the block supporting the Murree formation relative to the Indian craton. For the Neelum and Kaghan valleys, quantitative strain mapping shows a progressive increase of deformation northward. NRM directions rotate passively toward the cleavage plane which parallels the foliation of the AMS ellipsoids. NRM directions and AMS ellipsoids are deformed because of superposition of tectonic strain on a primary compactional strain. The AMS pattern is interpreted in light of this superposition, and a regional deformation path from south to north is suggested. A tectonic rotation model is proposed which is consistent with the transport directions around the Hazara-Kashmir Syntaxis and the rotation of thrust sheets indicated by the NRM data. This model relates the convergent transport directions with the mean indentation direction of India into Asia.
Key words: Structural geology, paleomagnetism, Hazara-Kashmir Syntaxis, Himalaya.

B/229. Boulin, J., 1981. Afghanistan structure, greater India concept and eastern Tethys evolution. Tectonophysics 72, 261-287.

The large and complex area between Central Asia and the Arabia-India block includes, from north to south, the Tien Shan and Hindu Kush-Kun Lun Hercynian belts, the Turkman-Farah Rud and Tanghla Shan Neokimmerian belt, the Zagros-Makran-Baluch-Himalayan Alpine belt and relics of corresponding oceanic spaces. The Angarian or Gondwanian affinities of the different blocks separated by these successive peri-Indian belts are discussed. An interpretation is proposed for the paleogeographic and structural evolution of this area, from Early Paleozoic to Present. This interpretation is based on geologic and paleomagnetic data and on global tectonic considerations. The Hindu Kush-Kun Lun pre-Hercynian ocean probably separated Laurasia from Gondwanaland. It was an Early Paleozoic Tethys (Tethys 1). The Tien Shan ocean may have been a marginal basin for the Hindu Kush-Kun Lun ocean. The Turkman-Farah Rud-Tanghla Shan pre-Neokimmerian ocean resulted from the break-up of the Gondwanaland margin. Its opening seems to have been related to the pre-Hercynian ocean closure resulting in the formation of a new Tethys (Tethys 2). Its subsequent closure may also have been related to the opening of the

Zagros-Baluch-Indus-Tsang Po pre-Alpine ocean (Tethys 3). According to this interpretation, Eurasia appears to have increased from Early Paleozoic to Cenozoic by successive accretion of cratonic blocks which came from the south through the Tethys. This evolution can be compared to the similar Mediterranean evolution. This interpretation is in agreement with the Greater India concept. However, the northern border of Greater India differs according to the stage of the Gondwanaland evolution which is considered. Actually, Greatest India extended north to the Caledonian belt and consequently has recorded the whole history of the Eastern Tethys.
Key words: Regional tectonics, Tethys, Afghanistan, Central Asia, India,

B/230. Boulin, J., 1988. Hercynian and Eocimmerian events in Afghanistan and adjoining regions. Tectonophysics 148, 253-278.

The area centered around Afghanistan is a collage of continental blocks derived from Gondwanaland. This collage comprises, among others:
(1) a Hercynian orogenic belt widely represented in Afghanistan and also by some sparse outcrops in the northern Iran; it is a subduction-type orogen constructed at the margin between the Paleotethys and the Turan-Turkestan-Tarim block;
(2) a northern Eocimmerian orogenic belt, widely represented in Afghanistan and the north of Iran; it is a collision-type orogen constructed in the same place as the Hercynian orogenic belt and resulted from the closure of the Paleotethys and the collision of the central Iran and central Afghanistan blocks with the Turan-Turkestan-Tarim block;
(3) a southern Eocimmerian orogenic belt of which outcrops are now confined to southern Iran but which may project beneath the Neogene and Quaternary formations of southern Afghanistan; it is a subduction-type orogen constructed at the margin between the Neotethys and the central Iran-central Afghanistan block, which itself was at that time subjected to regional extension; this belt is now incorporated in the Alpine-Himalayan orogen. The geology of these belts suggests that the opening of the Neotethys became effective only from the Permian or Triassic, and was in a Red Sea-type phase during the Upper Devonian. Its initial rifting possibly occurred during the Lower Paleozoic, much like the Paleotethys, in which initial rifting also occurred in Lower Paleozoic time and whose opening became effective from the Ordovician. Thus, each of the oceanic realms in this region appears to have possibly resulted from the same extension of Gondwanaland during the Lower Paleozoic after which they followed more or less different paths of evolution. Moreover, the proposed geodynamic interpretation implies that during the Permian and Triassic there was in this region a certain coexistence of the vanishing Paleotethys with the relatively young Neotethys, which was beginning to subduct.
Key words: Regional tectonics, Tethys, Hercynian, Eocimmerian, Afghanistan.

B/231. Bowersox, G.W. & Anwar, J., 1989. The Gujar Killi emerald deposit, Northwest Frontier Province, Pakistan. Gems and Gemology 25, 16-24.

Over the last decade, Pakistan has developed into an important source for many gem materials. A number of localities have been identified for emeralds in particular. This article reports on the emerald deposits in the valley of Gujar Killi, located in the Northwest Frontier Province. The occurrence, mining, and gemological properties are described. Reserves appear to be good, and increased mining activity suggests stronger production for the near future.
Key words: Gemstone, emerald, Gujar Killi, NWFP.

B/232. Bradshaw, E.J. & Crookshank, H., 1950. Search for oil in Pakistan. Geological Survey of Pakistan, Quetta, Record 2.

Key words: Hydrocarbons, oil, Pakistan.

B/233. Branson, C.C., 1935. A labyrinthodont from the Lower Gondwana of Kashmir and new edestid from the Permian of the Salt Range. Connecticut Academy of Arts and Sciences, Memoirs, 9, 19-26.

Key words: Palaeontology, Gondwana, Permian, Kashmir, Salt Range.

B/234. Bridge, J.S., 1996. Architecture of Miocene overbank deposits in northern Pakistan-Discussion. Journal of Sedimentary Research, Section B, 65, 401-403.

Willis and Behrensmeyer (1994) have presented a remarkably detailed description and analysis of the architecture of ancient overbank deposits from the Miocene Chinji Formation of northern Pakistan (see also Behrensmeyer 1987, Willis 1993a). They described meters-thick paleosols bounded sequences that are defined by an alternation of relatively mature paleosols and stratified deposits with a lesser degree of pedogenesis. They asserted that the mature paleosols represent relatively long periods of very low deposition rate, whereas the stratified deposits represent relatively short periods of high deposition rate. They proposed and evaluated five end-member hypotheses for the origin of the paleosol-bounded sequences. They concluded that the stratified deposits were formed by local rapid filling of low areas on the floodplain, independently of the position of major channels: such filling may have been a more or less continuous process, or may have been a short-lived event associated with river-channel avulsion. They specifically dismissed the possibility that the nature of the stratified deposits was related to the proximity of major channels and the growth of alluvial ridges. They also dismissed the possibility that paleosol-bounded sequences could have been related to regional variations in sediment supply and deposition rate, or to valley incision and filling. In my view, these far-reaching conclusions are flawed, for three main reasons: (1) whether or not the overbank sediment bodies appear to fill topographic lows in the paleo-floodplain depends critically on the way the stratigraphic cross sections were constructed, which was not justified adequately; (2) the hypotheses for the origin of the stratified deposits are misleading; and (3) the sections studied do not extend sufficiently in a direction normal to paleoflow direction to test adequately the hypotheses presented. I will expand upon these points in tum.
Key words: Miocene, paleosole, Chinji Formation, Siwaliks.

B/235. Bridge, J.S., Behrensmeyer, A.K., Khan, I.A., Willis, B.J. & Zaleha, M.J., 1997. Evolution of Miocene fluvial environments in northern Pakistan. Abstracts, 3rd GEOSAS Workshop on Siwaliks of South Asia, Islamabad. Geological Survey of Pakistan, Records 109, 20-23.

Fluvial deposits of the Miocene Siwalik Group (Chinji, Nagri, and Dhok Pathan Formations; age from 15 to 7 Ma), Potwar Plateau, Northern Pakistan were studied in order to: (1) reconstruct the nature and evolution of paleoenvironments across part of the ancient Himalayan foredeep; (2) assess depositional controls such as river diversions, tectonism, climate and base-level change, and; (3) examine the relationship between changing paleoenvironments and faunal evolution. Kilometers-long sedimentologic-paleomagnetic logs were constructed in three separate areas of the Potwar Plateau (near the towns of Chinji, Khaur, and Dma). Detailed sedimentological cross sections (up to 100 m thick and 4 km across), spanning different stratigraphic intervals in each area, were constructed using photomosoaics and closely spaced vertical logs. Litho- and chrono-stratigraphic correlation of the strata between the three study areas was attempted.
The strata comprise relatively thick (100 to 101 m) sandstone bodies and mudstones that contain thinner sandstone bodies (101 to 100m) and paleosols. Thick sandstone bodies are km to tens of km wide normal to paleoflow, and are composed of large-scale stratasets (storeys) stacked laterally and vertically adjacent to each other. These sandstone bodies are single or superimposed channel belts of major braided (mainly) and meandering rivers, and large-scale strata sets represent channel bars and fills. Channel belts were km wide, had bankfull river discharges on the order of 103 - 104 cumecs and braiding parameter upto to about 3. Individual channel segments had bankfull widths, maximum depths and slopes on the order of 102 in, 101 m and 104, respectively, and sinuosities around 1.1. Rivers of the Nagri Formation are 2 to 3 times wider and deeper than those of the Chinji and Dhok Pathan Formation. The rivers generally flowed to the southeast. Flow was perennial with seasonal flooding. These rivers are comparable to many of those flowing over the megafans of the modern Indo-Gangetic basin, and a similar depositional setting is likely.
Thin sandstone bodies within mudstone sequences extend laterally for on the order of 102 m and have lobe, wedge, sheet and channel-form geometries; they represent crevasse splays, levees, single sheet-flood deposits and floodplain channels. Mudstones are laminated and variably bioturbated/disrupted and represent mainly floodbasin and lacustrine deposits. Floodplain lakes were both ephemeral and perennial, were up to a few tens of km across and probably less than 10 m deep. Extremely disrupted strata with m-thick horizons with pedogenic features are ‘mature’

paleosols that extend laterally for tens of km. Many paleosols have a nodular calcite horizon overlain by a noncalcareous horizon, and were generally formed under relatively well-drained conditions. Other paleosols have matrix calcite and lack such distinct horizons, and formed in relatively poorly drained topographic lows. All mature paleosols indicate extended periods of slow deposition. A variety of features indicate episodic wetting and drying as water tables fluctuated seasonally. Paleosols are similar to modern alluvial soils of the Indo-Gangetic basin, which is consistent with interpretation of a monsoonal paleoclimate. Paleosol-bounded sequences are m to 1Gm thick, km to 10 km wide lenses of stratified, moderately disrupted overbank deposits bounded by mature paleosols. They are interpreted to represent periods of relatively rapid deposition, associated with progradation of crevasse s1lays-levees into low area of the floodplain, alternating with long periods (l03 - 104 years) of very low deposition rate.

Trace fossils and body fossils within all rock types indicate the former existence of terrestrial and aquatic vertebrates, molluscs (bivalves and gastropods), arthropods (including insects), worms, trees, bushes, grasses, and acquatic flora. Vertebrate remains are particularly common, invertebrate (mollusc) remains are uncommon, and plant fossils (including pollen and spores) are rare. Plant macrofossils occur as impressions in crevasse-splay mudstones, and tree-trunk casts in channel fills and upper portions of major channel fills, less common in other floodplain deposits, and relatively uncommon in major channel sandstones. Vertebrate fossils are, thus, more abundant in the Chinji and Dhok Pathan Formations than in the Nagri Formation, with the exception of Nagri locality Y311, that represents an unusual, fine-grained fill of a large-scale abandoned channel.

The proportion of sandstone bodies varies vertically on three scales in all study areas. Relatively small-scale variations are tens-of-in-thick alterations of thick sandstone bodies (major channel deposits) and mudstone-sandstone strata (overbank deposits), or paleosol-bounded sequences, that represent on the order of 103 - 104 years. These can be explained by repeated river avulsions that may be autocycle and/or triggered by tectonic activity. However, some paleosol-bounded sequences may result from local sbifls in deposition of crevasse splaysllevees without major-channel avulsion.

At an intermediate-scale are 100 m-scale variations in the proportion and thickness of thick sandstone bodies (representing on the order of 104 - l05 years).

Such variations are due to either changes in the thickness of channel-bar deposits or in the degree of superposition of channel belts. They can only be traced laterally for up to tens of km. Theoretical modeling indicates that increases in the proportion and thickness of major channel sandstone bodies can be explained by increasing channel-belt sizes (mainly), average deposition rate and avulsion frequency on a megafan comparable in size to modern examples. 100 in-scale variations could thus result from regional shifts in the position of major channels on a megafan, or temporal changes in sediment input and/or basin subsidence resulting in progradation and retrogradation of individual megafans.

The largest scale variations define Formations (i.e. 102 to 103 m thick, representing on the order of 105 -106 years). The Nagri Formation has more abundant and thicker and coarser grained sandstone bodies than the Chinji and Dhok Pathan Formations. This increase in thickness and abundance of sandstone bodies is due mainly to increase in thickness of channel-bar deposits (i.e. channel size), but also to increasing superposition of channel belts. As proportion of sandstone bodies increases, deposition rates increase and paleosols are less well developed. Formations can be correlated across the Potwar Plateau for at least 100 kin, although they may be diachronous by on the order of a million years. Formation boundaries in the Potwar Plateau decrease in age towards the west.

Formations and 100 in-scale stratal variations may be associated with regional changes in tectonic uplift, climate sediment supply and basin subsidence. The Nagri Formation possibly resulted from diversion of a relatively large river and its associated megafan to the Potwar Plateau area. River diversion or piracy was possibly associated with spatially variable increases in uplift and subsidence rates, and probably took place in the mountain belt. Alternatively, changing river sizes and sediment supply rates may be related to climate changes affecting the hinterland (but possibly also linked to tectonic uplift). The deposits generally yield no direct evidence for climate change in the sedimentary basin: however, independent evidence indicates global cooling throughout the Miocene, and the possibility of glacial periods (e.g. around 10.8 Ma, corresponding to base of Nagri Formation), fluctuations in the degree of glaciation of the higher Himalayas may have resulted in varying sediment supply to megafans on time scales of 104 to 106 years. Eustatic sea-level changes are associated with global climatic change: however, they are not directly related to Siwalik stratigraphic changes because the Potwar Plateau was 1000 km from the Miocene shoreline. There is a period of vertebrate faunal extinctions between 13 and 12 Ma that may be correlated with global cooling, and a faunal turnover near the base of the Nagri Formation may be related to faunal immigration during a sea-level low stand.

Stable carbon and oxygen isotopes in pedogenic carbonate nodules indicate a marked shift in vegetation and climate from 8 to 6 Ma. The shift from C3 and C4-dominated vegetation recorded in the carbon isotope shift, and the increase in soil evaporation inferred from the oxygen isotope shift, indicate intensification of the regional monsoon

and increased seasonality (warmer dry periods and more pronounced wet seasons). This climate change is not reflected in the alluvial architecture of the Dhok Pathan Formation, although there are some changes in paleosols that may be linked to the climate shift. However, the vertebrate fauna shows a prolonged period of turnover associated with this change, with declining species diversity and extinction of some notable taxa such as Sivapithecus. This is consistent with the replacement of woodlands and forest with drier, more open habitats. Thus, it appears that the history of the Siwalik biota was tied to climatic changes in the depositional basin and faunal migrations from other regions, and not to changes in the Siwalik fluvial systems that were more strongly linked to the tectonics and climate of the Himalayan source areas. Identification of specific controls on depositional environments, alluvial architecture and faunal change will require more sedimentologic-paleomagnetic studies from other parts of the basin.
Key words: Fluvial environments, Miocene, siwaliks.

B/236. Bridges, H.F., 1906. Hunza and Nagir glaciers. Geological Survey of India Records, 37(2), 221p.

Key words: Glaciers, Hunza, Nagir.

B/237. Bridges, H.F., 1930. Himalayan notes. Geographical Journal 75, 166-172.

Key words: Himalaya.

B/238. Brinckmann, R. & Rafiq, M., 1971. Landforms and soil parent materials in West Pakistan. Soil Survey of Pakistan, Lahore-Decca.

Key words: Geomorphology.

B/239. Brookfield, M.E., 1977. The emplacement of giant ophiolite nappes, 1, Mesozoic-Cenozoic examples. Tectonophysics 37, 247-303.

The occurrence of ophiolite nappes has been considered evidence for the siting of ancient subduction zones. A study of the detailed stratigraphy and plate motions associated with Upper Mesozoic to Pliocene ophiolite nappes of the Pacific, Indian and Mediterranean shows that transcurrent faulting during changes in relative plate motions is the major cause of initial ophiolite nappe emplacement. Giant ophiolite nappes are not related to subduction zones or island arcs.
Key words: Ophiolite, nappes, Mesozoic, Cenozoic.

B/240. Brookfield, M.E., 1980a. Reconnaissance geology of the Hushe and Saltoro-Kondus river valleys, Karakorum Mountains, Kashmir, Pakistan. Academia Nazionale dei Lincei 69, 248-253.

Key words: Reconnaissance, Kashmir, Karakoram.

B/241. Brookfield, M.E., 1980b. New radiometric dates (U/Pb, Rb/Sr, $Ar^{40}/Ar^{39)}$ from Kashmir (Northern India and Pakistan) and their bearing on the evolution of the Indus and Shyok suture zones. 24th International Geological Congress, Montreal.

Key words: Radiometric dating, Indus suture, Shyok suture, tectonics.

B/242. Brookfield, M.E., 1981. Metamorphic distributions and events in the Ladakh range, Indus suture zone and Karakorum Mountains. In: Saklani, P.S. (Ed.), Metamorphic Tectonites of the Himalaya. Today and Tomorrow's Publisher, New Delhi, 1-14.

In terms of simple metamorphic facies scheme and sketch map, the paper summarizes the metamorphic events and history of the hitherto little known areas of northwestern India and Pakistan (north of the main Himalayan ranges). The evidences suggest following four main phases of metamorphism:
(1) Mid-Cretaceous metamorphism was associated with the development of an island arc along the Indus suture zone. The volcanic arc core is represented by transitional low-intermediate pressure regional metamorphism, while in the south the fore-arc region represented by sedimentary and ophiolitic mélange contains fragmentary glaucophane schists.
(2) Late Eocene to Oligocene metamorphism was associated with the development of an Andean-type magmatic arc on the northern edge of the Indian plate (the Ladakh batholith complex). This consists of medium-pressure Barrovian regional metamorphism towards the east. At higher level, lower pressure metamorphism towards the west is observed.
(3) Miocene metamorphism was associated with the development of the Andean-type Karakorum magmatic arc on the southern edge of the 'Tibetan' plate. This has a relatively high pressure metamorphic belt in the south (the Shyok mélange) with a Barrovian medium-pressure belt in the north (Karakorum batholiths).
(4) Post-Miocene low-pressure regional metamorphism was associated with the late stage anatectic granites of the Karakorum mountains.
Key words: Metamorphism, Ladakh, Indus suture zone, Karakoram.

B/243. Brookfield, M.E., 1982. The sedimentology of Indus flysch and molasses, it's bearing on the evolution of the collision zones between India and Asia, and a comparison with the classic Swiss flysch and molasses. 11th Congress on Sedimentology, Hamilton (Canada), 37p.

Key words: Sedimentology, molasse, collision zones, India, Asia, Swiss.

B/244. Brookfield, M.E., 1993a. Paleodrainage patterns and basin evolution of the NW Himalaya. Abstract, Volume, 8th Himalaya-Karakoram-Tibet Workshop, Vienna, 7.

During the late Tertiary the NW Himalaya rose rapidly due to crustal shortening, thickening and differential erosion. At the same time adjacent basins subsided accumulating thick prisms of sediments, which were continually compressed, uplifted and eroded as thrust sheets migrated over them. The interplay of tectonism with erosion by changing river systems is particularly apparent in the Pamir arc, which indented Asia only within the last 20 ma, involving almost 1000 km northward thrusting of already assembled collision belts over the Tadjik marginal basin.
The age and nature of the foredeep sediments of the Tarim and Tadjik basins have been used to infer pulses of contemporary tectonism in the mountains. Net rates of erosion derived from radiometric and fission track dating, sediment budgets and river drainages can be compared with GROSS rates of uplift derived from fossil faunas and floras. These studies show that each range has an independent history of uplift and erosion within the framework of generally increasing late Tertiary uplift. And so has each basin. Deposition in basins is determined by the courses of the major rivers, which have not remained constant. The thickness of sediment accumulating in marginal basins and the isostatic uplift of ranges depends on when rivers changed their courses, on when and how much temporary storage occurred within intermontane basins, and the time at which the intermontane barriers were breached and their sediments eroded.
Establishing the Cenozoic courses of the major rivers of Central and Southeast Asia shows that coarse clastic sediment pulses cannot be used to infer increased tectonism in adjacent ranges, they may simply reflect river capture. Though this places constraints on the tectonic history of collision, it also provides an opportunity to reconstruct the landscape as well as orogenic evolution of the mountain belt.
Key words: Paleodrainage, basin evolution, Himalayan orogeny.

B/245. Brookfield, M.E., 1993b. The interrelations of post-collision tectonism and sedimentation in Central Asia. International Association of Sedimentologists, Special Publication 20, 13-35.

During the Late Tertiary the northwest Himalaya and adjacent ranges underwent progressively increasing uplift associated with crustal thickening and differential erosion. At the same time the adjacent Tarim and Tadjik basins

and the Himalayan foredeeps subsided accumulating thick piles of clastic sediments. The ages of these accumulations have been used to infer contemporary tectonism in the mountains. Radiometric and fission track dating together with faunal and floral studies and sediment budget and river drainage studies allow gross rates of uplift and subsidence to be compared with net rates for different areas. These studies show that the bulk of the derived clastics were eroded from the fronts of the Karakorum, Himalayan and Pamir allochthons during progressively increasing rates of uplift and thrusting from Early Miocene times onwards. Nevertheless, cooling Cenozoic climates, partly driven by uplift, have also contributed to increasing physical erosion and coarsening of the deposited sediments through time. Furthermore, each range shows an independent history of uplift and erosion within the framework of generally increasing uplift and erosion in Late Tertiary times. Contemporary deposition in adjacent basins is partly dependent on the timing of adjacent uplifts. But uplift and deposition also depend on erosion and deposition along the courses of major rivers which have not remained constant. The thickness· of sediment accumulating in marginal basins and the isostatic uplift of ranges depend on when the river changed its course, on when and how much temporary storage occurred within intermontane basins, and the time at which the intermontane barriers were breached and their sediments eroded. In some cases, e.g. the Indus, Tsangpo, Salween and Mekong, the rivers have even switched into different major oceans or basins. Coarse clastic sediment pulses cannot be used to infer increased tectonism in adjacent ranges.
Key words: Tectonics, sedimentology.

B/246. Brookfield, M.E., 1993c. The Himalayan passive margin from Precambrian to Cretaceous times. Sedimentary Geology 84, 1-35.

The Himalaya passive margin should be separated into the Indian Himalaya and the Pakistan Himalaya, divided by the Nanga Parbat-Haramosh basement uplift in the northwestern syntaxes. The Indian passive margin shows a complex history involving splitting of microcontinents off the northern Gondwana margin from early Paleozoic times until the Jurassic. In contrast, the Pakistan Himalaya formed part of the stable Indian shelf until separation from Africa started in the Jurassic. Each margin has a distinct stratigraphic history until the mid-Mesozoic after which they show similar histories until the Tertiary.
The Himalaya mountains in India consist of three distinct tectonic units juxtaposed during the Neogene by southward thrusting of the northern Indian Precambrian to Mesozoic passive margin. The Lesser Himalaya on the south forms a late Precambrian passive margin usually directly overlain by late Cretaceous to Tertiary clastics: its stratigraphy is closest to that of the Indian Shield. In contrast, the High Himalaya has a thin Ordovician to Carboniferous shelf sequence deposited after early Ordovician deformation and granite intrusion. Above this, thick Permian and Mesozoic shelf sequences mark the separation of continental blocks off the northern Indian margin and the opening of the Neotethys ocean. The North Himalaya formed the slope and basin of this ocean and consists of reactivated Paleozoic gneiss domes overlain by thick Mesozoic sediments which pass, in the northeastern Himalaya, into an enormously thick sedimentary sequence resting on oceanic crust.
Paleomagnetic and structural evidence indicates at least 500 km of southward thrusting along the Main Central Thrust between the Lesser and High Himalaya. This thrusting, together with a further 250 km of erosion at the front of the nappes, has removed the entire inner shelf of the Himalaya passive margin and can explain the startling contrast between the High and Lesser Himalaya stratigraphic sequences. But there are still discrepancies, particularly in the eastern Himalaya, where Precambrian basement is juxtaposed with the North Himalaya Mesozoic slope. These discrepancies can be partly resolved by strike-slip movements roughly parallel to the Himalaya which have removed parts of the northern Indian passive margin. Such faults of the requisite orientation, displacement and age occur in southeast Asia where their cumulative displacements can add up to several thousand kilometres. Similar faults, of undoubted pre-Tertiary age, occur in the Pakistan Himalaya. Here, the passive margin shows a much simpler history of Jurassic to Miocene subsidence.
Key words: Precambrian, Cretaceous, tectonics, crustal shortening, Himalaya.

B/247. Brookfield, M.E., 1998. The evolution of the great rivers systems of southern Asia during the Cenozoic India-Asia collision: rivers draining southwards. Geomorphology 22, 285-312.

During uplift of the Tibetan plateau and surrounding ranges, tectonic processes have interacted with climatic change and with local random effects (such as landslides) to determine the development of the major river systems of Asia. Rivers draining southward have three distinctive patterns that are controlled by different tectonic and climatic regimes. In central and southern Afghanistan, the rivers have moderate gradients and fan out from northeastern sources to disappear into arid depressions. Anti-clockwise rotation of southern Afghanistan, caused by differential compression and right-lateral shear, cut the rivers on the north, while increasingly arid conditions developed on the south as arc accretion in the Makran separated sources from the coastal rains. In Tibet and southeast Asia, the rivers are widely separated and have low gradients on the Tibetan plateau, higher gradients as they turn southwards into close and parallel gorges, before they fan out southeast to enter different seas. Differential shear and clockwise rotation between the compressing Tibetan plateau and Southeast Asia determined the great sigmoidal bends of this river system which was accompanied by increasing aridity, with truncation of river systems in the north and river capture in the south. In the Himalaya and southern Tibet, the main rivers have steep gradients where they cut across the Himalayan range and occasionally truncate former rivers with low gradients on the Tibetan plateau to the north. Southward thrusting and massive frontal erosion of the Himalaya caused progressive truncation of longitudinal rivers on the plateau, accompanied by river capture, and glacial and landslide diversions on the south. The drainage history of southern Asia can be reconstructed by restoring the gross movements of the plates and the tectonic displacement, uplift, and erosion of individual tectonic units. Most important changes in drainage took place in Pliocene to Quaternary times.

Key words: River systems, drainage evolution, collision, Cenozoic, India, Asia,

B/248. Brookfield, M.E. & Gupta, J., 1984. Permian fossils from the Shyok mélange, near Shigar, Baltistan, Pakistan. Bulletin of Indian Geologists Association 17, 39-44.

Key words: Palaeontology, Shyok, mélange, Shigar, Baltistan.

B/249. Brookfield, M.E. & Reynolds, P.H., 1981. Late Cretaceous emplacement of the Indus Suture Zone ophiolitic mélange and an Eocene-Oligocene magmatic arc on the northern edge of the Indian Plate. Earth and Planetary Science Letters 55, 157-162.

We report three 40Ar/39Ar dates (on stratigraphically located samples) of 82+/-6 Ma from a syenite cutting the Indus suture zone ophiolitic mélange and about 39 and about 45 Ma from granodiorite intrusions north of the suture zone. Sedimentological observations indicate Eocene to Miocene deposition of coarse clastics by very large braided and meandering streams in a continental back-arc setting. These observations suggest that the ophiolitic mélanges of the Indus suture zone were emplaced in the late Cretaceous, shortly after a major change in plate motions in the Indian Ocean: they further suggest that an Andean-type magmatic arc developed on the northern edge of the Indian plate during the Eocene and Oligocene.

Key words: Ophiolites, Indus Suture Zone, mélange, magmatic arc, Indian Plate, Late Cretaceous collision.

B/250. Brookfield, M.E. & Reynolds, P.H., 1990. Miocene $^{40}Ar/^{39}Ar$ ages from the Karakoram Batholith and Shyok Mélange, northern Pakistan, indicate Late Tertiary uplift and southward displacement. Tectonophysics 172, 155-167.

The magmatic arc of the Karakorum Mountains is separated from the Cretaceous-Tertiary Kohistan arc sequence by an ophiolitic mélange-the Shyok Mélange. Two views of the age of the Shyok Mélange and Karakorum arc are: (a) that they represent a mid-Mesozoic arc-trench complex which collided with the Kohistan arc in the Cretaceous before the closure of the main Tethys ocean to the south; and (b) that they represent a late Tertiary arc-trench complex which closed in the late Miocene, representing final subduction of Tethyan sea-floor. Whether final destruction of ocean crust took place in the Mesozoic or Tertiary has important implications for current models of the development of the Indian-Asian collision zone. Here are reported ages of between 20 and 8 Ma, suggesting that final assembly and uplift did not occur until the late Tertiary; and that the Shyok Mélange is the structural equivalent of the Main Central Thrust of the Himalaya to the east. Like the Main Central Thrust, the Shyok Mélange appears to mark intraplate continental subduction which is mainly responsible for Tertiary granitoid intrusion, deformation and uplift in the High Himalaya and Karakorum to the north.

Key words: Karakoram batholith, geochronology, Shyok mélange, tectonics.

B/251. Broughton, R.D. & Windley, B.F., 1988. The Central Himalayan gneisses in northern Pakistan. Journal of Geological Society of India, 31, 185-196.

Key words: Gneiss, Himalaya.

B/252. Broughton, R.D., Windley, B.F. & Jan, M.Q., 1984. Reaction isogrades and P–T estimates in metasediments on the edge of the Karakorum plate, Hunza, N. Pakistan. Abstracts, First Geological Congress, Lahore, p.58.

The Hunza area of North Pakistan contains a metasedimentary sequence on the southern margin of the Karakorum Plate. The sequence is largely pelitic with carbonate layers, cut by amphibolite and granitic sheets, and is bounded to the N E by the Karakorum batholith, and to the S W by the Northern Suture at Chalt. The grade of metamorphism increases from S W to N E and this is marked by variation in mineral chemistry, and changes in mineral assemblages at a series of reaction isograds, which separate zones in which stable mineral pairs are; garnet - chlorite, chloritoid-biotite, staurolite-biotite, kyanite - biotite and sillimanite-biotite from S W to N E respectively. A reaction isograd marked by the paragenesis; forsterite-diopside-calcite-dolomite occurs in the siliceous dolomites. The north-easterly dip of the isograds indicates that the zones are inverted. At Hunza, maximum metamorphic conditions given by pelitic rocks are 632^o C and 5.5 kb. The temperature obtained from calc-silicate rocks is 669^{o}C at 5.5 kb, with CO2, Fl 0.66. The inversion of the metamorphic zones was associated with major southward thrusting during collision of the Karakorum Plate with the Kohistan Arc.
Key words: Isogrades, P-T estimates, metasediments, Karakoram, Hunza.

B/253. Broughton, R.D., Windley, B.F. & Jan, M.Q., 1985. Reaction isogrades and P–T estimates in metasediments on the edge of the Karakorum plate, Hunza, N. Pakistan. Geological Bulletin University of Peshawar 18, 119-136.

The Hunza area of N. Pakistan contains a metasedimentary sequence on the southern margin of the Karakorum Plate. The sequence is largely pelitic with carbonate layers, cut by amphibolite and granite sheets, and is bounded to the N. E. by the Karakorum Batholith, and to the S. W. by the Northern Suture at Chalt.
The grade of metamorphism increases from S. W. to N. E., and this is marked by variation in mineral chemistry, and changes in mineral assemblages at a series of reaction isograds, which separate zones in which stable mineral pairs are: garnet-chlorite, chloritoid-biotite, staurolite-biotite, kyanite-biotite and sillimanite-biotite from S. W. to N. E. respectively. A reaction isograd marked by the paragenesis, forsterite-diopside-calcite-dolomite occurs in the siliceous dolomites, and the northeasterly dip of the isograde indicates that the zones are inverted.
At Hunza, maximum metamorphic conditions given by pelitic rocks are 669 $^{\circ}$C and 5.5 kb, with XCO_2, F1=0.66. The inversion of the metamorphic zones was associated with major southward thrusting during collision of the Karakorum Plate with the Kohistan Arc.
Key words: Isogrades, P-T estimates, metasediments, Karakoram, Hunza.

B/254. Brown, H.C., 1936. India's mineral wealth: A guide to the occurrences and economics of the useful minerals of the Indian Empire. With a Geological Map, Scale 1:45,000,000, Oxford University Press, London, 335p.

This is a pre-partition map of the Indian empire including the areas of the current day Pakistan. This might be one of the earlier accounts of the economic minerals found in this part of the subcontinent.
Key words: Economic minerals, Indian empire.

B/255. Brown, J.C. & Dey, A.K., 1955. India's Mineral Wealth; A guide to the occurrence and economics of the useful minerals of India, Pakistan and Burma. 3rd Edition 761p. Oxford University Press.

This is the 3rd edition of the manuscript of the same title, first published by J.C., Brown in1936 for the Indian Empire. It gives brief information on some of the minerals of northern Pakistan.

Key words: Economic minerals, Indian empire.

B/256. Brozovic, N., Burbank, D.W. & Meigs, A.J., 1997. Climatic limits on landscape development in the northwestern Himalaya. Science 276, 571-574.

The interaction between tectonism and erosion produces rugged landscapes in actively deforming regions. In the northwestern Himalaya, the form of the landscape was found to be largely independent of exhumation rates, but regional trends in mean and modal elevations, hypsometry (frequency distribution of altitude), and slope distributions were correlated with the extent of glaciation. These observations imply that in mountain belts that intersect the snowline, glacial and periglacial processes place an upper limit on altitude, relief, and the development of topography irrespective of the rate of tectonic processes operating.
Key words: Deformation, tectonics, NW Himalaya.

B/257. Brunet, M. & Heintz, E., 1983. Comparison between Late Miocene Mammalian faunas from Afghanistan and Indo-Pak Sub-continent: Paleo-biogeographic implications. Geological Bulletin University of Punjab 18, 3-8.

Localities of Tertiary fossils from Afghanistan have been placed in a biogeochronological sequence and correlation has been attempted with those of Greece, Turkey, Iran and Pakistan. It is concluded that faunas of Afghanistan and Pakistan were distinct about 8 Ma ago although geographically these were less than 300 km apart. Explanation is given of the differences.
Key words: Palaeontology, mammals, Miocene, siwaliks, Afghanistan, Pakistan.

B/258. Brunet, M., Heintz, E. & Battail, B., 1984. Molayan (Afghanistan) and the Khaur Siwaliks of Pakistan: An example of biogeographic isolation of Late Miocene mammalian faunas. Geologie en Mijnbouw 63, 31-38.

Refer to Brunet & Heins 1983 in the preceding account.
Key words: Biogeography, Miocene, mammals, siwalik, Afghanistan, Pakistan.

B/259. Brunschweiler, R.O., 1951. Lower Cretaceous fossils of the Yasin Group, Gilgit Agency. Geological Survey of Pakistan, Records 8 (2), p.27 (Appendix-C o Ivanac, Traves & King (196).

This s a paleontological study of the fossiliferous Yasin Group. The occurrence of the Lower Cretaceous corals from the area was first recorded by the author. He identified *Eugyra* cf. *neocomiensis* de FROMENTEL; *Calamophyllia* cf. *racilis* BLAINNIVLLE; *Thecosmilia* sp.; *Isastrea* cf. *regularis* de FROMENTAL; and *Montastrea* sp. The geological age of the Yasin Group is considered Barreminan-Aptian, as supported by the presence of a species of rudiste, *Horiopleura* cf. *lamberti* (MUN.-CHAT), common in the Lower Cretaceous of the Pyrenees.
Key words: Paleontology, Yasin Group, Gilgit, Hindu Kush, Karakoram.

B/260. Brunschweiler, R.O., 1956. Lower Cretaceous fossils of the Yasin Group, Gilgit Agency. Geological Survey of Pakistan, Records 8, 27p.

Key words: Fossils, Cretaceous, Yasin group, Gilgit.

B/261. Brunsden, D., 1984. The geomorphology of high magnitude-low frequency events in the Karakoram mountains. In: Miller, K.J. (Ed.), The International Karakoram Project, 1, 383-398, Cambridge University Press.

The conceptual basis of high magnitude-low frequency event studies in high mountains is describes and the use of a Transient Form Ratio to isolate the stability state of the landform evolution pattern is proposed. Methods of study and the use of the Karakoram Project (1980) for Hazard surveys are outlined.
Key words: Geomorphology, Karakoram.

B/262. Brunsden, D., Jones, D.K.C. & Goudie, A.S., 1984. Particle size distribution in debris slopes of the Hunza Valley. In: Miller, K.J. (Eds.), The International Karakoram Project 2, 536-580. Cambridge University Press.

The rock fall secree slope model in which there is a size difference down slope on sacress formed by rock fall processes was shown to apply to Karakoram screes. These simple relationships were shown to be disturbed by subsequent mass movement processes to produce distinctive patterns of stripes, festoons and scallops. The patterns are described for large and small screes and scallops. The patterns are described for large and small screes and various processes. Considerable differences in grain size are caused by dry grain flow, shallow sliding and mudflow or debris avalanche.
Key words: Debris slopes deposits, Hunza, Karakoram.

B/263. Brunsden, D., Jones, D.K.C., Whalley, W.B. & Goudie, A.S., 1984. Debris flows of the Karakoram mountains. In: Miller, K.J. (Eds.), The International Karakoram Project Proceedings, Cambridge University Press.

Key words: Debris flow, Karakoram.

B/264. Buchroithner, M.F., 1980. An outline of the geology of the Afghan Pamirs. Tectonophysics 62, 13-35.

In the Great Afghan Pamir (Pamir-e Kaland) the following formations can be distinguished, from bottom to top: Wakhan Fm. (3000–4000 m thick anchimetamorphic slates and sandstones with frequent intercalations of quartzites and rare beds of crystalline limestones; conodonts of Lower Triassic); Qala-e Panja Tonalite (epimetamorphic, cataclastic); Qal'a-e Ust Gneiss (meta- and orthogneisses); Issik Granodiorite (batholite of the Afghan Pamirs, equivalent to Baba Tangi-Lunkho Granodiorite; xenoliths, flow structures and diaphtoritic portions; Upper Jurassic to Eocene). The tectonics are determined by the Peripheric Southern Fault of the Pamirs and the Wakhan Fault, showing vertical dislocation up to 1000 m and sinistral thrusting in connection with the Western Himalayan Syntaxis. Late Variscan and Alpine deformations and an intensive middle Alpine metamorphism can be observed. Interpretations of satellite pictures lead to an insertion of the regional tectonic features into the model of plate tectonics of the Himalayan arc. The paper is of interest for those working in Chitral because some of the Pamir rocks extend there through Wakhan.
Key words: Tectonics, Afghanistan, Pamir.

B/265. Buchroithner, M.F. (Ed.), 1998. Geological map of Chitral 1:100,000. Dresden University of Technology, Germany.

As the title indicates this is an updated compilation of the geology of Chitral and northern Pakistan. Formations are arranged and briefly described in stratigraphic orders. Major structures are also shown.
Key words: Mapping, Chitral.

B/266. Buchroithner, M.F. & Gamerith, H., 1985. On the geology of the Tirich Mir area, central Hindu Kush (Pakistan). Jahrbuch der Geologischen Bundesanstalt (Wien) 128, 367-381.

An outline of the geology of Central Chitral (Hindu Kush, Pakistan) with emphasis on the Tirich Mir Area is given. Descriptions of rock units and structure shall serve as explanatory notes on a new geological map 1:50.000 of the Tirich Mir Massif (enclosure).
Key words: Tectonics, Tirich Mir, Hindu Kush.

B/267. Buchroithner, M.F. & Kostka, R., 1986. Zur herstellung einer topographisch-thematischen karte des Tirich Mir-Gebietes (Hindukusch). Kartographische Nachrichten 36, 171-179.

Key words: Topography, mapping, Tirich Mir.

B/268. Buddruss, G., 1991. On artificial glaciers in the Gilgit Karakorum. Pakistan Archaeology 26, Silver Jubilee Number, Volume 1, 251-262. [Revised in: Studien zur indologie und Iranistik 18, 77-90, 1993, Reinbek].

Key words: Glaciers, Gilgit, Karakoram.

B/269. Buffetant, E., 1978. Crocodilian remains from the Eocene of Pakistan. Abstract, Nuncius Jahrbuch Geology Paleontologia 156, 262-283.

Key words: Palaeontology, Eocene.

B/270. Bughio, G.M. & Khan, N.A., 1970. Report on copper mineralization, Surgin glacier area, Gilgit Agency. West Pakistan Industrial Development Corporation, 34p.

Key words: Mineralization, copper, Surgin glacier, Gilgit.

B/271. Bukhari, K., Ahmad, N. & Sajjad, W., 1998. Effect of Mardan Scarp Project on ground water conditions in parts of Mardan and Charsadda District, N.W.F.P. M.Sc. Thesis, University of Peshawar, 47p.

Key words: Groundwater, scarp project, Mardan, Charsadda.

B/272. Buksh, M.N., 1962. Radioactivity of green sand from Chichali Pass area of Kalabagh, District Mianwali. Pakistan Journal of Scientific and Industrial Research 5, 48-49.

Key words: Radioactivity, Chichali pass, Kalabagh, Mianwali.

B/273. Buksh, M.N. & Mohammad, F., 1963. Preliminary survey and chemical investigation on iron ore of Khyber Agency. Pakistan Journal of Scientific and Industrial Research 6(1), 21-24.

Iron ore outcropping at several localities near Jamrud and elsewhere was found to be too siliceous for profitable beneficiation. The occurrences are briefly described, and the hematitic ore at Lashoora is described in greater detail because of its larger size and relatively high iron content.
Key words: Iron ore, Khyber Agency.

B/274. Bunch, T.E. & Okrusch, M., 1973. Al-rich paragasite. American Mineralogist 58, 721-726.

Two Al-rich amphiboles were found in a corundum- and spinel-bearing calcite marble together with minor phlogopite, margarite, anorthite, and sphen or rutile. Microprobe analyses give half their unit cell contents as:
Amphibole AA-5, $Na_{0.54}$ $K_{0.16}$ $Ca_{1.99}$ $Mg_{3.35}$ $Fe_{0.01}$ $Ti_{0.16}$ $Al^{vi}_{1.47}$ $Al^{iv}_{2.26}$ $Si_{5.74}$ $OH_{1.4}$ $F_{0.40}$ $Cl_{0.07}$;
Amphibole HA-l/2, $Na_{0.67}$ $K_{0.17}$ $Ca_{1.99}$ $Mg_{3.62}$ $Fe_{0.07}$ $Ti_{0.27}$ $Al^{vi}_{1.12}$ $Al^{iv}_{2.25}$ $Si_{5.75}$ $OH_{1.05}$ $F_{0.55}$ $Cl_{0.02}$.
Amphibole AA-5 is the most aluminous yet found in nature (22.6 wt percent Al2O3) and contains essentially no Fe (total iron as FeO : 0.05 wt percent).
Both amphiboles are too rich in Al^{iv} (viz, high Al_2O_3, combined with low SiO_2) to consider them as mixed crystals strictly intermediate between pure pargasite and pure tschermakite. Al-rich pargasite appears to be a suitable name for amphiboles of this composition, owing to the fact that more than 50 percent of their structural formulae can be recalculated in terms of a hypothetical end-member molecule Al-pargasite, $(Na,K)Ca_2Mg_3Al^{vi}2$ Al^{iv}_3 $Si_5O_{22}(OH,F)_2$, which conforms to the limiting Al^{iv}/Al^{vi} ratio of Ca-amphiboles statistically evaluated by Leake (1965, 1971).
The water determination and X-ray powder data are given for one of the amphiboles but not for the other owing to insufficient material. Conditions for the crystallization of the Al-rich amphiboles are briefly discussed.
Key words: Mineralogy, amphiboles, Hunza.

B/275. Bundschun, J., 1992. Hydrochemical and hydrogeological studies of groundwater in Peshawar Valley, Pakistan. Geological Bulletin, University of Peshawar 25, 23-37.

In September 1988 a comprehensive three months program for hydrogeochemical groundwater investigations in Peshawar Valley in the North West Frontier Province (NWFP) of Pakistan was carried out. Its main aim was to classify the groundwater chemically in order to limelight the regional differences and highlight problems related to drinking and irrigation water in the region. About 100 water samples were collected from wells and analyzed. The elevation of the groundwater table in Peshawar Valley is < 5 m deep, except in areas near the mountains and in the southeast where it ranges from 5 to > 30 m. There is a general groundwater flow towards the center of the basin from where the discharge is towards the Indus Valley. It has been noticed that the electrical conductivity (EC-values) increases from < 800 S/cm near the mountains to a maximum of 7800 S/cm in the center of the basin. Similar is the case of mineralization.
The groundwater has been classified according to PIPER. In Peshawar Basin predominantly low mineralized groundwaters of the type “normal alkaline earth freshwater prevailing hydrogencarbonatic” and “normal alkaline earth freshwater with higher contents of alkalies prevailing hydrogencarbonatic” are present. These groundwaters are of good quality. Only in its central part highly mineralized groundwater of the type “alkaline freshwater either hydrogencarbonatic or sulfatic-chlorotic” are found. This high mineralization in combination with the low depth of the groundwater table causes salification of the soils in the center of Peshawar Basin, i.e. Risalpur and its surroundings. It is concluded that the use of such highly mineralized drinking and irrigation water should be abandoned as soon as possible because of the expected hazards to human health and irrigation. It is highly recommended that deeper wells should be drilled to find low mineralization groundwater in this area.
Key words: Hydrochemistry, hydrogeology, groundwater, Peshawar Valley.

B/276. Burbank, D.W., 1982. The chronologic and stratigraphic evolution of the Kashmir and Peshawar intermontane basin, Northwestern Himalaya. Ph.D. Thesis, Dartmouth College, Hanover, New Hempshire, USA, 291p.

Consult the following account for further information.
Key words: Chronology, stratigraphy, intermontane basin, Kashmir, Peshawar, Himalaya.

B/277. Burbank, D.W., 1983a. The chronology of intermontane-basin development in the northwestern Himalaya and the evolution of the northwest syntaxis. Earth and Planetary Science Letters 64, 77-92.

The Northwest Syntaxis delineates a complex zone where the northwesterly trending Himalayan Ranges meet the northeasterly trending Hindu Kush and Indus Kohistan Ranges. The southern margin of the Hindu Kush-Himalayan collisional belt is delineated by a series of imbricate thrusts that transect the northern edge of the modern Indo-

Gangetic foredeep. The Kashmir and Peshawar Basins are embedded in this still-developing thrust belt and are symmetrically oriented about the Northwest Syntaxis.

Consideration of chronologic, stratigraphic, structural, and geophysical data from the syntaxial zone permits the construction of a model for intermontane-basin development and the evolution of the Northwest Syntaxis during the Late Cenozoic. The formation of the Kashmir and Peshawar Basins results from the transfer from the north of the locus of thrusting and uplift to the southern margins of the basins. During the Pliocene, the morphotectonic emergence of the ancestral Pir Panjal and Attock Ranges along the southern margins of the two basins coincides with changes in the patterns of sedimentation and deformation both within the basins and in the bounding foredeep to the south. Contrasting styles of tectonic deformation on opposite sides of the Syntaxis are interpreted as a response to differences in the strength of sediment-basement coupling across the Syntaxis.

Key words: Chronology, intermontane basin, Himalaya.

B/278. Burbank, D.W., 1983b. Multiple episodes of catastrophic flooding in the Peshawar basin during the past 700, 000 years. Geological Bulletin, University of Peshawar 16, 43-49.

At least 40 catastrophic floods inundated the Peshawar Basin in prehistoric times. A sequence of graded beds up to 25m thick near Paran records these flood events. These older floods resulted from significantly higher flows than those of the well-documented floods of 1800's. Such floods can be a real threat to the safety of Tarbela Dam and a careful monitoring of the Indus and its major tributaries is required and suggested.

Key words: Floods, Peshawar Basin, Himalaya.

B/279. Burbank, D.W., 1984. A brief normal-polarity magnetozone in the post-olduvai sediments of northern Pakistan. EOS 65, p.864.

Key words: Magnetism, polarity, sediments.

B/280. Burbank, D.W., 1991. Models of aggradation versus progradation in the Himalayan Foredeep. Geologisch Society of America, Special Paper 232, 113-128.

A frequent goal of decompaction analysis is to reconstruct histories of basin subsidence and tectonic loading. In marine environments, eustatic and paleobathymetric uncertainties limit the resolution of these reconstructions. Whereas in the terrestrial basins, these ambiguities are absent, it is still necessary to account for depositional slopes between localities in order to analyze three-dimensional patterns of subsidence. We define two end-members for depositional surfaces: aggradation and progradation. The relative importance of either end-member is a function of the interplay between the rate of net sediment accumulation and the rate of basin subsidence. The models predict the patterns of major drainages (transverse versus longitudinal) and the way in which provenance should be reflected within different portions of a basin. Consequently, paleocurrent and provenance data from the ancient stratigraphic record can be used to distinguish between these endmembers. The subhorizontal depositional surfaces that dominate during times of aggradation provide a well-defined reference frame for regional analysis of decompacted stratigraphies and related subsidence. Depositional slopes during progradation cannot be as precisely specified, and consequently yield greater uncertainties in reconstructions of subsidence. These models are applied to the Mio-Pliocene foreland basin of the northwestern Himalaya, where sequences of isochronous strata have been analyzed throughout the basin. These time-controlled data delineate a distinctive evolution from largely aggradational to largely progradational depositional geometries as deformation progressively encroaches on the foreland. Such a reconstruction of past depositional surfaces provides a well constrained reference frame for subsequent integration of subsidence histories from throughout the foreland.

Key words: Agradation, progradation, foredeep, Himalaya.

B/281. Burbank, D.W. & Beck, R.A., 1989a. Synchronous sediment accumulation, decompaction and subsidence in the Miocene foreland basin of northern Pakistan. Geological Bulletin University of Peshawar 22, 11-24.

Previous magnetostratigraphic studies in northern Pakistan provide a tightly constrained temporal framework within which to analyze the sediment accumulation history of the northwestern Himalayan foreland basin. Paleocurrent and provenance data indicate that a longitudinal drainage system flowing to the ESE persisted through much of the middle and late Miocene deposition. The subhorizontal cross-sectional surfaces defined by the paleodrainage configurations provide a reference frame for analyzing subsidence histories. Six magnetic sections in the Potwar Plateau have been decompacted as a function of burial depth and lithology to provide both accumulation and subsidence records. These records demonstrate consistently higher amounts of accumulation and subsidence in the northern portions of the basin, but also indicate that events of tectonic loading were experienced synchronously across the basin. Inflections in the curves of tectonically induced subsidence suggest that an important interval of thrust loading began ~ 11.5 Ma and terminated ~8 Ma.

Key words: Magnetostratigraphy, sediments, Himalayan Foreland Basin, siwaliks.

B/282. Burbank, D.W. & Beck, R.A., 1989b. Early Pliocene uplift of the Salt Range; Temporal constraints on thrust wedge development, northwest Himalaya, Pakistan. In: Malinconico, L.L. & Lillie, R.J. (Eds.), Tectonics of the Western Himalayas. Geological Society of America, Special Paper 232, 113-128.

Recent chronologic and stratigraphic studies in the northwestern Himalayan foreland basin have led to better constrained deformational and depositional histories. In order to test the hypothesis that considerable pre-Pleistocene uplift occurred in the Salt Range of northern Pakistan, the stratigraphic record adjacent to the central and eastern Salt Range has been examined. Unconformities, paleomagnetically documented tectonic rotations across these unconformities, and changes in the paleocurrent directions, provenance, and rates of sediment accumulation serve to delineate an interval of early Pliocene uplift of the Salt Range, as well as several late Pliocene-Pleistocene uplift events in thin range and adjacent structures. Stratigraphic, reflection seismic, and structural data indicate that these uplift events resulted from thrusting related to the salt- lubricated Potwar detachment. When considered in conjunction with the chronology of deformation in other parts of the foreland, these data clearly indicate that out-of-sequence thrusting has occurred on a large scale (>100 km) during the past 6 m.y. This pattern of deformation supports the concept that an irregular spatial and temporal distribution of shortening should be expected to occur within an advancing thrust wedge.

Key words: Structure, Pliocene, Salt Range.

B/283. Burbank, D.W., Beck, R.A. & Mulder, T., 1996. The Himalayan foreland basin. In: Yin, A. & Harrison M. (Eds.), The Tectonic Evolution of Asia, Cambridge University Press, 149-189.

Tectonic loading during the Cenozoic growth of the Himalaya created the Indo-Gangetic foreland basin, a flexural depression that is the largest terrestrial foreland basin on the earth's surface. Stratigraphic, chronologic, petrographic, sedimentological and structural data from across the foreland are synthesized here to produce an overview of the Cenozoic evolution of this basin. Within the foreland, variations in crustal rigidity along the strike and the presence of long-lived basement faults have modulated its width and large-scale subsidence patterns. During most of the Cenozoic, the rates of migration of the distal basin pinch-out and of the foreland depocenter suggest that about 20% of the Indo-Asian convergence has been accommodated by thin-skinned thrusting within the foreland, often related to detachments localized at the top of the basement or in incompetent foreland strata, and by thrusts with hanging walls more than 4-10-km thick along its proximal margin. Episodic southward relocation of these basin-margin thrusts has served to define large intermontane basins.

Although the early foreland deposition is poorly documented, ≥8-km of Paleogene strata have accumulated in proximal locations and show clear Himalayan derivation. Neogene deposition encompasses the Siwalik Group strata of Miocene and younger age. In northwestern Pakistan and parts of India and Nepal, excellent time controls derived from magnetostratigraphic studies permit detailed correlations, analyses of accumulation and subsidence patterns, and delineation of the interrelationships between deformation and deposition. During early and middle Miocene times, axial rivers, fed by numerous oblique tributaries, appear to have followed southeastward from northwestern Pakistan into the Ganges drainage. In northwestern Pakistan, a major stratigraphic change occurred at about 11 Ma: Accumulation rates increased 30-200%, sandstone abundances doubled, fluvial discharges increased fivefold and a major influx of detritus occurred, attributed to unroofing of the Kohistan island-arc. Upward coarsening and accelerated accumulation also prevailed in India and Nepal. Those changes are interpreted as having resulted from initial motion and loading by the Main Boundary Thrust at about 11 Ma, approximately 5 m.y. earlier than previously documented.

Proximal portions of the foreland are more abundantly represented within the preserved Upper Neogene strata. As deformation encroached on the foreland, depositional environments and regimes of accumulation and erosion became increasingly heterogeneous. On the basis of scale, petrology, and dispersal patterns, often four river systems can be delineated within the foreland as it became structurally disrupted: an axial river, large transverse rivers with hinterland catchments, and rivers sourced on newly created intra-foreland uplifts. Late Miocene-Pliocene growth of the Salt Range at the southern limit of a 100-km wide salt-lubricated detachment in northwestern Pakistan initially created a large piggyback basin that localized the ancestral Indus River. Continued shortening caused diversion of the Indus to the southwest, coinciding with rapid accumulation and southward pinch-out migration in the Trans-Indus region. Large-scale out-of-sequence thrusting occurred in northwestern Pakistan between 6 Ma and 1 Ma, coeval with deposition Plio-Pleistocene intermontane basins ponded behind major basin-bounding thrusts. Across the foreland, records of initial conglomeratic strata indicate highly diachronous progradation (ranging from >8 to <1 Ma) that was strongly influenced by fluvial interactions with local folds and thrusts. Whereas tectonic loading appears to continue to control depositional patterns in the Indus foreland, changes in the position of the axial river and in cross-sectional stratal geometries suggest that erosional unloading during the past 4-5 m.y. has become increasingly important in the Himalaya adjacent to the Gangetic foreland. This may be a response to expanding glacial climates. In contrast, the inferred strengthening of the Asian monsoon at about 7-8 Ma does not appear to have led to an increased detrital-sediment flux to the foreland.

Major unresolved problems in the Himalayan foreland included the following: our poor understanding of its Paleogene history; sparse reliable chronologic control in the central and eastern foreland; absence of clear "fingerprinting" that could tie foreland strata to specific hinterland source areas; inadequate seismic analysis of foreland structure; poorly understood climatic influences on deposition and erosion; and uncertainties regarding strain partitioning and its variation along strike within the foreland.

Key words: Tectonics, Foreland Basin, siwaliks, Himalaya.

B/284. Burbank, D.W., Beck, R.A., Raynolds, R.G.H., Hobbs, R. & Tahirkheli, R.A.K., 1988. Thrust and gravel progradation in foreland basins: A test of post-thrusting gravel dispersal. Geology 16, 1143-1146.

The use of gravels as syntectonic indicators of thrusting has recently been questioned by foreland-basin models that assign gravels to a post-thrusting interval of progradation, except in very proximal areas. On the basis of precise temporal control provided by magnetostratigraphically dated sections, the history of gravel progradation after a major thrusting and uplift event in the northwestern Himalaya is shown to be a virtually syntectonic phenomenon. Despite considerable crustal subsidence driven by a thick-skinned thrust, gravels prograded □70 km during a 1.5-m.y.-long thrusting event. By 3 m.y. after the start off thrusting, gravels extended more than 110 km into the basin. Although delayed gravel progradation appears appropriate for many Rocky Mountain foreland basins, it is clearly not valid for the Himalaya. We attribute the difference in depositional response between these basins to differences in the quantity of sediment supplied to them (sediment starved vs. overfilled), the availability of resistates in the source area, and the size of the antecedent drainage.

Key words: Tectonics, structure, Foreland Basin, siwaliks, Himalaya.

B/285. Burbank, D.W. & Johnson, G.D., 1982. Intermontane-basin development in the past 4 Myr in the north-west Himalaya. Nature 298, 432-436.

Through the combined use of magnetic-polarity stratigraphy with fission-track dating of volcanic ashes, a new chronology, spanning 4 Myr, has been developed for the intermontane basin of Kashmir in the northwestern Himalaya. Additional information on the basins' configuration can be seen above in Burbank 1983.

Key words: Tectonics, Intermontane basin, Himalaya.

B/286. Burbank, D.W. & Johnson, G.D., 1983. The Late Cenozoic chronologic and stratigraphic development of the Kashmir intermontane basin, northwestern Himalaya. Palaeogeography, Palaeoclimatology Palaeocology 43, 205-235.

The intermontane basin of Kashmir developed within the thrust-faulted, southern margin of the Himalayan Range. Detailed lithostratigraphies, magnetic-polarity stratigraphies, and fission-track dates on enclosed volcanic ashes were determined at four separate localities in order to develop a chronology of the Late Cenozoic evolution of the Kashmir Basin.

The results indicate that sedimentation had commenced by about 4 m.y. ago. Since then, over 1300 m of sediments have aggraded at inferred average rates varying from 16 to 64 cm per 1000 yr. Lacustrine and deltaic sediments dominate the Kashmiri sequences and appear to respond sensitively to tectonic events along the basin margins. Conglomerates shed from the faulted basin margins at about 1.7, 2.1, 2.7, and 3.0–3.5 m.y. ago punctuate the predominantly low-energy, fluviolacustrine depositional record. Paleocurrent analyses indicate a switch from northeasterly derived conglomeratic facies to southwesterly derived ones about 1.7 m.y. ago. This transition reflects enhanced activity along the Main Boundary Thrust complex to the southwest and an apparent diminution of faulting along the northeastern margin of the basin. In the Pir Panjal Range, 1400–3000 m of uplift at inferred rates of up to 10 mm yr^{-1} have terminated widespread sedimentation within the Kashmir Basin since the middle Pleistocene.

Key words: Chronology, stratigraphy, Late Cenozoic, Kashmir.

B/287. Burbank, D.W., Leland, J., Fielding, E., Anderson, R.S., Brozovic, N., Reid, M.R. & Duncan, C., 1996. Bedrock incision, rock uplift and threshold hillslopes in the northwestern Himalayas. Nature 379, 505-510.

The topography of tectonically active mountain ranges reflects a poorly understood competition between bedrock uplift and erosion. Dating of abandoned river-cut surfaces in the northwestern Himalayas reveals that the Indus river incises through the bedrock at extremely high rates (2–12 mm yr-1). In the surrounding mountains, the average angles of hillslopes are steep and essentially independent of erosion rate, suggesting control by a common threshold process. In this rapidly deforming region, an equilibrium is maintained between bedrock uplift and river incision, with landsliding allowing hillslopes to adjust efficiently to rapid river down-cutting.

Key words: Topography, uplift, erosion, Indus, Himalaya.

B/288. Burbank, D.W. & Raynolds, R.G.H., 1984. Sequential Late Cenozoic structural disruption of the northern Himalayan foredeep. Nature 311, 114-118.

Chronologies for the Siwalik molasse and intermontane basins along the southern margin of the Himalaya and Hindu Kush Ranges constrain the timing and pattern of facies migration and structural disruption of the Indo-Gangetic foredeep. This synthesis indicates that quiescent intervals are punctuated by pulses of rapid deformation as thrusting migrates in a stepwise fashion across the foredeep.

Key words: Structure, tectonics, foredeep, siwaliks, Himalaya.

B/289. Burbank, D.W. & Raynolds, R.G.H., 1988. Stratigraphic keys to the timing of thrusting in terrestrial foreland basins: Applications to the northwestern Himalayan. In: Kleinspehn, K.L. & Paola, C., (eds,) New perspectives in basin analysis. Springer Verlage, New York, 331-351.

Key words: Stratigraphy, tectonics, Himalaya.

B/290. Burbank, D.W., Raynolds, R.G.H. & Johnson, G.D., 1986. Late Cenozoic tectonics and sedimentation in the north-western Himalayan foredeep: II. Eastern limb of the Northwest Syntaxis and regional synthesis. In: Allen, P.A. & Homewood, P. (Eds.), Foreland Basins. Special Publication of the International Association of Sedimentologists, Special Publication 8, 293-306.

Key words: Cenozoic tectonics, sedimentation, Himalaya.

B/291. Burbank, D.W. & Tahirkheli, R.A.K., 1985. The magnetostratigraphy, fission-track dating, and stratigraphic evolution of Peshawar intermontane basin, northern Pakistan. Geological Society of America, Bulletin 96, 539-552.

The Peshawar basin is situated along the junction of the northern margin of the Indo-Gangetic foredeep and the southern margin of the Hindu Rush-Himalayan Ranges. During the late Cenozoic, southward encroachment of tectonic disruption into the foredeep terminated molasse deposition and delineated the Peshawar intermontane basin through uplift of the Attock Range along the southern margin of the basin. In this study, magnetostratigraphy, fission-track dates on volcanic ashes, and stratigraphic data are used to define the chronologic and stratigraphic evolution of the basin.

Following a late Miocene to Pliocene interval of folding and thrusting of the preexisting molasse sediments, deposition began in the Peshawar basin by at least 2.8 m.y. ago. Subsequently, >300 m of basin-filling sediments accumulated at rates averaging 15 cm/1,000 yr. Northward progradation of alluvial-fan deposits from the uplifted basin margin had begun by 2.6 m.y. ago and continued at an inferred rate of 2 cm/yr. Proximal to the Attock Range in the south, alluvial-fan facies persisted until 0.6 m.y. ago. Contemporaneous sediments closer to the basin center demonstrate the presence of rapid facies transitions to extensive floodplain and shallow-lacustrine depositional environments. Widespread intermontane-basin sedimentation was terminated by accelerated uplift of the Attock Range after □0.6 m.y. ago. Subsequently, during the Brunhes chron, catastrophic floods have periodically inundated the Peshawar basin. Continuing tectonic deformation of the basin is indicated by uplifted flood deposits, offset terraces, and modern seismicity.

Key words: Chronology, magnetostratigraphy, Peshawar basin.

B/292. Burchfield, B.C. & Royden, L.H., 1985. North-South extension within the convergent Himalayan region. Geology 13, 679-682.

Recent work by Burg et al. (1984) indicates the presence of east-west-striking, gently north-dipping normal faults in the Higher Himalayas and southern Tibet that formed during postcollisional convergence of India and Tibet. These faults extend for at least 800 km along strike. We interpret these normal faults as probable late(?) Miocene extensional features with perhaps several tens of kilometres of down-to-the-north displacement. A simple elastic model suggests that these normal faults may have formed during gravitational collapse of the Miocene topographic front between India and Tibet. In this interpretation, gravitational collapse occurred by southward motion, relative to India and Tibet, of a wedge of crustal rocks bounded above by gently north-dipping normal faults and below by thrust faults that probably dip north. North-south extension produced in this way is probably confined to upper crustal levels only and does not reflect regional extension of the entire lithosphere.

Key words: Structure, collision, Tibet, Himalaya.

B/293. Burg, J.P., Bodnier, J.L., Chaudhry, M.N., Hussain, S.S. & Dawood, H., 1998. Intra-arc mantle-crust transition and intra-arc mantle diapirs in the Kohistan Complex (Pakistan Himalaya). Petro-structural evidence. Terra Nova 10, 74-80.

The Jijal and Chilas complexes have been interpreted previously as the lower level of the layered Kohistan Island Arc, in Pakistan. We provide petro-structural evidence for melt-consuming reactions between mantle rocks and infiltrated, volatile-rich magmas in both complexes. Precipitate minerals in Jijal and Chilas suggest that melt-rock reaction occurred at higher pressure in Jijal than in Chilas. The early appearance of orthopyroxene in Chilas and the spatial relationship of the ultramafics rocks with quartz-bearing norites indicate that the reactant melt was more silicic. We argue that the Jijal complex includes the infra-arc crust/mantle boundary and that ultramafics associations of the Chilas complex are apics of possibly younger, intra-arc mantle diapirs.

Key words: Petrology, mantle, Jijal, Chilas, Kohistan complex.

B/294. Burg, J.P., Bodinier, J.L., Chaudhry, M.N., Hussain, S.S., Dawood, H. & Garrido, C.J., 1999. Mantle-crust and mantle diapers in the Kohistan arc complex (Pakistani Himalaya). Petro-structural evidence. J. Conference Abstract 4. European Union of Geology Meeting, Strausbourg, p.396.

Consult the preceding account for further information
Key words: Petrology, mantle, Jijal, Chilas, Kohistan complex.

B/295. Burg, J.P., Bodinier, J.L., Chaudhry, N., Hussain, S.S., Dawood, H. & Garrido, C.J., 1999. Mantle-crust transitions in the Kohistan Arc Complex (Pakistani Himalaya). Terra Nostra 99, Abstract Volume, 14th Himalaya-Karakoram-Tibet Workshop, Kloster Ettal, Germany, 16-18.

The Kohistan complex is an island arc obducted during the Mesozoic onto India along the Indus Suture We have recognized two units containing ultramafic rocks in this complex: (I) the Jijal unit, which is the lowermost part of the exposed arc and (2) the Chilas unit, which configures the core of the arc. Our observations indicate that the ultramafic rocks are exhumed mantle rocks that record distinct evolution and different depths of equilibration. The Jijal unit includes the arc crust-mantle boundary and contains mantle rocks equilibrated in the Ariegite subfacies. The Chilas ultramafic associations are apexes of intra-arc mantle diapirs with ultramafic rocks equilibrated in the plagioclase peridotite facies.
The lower part of the Jijal section (‘the mantle section’) is dominated by dunites and wehrlites interlayered with subordinate pyroxenites. The presence of harzburgites, with a high-temperature tectonite microstructure, indicates that peridotites were part of a residual ‘arc mantle’. Flames of dunite in websterites indicate that these rocks have replaced peridotites through magma-consuming melt-rock reactions, at P-T conditions close to the peridotite solidus. The proportion of mafic rocks (websterite and minor hornblendites and garnetites) increases up-section, up to a sharp intrusive contact between ultramafic rocks and overlying garnet granulites. The latter facies is derived from garnet gabbro. The contact dips gently to the north, parallel to the pyroxenite-peridotite layering. We interpret this boundary as the exhumed petrological arc-‘Moho’.
The Chilas section includes a series of ultramafic bodies and gabbro norites. Gabbro-norites display magmatic/cumulitic textures. Ultramafic rocks, however, show microstructure typical of mantle rocks, notably, porphyroclastic textures in wehrlites and harzburgites and coarse-grain textures in plagioclase-bearing dunites. The contact between ultramafic rocks and gabbro-norites is steep and underlined by strongly metasomatised rocks, such as hornblende and/or plagioclase pyroxenites. This metasomatic aureole is indicative if extensive reaction between peridotites and infiltrated melt, implying that the mantle rocks were intruded at high, near-solidus conditions within partially consolidated norites. Interstitial plagioclase and diffuse impregnations of gabbro-norite are further indications if magma percolation in peridotites. Thereafter, upon cooling, the peridotites were fractured, intruded by magma dikes and eventually brecciated and finely dispersed in the gabbro-norite. These final evolutionary stages are exemplified by the occurrence of steeply dipping, intrusive gabbro-norite layers in peridotites, blocks of peridotites in gabbro-norites and olivine xenocrysts in graded cumulate layers. These cumulate layers describe a large antiform. To integrate small (reactional and intrusive contacts) and large (antiformal) scale observations, we interpret the Chilas ultramafic bodies as pieces of intra-arc mantle diapirs. These mantle diapirs indicate rifting of the Kohistan arc during a major tectonic event that should be considered in any collisional model of the area.
Key words: Indus suture, Jijal, Chilas, Mesozoic, Kohistan complex.

B/296. Burg, J.P., Chaudhry, M.N., Ghazanfar, M., Anczkiewicz, R. & Spencer, D.A., 1996. Structural evidence for backsliding of the Kohistan arc in the collisional system of NW Pakistan. Geology 24, 739-742.

In the Naran region of the Pakistan Himalayas, a regionally distributed second generation of folds results from northward-directed shear deformation. These folds are collapse structures associated with back sliding of the hanging wall, namely the Kohistan paleo-island arc. They are explained by a geometrical model that combines coeval vertical and horizontal shortening. Accordingly, they are synconvergence collapse features that indicate at least 5-km of vertical shortening of the imbricate thrust slices derived from the Indian continent in the northwest Himalayas.

Key words: Tectonics, extensional faults, Kohistan, Himalaya.

B/297. Burg, J.P. & Podladchikov, Y., 1998. Bending of syntaxes: consequences. In: Hamidullah, S., Lawrence, R.D. & Jan, M.Q. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 39-41.

Syntaxis areas where orogenic structures seem strongly bent around a vertical axis are fundamental features of modem collisional orogens. The still active Himalayan mountain belt is one example that terminates at both ends into nearly transverse syntaxes. The West and East Himalayan syntaxes (named after the Nanga Parbat and Namche Barwa, respectively) are crustal antiforms in which granitic and migmatitic rocks yield Cenozoic to very recent apparent ages.

The first part of this talk will emphasise that both syntaxes present remarkably similar thermo-mechanical evolution of basement rocks overprinted by Himalayan metamorphism and Pliocene-Pleistocene high-grade metamorphism and anatexis. Both straddle the same Neogene time span and have undergone rapid denudation, which links their still going growth to the uplift that produced Tibet in the last few million years. A rise of the Moho level is recorded under the Nanga Parbat. No information on the topic seems available beneath the Namche Barwa. In Pakistan, the Hazara-Kashmir Syntaxis is the southern continuation of the Nanga Parbat Syntaxis. In the Arunachal Himalaya, the Siang antiform appears as the southwestern continuation of the Namche Barwa syntaxis. All interpretations point to crustal scale folding as the driving mechanism that has produced these orogenic structures.

Folding and buckling instabilities as a response to layer parallel shortening are well-investigated features in geodynamics. Classical theories are restricted to initial stages of the instability development and to linear viscous, elastic and visco-elastic rheologies. Recent theoretical developments extend to waning stages of folding and to non-linear visco-plastic rheologies. However, gravity plays a fundamental role at a crustal or lithospheric scale, which means that new methods are needed to model folding of the oceanic and continental lithospheres. We employ 2-Dimension FEM modelling to study shortening of the continental lithosphere driven by far field motions of relatively rigid plates over an invisid substratum (asthenosphere). Features of the model are:

Visco-elasto-plastic rheology. Viscous deformation is power law creep. Plastic yielding is according to Mohr-Coulomb plasticity.

There are three compositional layers, upper felsic crust 25 km, lower mafic crust 15 km, subcrustal olivine lithosphere 70-140 km. Boundary conditions are free surface, erosion and zero temperature at the top; zero differential stresses and fixed temperature at the bottom, compressional velocity and no heat flux at the lateral boundaries. Erosion is modelled according to linear diffusion equation.

Second order implicit FEM is used to discrete the momentum and heat transfer equations. Because of the number of parameters controlling the style of folding we do not attempt any systematic study. We restrict ourselves to a particular example of continental shortening - the West and East Himalayan "syntaxes".

Modelling yields the following results:

Only cold (strong) lithospheres exhibit buckling with a wavelength of ca. 200-km. Significant amplification is achieved in the overall strain range of 10-25%.

Topography due to buckling is up to 5-10 km. Exhumation is limited by fold locking and the typical amount is ca. 20 km.

After locking up the first anticline, lateral fold propagation occurs.

The Moho is uplifted beneath crustal antiforms and one can define several Mohos at strongly deformed stages.

High heat fluxes are detected within the antiforms whilst tectonic overpressure as high as twice of the lithostatic value may build in limb areas.

There are broad small amplitude depressions around the growing anticline.

We extend point 6 to discuss the development of synformal basins on both sides of crustal antiforms. We propose that the Peshawar and Kashmir basins are such structural depressions. The synclinal Peshawar basin to the west is readily seen on any geological map as a structural analogue of the synclinal Kashmir basin to the east of the Hazara-Kashmir Syntaxis. This relationship and the possible correlation between these two synformal depressions were noted by. Like the Karewas of Kashmir, the Peshawar basin has a thick Plio-Pleistocene to recent fill of alluvial sediments that began around 4 My. ago. We note that both basins have the same beginning age as the syntaxis and that sedimentation developed in both basins, although their bulk history is that of surface uplift. Our interpretation explains the location of both basins, which a ramping interpretation does not.

The kinematic model involving crustal folding to explain the Himalayan syntaxes is verified by our FEM dynamic modelling. In addition, first order features of the "cold model" of lithospheric folding fit well geological observation. We conclude that buckling is a basic response of the continental lithosphere to shortening. We emphasise that dominant geological and physiographic features of Northern Pakistan formed during the last 4 Ma have been controlled by the growth of the Nanga Parbat syntaxis. This is true also for the less known eastern Himalayan Syntaxis.
Key words: Orogeny, structural geology, Himalayan Syntaxis.

B/298. Burg, J.P. & Podladchikov, Y., 2000. From buckling to asymmetric folding of the continental lithosphere: numerical modeling and application to the Himalayan syntaxes. 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, 219-236.

The eastern and western Himalayan syntaxes are large-scale, coeval antiforms developed late in the history of India-Asia collision. We use two-dimensional finite element models of lithospheric folding to develop a mechanically plausible structural interpretation. The models mimic the coeval development of adjacent synformal basins, analogous to the Peshawar and Kashmir basins on either side of and adjacent to the western syntaxis. Pure-shear thickening and symmetric buckling accommodate shortening until, at a certain strain, an asymmetric thrust-like flow pattern occurs on a crustal to lithospheric scale. Similarities between geological data and calculated models suggest that lithospheric buckling is a basic response to large-scale continental shortening. To generalize these results, we suggest that a typical shortening history would include: (1) locking of an early thrust system in hinterland regions, followed by (2) pure shear shortening and symmetric buckling o the shortened lithosphere, and (3) loss of symmetry leading to the formation of an asymmetric fold in which a new thrust system will nucleate.
Key words: Tectonics, crustal shortening, Himalaya.

B/299. Burgisser, H.M., Gansser, A. & Pika, J., 1982. Late glacial lake sediments of the Indus Valley area, north western Himalayas. Ecologae Geologiae Helvetiae 75, 51-63.

Key words: Glaciers, sediments, Indus Valley, Himalaya.

B/300. Buri, C.Z., 1965. A new Permian Epimastopora (calcareous alga) from Hunza Valley (Western Karakorum). In: Italian Expeditions to the Karakorum (K2) and Hindu Kush, (A. Desio leader), Scientific Reports IV (1), 79-88. Paleontology-Zoology-Botany. Brill, Leiden.

This paper reports on a new species of Epimastopora alga of Permian age from Hunza.
Key words: Palaeontology, Permian, Hunza, Karakoram.

B/301. Burnes, A., 1833a. On geology of the transect from NW India to Caspian. Geological Society of London, Transaction Series 2-3.

Key words: Geology, India, Caspian.

B/302. Burnes, A., 1833b. Substance of a geographical memoir on the Indus. Royal Geographic Society Journal 3.

Key words: Geography, Indus.

B/303. Burrard, S.G., 1915. On the Origin of the Indo-Gangetic Trough, commonly called the Himalayan Foredeep. Proceedings of the Royal Society, 91A, 220-238.

1. The Question under Discussion.

The plains of ISTorthern India consist of alluvial deposits brought down by the Rivers Indus and Ganges. These plains conceal from our view a deep trough that has been formed in the solid rock of the Earth's crust. The trough is bounded on the north by mountains of the tertiary age and on the south by an ancient pre-tertiary tableland. North of the trough the Earth's crust has undergone continual compression, disturbance, and uplift since the beginning of the tertiary age ; south of the trough it has remained undisturbed since the close of the paleozoic era. On Fig. 1 are shown the Indo-Gangetic trough, the mountainous area on its north, and the tableland on its south.

From the writings of Suess, the Indo-Gangetic trough has come to be called the Himalayan foredeep. In this paper is proposed to consider one question only, namely, the origin of the Himalayan foredeep

2. The Zone of Low Density in the Crust,

In 1912 I published a paper in which I endeavoured to show that a zone of low density underlies the Indo-Gangetic alluvium and skirts the southern foot of the Himalaya Mountains. The existence of this line of low density in the crust has not been disputed. Its significance lies in the fact that it furnishes an argument against Prof. Suess's theory of Himalayan formation. Prof. Suess held that the mountains of Tibet and Persia are advancing southwards in a great series of folds. Mr. Hayden, Director of the Geological Survey of India, writes that the great series of folds in Central Asia are supposed to have been caused by a horizontal thrust from the north.5

Key words: Tectonics, Himalayan Foredeep.

B/304. Burrard, S.G., 1930. The Himalayan ranges and Godwin Austen’s map. Geographical Journal 75, 35-37.

There were one or two points in your article on the Indian Border, G.J., September, p. 274, which were not quite fair to the Survey of India. You are quite mistaken in thinking that the ideas of Godwin Austen have dominated the survey for fifty years or that our maps are dependent on geology. I have never seen that map in any Indian drawing-office, I have never heard it quoted, and have never used it myself. The reason that the successive maps of Tibet from Walker's downwards all resemble one another is that they are all based on the same topographical data, the later maps having additional data. All our maps of Tibet are purely topographical; geology does not enter; there have been no geological surveys, and if there had been, we never use geology in topographical maps.

In all branches of knowledge generalization is necessary and difficult. Geographers are obliged to generalize, and to produce diagrammatic maps of complicated mountain systems. These diagrams are required as index maps, and for bird's-eye views. If we plot all the known peaks above 16,000 feet, the points on our charts arrange themselves in curvilinear alignments. I am no advocate of "ranges"; as a geologist Hayden was opposed to long ranges, because the eastern part of the Himalayan range was of a different age from the western. But Hayden, like myself, could not but see that the high points of Tibet insisted on grouping themselves in curvilinear arrangements, and a "range" is merely an abbreviation for curvilinear arrangement. We have to keep quite separate the question of the continuity of ranges from east to west, and the continuity of their names throughout their lengths. As to the continuity of ranges the topographical data lead to the idea that the plateau of Tibet is traversed from west to east by long continuous ranges. If a range does sink into the plateau here and there, it seems to reappear on the same alignment a little farther on. Between the ranges the plateau seems to consist of level strips. There has been no topographical survey; but there have been scattered surveys form east to west and from north to south, and they all con- firm the view of parallel ranges.

As to continuity of names across the plateau, everyone would like to find Tibetan names. No one wants to extend the name Karakoram east of the Karakoram region: it would be a mistake. The Map of Tibet, 1914, which you quote, had a very unfortunate error, which was not noticed by the scrutineer; the drawing-office was short-handed, and this mistake crept in. The draughts-man entered the name Karakoram too far east. This was a mere slip; there was nothing intentional about it. I have never heard any surveyor advocate the extension of the name Karakoram east of the Shyok basin. The name has not been limited in area with the same definite precision as a state boundary. But just as the name of this range is automatically changed to Hindu Kush, as it proceeds westwards into Afghanistan, so we may hope that it will one day take on a Tibetan name as it proceeds eastwards.

With regard to your remark about the Ladakh and Kailas ranges extending eastwards to 920, there is no doubt that these two ranges are very long alignments of elevated points. The apparent breaks in their continuity are mentioned on pp. 93 and 95, Part II (Burrard and Hayden's sketeh). These breaks are probably only dips of the alignment below the high level of the plateau. The difficulties of naming these long ranges, when there are no Tibetan names, were painfully present to Hayden and myself in 1907. Our critics may say, "How absurd to extend the names Ladakh and

Kailas through so many degrees of longitude!" The names affixed to these two ranges were given in 1852-53 by Cunningham, a careful, scientific and erudite explorer; we followed Cunningham, and in the absence of Tibetan names we continued Cunningham's names throughout the eastern prolongations of his range- alignments. In taking this step and in avoiding inventions of new names, we were only actuated by the wish to leave the whole question open for final consideration when the time had become ripe. We thus saved our successors from the complications of having new names started which might prove unsuitable. I may say that in 1907 we consulted every known authority about these ranges, and we received the universal advice: "the time is not ripe; leave the question alone."
The ranges of Tibet seem to open like a fan, and to be squeezed together at the north-western end. But the same elevated alignments seem to persist even when squeezed and pushed north-west.
Key words: Godwin Austen, Karakoram, Hindu Kush, Himalaya.

B/305. Burrard, S.G. & Hayden, H.H., 1933-34. A sketch of the geography and geology of the Himalayan Mountains and Tibet. Four volumes (2nd Edition. Revised by S. Burrard and A.M. Heron.) New Delhi.

This is a reproduction of a book published before 1923. This book may have occasional imperfections such as missing or blurred pages, poor pictures, errant marks, etc. that were either part of the original artifact, or were introduced by the scanning process. We believe this work is culturally important, and despite the imperfections, have elected to bring it back into print as part of our continuing commitment to the preservation of printed works worldwide. We appreciate your understanding of the imperfections in the preservation process, and hope you enjoy this valuable book.
Key words: Geology, geography, Himalaya, Tibet.

B/306. Burtman, V.S., 1983b. Development of the Pamir–Punjab syntaxis. Geotectonics, 16, 385–393.

Key words: Syntaxis, Pamir, Punjab.

B/307. Butler, B.C.M., 1963a. An occurrence of nephrite jade in West Pakistan. Mineralogical Magazine 33, 385-393.

Two pebbles of good quality nephrite jade from the riverbed of the Teritoi, Kohat District, West Pakistan, are described. One pebble is pale greenish white and has specific gravity 2.954, and the other is spinach green with specific gravity 3.021. Under the microscope both consist of sub-parallel bundles of tremolite fibers. The discovery is of significance in relation to the problem of the origin of the raw material of Indian carved jade. The pebbles are thought to be derived from the Siwalik sediments.
Key words: Jade, Kohat, siwaliks.

B/308. Butler, B.C.M., 1963b. Nephrite jade in West Pakistan. Journal of the Royal Asiatic Society, (3 &4), 130-139.

Consult the preceeding account for further information.
Key words: Jade, Kohat, siwaliks.

B/309. Butler, B.C.M., 1965. Epidiorite-limestone contact relations at Burawai, Hazara district, West Pakistan. Mineralogical Magazine 34, 82-91, 2 Pl.

Mineral assemblages in calcareous rocks upto 6 ft from the contact of an epidiorite sill are interpreted as a result of regional metamorphism superimposed on an earlier thermal metamorphism in which potassium metasomatism occurred. The sill, originally a dolerite, is 70-100 ft thick and now consists of green amphibole, oligoclase, and sphene. The rocks 6 ft from the contact are impure calcareous rocks with microcline, epidote and zoisite, oligoclase,

pale green pyroxene, actinolite amphibole, and quartz. At 4 ft from the contact calcite, microcline, Ca-rich garnet (n 1.760), zoisite epidote, and pyroxene are the chief components. Nearer to the contact the abundance of garnet increases, but in the last foot of the contact garnet is absent and the assemblage is epidote-amphibole-calcite-quartz. Numerous model analyses are given.
Key words: Petrology, metamorphism, Hazara.

B/310. Butler, R., 1995. When did India hit Asia? Nature 373, 20-21.

Key words: Tectonics, India, Asia.

B/311. Butler, R., Jones, C., Treloar, P. & Wheeler, J., 1991. Tectonic evolution of the Nanga Parbat massif insights from the central-southern segment. Abstract Volume, 6th Himalaya-Karakoram-Tibet workshop, Auris, France, 23.

The Nanga Parbat massif represents the northern-most continuous outcrop of the Indian continent within the Himalayan collision belt, exhumed from beneath the overriding Kohistan arc terrane by young thrust activity. Recent work has concentrated on the uplift neotectonics, effect which are concentrated on the western margin of the massif.
The internal structure of the Nanga Parbat massif is schematically represented as antiformal, with the early high strain contact between Kohistan-Ladakh and Indian continental material (a possible MMT analogue) defining this structure. However, recent studies of the internal structure of the massif (Wheeler, Potts and Treloar) along the accessible Indus transect suggest otherwise. This work defined two major antiformal structures in foliation of the Nanga Parbat basement. In this contribution we present new results arising from two expeditions into the Nanga Parbat massif, both of necessarily of a reconnaissance nature: the Durham University geological expedition in 1998 and a NERC-funded trip in 1990.
Our studies in the heart of the massif to the south attempted to trace the composite antiformal structure determined on the Indus section. Our more recent work suggests a rather more complex arrangement. Foliation on the western side of the massif is concordant to the early high strain contact with Kohistan (subtracting the affects of local neotectonic faulting), consistent with the antiformal model. However, work along the Astor valley transect did not reveal a major antiformal closure. Rather the structure is of an asymmetric west-gaping synform with foliation on the eastern margin dipping steeply east, beneath Kohistan (Ladakh). The penetrative stretching lineation plunges N in the E and NE in the W with a gradual change in trend. Further insights from the Rupal transect allows a second major south-gaping closure to be mapped, with an apparently high strain upper limb (outcropping on the Rupal face and summit of Nanga Parbat). The lower, south-dipping limb, while also high strain, contains a south-plunge stretching lunation. We discuss the interpretation of these unexpected structures, specifically the relationship between position on large-scale folds, shear criteria and orientation of lineations. However, the age of some fabrics in the massif, despite the “Himalayan” trend of stretching lineations, is not necessarily Tertiary. A suit of biotite granite bodies, mineralogically distinct to the late two-mica leucogranite veins of the massif, crosscut fabric. Therefore we also discuss the problems of identifying Himalayan deformation from much earlier tectonics within basement of the Indian continent. Work is underway investigating these topics.
Key words: Tectonics, MMT, Nanga Parbat, Kohistan.

B/312. Butler, R.W.H., 1985. Relationships between crustal scale thrusting, subduction and lithospheric flexure on the NW margin of the Indian Continent. Abstract Volume, 1st Himalayan Workshop, Department of Geology, University of Leicester.

Data from magnetic anomaly stripes on the floor of the Indian Ocean suggest that 1500-2500 km of relative convergence has occurred between Indian and stable Asia since the abutment of the two continental masses in the middle Eocene. This has been accommodated by southward directed thrusting within the Indian crust together with other shortening processes in the Himalayan hinterland. To the west, oceanic subduction has continued throughout this period beneath the Makran forearc. This contribution explores the ways in which crust and mantle stacking varies within the Himalayan belt and links through the Makran region, together with the control these geometries on patterns of flexural basin development on the Indian Continent.

This study is underpinned by a balanced cross-section, constructed from the Punjab foreland to the main Mantle thrust in northern Pakistan. This restores upper crustal thrust systems to a width in excess of 720-km with an implicit shortening of at least 470-km. A further 150-km displacement on MMT, amounting to simple subduction of Indian lithosphere, preceded this shortening. Indian lower crust of the western Himalayas has been stacked beneath the Asian hinterland, possibly as far north as the Pamirs while in the central Himalayas whole crustal stacking occurs directly beneath the thrust belt. This has resulted in a greater topographic elevation in the central Himalayas and gravity modeling has suggested that this topographic load account entirely for the flexural depression of the adjacent foreland. However, in western Pakistan the lower Indus basin has a similar width (c. 300-km) and inner depth (c. 7-km) as the main Punjab-Gangetic foreland basin. Yet in these western regions the orogenic belt has a relatively low topographic elevation (average less than 2-km) so that an extra, subsurface load is required to drive the flexural basin. This can be provided by the adjacent oceanic lithosphere which has been subducted below the Peshawar basin which overlies thrust systems in northern Pakistan. These interpretations suggest that load stresses in the subducted oceanic lithosphere can be transmitted across the adjacent continental lithosphere, which must be coupled at depth. This argues against the concept of India behaving as a rigid indenter with respect to Asia but supports models of thrust continuity within the convergent plate system.
Key words: Tectonics, structural geology, Indian plate.

B/313. Butler, R.W.H., 1986. Thrust tectonics, deep structure and crustal subduction in the Alps and Himalayas. Journal of the Geological Society of London 143, 857-873.

The structural restoration of collision orogenic belts onto crustal templates provides important insights into the tectonic evolution, deep structure and amounts of plate convergence after the initial contact between two continental masses. Balanced cross-sections have been constructed, parallel to the local displacement directions, across the western Alps and western Himalayas and demonstrate very large amounts of crustal shortening above intra-crustal detachments. To achieve a balance, substantial volumes of lower crust must have been subducted beneath the two tectonic hinterlands. A model of eclogite metamorphism is invoked to facilitate this subduction and to explain the varying isostatic responses of the Alpine and Himalayan hinterlands. Patterns of eclogite metamorphism are controlled by the geometry of thrust profiles on a lithospheric scale: the development of crust-mantle detachments being of crucial importance. Such a profile is proposed for the Himalayas, suggesting that relatively small volumes of the footwall crust succumbed to eclogite metamorphism. In the Alps however, a steeper thrust profile apparently developed, emplacing mantle onto crust, causing wholescale eclogite metamorphism in the underlying Franco–Swiss crust. The resultant density increase would provide a mechanism of isostatic collapse and flexural subsidence in the Po plain region.
Key words: Tectonics, structure, subduction, Alps, Himalaya.

B/314. Butler, R.W.H., 2000. Structural evolution of the western margin of the Nanga Parbat massif, Pakistan Himalaya: insights from the Raikhot-Liachar area. 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, 51-75.

There are several competing interpretations of the structure of the margins of the Nanga Parbat massif: that the massif is bounded by original suture between the Indian continent and the Kohistan-Ladakh island arc-the Main Mantle Thrust; that the massif is entirely bounded by neotectonic faults; that it is bounded by a combination of early and late faults and shear zones. If the marginal structures of the massif are to be related to local and regional geo-tectonic evolution then their correct characterization is critical. The Raikhot Bridge area on the western margin of the massif is useful in this regard, as it provides accessible and near-continuous outcrops. This contact, sometimes called the Raikhot Fault, is composite. Sheared metagabbros of the Kohistan arc are juxtaposed tectonically against metasediments and orthogneisses of the Nanga Parbat massif along an early ductile shear contact, developed under amphibolite facies conditions. In this regard it may be a preserved segment of the Main Mantel Thrust. However, this ductile shear zone has been strongly modified, flattened and rotated, and is cut by younger shears and faults. The original kinematics of the shear zone has been largely overprinted by these subsequent deformations. The younger structures include NE-SW striking, dextral strike-slip faults and a major top-to-NW thrust and shear zone. A sequence of metamorphism, deformation and igneous emplacement may be used to study the history of structural evolution within the massif. The use of a single name (e.g. Raikhot Fault) for the present-day map contact between the Nanga Parbat massif and neighboring Kohistan is misleading. The early contact (termed here the Phusparash Shear Zone, possibly the northeastern continuity of the Main Mantle Thrust) is modified by the Buldar Fault Zone (dextral strike-slip) and the Liachar Thrust Zone (top-to NW carriage of the Nanga Parbat massif across the Phuparash Shear Zone and onto Kohistan). The activity of the Buldar Fault and Liachar Thrust Zone continued during exhumation of the massif, through amphibolite facies to the Earth's surface. The interaction between these structures is at present unknown. However, establishing these and similar interactions within the Nanga Parbat area remain central to establishing the role of regional NE-SW dextral transpression in the modern structure of the massif.

Key words: Structure, Raikhot-Liachar, Nanga Parbat, Himalaya.

B/315. Butler, R.W.H. & Coward, M.P., 1989. Crustal scale thrusting and continental subduction during Himalayan collision tectonics on the NW Indian plate. In: Burchfiel, B.C. & Sengor, A.M.C. (Ed.), Tectonic evolution of Tethyan Regions Proceedings. NATO ASI, Kluwer, Dordrecht C259, 387-413.

Following the subduction of Tethyan oceanic lithosphere beneath Asia and Kohistan the continued convergence between the upper plate and the Indian continent led to thrust stacking of Indian crust to form the Himalayas. This lasted from Oligocene to Recent times and in an attempt to evaluate displacements, a series of balanced cross-sections have been constructed across the belt. In Pakistan these illustrate that over 600km of relative convergence between India and the Kohistan complex north of the Eocene suture zone has occurred by SSE-directed thrusting. This deformation only involves Indian upper crust at present outcrop levels so that the lower crust and remaining lithosphere must have been subducted beneath Kohistan and Tibet. The northern edge of the Indian lower crust may lie beneath the Pamirs. Similarly large amounts of shortening (several hundred kilometres) are implied by other balanced crustal sections through the central Himalayas and western Pakistan. The continuity of thrust systems around the NW margin of the Indian continent is proposed so that thrusts which stack continental crust step off into oceanic lithosphere in the west. This thrusting mechanism accounts for a substantial fraction of the total, 1200–2000km relative convergence between stable India and Asia. Further shortening in the Tibetan region which developed after the Eocene continent-continent collision must be added to the displacements on thrusts which stack Indian lithosphere. Deformation within the entire collision zone approximates more closely to an essentially vertical plane strain model rather than to a process of lateral expulsion of Tibet towards the east.

Key words: Tectonics, subduction, Indian Plate, Himalayan collision.

B/316. Butler, R.W.H., Coward, M.P., Harwood, G.M. & Knipe, R.J., 1987. Salt control on thrust geometry, structural style and gravitational collapse along the Himalayan mountain front in the Salt Range of northern Pakistan. In: Lerche, I. & O'Brien, J.J. (Eds.), Dynamic Geology of Salt and related Structures. Academy Press, Orlando, FL, United States, 339-418.

Key words: Salt, thrust geometry, Salt Range, Himalaya.

B/317. Butler, R.W.H., George, M., Harris, N.B.W., Jones, C., Prior, D.J., Treloar, P.J. & Wheeler, J., 1992. Geology of the northern part of the Nanga Parbat massif, northern Pakistan and its implications for Himalayan tectonics. Journal of Geological Society of London, 149, 557–567.

The northern outcrop termination of Indian continental crust lies at the Nanga Parbat massif, from where this contribution presents new field data. The tectonic contact with the structurally overlying Kohistan island arc is concordant and ductile, is associated with interleaving of Nanga Parbat and Kohistan lithologies, and may be correlated with the Main Mantle thrust found elsewhere in the NW Himalayas. This ductile shear zone is locally overprinted by cataclastic faults associated with exhumation of the massif but overall, the northern outcrop termination of the massif is controlled by erosion through a gently, northward-plunging antiformal structure. This folds both the Main Mantle thrust and the underlying, concordant 'Layered Unit' of the Nanga Parbat basement. Thus there is no indication that the massif acted as a promontory to the Indian continent during collision nor that it is a structure entirely bound by neotectonic faults. Ductile shear fabrics associated with the 'Main Mantle thrust' are

cross-cut by leucogranite sheets and pegmatites. These may represent the stockwork to a significant crustal-melt granite body described here in the northern massif. This Jutial granite shows many geochemical characteristics in common with similar bodies in the High Himalayas which are consistent with anatexis of the buried Indian continental basement rocks. However, the granite is enriched in heat producing elements (particularly Th: 22 ppm) and shows extremely high 87Sr/86Sr ratios (>0.88). The high concentrations of radiogenic Sr are also an attribute of a suite of hitherto enigmatic leucogranitic pegmatites that laces the Nanga Parbat massif, suggesting that these may represent a stockwork to a largely buried body of which the Jutial granite is a small exposure. The enrichment in heat-producing elements within the granite may reflect similarly high heat production in the source Indian continental crust requiring in turn a fundamental re-examination of the thermal evolution of this crust during Himalayan metamorphism and exhumation.
Key words: Tectonics, MMT, Nanga Parbat, Himalaya.

B/318. Butler, R.W.H. & Harris, N.B.W., 1990. The Himalayas. The Open University, Milton Keynes, UK, 59p.

Key words: Himalaya.

B/319. Butler, R.W.H., Harris, N.B.W. & Whittington, A.G., 1997. Interactions between deformation, magmatism, and hydrothermal activity during active crustal thickening: A field example from Nanga Parbat, Pakistan Himalayas. Mineralogical Magazine, 61, 37–52.

The Nanga Parbat massif is a rapidly eroding, thrust-related antiform that is distinct from other regions of the Himalayan orogen in being both intruded by Late Miocene-Pliocene anatectic granites and permeated by a vigorous hydrothermal system. Exhumation is achieved by erosion during thrusting along the Liachar thrust in the apparent absence of extensional tectonics. At depths in excess of 20 km, small batches of leucogranitic melt have been generated by fluid-absent breakdown of muscovite from metapelitic lithologies. These melts ascend several kilometres prior to emplacement, aided by low geothermal gradients at depth and by interaction with meteoric water as they reach shallow levels. At intermediate depths (approximately 15 km) limited fluid infiltration is restricted to shear zones resulting in localised anatexis. Within the upper 8 km of crust, magmatic and meteoric fluid fluxes are channelised by active structures providing a feedback mechanism for focusing deformation. Leucogranite sheets show a range of pre-full crystallization and high-temperature crystal-plastic textures indicative of strain localisation onto these sheets and away from the country rocks. At subsolidus temperatures meteoric fluids promote strain localisation and may trigger cataclastic deformation. Since near-surface geothermal gradients are unusually steep, the macroscopic transition between distributed shearing and substantial, but localised, cataclastic deformation occurred at amphibolite-facies conditions (approximately 600 degrees C). Even with the greatest topographic relief in the world, the meteoric system of Nanga Parbat is effectively restricted to the upper 8 km of the crust, strongly controlled by active structures.
Key words: Deformation, magmatism, crustal thickening, Nanga Parbat, Himalaya.

B/320. Butler, R.W.H., Owen, L.A. & Prior, D.J., 1988. Flash floods, earthquakes and uplift in the Pakistan Himalayas. Geology Today, 4, 197–201.

Catastrophic flooding of parts of the frontal plains of the Pakistan Himalayas has occured throughout the historical past. The largest recorded flood (1841) originated from an earthquake triggered landslip from the flanks of Nanga Parbat, which blocked the Indus river for six months. The earthquake probably occurred on the Liachar thrust, which has been responsible for uplifting the amphibolite facies Nanga Parbat gneisses to the Earth's surface in the last 10 million years. These movements raise serious problems for hydroelectric engineering project in this and other active mountain belts.
Key words: Natural hazards, floods, earthquake, uplift, Himalaya.

B/321. Butler, R.W.H. & Prior, D.J., 1988a. Tectonic control on the uplift of the Nanga Parbat Massif, Pakistan Himalayas. Nature 333, 247-250.

Cenozoic mountain belts like the Himalayas contain regions that experienced rapid uplift in comparison with the areas around them. Whether this uplift occurred by buoyant rebound of previously thickened crust or during the crustal thickening process itself is uncertain. Here we show, however, that the 7 mm yr–1 Recent uplift of the Nanga Parbat massif, Pakistan Himalayas, was accomplished during NW-directed thrusting located along its western margin. This 3-km-wide Liachar thrust zone operated from amphibolite facies to the present topographic surface and accommodates substantial crustal shortening. The adjacent Indus river valley, itself cut by seismogenic faulting, completely transects the massif, showing that erosion keeps pace with geologically rapid thrust uplift.
Key words: Tectonics, uplift, Nanga Parbat.

B/322. Butler, R.W.H. & Prior, D.J., 1988b. Anatomy of a continental subduction zone: the Main Mantle thrust in Northern Pakistan. Geologische Rundschau 77, 239-255.

Key words: Tectonics, subduction, MMT.

B/323. Butler, R.W.H., Prior, D.J. & Knipe, R.J., 1989. Neotectonics of the Nanga Parbat Syntaxis, Pakistan, and crustal stacking in the northwest Himalayas. Earth and Planetary Science Letters 94, 329-343.

The northwest termination of the Himalayan arc is marked by two large antiformal structures, termed syntaxes, and a NW-SE zone of intermediate depth earthquakes which have yielded both strike-slip and thrust-sense fault-plane solutions. This contribution presents new structural data from the Nanga Parbat area, the northern syntaxis, one of the fastest rising portions of the orogen (7 mm yr 1). Our studies show uplift related to syntaxis growth to be accommodated by structures located along its western margin. Fault kinematics in the southern part of the margin indicate NW-directed thrusting along a shear zone and high level cataclastic faults, termed the Liachar thrust zone. This carries amphibolite facies basement rocks out onto Quaternary sediments. Further north along the western margin active faults are dominantly dextral strike-slip, oriented north-south (e.g. the Shahbatot fault). Overprinting relation- ships suggest that the strike-slip fault zone has migrated southwards into the NW-directed thrust zone. These relationships are consistent with the northwest termination of the arcuate Himalayan thrust belt at a lateral tip generating folding and radial thrust directions. Faulting patterns at Nanga Parbat suggest that this tip zone has migrated southwards. Active faulting is now concentrated in the northwest continuation of the Hazara (southern) syntaxis, along a seismogenic strike-slip and thrust zone. These deep level tips lie on the crustal stacking thrusts which cut through the higher level, SSE-directed thrusts of Pakistan.
Key words: Neotectonics, crustal thickening, Nanga Parbat.

B/324. Butler, R.W.H., Wheeler, J., Treloar, P.J. & Jones, C., 2000. Geological structure of the southern part of the Nanga Parbat massif, Pakistan Himalaya, and its tectonic implications. 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, 123-136.

The Nanga Parbat massif lies in the core of the major north-south trending, broadly upright antiform that marks the NW syntaxis of the Himalayan arc. However, this antiformal structure is not evident in the trend of foliation and banding within the central and southern parts of the massif. Reconnaissance field studies in this region (Astor, Rama and Rupal areas) have delineated an important shear zone with top-to-the-south overthrust kinematics. This Rupal Shear Zone carries the migmatitic core of the massif onto non-migmatitic metasediments locally termed the Tarshing Group. The shear zone traces north into a broad high strain zone of steep foliation with gently plunging mineral elongation lineations with no consistent sense of shear. A tentative model is proposed whereby top-to-the-south overshear in the Rupal area passes northwards into a steep belt of apparently constrictional N-S elongation. This type of large-scale transpression may record the early growth of the syntaxis. However, relating these structures to Himalayan orogenesis and the amplification of the NW syntaxis is problematic. The Nanga Parbat massif displays a long and complex history of polyphase deformation, metamorphism and magmatism, as might be expected of a terrane derived from the basement of the Indian sub-continent. Although at least the alter part of the constrictional

steep belt developed with syn-kinematic leucogranite instructions (<10 Ma), the old age limit on the Rupal Shear Zone remains unconstrained.
Key words: Structure, Nanga Parbat massif, Himalaya.

B/325. Butt, A.A., 1962. Remarks on the proposed "Abbottabad Group" of Gardezi and Ghazanfar. Geological Bulletin, Punjab University 7, 69-80.

Key words: Stratigraphy, Abbottabad, Hazara.

B/326. Butt, A.A., 1969. A note on the Cretaceous Tertiary boundary in Hazara, West Pakistan. Geological Bulletin, Punjab University 8, 73-78.

Middlemiss (1896, pp. 39-40) described grey limestone (proposed as Kawahgar Formation by the Stratigraphic Committee of Pakistan, 1969), of doubtful age, which underlies the Paleogene formations in the Hazara District of West Pakistan. Latif (1962, p. *57)* pointed out that the limestone belongs to the Upper Cretaceous age because of the presence of foraminifera Globotruncana, Heterohelix, Rugoglobigerina and
Pseuclatextularia, which he identified by examining thin sections of the rock from certain localities, namely, Darband, Dungagali and Khan.
If we consider the lithological characteristics of the Kawahgar Formation in the district, we find that the formation is present, as a hard and very fine-grained, well-bedded, light grey limestone for which reasons the foraminifera can only be examined under thin sections. However, at some localities, for example at Changlagali (1" 43 *G/5)* along the Murree-Nathiagali road, which is regarded here as one of the reference sections; nearly 13 miles east of the Jabri Forest Rest House along the Lora-Maqsood road (1" 43 G/1), this formation is predominantly represented by very thinly-bedded pale weathering marls which, on treatment with peroxide, yield loose fossil specimens. It is from the latter locality that the foraminifera, because of their better preservation, mentioned below are discussed and illustrated (Coll. Aftab, 1966, sample 9125) for the first time.
The boundary between the Kawahgar Formation and the overlying dense grey, nodular limestone, the Lockhart Limestone (name proposed by the Stratigraphic Committee of Pakistan, 1969) is marked by a laterite band of few feet in thickness. This band is very conspicuous in the field and can be used as a marker bed for the purpose of mapping.
The sampling from the marls of the Kawahgar Formation from the above mentioned localities, has shown the presence of well-preserved globotruncanids. The species/subspecies encountered are Globotrunncana limelano, G. fornicata, G. ventricosa and G. concavata carinata. Moreover, Heterohelix globulosa, H. reussi and Rugoglobigerina rugosa also form part of the planktonic association. Rugoglobigerina rugosa, recorded here as few specinxns, however, has not been illustrated. This assemblage suggests that the Kawahgar Formation ranges from Coniacian upto the Campanian.
Reviewing the Cretaceous-Tertiary succession in Hazara, we find that the Kawahgar Formation marks the end of the Cretaceous period. The Paleocene begins with a new transgressive phase which is represented by nodular limestone, the Lockhart Limestone that overlies the Kawahgar Formation. The Lockhart Limestone shows an abrupt change in lithology as well as in the faunal composition. The pelagic foraminifera1 association of the Kawahgar Formation is entirely absent and the fauna is now composed of the benthonic larger foraminifera1 species such as Lockhartia haemei, Miscellanea miscella, Ranikothalia soldadensis (= R. sirtdensis), Davicesina khatiyohi and Discocyclina ranikotensis suggesting an Upper Paleocene age. At this stratigraphic level, similar lithologic as well as paleontologic changes have been observed by the author in the Kala Chitta and the Samana Ranges pointing towards a similar stratigraphic break. Further research is, however, in progress to discuss, in detail, the foraminiferal assemblages of these regions and their stratigraphic implications.
Key words: Stratigraphy, Cretaceous, Tertiary, Hazara.

B/327. Butt, A.A., 1970. The Cretaceous Tertiary boundary in Hazara, West Pakistan. Abstracts, 21st /22nd All Pakistan Science Conference, Rajshahi, p. H3.

Key words: Stratigraphy, Cretaceous, Tertiary, Hazara.

B/328. Butt, A.A., 1972. Problems of stratigraphic nomenclature in the Hazara District, NWFP, Pakistan. Geological Bulletin, University of Punjab 9, 65-69.

Three formations, Hazara Formation, Abbottabad Formation and Kihal Formation, the last two with five and two members respectively, are recommended for the unfossilferous sequence of the (?) Paleozoic of Hazara stratigraphy, as opposed to Hazara Group and Abbottabad Group of Latif (1970).
Key words: Stratigraphy, Hazara.

B/329. Butt, A.A., 1973. The Kawagarh Formation in Kala Chitta. Abstracts, 24th Pakistan Science Conference, Islamabad, p.H-4.

Key words: Stratigraphy, Kawagarh Formation, Kala Chitta.

B/330. Butt, A.A., 1986. The Concept of Unconformity in the Geological Record. Kashmir Journal of Geology 4, 155-158.

The stratigraphic concept of the residual deposit – the laterite is believed to form basis for recognition of the Paleocene succession of the Kohat-Potwar-Hazara province of northern Pakistan and thus enables to decipher the presence or absence of the Hangu Formation, the oldest formation of the Paleocene.
Key words: Stratigraphy, unconformity, Potwar, Kohat, Hazara.

B/331. Butt, A.A., 1987a. The Paleogene stratigraphy of the Kala Chitta Range, Northern Pakistan. Acta Mineralogica Pakistanica 3, 97-110.

The geology of the Kala Chitta Range is an integral part of the structural units of the Kohat-Hazara region, northern Pakistan. The sedimentary geology of the Kala Chitta Range has similarities with the adjoining areas. However, there are certain differences in the stratigraphy and the geology history. The structural evolution of the Kala Chitta Range began in the Mesozoic time and attained its maximum by the end of the Eocene time. The deposition of the Upper Cretaceous (Coniacian-Campanian) Kawagarh Formation in a narrow belt along the northern part of the Range, intergradation of the Upper Paleocene (Thanetian) sedimentary facies, the continuity of the stratigraphic and the paleogeographic pattern from north to south by a southward trend of younging of strata, especially during the Middle Eocene, are some of the salient geological features of this structural entity. First major stratigraphic break between the Upper Cretaceous Kawagarh Formation (Coniacian-Campanian) and the Upper Paleocene (Thanetian) Lockhart Limestone is marked by a ferruginous pisolite. The second major break between the Middle Eocene Kohat Formation and the Miocene Murree Formation is marked by a pebbly deposit-the Fatehjang Member. An attempt is made to review the stratigraphic, biostratigraphic as well as the paleogeographic setting of the region in the context of basin analysis framework.
Key words: Stratigraphy, paleogene, Kala Chitta.

B/332. Butt, A.A., 1987b. The Ranikothalia Sindensis zone in Late Paleocene Biostratigraphy. Acta Mineralogica Pakistanica 3, 111-115.

The foraminiferal genus Ranikothalia characterizes the Upper Paleocene (Thanetian) succession of Pakistan and elsewhere in the world, but does extend rarely into Lower Eocene. A closer examination of several Upper Paleocene species from various world localities demonstrates that the open spiral complanate forms may be identified as Ranikothalia sindensis (Davies), which has been illustrated hare from the Upper Paleocene Lockhart Limestone of the Kala Chitta Range, northern Pakistan. In view of its stratigraphic value, it is strongly advocated that the Ranikothalia sindensis Zone be incorporated within the Upper Paleocene (Thanetian) in the Paleogene stratigraphic correlation scale of Cavelier and Pomerol (1983). This would be one step forward towards refinement of the Paleogene biostratigraphy on the basis of benthonic larger foraminifera.
Key words: Stratigraphy, biostratiraphy, Ranikothalia, Late Paleocene.

B/333. Butt, A.A., 1988a. Upper Cretaceous foraminferal biostratigraphy of Pakistan. Acta Mineralogica Pakistanica 4, 90-95.

The Upper Cretaceous succession of Pakistan covers a time interval from Cenomanian to Turonian but largely, Coniancian to Campanian and a Maastrichtian interval. Deposition of the Kawagarh Formation in northern Pakistan and correspondingly the Parh Limestone in southern Pakistan (Coniancian to Campanian in age) is the result of a major transgression along the north-western margin of the Indian Plate, whereas the Maastrichtian interval records a major regression, marked either by the complete absence of the Maastrichtian deposits in northern Pakistan or by the development of a regional blanket of regressive facies of the shallow-water Pab Sandstone in southern Pakistan. Uninterrupted succession argillaceous deposits, the Korara Shale, across the Cretaceous-Tertiary boundary in the Kirthar Range (Gaj River section) containing Maastrichtian and Danian planktonic foraminifera in continued sedimentary environments, is among the very few world-wide examples of continuous section across the boundary.
Key words: Biostratigraphy, Cretaceous, foraminifera.

B/334. Butt, A.A., 1988b. Some geological aspects of the Hazara arc, Northern Pakistan. Acta Mineralogica Pakistanica 4, 147-150.

For details consult Butt, 1992 below.
Key words: Structure, Hazara Arc.

B/335. Butt, A.A., 1991. Plate tectonics and the upper Cretaceous stratigraphy of Pakistan along the northwestern margin of the Indian Plate. Abstracts, 1st Postgraduate Training Course in Plate Tectonics, Punjab University, Lahore, 13-14.

In terms of sedimentary geology, global marine transgression (sea-level rise) has been expressed as an episode of active plate movement, drowning the margins and many inland depressions of the world continents with shallow epicontinental seas. This significantly expanded the world oceanic environments favourable for flourishment of marine organisms, whereas global marine regression is an episode of slow plate movement causing major lowering of the sea-level. It means that the epicontinental seas and much of the continental shelf areas were periodically drained, thereby reducing world oceanic environments considerably. The shrinking of world oceanic environments caused extinction of marine organisms.
The Upper Cretaceous stratigraphy of Pakistan is interpreted to fit into this concept along the northwestern margin of the Indian Plate. The deposition of the Upper Cretaceous (Coniacian-Campanian) Kawagarh Formation in northern Pakistan and correspondingly Parh Limestone in southern Pakistan, has been interpreted as a result of active plate movement causing major regional flooding (marine transgression) along the northwestern margin of the Indian
Plate, thus causing expansion of marine environments favourable for the flourishing of the marine organisms. This is manifested by the presence of varied age-diagnostic globotruncanied fauna in these stratigraphic units.
The Maastrichtian tine interval envisages a major episode of "draining off" regression the northwestern margin of the Indian Plate - a period of destruction of marine environments creating limited shallow-water living space, which amounts to a major extinction of the marine organisms.
The reduced marine environments in northern Pakistan are, therefore, refloated by the complete absence of the Maastrichtian sediments (total "drain off" of the shelf areas), while there is a development of regional blanket of regressive clastic facies in southern Pakistan --- the shallow-water Pab Sandstone resulting from the lowering of sea-level. This created a sedimentary facies almost barren of marine organisms except for a very rare reported occurrence of a Maastrichtian orbitoidal foraminifer Lepidobitoides minor (Vredenburg, 1908). The rare occurrence, however, is in harmony with respect to the shrinking environments
Key words: Plate tectonics, stratigraphy, Cretaceous, Indian Plate.

B/336. Butt, A.A., 1992. Geological framework of the Hazara arc. Abstracts, First South Asia Geological Congress, Islamabad, p.8.

The Hazara Arc forms part of the western limb of the Hazara-Kashmir Syntaxis and the closely situated geological segment of the Azad Kashmir from the towns Balakot to Muzaffarabad appears to form an integral part of the Hazara Arc. This interpretation gains support on the basis of following criteria: 1. The structural configuration of the Hazara Arc and, in its immediate neighborhood, the presence of dislocated lobe shaped geological segment of Azad Kashmir between the towns Balakot and Muzaffarabad. The dislocated junction between the geological segment of Azad Kashmir and t'1emain Hazara Arc can be visualised as a result of structural complexities caused by the Nathiagali Thrust merging further into the Main Boundary Thrust.
2. The extension of the stratigraphic units of the Hazara Arc into the neighbouring geology of Azad Kashmir, 3. The location of the town Balakot at the northern tip of the Hazara Arc.
Our interpretation based upon the structural setting, stratigraphic framework and the geographical location appears most appropriate for the definition of the Hazara Arc. Major geological events which occurred in the Hazara Arc can be summarized as follows: 1. A major Paleozoic stratigraphic gap crossing over to the Triassic. 2. Cretaceous-Tertiary unconformity (Maastrichtian-Danian interval) marked by residual deposits. 3. Marked southward depositional shift during the Middle Eocene Kuldana Formation towards the adjoining Potwar Basin. 4. A major depositional break from Upper Eocene to Oligocene which marked an end to the maximum stratigraphic and structural evolution in the Hazara Arc. 5. Creation of the Hazara arc as a hinterland to the adjoining actively subsiding Potwar Basin during the Miocene. This structural framework brought prominence to the Miocene sedimentation (Murree Formation) to the actively subsiding Potwar Basin, while it formed a southernmost bordering belt of the Hazara Arc.
Key words: Balakot, Muzaffarabad, Hazara Arc.

B/337. Butt, A.A., 1992-93. Plate tectonics and the upper Cretaceous stratigraphy of Pakistan along the northwestern margin of the Indian Plate. Regional Postgraduate Training Course in Plate Tectonics, Punjab University, 43-44.

Key words: Plate tectonics, stratigraphy, Cretaceous, Indian Plate.

B/338. Butt, A.A. & Malik, M.H., 1973. Revised geological map of south east Hazara - Evaluation as a field guide. Abstracts, 24th Pakistan Science Conference, Islamabad, H-4 - H-5.

Key words: Geological map, Hazara.

B/339. Butt, G.D., 1993-95. Study of Geo-aspects of barrage and its related structures of Ghazi Barotha Hydropower Project. M.Sc. Thesis, Punjab University, Lahore, 81p.

Ghazi Barotha Hydropower project is named after the village Ghazi near Tarbela and near Attock .It is basically a hydropower project which consists of second biggest channel of the world. This project was started in 1989. It is eight year project, and was expected to complete in 1997 to 1998. Due to some financial constraints and political problems for land acquisition, the project is delayed by 4-5 years. The project is a joint venture of five different companies in which two of these are national and three companies are international named as:
* Pakistan Hydro Consultants (P.H.C.)
* National Engineering Services of Pakistan (NESPAK) (Pvt.) Ltd.
* Associated Consulting Engineers (A.C.E.) (Pvt.) Ltd.
* Binnie and Partners (Overseas) Ltd.
* Ghazi Barotha Contractors (G.B.C.)
* Ewbank Preece Ltd.
* Harza Engineering Company International. ,

The project is started on the idea that the overflow water from Tarbela should be reused for electricity. A concrete line channel is proposed on the left side of the area, 7 km down stream of Tarbela. It follows a gentle slope up to Attock and then a sharp head difference of about 250 feet is available at Barotha providing a suitable head for hydropower generation.
Key words: Engineering geology, Ghazi Barotha, Hydropower, Hazara.

B/340. Butt, I.H., 1997-98. Geological mapping of Rawalakot Area with special emphasis on engineering characteristics of soils. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 40p.

A number of static and dynamic tests have been performed in order to investigate the basic nature of the natural soils during testing. The samples tested cover a large variation in composition and dynamic behaviour. The test enables to study how the tests can be applied for land use. Void ratio, laboratory consolidation history settlement history can be established.

Clays, silty clays and inhomogeneous soils including consolidated soft clays, a slightly overconsolidated silty clays and a stiff overconsolidated clays were tested. The results indicate that the bearing capacity directly depends on the load. For foundations on clay soils the pore pressure is a good parameter, for the pore pressure dissipation and redistribution can easily be measured. The liquid limit, plastic limit, compaction and grain size distribution are within the ASTM specifications. The results indicate that most of the soils are firm and are good for sale construction of local purposes. The key parameters in the stress-strain relationship is the shear stress and the effective stress which are still to be investigated.

Key words: Soil, engineering geology, Rawlakot, Kashmir.

B/341. Butt, K.A., 1981a. Hydrothermal phenomenon associated with Lahor pegmatoid granite complex, Kohistan. Geological Bulletin, University of Peshawar 14, 85-93.

Pb-Zn-Mo and uranium mineralization spatially associated with Lahor pegmatite / granite complex and enclosing metasediments is examined in the light of new data on ore minerals. Several ore paragenetic associations are described and it is concluded that polyphase mineralization processes are responsible for the ore associations described.

Key words: Hydrothermal process, mineralization, granite, pegmatoid, Besham.

B/342. Butt, K.A., 1981b. Pyrochlore group minerals in carbonatites from Loe-Shilman, Khyber Agency, NWFP, Pakistan. Geological Bulletin University of Peshawar 14, 111-122.

Metamict, partially metamict and non metamict species of pyrochlore group minerals have been identified from a sheet like carbonatite complex in Loe-Shilman, Khyber Agency. Microscopy, X – ray diffractometry and partial chemical analyses are reported which indicate a chemical and structural variability between various species of pyrochlore. A multiplicity of intrusive activity is considered to be responsible for the variations described.

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

B/343. Butt, K.A., 1983a. Komatiitic Affinities of Ultramafic Rocks, Serpentinites and ultramafic amphibolites in the amphibolite belt of Northern Pakistan. Kashmir Journal of Geology 1, 43-48.

A review of komatiites is presented and the existing chemical and petrographic data on amphibolites of Dir, Swat, Kohistan, Thak Valley, Nanga Parbat and Astor is re-evaluated. This study suggest that the association of amphibolites, ultramafic rocks, serpentinites, talc-carbonate rocks with occasional occurrence of pillow structures and ultrabasic volcanic breccias, all suggest komatiitic to tholeiitic affinities. Much of the ultrabasic material occurring within the amphibolite belt is interpreted to be submarine ultramafic to high MgO basaltic volcanic flows and minor intrusions. An oceanic crustal model proposed for this belt (Butt et al. 1979) is therefore further substantiated.

Key words: Petrography, komatiite, amphibolite belt, Kohistan.

B/344. Butt, K.A., 1983b. Tectonic environments for Ni and Pt group elements sulphide deposits in northern Pakistan. 2nd National Seminar on Development on Mineral Resources, Peshawar, 1, 21–24 May, 8p.

Nickel mineralization reported from Swat and Dir Districts are described with reference to their immediate geological and tectonic environments. Two types of environment of the ultramafic rocks hosting Ni mineralization have been distinguished; Synvolcanic and Alpine type. The significance of these environments with respect to their potential as hosts for sizable Ni and platinum group element sulphide deposits is discussed.
Key words: Ni-Pt group sulphides, tectonics, Swat, Dir.

B/345. Butt, K.A., 1983c. Petrology and geochemical evolution of Lahor pegmatoid/granite complex, northern Pakistan, and genesis of associated Pb-Zn-Mo and U mineralization. In: Shams, F.A. (Ed.), Granites of Himalayas, Karakorum and Hindu Kush. Institute of Geology, Punjab University, Lahore, 309-326.

The study describes a detailed account of the geology of lahor pegmatite-granite complex. Field relations, texture, major and trace element chemistry are used to arrive at conclusion that the complex formed by in situ melting of pre-existing metamorphites. Metallic mineralization associated with the complex is interpreted to have been mobilized by hot fluids produced during anatexis but the source of metals probably lay in the metamorphites. Lahor pegmatoid complex is correlated with the nanga parbat-haramosh migmatitess and their significance at the plate-scale is discussed.
Key words: Hydrothermal process, granite, pegmatoid, Lahor.

B/346. Butt, K.A., 1988. Geology of Koh-i-Sufaid Mountain, north of Parachinar and its correlation with other areas of comparable geology and mineralization. Geological Bulletin, University of Peshawar 21, 57-69.

Geology of Koh-I-Sufaid imbricate zone, North of Parachinar is described and compared with similar occurrences in Thakot-Besham and Nanga Parbat-Haramosh area. Ductile deformation exposed in the migmatitic rocks of these areas is interpreted to be due to structurally up thrown block of deep seated rocks along the older strike slip faults which have developed a significant vertical component during their re-activation under the influence of Himalayan orogeny.
Key words: Tectonics, structure, Koh-i-Sufaid, Parachinar.

B/347. Butt, K.A., 1989a. Uranium occurrences in magmatic and metamorphic rocks of northern Pakistan. In: Uranium Deposits in Magmatic and Metamorphic Rocks. Proceedings of the Technical Committee Meeting, Salamanca 29, 1986. IAEA, Vienna, Austria, 131-154.

Key words: Radioactive minerals, uranium, metamorphic rocks.

B/348. Butt, K.A., 1989b. Release of uranium through cataclastic deformation of Mansehra granite gneiss and its precipitation in the overlying montane basin in northern Pakistan. In: Uranium Deposits in Magmatic and Metamorphic Rocks. Proceedings of the Technical Committee Meeting, Salamanca 29, 1986. IAEA, Vienna, Austria, 155-166.

The Mansehra pluton belongs to a discontinuous belt of two mica granites of the Lesser Himalayas. The Mansehra granite is generally foliated except in the area around Mansehra. Several phases of granitic activity have been reported from the Mansehra complex. Shams and Rahman have demonstrated that the younger phases tend to be enriched in Na_2O. The northern edge of this sheet-like granitic mass has undergone extensive cataclastic deformation, resulting in the formation of shear zones, mylonites and cataclasites. A chemical comparison of crushed granite with granite outside the shear zone suggest little chemical reconstitution in terms of major elements during cataclastic deformation. A huge shear zone in albitized granite gneiss has yielded secondary uranium minerals at water seepage, suggesting a liberation of uranium. Hydrogeochemical survey of the crushed granite and adjoining areas suggest that uranium from crushed granite was easily leachable in comparison with rocks outside the

shear zone. The uranium thus liberated was trapped in a Pleistocene sequence of clays and unsorted fluviatile sand overlying the granite and country rock metamorphics.
Key words: Economic geology, uranium mineralization, cataclastic deformation, Mansehra Granite.

B/349. Butt, K.A., 1990. Ultrapotassic hypabyssal rocks from Khyber Agency. Abstracts, 2nd Pakistan Geological Congress, University of Peshawar, p.23.

Ultrapotassic rocks of a possible subvolcanic hypabyssal environments are described from Khyber Agency. These rocks contain sanidine as a major rock forming mineral. Other minerals include calcite, phlogopite, sodalite, fluorite, zircon and zeolites. Textural data suggest that these rocks crystallized under high-T conditions characteristic of high level subvolcanic environments. A predominance of K_2O over Na_2O is characteristic of these rocks. On the basis of chemical data presented, these rocks have been classified as LAMPROITE of "GROUP III" (Foley et al. 1987).
Petrogenetic models for the origin of these rocks are discussed.
Key words: Ultrapotassic rocks, petrography, Khyber Agency.

B/350. Butt, K.A., 1994. Evidence of Pleistocene thrusting in Ahl area, Mansehra, Pakistan. Pakistan Journal of Geology 2 & 3, 73-77.

Key words: Structural geology, Pleistocene, Ahl, Mansehra.

B/351. Butt, K.A., 1995. Lithium mineralization in gem bearing complex pegmatites in Nanga Parbat Haramosh massif and Asiatic mass, N. Pakistan. Abstracts, International Symposium on Himalayan Suture Zone of Pakistan. Pakistan Museum of Natural History, Islamabad, p.16.

Pegmatite rocks associated with Oligocene two-mica granites of the Asian plate as well as pre-Cambrian granites of the Nanga Parbat Haramosh Massif on the Indo-Pak plate have been investigated for their Li content. The pegmatites are of two distinct metaklogenic types, one showing enrichment towards lithium and the other to REE.
Key words: Lithium mineralization, pegmatites, Nanga Parbat-Haramosh.

B/352. Butt, K.A., 1997. An assessment of uranium favourability of granitic rocks of Indo-Pak plate in northern Pakistan. Abstracts, National Symposium on Economic Geology of Pakistan, Islamabad, 1p.

An assessment of the granitic rocks of Indo-Pakistan plate for their favourability to host uranium deposits is presented. Mathews (1978) arrived at a set of recognition criteria including tectonic setting, host rock lithology, host rock texture, mineralogy, chemistry, alteration, geometry of mineralization and rock associations. Comprehensively compatible data on all these aspects of granitic rocks of Indo-Pakistan plate is not available. This paper, however, is an attempt to present a compilation of the available geological data along with more than 400 new chemical and petrographic analyses in order to arrive at a preliminary assessment of favourability of the granitic rocks of Indo-Pak plate.
Three groups of granitic rocks have been identified from the Indo-Pak plate in North Pakistan. Only one group has been interpreted to be favourable for hosting uranium deposits. This assessment would result in a substantial reduction in the size of the target area for uranium exploration in these granitic environments.
Key words: Uranium, granite, Indo-Pak plate.

B/353. Butt, K.A., 1997. Ruby mineralization at Nangi-Mali upper Neelum valley, Azad Jammu and Kashmir. Abstracts, National Symposium on Economic Geology of Pakistan, Islamabad, 1p.

Regional geological set-up and detailed local geology of Nangi-Mali ruby occurrence is described. Based on geology petrography and mineralogy of the occurrence a genetic model for the mineralization is proposed potential of this model's applicability in prospection of ruby in the higher Himalayan region of Pakistan is discussed.

Key words: Gems, ruby, petrography, Neelum valley.

B/354. Butt, K.A., Arif, A.Z., Ahmed, J., Ahmed, A. & Qadir, A., 1989. Chemistry and petrography of the Sillai Patti carbonatite complex, north Pakistan. Geological Bulletin, University of Peshawar 22, 197-215.

Detailed geology, petrography and chemistry of Sillai Patti sheeted carbonatite complex is presented. The complex is an anastomosing set of dykes intruding metamorphics of possible Proterozoic age. The complex is interpreted to be a product of multiple intrusions. The early phase of the intrusion is represented by peralkaline ultrabasic rocks (pyroxenites). This was followed by the intrusion of carbonatites and its attendant fenitization. There is a considerable petrographic and chemical variability in the complex, which is considered to be a function of varying degree of fenitization and hybridization of the earlier ultrabasic rocks by the carbonantite dykes.
Key words: Geochemistry, petrography, carbonatite, Sillai Patti, Malakand Agency.

B/355. Butt, K.A., Chaudhry, M.N. & Ashraf, M., 1980. An interpretation of Petrotectonic Assemblage West of Western Himalayan Syntaxis in Dir District and adjoining areas in Northern Pakistan. Geological Bulletin, University of Peshawar 13, 79-86.

A review of the geology of areas west of western syntaxial bend of Himalayas in Dir district and adjoining areas of northern Pakistan is presented. Several geotectonic regimes have been recognized and it is proposed that the well-known Indus ophiolite suture in this area is represented by amphibolite/ophiolite belt of Dir. These ophiolites are thought to have generated in an ocean and that their emplacement involved initially an ocean-continent type of plate interaction followed much later by continent-continent collision.
Key words: Tectonics, petrology, amphibolite, ophiolite, Dir, Himalaya.

B/356. Butt, K.A, Chaudhry, M.N. & Ashraf, M., 1985. Evidence of an incipient Palaeozoic ocean in Kashmir, Pakistan. Kashmir Journal of Geology 3, 87-102.

The Himalayas are interpreted to have formed by continent-continent collision between Indo-Pak plate and Asia. This event has been dated to be Eocene. Prior to the collision however, tectonics of the passive northern margin of the Indian plate has rarely been examined although these older rocks constitute a significant part of the Himalayan region especially the southern Kohistan ranges of Yeats & Lawrence (1984). Geochemistry of the Panjal volcanics is used to demonstrate that these represent an incipient ocean floor which lay between the Gondwana and Kashmir-Hazara microcontinent prior to the break-up of India from Gondwana.
Key words: Paleozoic, oceanic rocks, Panjal volcanic, tectonics, Kashmir.

B/357. Butt, K.A., Chaudhry, M.N. & Ashraf, M., 1987. Evidence of an incipient Paleozoic ocean in Kashmir, Pakistan- A reply. Kashmir Journal of Geology 5, 127-132.

Geochemical data presented in the paper Butt et al. (1985) is shown to be comparable to the data published by other authors on Panjal volcanics. Repeat analysis of 40 rock samples (to be published elsewhere) confirm high Al2O3 and low to moderate TiO2 and low MnO2 values.

The treatment certainly does not prove that Panjal basalt are MORB and the same was never claimed. Similarly the problem of these rocks being tholeiitic, alkaline or otherwise is also apparent from data of Gupta et al (1983) and Pareek (1983). Instead a transitional nature of these basalts was suggested which may have formed in an incipient ocean. The first stage in the evolution of an ocean is widely accepted to be an "Intracontinental rift" and successive developmental stages from a rift to and oceanic environment must involve an evolutionary process of development of oceanic crust between these two end members. The transitional nature of these basalts was proposed in this study.
Key words: Paleozoic, oceanic rocks, Panjal volcanic, tectonics, Kashmir.

B/358. Butt, K.A. & Khalid, M.M., 2001. Interpretation of satellite image to delineate the lineaments and natural drainage in and around Islamabad and their impact on environment. Abstracts, 4th Pakistan Geological Congress, Islamabad, p.42.

Islamabad capital city of Pakistan is situated at the foothills of Margalla, which are considered to be in close proximity of Main Boundary Thrust (MBT).
Satellite image interpretation reveals that a number of lineaments abutting with MBT pass through the well-planned city of Islamabad. Most of the civil structures have been made in close proximity to these lineaments without any consideration for a special foundation design due to which cracks have been reported to develop in these buildings.
The streams originating from the hills surrounding Islamabad have also been blocked by manmade structures, which obstruct the natural seepage during rainfall and cause maximum surface runoff. This tremendously increased in the runoff input of water to Nala Lai. Due to this fact intensity of flood in Lai Nala has been increased in recent years.
Key words: Remote sensing, drainage, Islamabad.

B/359. Butt, K.A. & Khan, T.M., 1992. Uraniferous black shales of Pakistan. Abstracts, First South Asia Geological Congress, Islamabad, p.8.

The graphitic-metapelites of NW Pakistan and Azad Kashmir are exposed in a zone of thrust tectonics, and are scattered in the form of continuous beds and lenses in various nappes. These are highly radioactive at places but the equivalent chemical uranium is found to be lower than its radiometric equivalents. Based on petrography and X-Ray diffraction studies a classification of black shales of Pakistan is presented. The chemical composition of the graphitic-metapelites indicates that the rocks from Tarbela area are more siliceous and contain more organic C compared to the rest of the exposures of the graphitic-metapelites. Due to their fine-grain-size, dark colour and Fe oxidation along fractures the rock types are classified as black shales. According to this classification the graphitic-metapelites from Tarbela area are siliceous and the graphitic-metapelites from other areas are dominantly argillaceous-siliceous with high normative quartz. Uranium and other associated elements are concentrated in the upper parts of the graphitic-metapelites. Compared to the metal rich black shale deposits elsewhere in the world, these rocks are enriched in U, V, Ba and Pb. Precipitation of these elements from saline waters is suggested rather than normal seawater. However, sulphidization of Fe by hydrogen sulphide has played some role in the concentration of elements from saline waters. Precipitation of the elements has taken place In oxygenated waters in a transitional environment close to the continent. The black shales were deposited in multiple basins characterized by different sources of supply of the elements to these basins.
Key words: Mineral exploration, petrography, XRD, black shale, uranium, Kashmir, Thakot, Tarbela..

B/360. Butt, K.A. & Mahmood, K., 1983. Munirite, naturally occurring sodium vanadium oxide hydrate, a new mineral. Mineralogical Magazine 47, 391-392.

Munirite was found in the sandstones of Siwaliks formation of mid-Miocene to Pleistocene age. It occurs as small globular clusters of acicular crystals (2 to 3 mm long). Analysis gave V20S 67.46, N_20 22.91, and H_20 10.26%. The X-ray powder diffraction pattern shows remarkable similarity to a synthetic compound NaV03 '1.9H20 (Lukacs and Strausievici, 1962). The new mineral was collected from Siwalik sandstones in Bhimber area, Azad Kashmir, Pakistan.
It crystallizes as radiating fibrous aggregates on outcrops as well as on the walls of exploratory trenches. The new mineral has been named after Mr Munir Ahmad Khan, Chairman of the Pakistan Atomic Energy Commission, who instituted the Mineral Research Laboratories in the Commission. The name and data have been approved prior to publication by the Commission on New Minerals and Mineral Names, IMA. Type material has been deposited with the Hard rock Division, Atomic Energy Minerals Centre, PO Box 734, Peshawar, Pakistan, and the British Museum (Natural History).
Key words: New mineral, sandstone, siwaliks, Azad Kashmir.

B/361. Butt, K.A. & Mahmood, K., 1986. Unit cell dimensions of uraninites from various geological environments in Pakistan. Acta Mineralogica Pakistanica 2, 47-52.

Key words: X-ray crystallography, uraninite.

B/362. Butt, K.A., Malik, R.H. & Khan, A., 1997. Geology of gem bearing complex pegmatites from upper Neelum Valley Azad Kashmir. Geological Bulletin, Punjab University 31 & 32, 127-132.

Geology of Janawai-Folowai area in upper reaches of Neelurn valley, Azad Kashmir is presented. The geology of the area is divided into two units. A migmatitic basement complex consisting of high grade pelitic gneisses, migmatites and sheet granites thrusted on to the high grade dominantly calcareous metasediments. This area is the host of a number of lithium and rare earth enriched complex pegmatites. These pegmatites have been reported to contain gem bearing cavities. This study suggests a tectonic classification of the pegmatites of this area and it is proposed that this classification has a potential in discriminating between Li, rare metal and Gem producing pegmatites from barren pegmatites.
Key words: Gems, pegmatites, Neelum valley, Azad Kashmir.

B/363. Butt, K.A. & Qadir, A., 1987. Discovery of lepidolite from Shengus area, Gilgit, Pakistan. Geological Bulletin, Punjab University 22, p.153.

Several pegmatite localities in Gilgit and Chitral were sampled in a bid to investigate their Lithium content.
There are a few unpublished previous reports about pink micas from northern area i.e. Ruby mines of Hunza area etc. Some of these samples were analysed and were found to be rose muscovite (Nawaz, Personal Comm.). Kazmi et-a1. (1985) reported an occurrence' of lepidolite from Bulechi area in Gilgit. However they did not produce supporting mineralogical or chemical data.
Mica samples of various colours were collected from Chitral areas and analysed for Lithium. It has been observed that pink, greenish, smoky and colourless micas from these pegmatites contain anomalously high Lithium but do no approach the Li2O concentration to be classified as Lepidolite.
Garam Chashma area in Chitral contains micas with highly anomalous Li2O content of the order of 0.45% Li2O. Associated white micas within a single body of pegmatite clearly fall in two categories in terms of their Lithium content.
(i) Lithium rich micas, O.45% Li_20
(ii) Lithium poor micas, 0.008% Li_20
None of the muscovite analysed from this area approached lepidolite.
Similar sampling was carried out in Shingus (Gilgit) area. Once again associated micas gave two populations:
1. Lithium rich micas 4.24% Li_2O
2. Lithium poor micas. 0.05% Li2O
Lithium rich micas of shingus area can be classified as Lepidolite. Considering the similarity of Lithium distribution patterns in the two areas, it is concluded that the complex pegmatites in Chitral also hold a good potential for the discovery of Lithium minerals. It may be added that this is the first report in Pakistan wherein the occurrence of Lepidolite has been confirmed on the basis of chemical data.
Key words: Lepidolite, Shengus, Gilgit.

B/364. Butt, K.A. & Shah, Z., 1985. Discovery of blue beryl from Ilum granite and its implications on the genesis of emerald mineralization in Swat District. Geological Bulletin, University of Peshawar 18, 75-81.

Geological mapping of toposheet 43 B/6 in Buner Valley, District Swat is presented. Petrographic and mineralogical data on veins associated with Ilum granite have revealed a complex assemblage produced by multiphase hydrothermal activity. Some of these veins have been cataclastically deformed along with the granite body, whereas others show minor or no cataclasis and are hosted in post-cataclasis joints.
A genetic relationship between the granite and associated veins is proposed from field criteria. Hydrothermal veins associated with Ilum granite contain blue beryl. A granitic source forms the beryl and possibly for spatially associated emerald mineralization is postulated.
Key words: Gemstones, beryl, emerald, granite, Ilum, Swat.

B/365. Butt, K.A., Zafar-ul-Islam, Chaudhry, M.I. & Khan, J.A., 1994. Discovery of early Permian carbonatic to melilititic/nephelinite glassy flows in eastern Salt Range, Pakistan: Kashmir Journal of Geology, 11-12, 105-112.

Key words: Salt Range, Permian.

B/366. Butt, K.A. & Zaidi, M.M.S., 1969. Petrology of Thak Valley igneous complex. M.Sc. Thesis, Punjab University.

Thak valley comprises a variety of plutonic and volcanic rocks, including large quantities of gabbroic rocks, and diorites. These rocks show local deformation and metamorphism. The work involved mapping and sampling, and gives details of the petrography of various rock-types.
Key words: Petrology, Chilas.

B/367. Butt, M.H., 1972. Magnetic survey in upper Kurram Agency, North West Frontier Province, Pakistan. Geological Survey of Pakistan, Information Release 45, 9p.

Key words: Geophysics, magnetic survey, Kurram Agency.

B/368. Butt, M.H., 1976. Gravity survey for Lead–Antimony Ore in Shoghor area, Chitral, Pakistan. Geological Survey of Pakistan. Information Release. 96, 10p.

This is a report to check the presence of Lead-Antimony mineralization along the fault contact between Marble and black Phyllite. Gravity measurement techniques are used. The anomalous area is recommended for more study.
Key words: Geophysics, gravity, lead-antimony, mineralization, Chitral

B/369. Butt, M.H., 1989. Resistivity measurement along the proposed 500 km transmission line from Kushab to Tarbela, Pakistan. Geological Survey of Pakistan, Information Release 416.

Key words: Geophysics, resistivity, Khushab, Tarbela.

B/370. Butt, M.H. & Latif, A., 1992. Production of major minerals of Pakistan 1947-1989. Geological Survey of Pakistan, Information Release 512, 28p.

The term mineral is used for any of the large group of natural inorganic substance having homogeneous structure, a specific chemical composition, uniform physical characteristics and usually a definite form of crystal. In broader terms it refer to all products (solid or liquids) derived from the mineral kingdom including energy raw materials.
It is felt generally by all those concerned with and interested in mineral development that essential information regarding the minerals sector is not accessible easily, hence the pace of mineral development is restricted, which is extremely important for industrial development of the country. As a result, if on one hand exploitation of indigenous mineral resources has not expanded rapidly, on the other hand extent of their industrial utilization has remained rather restricted, so this foreign exchange deficient country is importing a lot of common mineral based commercial products, which can easily be available to the consumer in the coal currency.
Geological Survey of Pakistan (GSP), an attached department of the Federal Ministry of Petroleum and Natural Resources, is also aware of this situation and since its establishment (i.e. 1947), it has tried to find the new minerals by the application of most modern techniques and knowledge. A lot of new discoveries have been made by this organization, starting from Coal Copper, fluxes, Fertilizer, China clay, Silica Sand, Bauxite, Lead zinc, Manganese, Uranium to the latest discovery of high grade iron ore in Chiniot-Sargodha area.
It is the joint effort of private and public mineral enterprises, supplemented by the mineral-surveying national organization that the mineral sector share in the Gross National Product of Pakistan rose from Rs. 793 million in

1947 to Rs. 14767 million in 1987-88, a nineteen fold increase in real terms and in percentage share to GNP, it rose from 0.75% in 1947 to 2.27% in 1987-88, a threefold increase.
The aim of present report is to highlight the production of major minerals of Pakistan from 1947-1989 and represent these figures in the form of graph to tell the reader at a glance about the ups and downs of a particular commodity. For interested readers it also gives the physical properties, diagnostic features, occurrence and uses on the opposite page.
Key words: Minerals, economic geology.

B/371. Butt, S., 1987. Crustal thickness and basement depth mapping using integrated gravity and magnetic surveys and geological sampling along Gayal-Thakot section of the Karakoram Highway 1986-87. M.Sc. Thesis, Quaid-i-Azam University, Islamabad, 88p.

Key words: Geophysics, gravity, magnetic, crustal thickness, KKH.

B/372. Butt, Z.H., 1988-90. Petrology of the Jijal and Pattan complexes between Gantar and Baleja (N.W.F.P.) with special emphasis on petrogenesis of the Pattan complex. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 69p.

A geological map is presented at a scale of 1:25000 covered by topo sheet No. 43 F/1 issued by the Survey of Pakistan. The rock sequence in the project area is the part of eastern Jijal and Pattan Complexes. The Jijal Complex in the project area is thinned out due to the intersection of MMT and Pattan faults as compared with the western part of the Jijal Complex. It is relatively fresh and massive on the KKH section, but in our project area the Jijal Complex has imprints of metamorphism but is the least metamorphosed among series of meta-plutonic complexes. The Pattan Complex (lowest part of the so called Kamila amphibolites) is considered here as a metamorphosed basic plutonic complex. The rocks of the complex exhibit relic igneous textures, at places but the mineral assemblages correspond to the low pressure metamorphic assemblages from green schist to granulite facies. Field and petrographic studies show that the Jijal Complex is formed within a separate magma chamber and is predominantly igneous in nature. The Jijal rocks are considered younger than overlying metamorphosed series of plutonic complexes (earlier known as Kamila amphibolites). The plutonic complexes have been metamorphosed under low pressure dynamothermal metamorphism during the development of northern suture (MKT).
Key words: Petrology, ultramafics, Jijal, Pattan, Kohistan arc.