K/1. Kadri, I.B., 1995. Petroleum Geology of Pakistan. Pakistan Petroleum Ltd., 275p.

This book provides information relevant to various aspects of petroleum geology in Pakistan, including stratigraphy, structure and geophysical data. Areas of interest in northern Pakistan, the focus of the present work, are also included.
Key words: Petroleum geology, structure, stratigraphy, geophysics.

K/2. Kadri, I.B. & Abid, M.S., 1986. Geology of hydrocarbon accumulations in Pakistan. Preprint, 6th Offshore South East Asia Conference, Singapore, 226-235. 6 figures, 1 table.

Key words: Hydrocarbons.

K/3. Kafarsky, A.K. & Abdullah, J., 1976. Tectonics of North–East Afghanistan (Badakhshan, Wakhan, Nurestan) and relationship with the adjacent territories. In: Geotetonica della zone orogeniche del Kashmir Himalaya–Karakorum–Hindu Kush–Pamir (Roma, 1974). Accad. dei Lincei. Rome, 87–113.

Key words: Tectonics, Himalaya, Karakoram, Hindukush, Afghanistan.

K/4. Kaila, K.L., 1981. Structure and seismo-tectonics of Himalaya-Pamir-Hindu Kush region and the Indian Plate boundary. In: Gupta, H.K. & Delany, F. (eds.), Zagros-Hindu Kush-Himalaya Geodynamic Evaluation. American Geophysical Union, Geodynamic Series 3, 272-293.

Key words: Tectonics, structure, Indian Plate, Pamir, Hindukush, Himalaya.

K/5. Kaila, K.L., Chowdhury, K.R., Krishna, V.G., Dixit, M.M. & Narain, H., 1983. Crustal structure of the Kashmir Himalayan and inferences about the asthenospheric layer from DSS studies along the international profile Qarrakol (Karakull) Zorkol-Nangaparbat-Srinagar. Bollettino di Geofisica Teorica ed Applicata. Pamir-Himalaya, 25, 221-234.

Key words: Structure, upper mantle, Kashmir, Himalaya.

K/6. Kaila, K.L. & Rao, N.M., 1979a. Seismotectonics of Himalayan belt and the deep tectonic features of the Pamir-Hindu Kush regions. Geophysics Research Bulletin 17, 4.

Key words: Tectonics, seismicity, Himalaya, Hindukush.

K/7. Kaila, K.L. & Rao, N.M., 1979b. Seismic zoning maps of the Indian subcontinent. Geophysics Research Bulletin, NGRI Hyderabad, 17, 293-301.

Key words: Tectonics, seismicity, Himalaya, Hindukush.

K/8. Kakar, S.K., Mian, S.B. & Khan, J., 1971. The geology of Jandul valley, Western Dir. Geological Bulletin, University of Peshawar 6, 54-73.

The geology of Jandul Valley consists of Palaeozoic metamorphic rocks of amphibolite facies, intruded by igneous rocks in Jurassic-Cretaceous times. The plutonic rocks consist of an earlier phase of diorites, granodiorites, and granites and an apparently later phase of norites, hornblendites, pyroxenites and peridotites.
The Mesozoic magmatism was followed by volcanic activity in the Tertiary times. These, consisting of andesitic and dacitic tuffaceous rocks, are intimately inter-bedded with fossiliferous metasedimentary rocks of phyllite grade. This phase is characterised by the intrusion of porphyry dykes, which were probably the main feeds at the time. This was followed by a phase of granite and diorite dyke intrusions. Next quartz and pegmatite veins formed, followed by a final stage of dolerite dyke intrusions. Extension sporadic copper-mineralization is associated with the volcanism.
Structurally, the region is complexly folded and faulted. The main bodies of the intrusive and extrusive rocks seem to be located along a thrust zone. At least three tectonic stages are discernible in the area.
Key words: Metamorphism, magmatism, petrography, Jandul.

K/9. Kaleem, M., Qureshi, A. & Ahmed, M., 2001. Geologic map of the Kala Chitta Range, northern Punjab, Pakistan. Geological Survey of Pakistan (scale 1: 50,000).

Key words: Geologic map, Kala Chitta Range

K/10. Kalim, H.R. & Ali, M., 1985. Petrography and geochemistry of a part of Ambela Granitic Complex. M.Sc. Thesis, University of Peshawar, 129p.

This account describes the petrographic and geochemical aspects of the Ambela granites in Buner area of the swat district.
Key words: Petrography, geochemistry, granites, Ambela, Buner, Swat.

K/11. Kalpna & Chander, R., 1994a. A simulation of reservoir induced seismicity at the Tarbela Reservoir. Abstracts, First South Asia Geological Congress, Islamabad, p.19.

Consult the following account for further information.
Key words: Seismicity, dams, reservoirs, Tarbela.

K/12. Kalpna & Chander, R., 1994b. A simulation of reservoir induced seismicity at the Tarbela Reservoir, Pakistan. In: Ahmed, R. & Sheikh, A.M. (eds.), Geology in South Asia--I. Proceedings of the First South Asia Geological Congress, Islamabad, 1992. Hydrocarbon Development Institute of Pakistan, Islamabad, 354-357.

Tarbela Dam on the Indus River is a unique case for the Himalayan regions as a whole in that high quality pre- and post-Impoundment seismicity data are available. A recently published analysis of post-Impoundment data for nine years suggests that earthquakes in 20 km radial zone centered on the reservoir are suppressed when the reservoir levels are high and they reappear again during periods of low water stand in the reservoir. In this rectangular lake. We find that upper crustal faults deduced from published composite fault plane solutions for pre-Impoundment earthquakes in the same radial zone could also be the seats of the earthquakes observed during periods of low water level in the reservoir. The importance of this case history for the possibility of reservoir induced seismicity at future sites of high dams in the Himalaya cannot be over emphasized.
Key words: Seismicity, dams, reservoirs, Indus River, Himalaya.

K/13. Kamal, S., 1986-88. Lithostructural mapping and geology of Bagh-Sehri Area, District Abbottabad. M.Sc. Thesis, Punjab University, Lahore, 108p.

Key words: Lithostructure, Abbottabad.

K/14. Kaneda, H., 1993. Mineralogy and mineral alteration of the Kalam volcanics in Kalam, Swat valley-a supplement to the paleomagnetic study. Proceedings of Geoscience Colloquium, Geoscience Lab, Geological Survey of Pakistan, Islamabad. 6, 60-65.

A rock sample collected from the Kalam volcanics for paleomagnetic study, was examined by optical microscopy. This note describes the mineralization process of Fe-Ti-oxide and –hydrate minerals which are closely concerned to magnetic properties of the rock. Detailed magnetic data are given in the paper by Ahmad, M.A. et al. 1993.
Key words: Mineralogy, paleomagnetism, volcanics, Kalam, Swat valley.

K/15. Kaneda, H., Karim, T., Yoshida, M., Ahmad, M.N. & Ali, M., 1996. Ore mineralogy and geomagnetic anomaly of Kaldam Gol skarn-type copper ore, Chitral, northern Pakistan. Extended Abstracts, International Seminar on Paleomagnetic Studies in Himalaya-Karakoram Collision Belt and Surrounding Continents, November 20-21, 1996, Islamabad. Geosciences Lab, Geological Survey of Pakistan, Islamabad, 128-129.

The Kaldam Go1 copper orebody is located at Chitral district, northern Pakistan. Geology around the ore showing consists of alteration of shale and limestone belonging to Gawuch formation of Cretaceous age. At the southern area bordering on the Gawuch formation, acidic to intermediate igneous rocks are distributed widely. The ore mineralized zones occur along the boundaries between limestone and shale. Judging from the geologic feature and mineralogical observation of ore specimens, the copper ore showing can be considered to belong to a skarn-type deposit. Detailed mineralogical studies have been camed out by means of XRD, optical ore microscopy, and rock-magnetic method (Table 1).
Mineral species are divided into two groups, that is, one is primary minerals and another is secondary minerals: The primary minerals are classified into the following three assemblages: (1) magnetite-andradite-chalcopyrite-quartz, (2) clinopyroxene- quartz-calcite-chalcopyrite-pyrite, and (3) epidote-clinopyroxene-quartz-calcite-pyrite-sphalerite. In addition, the volcanic rocks which weakly skarnized and mineralized and highly silicified, show the mineral assemblage quartz-epidote-calcite-pyrite-chalcopyrite- sphalerite. These mineral assemblages and their zonal distribution reveal the feature of typical skarn-type ore. Secondary minerals occur replacing magnetite, chalcopyrite and occasionally pyrite. Maghemite and goethite are the most common minerals of supergene alteration after magnetite. Goethite also occurs replacing chalcopyrite.
Secondary minerals after chalcopyrite are covelline, chalcocite, cuprite, malachite and brochantite. Primary magnetite and secondary (supergene) maghemite are the main source generating strong geomagnetic anomaly around the ore minerlization zone, which makes possible to model the subsurface structure.
Key words: Mineralogy, magnetism, copper ore, Kaldam Gol, Chitral.

K/16. Kaneda, H., Karim, T., Yoshida, M., Ahmad, M.N. & Ali, M., 1997. Ore mineralogy and geomagnetic anomaly of Kaldam Gol skarn-type copper ore, Chitral, northern Pakistan. In: Khadim, I.M., Zaman, H. & Yoshida, M. (eds.), Paleomagnetism of Collision Belts. Geoscience Laboratory, Geological Survey of Pakistan, Islamabad, 177-184.

Consult the preceding account for further information.
Key words: Mineralization, ores, copper, Chitral.

K/17. Kaphle, K.P., 1973. Thesis on geology and petrology of southern Dir with special emphasis on amphibolites. M.Sc. Thesis. Punjab University, Lahore.

Southern Dir is a part of the Kohistan terrain. This work provides petrographic information on the rocks, with special reference to amphibolites which may have been derived from different paerntages.
Key words: Petrography, petrology, amphibolites, Dir.

K/18. Kapoor, S.K., Bhattacharya, D.K., Chakravarty, A.R. & De. N., 1976. Bibliography on Himalayan Geology. Part I: Bibliography, Geological Survey of India. 101p.

This is the first part of the bibliography of NW Himalaya, Pakistan.
Key words: Bibliography, Himalaya.

K/19. Karavchenkov, K.N., 1964. Soan Formation-upper unit of Siwalik group in Potwar. Science and Industry 2 & 3, 230-233; Karachi.

Key words: Soan Formation, siwalik group, Potwar.

K/20. Karim, A. & Sufyan, M. 1986. Mineralogy, petrology and geochemistry of dolerite dykes in Attock Cherat Range, NWFP. M.Sc. Thesis. Geology Department, Peshawar University.

Dolerite dikes around the Peshawar plain intrude a sequence of rocks, ranging in age from Precambrian to Permian. It is implied that they were intruded during a regional episode of crustal distention in Permo-Triassic times. A study of dikes in Attock-Cherat range, in an area of about 80 km^2 shows that the dolerites are oriented E-W. The dikes reach upto 10x1000 meters in size and are locally more abundant. They area variably altered, and are classified into (a) sheared, (b) medium grained and (c) Coarse grained dolerites.
Chemically the rocks are quartz and hypersthene normative theollites of continental flood basalt affinities. The rocks are dominantly composed of plagioclase (An $_{48-71}$) enclosed ophiticaly in clinopyroxene. Quartz, magnetite and ilmenite are accessory phases whereas alteration in many rocks has led to the development of abundant epidote, calcite, clay, chlorite, and biotite. Complex grains of clinopyroxene containing domains of augite, ferroaugite, and pigeonite have been studied in detail. A temperature estimate within the range of 1050-1270º has been made for these rocks.
Key words: Mineralogy, petrology, geochemistry, dolerite, Attock-Cherat.

K/21. Karim, E., 1998-99. Geological mapping of Muzaffarabad-Chattar Kalas area with special emphasis on slope instability analysis and Hazards evaluation of Abhal area, Muzaffarabad (A.K.). M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 99p.

About 100 sq. Km area including the landslided parts was mapped to find out the possible solution of this hazard. The study was carried out to understand the landslide problems in the area. The Abhal landslide was studied in detail based on its large size and proximity to foot-tracks, residential buildings and land property. Presence of MBT, heavy rain fall, toe-cutting by river Jhelum, steep slopes and water seepages contribute to landsliding in the area. The principal types of failure in the area have been recognized as slumps, earth flows, rock fall or combination of these three types. Soil samples were collected from the slided areas to evaluate the engineering properties of soil that contribute the failure. It includes Atterberg limits, natural water content, specific gravity, plasticity character, compaction and swelling. To establish the causes of landslides all the information and field data were collected. The results suggested that the failure occur due to high swelling potential of soils, steep slopes and presence of active fault (MBT).
Key words: Mapping, slope stability, Muzaffarabad.

K/22. Karim, T., 1993. An overall review of geology and economic minerals of Abbottabad area, Hazara, northern Pakistan. Proceedings of Geoscience Colloquium (Geoscience Lab, Geological Survey of Pakistan, Islamabad) 5, 79-86.

The Hazara area lies on the western flank of the Hazara-Kashmir syntaxial belt, and is bounded by the Main Mantle Thrust in the north and Main Boundary Thrust in the south. The southern part of the area consists mainly of sedimentary rocks ranging in age from Precambrian to Miocene. It is underlain by granite and quartzo-felspathic schists, which increase in metamorphic grade towards the north. The paper gives reference to the previous literature,

and contains a regional map and a colored geological map of Kakul-Abbottabad area. Descriptives notes are given on Precambrian, Cambrian, Jurassic, Cretaceous, and Tertiary rocks. Deposits of phosphate, magnesite, barite and soapstone are briefly described. The area also contains limestone and gypsum.
Key words: Minerals, economic geology, Abbottabad.

K/23. Karim, T., 1995. Preliminary results of study on genesis of Kumhar magnesite, Hazara, Pakistan. Proceedings of Geoscience Colloquium (Geoscience Lab, Geological Survey of Pakistan, Islamabad) 11, 181-188.

Out of fourteen lenticular bodies of magnesite ore in Kumhar, lens 1 and 2 are the biggest and have been studied in more detail. Total reserves are 6.2 million tons, (mt) and proved reserves of lense 1 and 2 are 2.98 mt with an average of 45% MgO. The magnesite may have formed due to hydrothermal activity. Solutions rich in Mg replaced ca in the host dolomitic limestone of the early Cambrian Abbottabad formation and which resulted in formation of magnesite. Homogenization temperature of fluid inclusions, varying from 150^0 C to 350^0 C, suggests closed relationships of hydrothermal activity with magnesite mineralization.
Key words: Magnesite, Abbottabad..

K/24. Karim, T. & Kaneda, H., 1994. Kumhar magnesite ore mineralization, Abbottabad, NWFP., Pakistan. Proceedings of Geoscience Colloquium (Geoscience Lab, Geological Survey of Pakistan, Islamabad) 8, 5-36.

The stratigraphy of the Abbottabad area is given with brief descriptions of various rock formations. Kumhar magnesite deposit is composed of 14 lens shaped ore bodies. One of these has been studied in the field as well as by petrography, XRD, and DTA/TG analytical techniques. Fluid inclusions and geochemical studies have also been performed.
Based on fluid inclusion studies and the field evidence, it is concluded that the Kumhar ore deposit was formed by hydrothermal activities which caused the replacement of the host dolomitic rocks. In addition, the mineralogical features are as follow: (1) ore is consisted of magnesite, calcite, talc and small amount of quartz, (2) dolomite, the host rock, is weakly disseminated with secondary calcite, quartz and talc, and (3) talc usually occur at the marginal parts of magnesite ore body and in the dolomite near the magnesite body. The geochemistry of ore-forming fluids of the Kumhar deposit is quite similar to the one of hydrothermal vein type deposits based on the fluid inclusion studies. This suggests that the related igneous rocks exist necessarily in the near area. In this area, a lot of mineralized showings such as barite, soapstone, gypsum and Pb-Zn sulphides in addition to magnesite have been observed. In order to examine the mineralization in this area, the study of ore-forming fluids and related-igneous rocks should be carried out in more detail through the fluid inclusion studies.
Key words: Stratigraphy, magnesite, Abbottabad, Hazara.

K/25. Karim, T. & Khan, S.R., 1986. Geological map of Darazinda (38 O/7), D.I. Khan District, Scale 1:50,000. Geological Survey of Pakistan, Quetta. Map Series III.

Key words: Geological map, D.I.Khan.

K/26. Karim, T. & Khan, S.R., 1989. Regional geology of Koga quadrangle, Swat district, NWFP, Pakistan. Geological Survey of Pakistan. Information Release, 437.

Key words: Mapping, geology, Koga, Buner, Swat.

K/27. Karim, T. & Luadthong, S., 1972. Geology of the eastern of Jandul valley. M.Sc. Thesis, University of Peshawar, 55p.

Some information is covered under Kakar et al. (1971).
Key words: Geology, metasediments, granites, Jandul, Dir.

K/28. Karsten, C.G.B., 1864. The salt mines of Kohat. In: Lehrbuchder Salinen Kunde, Vol. 1, 16 and Vol. 1, 12; Berlin.

This is amongst the earliest reports on the Kohat (bahadurkhel) salt mines.
Key words: Salt mines, Kohat, Karak.

K/29. Kato, K., Sasahara, H., Hirayama, J., Khan, S.R. & Sano, S., 1993. Preliminary geochemical exploration of chromite deposit in Malakand. Proceedings of Geoscience Colloquium, Geoscience Lab, Geological Survey of Pakistan, Islamabad 6, 35-41.

The Malakand ophiolite contains chromite pods, lenses, and stringers. Sixty out of 62 chromite bodies occur in harzburgite-dunite unit. 37 samples have been analysed for Cr, Si, Al, Fe, Mg, Mn, Co, Cu, P, W and Zn.
Key words: Geochemical exploration, chromite, Malakand.

K/30. Kausar, A.B., 1971. Geology and petrology of Timurgara, Lal Qila area, District Dir. M.Sc. Thesis, Punjab University, Lahore, 133p.

This area is occupied by amphibolites, metagabbros and small intrusions. Petrography of the rocks is given.
Key words: Petrology, Timurgara, Lal Qila, Dir.

K/31. Kausar, A.B., 1987. Geological map of Karor (43 G/6), Rawalpindi District, Sheet No. 10, Scale 1:50,000. Geological Survey of Pakistan. Map Series IV; Quetta.

Key words: Geological map, Karor, Rawalpindi.

K/32. Kausar, A.B., 1994a. Alteration study of Ca-Fe skarn at Markoi, Kohistan island arc, Gilgit, northern Pakistan. Proceedings of Geoscience Colloquium, Geoscience Lab, Geological Survey of Pakistan, Islamabad 8, 37-56.

In the Kohistan arc, Northern Pakistan, small lenses of skarn formed in Jurassic (?) limestone and clastic sediments adjacent to the Cretaceous to Tertiary Kohistan batholith. This composite batholith includes the Barite monzonite pluton that hosts porphyry copper mineralization. The Markoi skarn replaces limestone and volcanic rocks is a zone 180 meters by 40 meters along the contact with the potassically altered pluton. The units enclosing the limestone and calcareous sandstone were extensively metasomatized, as were outlying intrusion of Kohistan batholith.
Skarn alteration is divided into eight mineralogical zones away from the pluton to limestone: (1) epidote-amphibole-chlorite zone (2) magnetite-quartz zone (3) epidote-biotite zone (4) epidote-amphibole (actinolite)-magnetite zone (5) epidote-amphibole zone (6) pyroxene-amphibole zone (7) feldspar zone (8) garnet-calcite zone. Alteration zonation is dominantly controlled by faults (?), fractures and sedimentary bedding and composition. The garnet-calcite and magnetite-quartz zones are exoskarn formed in limestone and calcareous sandstone, and the other six zones are endoskarn formed in intermediate volcanic rocks. The andradite molecule of garnet increases in the limestone side. The zoning in exoskarn is in part the result of decrease in the chemical potential of A1203 towards the limestone, where the zoning endoskarn is attributed to a decrease of the chemical potential of CaO towards the pluton. Comparison of bulk chemical compositions in altered and unaltered limestone and calcareous sandstone indicates that alteration was accompanied by overall addition of SiO2, A12O3, FeO and MnO and depletion of CaO and **I** CO2; addition of Cu, Pb, and Zn in the garnet-calcite zone. Skarn and ore minerals were formed in the sequence skarn minerals - magnetite – chalcopyrite - pyrite sulfides, and occur in the garnet - calcite zone.
Key words: Skarns, Markoi, Gilgit, Kohistan.

K/33. Kausar, A.B., 1994b. Kohistan batholith in the Kohistan Island Arc, western Himalaya of northern Pakistan: Temporal variation in mineralogy and petrology. Abstract volume International Joint Symposium IGCP Project 283–321–359, 41–45.

Kohistan batholith is a huge body of various types of granitic rocks. This paper describes temporal variations in the petrographic characteristics of the batholith.
Key words: Batholith, Kohistan, Himalaya.

K/34. Kausar, A.B., 1994c. Alteration study of Ca-Fe skarn at Markoi, Kohistan island arc, Gilgit, northern Pakistan. Geoscience colloquium, Geoscience labs, GSP, Islamabad. 8, 37-56

Key words: Skarns, Markoi, Gilgit, Kohistan.

K/35. Kausar, A.B., 1995a. Petrology of the Kohistan arc and hosted hydrothermal sulfides, Gilgit area, Pakistan. M.S. Thesis. Oregon State University, U.S.A., 119p.

Key words: Petrology, sulfides, Gilgit, Kohistan.

K/36. Kausar, A.B., 1995b. Rare Earth Elements variation across the Kohistan batholith, Gilgit area: Their implications for batholithic petrogenesis. Abstract Volume, 10^{th} Himalaya-Karakoram-Tibet Workshop, (ETH Zurich) Switzerland.

During a time span of approximately 70 to 80 Ma beginning in Upper Cretaceous / Lower Jurassic a sequence of plutonic rocks was formed in the middle to northern part of the Kohistan terrane known as the Kohistan batholith. Commonly arranged in elongate, arcuate batholithic belts along the southern margin of the Asian plate, these rocks are generally interpreted as the products of intra-oceanic island arc (?) which formed during episodes of convergence between the Asian and Indian plates. It is analogous to the Ladakh batholith in northwest India and the Gangdese batholith in the south Tibet (Heim and Gansser, 1 939; Allegre et al., 1984; Searle et al., 1987). Investigations of how these batholitic rocks formed are fundamental to our understanding of the growth and evolution of the Kohistan terrane and of Kohistan batholith crust in general.
Individual plutons of Kohistan batholith range in lithology from gabbro to granite, which is also a characteristic feature of I-type granitoid batholith. There have been fewer attempts, however, to look at the origins of diversity among different intrusions within the same batholith. An important objective in the study of the Kohistan batholith is to establish how their characteristics are related to the tectonic environments in which they are formed. Extensive early studies (Petterson and Windley, 1985; Petterson and Windley, 1991) examined the systematic petrological and geochemical characteristics of these batholiths and established the plutonium and volcanism in a generally arc-related environment, but the exact relationships between components of the sequence are still speculative. Using our data and other published information we evaluate the relationships between the different rock units and this have revealed remarkable regularities of longitudinal trends and persistent regional asymmetries in petrological, geochemical, isotopic and geochronological characteristics from north to south in Gilgit area (Petterson and Windley, 1985; Treloar et al., 1 989; Petterson, 1984; Petterson and Windley, 1991). The asymetries have gradients transverse to the structural axis of the batholith and therefore appear to bear some fundamental relationship to its origin. The purpose of this paper is focussed on the REE geochemistry of the major rocks of Kohistan batholith and Rakaposhi volcanics and is used to provide insights into the sources, generation and evolution of the batholithic magmas.
Regional Geology
The Kohistan block of northern Pakistan has been recognized as a Mesozoic intra-oceanic island arc and is sandwiched between the Asian and Indian plates (Fig. 1; Tahirkheli et al., 1980; Bard et al., 1980; Coward et al., 1982). During the collision, this arc was partially thrust under the Asian plate during 75 to 102 Ma, based on Rb-Sr ages of syn-collisional granitoids and then obducted onto the Indian plate. The resulting terrane exposes a virtually complete section from its ultramafic at the deepest to surface volcanic rocks through the crust of an oceanic island arc. The terrane is rimed on the north by the Main Karakoram Thrust (MKT) and is bounded on the south by the Main Mantle Thrust (MMT). South of the MKT are the metasediments of Yasin Group and then volcanic and

volcaniclastic rocks dominate the prebatholithic section along the northern flanks of the Kohistan block. The plutons of the Kohistan batholith were emplaced into thick metavolcanics to the north and metasediments to the south in the Gilgit area, which comprises the focus of this research. The Kohistan batholith followed by a succession of massive diorites and layered gabbros that comprise the Chilas lower crustal mafic cumulate complex. To the south of Chilas complex is the belt of banded amphibolite, amphibole schists and pelitic schists of the Komila amphibolites and are associated with intrusions of hornblendite, diorite and anorthosite (Coward et al.., 1987). South of the Kamila amphibolites is the deepest levels, basic intrusives occur with garnet-granulite facies assemblages indicating conditions of 670-790 0C 12-14 kbr (Jan and Howie, 1981) and they are considered to be either, a tectonic block from the deeper part of Chilas complex or a lower crustal fragment from an arc distinct from the Kohistan arc (Coward et al., 1987) .The Jijal complex is bounded on the south by the MMT, marked in places by a mélange of blueschists, greenschists, piedmontite schists and serpentinites probably derived from the Kohistan arc.

Brief Review and Setting of Kohistan Batholith.

The Kohistan batholith, an arcuate-shaped intrusion measuring 2700 km along the southern margin of the Asian plate, is part of the Trans-Himalayan batholith. The batholith is a composite body made up of a juxtaposition of large plutonic units displaying major differences in age, mineralogical-chemical composition and tectono-metamorphic history. Plutons are generally a few kilometers to a few tens of meters in dimension, although internal intrusive units have only been well defined in a few detailed studies of specific bodies. The intrusions also vary in composition, e. g., tonalite to granodiorite (Matum Das pluton), quartz diorite (Jutal pluton), and monzonite (Barst, Dainyor, Manu Gah and Sakwar plutons). Lithological zonation was not observed in the portion of the complex observed in Gilgit area. The presence of internal boundaries on most outcrops is interpreted as the successive intrusion of relatively small batches of magma of varying composition. Petterson and Windley (1 985) described at least 20 separate, discrete plutons in the Kohistan batholith. Their geochronology indicates a 70 Ma time span for the intrusions in the Kohistan batholith approximately from 100 to 30 Ma. Magmatic activity started during the Early Cretaceous (Rb-Sr whole rock isochron age of 102 ± 12 Ma for the early, deformed Matum Das pluton), and the last magmatic phase occurred in Neogene (muscovite K-Ar age of 20 Ma for the last Parri aplite/pegmatite). Petterson and Windley (1985) proposed that the batholith can be divided into three stages: first stage plutons, referred to as earlier deformed plutons; second stage plutons, referred to as undeformed plutons; and late stage plutons, referred to as layered aplite-pegmatite sheets which have been intruded into the first and second stage plutons. Based on paleogeography, petrology, and chemical composition, I have further refined and sub-divided the plutons in Gilgit area into two distinct magma series: the sodic series (low-K) is present to the north of the Nomal - Barit volcanic septum and both deformed and undeformed potassic series (medium- to high-K) lie to the south of this septum (Fig. 2).

The deformation of Rakaposhi volcanics and northern deformed plutons (Maturn Das plutons) was accompanied by metamorphic recrystallization of igneous minerals from upper greenschist to amphibolite facies at 76 ± 6 to 82 Ma (Treloar et al., 1989). The southern deformed plutons (Barit pluton) were cooled through about 500 0C to 5300C, the Ar-blocking temperature of hornblende at approximately 48 ± 1 Ma. Figure 2 indicates that from north to south there is a gradual cooling decrease in age of biotite Ar-Ar ages from 50 Ma to 20 Ma, which reflects more recent uplift and cooling through about 300 0C (the biotite Ar-blocking temperature). In contrast, the hornblende ages indicate a sudden break at the Nomal-Barit septum of the Rakaposhi volcanics which separates the deformed sodic series plutons from the deformed potassic series plutons. This septum suggests a fault between these two series, which more recently, has uplifted the southern block through the 500-530 0C isotherm at about 50-55 Ma, where hornblende Ar-blocking temperatures were achieved. Thus, the data suggests that uplift and unroofing was earlier north of the Nomal-Barit septum than to the south

Tonalites and low-K granodiorites, the most common rock types in the sodic series, display a limited range in modal and chemical composition and have several unifying characteristics. They are feldspathic, containing 45-50 per cent unzoned andesine to oligoclase and 0-1 per cent alkali feldspar. Quartz contents are typically 1 5-25 percent. Biotite is the major mafic constituent with minor hornblende yielding colour indices of 8-12 for most. The southern portion (potassic series) of the Kohistan batholith is characterized by a diversity of lithologic types, with gabbro, monzodiorite, monzonite, quartz monzodiorite, and granodiorite joining minor tonalite as common rock types. Gabbro with only minor quartz is not transitional to the more felsic rocks, but forming apparently independent intrusive bodies. Plagioclase in the potassic series is zoned than that in the sodic, low-K rocks. The more distinctive petrographic feature of the potassic series is the presence of thick subhedral books of biotite with more hornblende, which contrast with the small anhedral books of biotite present in the sodic series. This suggests that the potassic suite magma had a higher water content, which has been shown to produce early hornblende and biotite crystallization in granite melting experiments (Naney and Swanson, 1980). In the southern ranges of Kohistan batholith, tonalite appears to drop somewhat in abundance, being supplanted by monzogranite.

Major and trace geochemical evidence indicates that the sodic and potassic series are compositionally distinct from one another. The most important geochemical variations are higher K20 content and K2O/Na2O ratio at given SiO2, and the higher concentration of the K-group elements (Ba and Rb) and of highly charged cations (Th and Zr) in the potassic series relative to those of the sodic series rocks. The sodic series contain little MgO relative to FeO (total Fe) (MgO/MgO+FeO= <0.5). The compositional gap between the two series is also visible with respect to Nb, Ce, Zr, and Nd (e.g., Petterson and Windley, 1991). These compositional variations cannot be explained in terms of simple fractionation/melt processes. The goals are to distinguish among different major petrogenetic processes and to limit the composition of the source region or parental melts as proposed four different sources for these plutons by Petterson and Windley (1991).

Sr concentrations in whole rocks show a well-defined increase southward across the Kohistan batholith, with a second-order dependence on rock type. Similarly Rb concentrations also show a well-defined increase from north to south but are dependent on rock type in the potassic series. Both Sr and Rb show a marked step at Nomal-Barit volcanic septum. A similar step has been noted for Sr isotopic compositions. Rb-Sr isotopic studies in the Gilgit area of the batholith have revealed systematic geographic variations in initial 87Sr/86Sr ratios of whole rocks which rises from 0.7039 in the north to more than 0.7049 in the south (Petterson and Windley, 1985).

REE Chemistry in Kohistan Batholith

Chondrite-normalized REE patterns of Rakaposhi volcanics, sodic and potassic series are presented graphically in Figure 3a,b. The Rakaposhi volcanics and sodic series have low total REE (8xchondritec abundances) leading to generally increase from La to Lu on a chondrite normalized diagram. In all these rock types REE patterns are flat with La/Yb ratios of 1.15 to 2. Only a few samples of volcanics show slightly higher La/Yb ratios 4 to 5. Rocks corresponding to potassic series have higher total REE contents (10xl00xchondritic abundances) with higher La/Yb ratios (11 to 28). The slope of LREE is steep and linear and corresponds to the medium- to high-K orogenic andesites (Jakes and Gill, 1970; Gill, 1981). The REE patterns of the rocks fall naturally into two principal REE fractionation groups and this variation is transverse to the structural trends but generally parallel to petrologic and geochronologic properties of the batholith. The Barit-Nomal volcanic septum probably marks the discontinuous zone between the northern and southern regions and transition between them therefore appears to be abrupt.

One of the most surprising feature of the data within the northern region is that the Matum Das tonalite, which intruded into metabasites have the same overall REE pattern shape as the metabasites, but differ from them in having abundances in REE and no Eu anomalies. The flat REE distribution patterns are considered to be typical for mantle derived rocks from a MORB like source (Johnson et al., 1 990) at relatively high degrees of melting without major crustal contamination. Garnet was not a residual phase because the heavy REE are not depleted. Such rocks typically occur in tholeiitic island arc basalts (e.g. Wilson, 1989). Southern regions plutons (potassic series) have nearly identical ranges in REE contents (Fig. 3b) with no Eu anomalies and cross-cutting each other near medium-REE. The single monzogabbro (sample KA-1 5) is somewhat more steeply fractionated across the heavier REE than the monzodiorites. Similar source rocks and similar conditions of melting in the source of the parent magmas should result in consistent ratios at least of some trace elements, as already shown for the REE. Compared to the nearly flat relatively heavy REE abundances of the northern region (sodic series) rocks, the fractionated REE patterns of the southern regions rocks (potassic series) require the involvement of a phase or phases that would preferentially fractionate as well as retain in abundance the HREE. The REE geochemistry of the southern regions of the Kohistan batholith differs from that of oceanic island arcs in the presence of strongly HREE depleted and fractionated magmas. The sharp break in lithological diversity between the sodic and potassic series is suggestive of a major modification or readjustment to phase equilibria controls on magma compositions.

The regional variation in REE from north to south in Kohistan batholith is marked by depletion in LREE in the sodic series; fractionation in middle to heavy REE in the potassic series; no Eu anomalies and an increase in Sr contents. A single condition which can appear to satisfy the above observations is a phase transition in the residual mineralogy of compositionally similar source materials; from a plagioclase-bearing gabbroic assemblage for the sodic series to garnet-bearing, plagioclase poor (ga-amphibolite) assemblages for the potassic series (e.g., Gromet and Silver, 1987).

Key words: REE, petrogenesis, Kohistan batholith, Gilgit.

K/37. Kausar, A.B., 1995c. Alteration study of Ca-Fe skarn at Markoi, Kohistan island arc, Gilgit, northern Pakistan. Geologica 1, 1-14.

Key words: Skarns, Markoi, Gilgit, Kohistan.

K/38. Kausar, A.B., 1998. L’arc sud Kohistan, N. Pakistan: Evolution petrologique et distributions des elements et mineraux du groupe du platine. Ph.D. Thesis, Goseph Fourier University, Grenoble, France, 280p.

Platinum group elements occur in mafic-ultramafic complexes, in some cases in exploitable quantities. These noble elements have also been the subject of preliminary studies in the Chilas and Jijal mafic-ultramafic complexes of the Kohistan island arc. This is a detailed study of the mineralogy, chemistry, and petrology of the platinum group elements in the Kohistan rocks. They are associated with both silicate rocks and chromitites. For more information, see Kausar et al. (2001).
Key words: Platinum group elements, petrology, Jijal, Chilas, Kohistan.

K/39. Kausar, A.B., 1999. Hydrothermal alteration and sulphur isotopic study of sulphide deposits, Gilgit area, Kohistan arc, Pakistan. Geologica 4, 1-32.

Sulphide mineralization in the Gilgit area is hosted in the Kohistan arc terrane, which is a tectonic block lying between the Asian plate to the north and Indo-Pakistan plate to the south. These ore deposit include volcanogenic massive sulphide at Jutial and possibly Garesh and porphyry copper at Nomal and Barit. At Garesh, two pyrite-rich (pyrite 3-5%) lenses occur within the volcanic stratigraphy. The alteration is marked by secricite-chlorite (plagioclase-destructive alteration) in the center and is surrounded by albite-hornblende-epidote-biotite (propylitic) within submarine mafic and silicic lavas and tuffs. Pyrite is both disseminated and in quartz veins, and is associated with slightly anomalous values of Cu, Zn, Pb, and Au (average values 47, 21, 18, and <1 ppm, respectively). The Garesh zone is interpreted as a hydrothermal feeder zone of a submarine volcanogenic massive sulphide. At Jutial one or two well-defined layers of massive pyrite (>80 vol. %) approximately 1-3 meter thick are strataform in the Jutial quartzo-feldspathic paragneiss derived from a greywacke sequence. Hydrothermal alteration intensity ranges from weak along the flank (up to 50 m), to intense in the massive sulphide zone, where the entire host rock has been altered to sericite-chlorite-quartz-pyrite. This inner zone is surrounded by semi-massive sulphide consisting of pyrite (20-40 vol. %). The outermost alteration zone is garnet-biotite-muscovite-pyrite. The Jutial prospect is hypothesized to be a Besshi-type volcanogenic massive sulphide with 11 ppm Cu, 15 ppm Zn, 8 ppm Pb and 31 ppm Co.
At Nomal, sulphide mineralization and hydrothermal alteration in the sodic Matum Das composite pluton is centered in the Nomal quartz porphyry. The hydrothermal alteration consists of a central mixed assemblage of sericite+chlorite+biotite+pyrite (potassic-sericitic) zone (300 m wide and 1800 m long), which passed outward into a garnet subzone and then into the propylitic alteration (albite-epidote-actinolite-chlorite-calcite). Pyrite is both disseminated and associated with quartz veins in the potassic-sericitic zone, which averages 85 ppm Cu, 45 ppm Zn, 15 ppm Mo and Au <0.2 ppm. The Barit copper porphyry occurs within the Barit pluton of the deformed potassic suite, and is associated with skarn in adjacent carbonate wallrocks at Markoi. Hydrothermal alteration is characterized by pervasive and widespread biotite-epidote-calcite-K-feldspar (potassic) and younger-fractured controlled sericite-chlorite-clay (sericitic) assemblages. Up to 0.2 wt. % copper occurs in quartz-chalcopyrite veins and stockwork fracturing and is associated with potassic alteration. Sulphur isotopic compositions of sulphide from all the prospects range from –1.01 to +3.6 per mil and are interpreted to indicate sulphur is primarily of magmatic origin.
Key words: Hydrothermal alteration, sulphur isotopes, sulphide deposits, Gilgit, Kohistan arc.

K/40. Kausar, A.B. & Khan, T., 1996. Peridot mineralization in the Spat ultramafics sequence, Naran-Kohistan, Pakistan. Geologica 2, 69-75.

Gem quality peridot (Mg-rich olivine of yellowy green colour) occurs in the Indus suture zone at Sapat along the Kaghan-Kohistan drainage divide. The host rocks are metamorphosed peridotite. The geology and petrology of the rocks and occurrence and mineralogy of the peridot are described.
Key words: Mineralization, ultramafics, peridot, Sapat, Kaghan, Kohistan.

K/41. Kausar, A.B. & Picard, C., 2001. Distribution of platinum-group-elements in silicates lithologies and chromite-rich rocks in within the Sapat and Thak gah mafic-ultramafic complexes, Kohistan arc, Pakistan. Journal of Asian Earth Sciences 19, p.33.

The data on Thak Gah rocks, which are a part of the mafic-ultramafic rocks of the Chilas complex, are given in Kausar et al. (2001).
Key words: PGE, ultramafics, chromitites, Sapat, Thak, Kohistan.

K/42. Kausar, A.B., Picard, C. & Guillot, S., 1998. Evidence for high-temperature-pressure crystallization during early magmatism of the Kohistan arc, Northern Pakistan. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 91-93.

In the southern Kohistan arc, the Jijal ultramafic complex is commonly interpreted as an assemblage of alpine-type ultramafic rocks intruding garnet granulites (Jan & Howie, 1981) or as the remains of a magma chamber (Coward et al., 1987; Miller, 1991) that formed at the base of an immature intra-oceanic island arc in response to northward-directed subduction of neo-Tethys ocean lithosphere during Late Jurassic and Cretaceous. Located just north of the MMT, it was tectonically emplaced over the gneissic basement of the Indian plate at 50 to 45 Ma.
Jijal complex contains two distinct sections. The basal section is composed of ultramafic rocks consisting basically of layered dunites and pyroxenites. Pyroxenites display large variations in mineralogy and are subdivided into four mappable macro-rhythmic units: olivine clinopyroxenite, websterite which evolves to garnet websterite and garnet clinopyroxenite to the top. The upper section is mainly composed of banded garnet gabbro with small amounts of garnet hornblendites.
All the ultramafic rocks present cumulative textures. The LREE depleted chondrite normalized patterns of pyroxenites (0.07< (La/Yb) n<1.09) are consistent with pyroxene accumulation. In the garnet gabbros chondrite-normalized patterns are more REE enriched and are slightly depleted to flat (0.64<(La/Yb)n<1.26). Crystallization of olivine and pyroxene minerals in ultramafic section can account at least partially for the LREE enrichment in garnet gabbro as these rocks are resulting from crystallization of residual liquids (Mg# = 0,79 to 0,71). MORB normalized trace element pattern for garnet gabbro shows negative Ta and Nb anomaly, similar to modern arc related basaltic to andesitic rocks. This consistent REE behaviour supports the operation of magmatic crystallization processes and lends confidence to the application of mineral/melt fractionations to the interpretation of the course of plutonic crystallization differentiation.
The mineral chemistry also indicates that the Jijal complex represents a magmatic sequence formed by successive fractional crystallization. The ferromagnesian minerals show large chemical variations in accordance with the lithological change in the series from dunite - olivine clinopyroxenite-websterite-garnet websterite - garnet clinopyroxenite to garnet gabbro. Mg content of olivine regularly decreases from Fo94 to Fo78. Clinopyroxene is also characterized by continuous compositional variation from $Ca_{48}Mg_{49}Fe_3$ in dunite to $Ca_{49}Mg_{33}Fe_{18}$ in garnet gabbro. Al and Ti contents of clinopyroxene increase with decrease of Mg numbers (Mg/(Mg+Fe). Orthopyroxene probably crystallized late with Mg number 85 in the earlier stage to 76 in the later. The slight variation in garnet composition is characterized by $Al_{37}PY_{30}Gr_{29}SP_2Ad_2$ in garnet websterite to $A1_{43}PY_{33}Gr_{21}Sp_1Ad_2$ in garnet gabbro.
The presence of abundant olivine clinopyroxenite and websterite, mineral chemistry of these ultramafic-mafic cumulates, as well as the petrological and field data are not consistent with crystal-liquid fractionation of a primitive basaltic magma at low pressures. It is proposed on the basis of mineral chemistry, crystallization sequences, garnet-clinopyroxene thermometry that the basal sequence of the Jijal complex was crystallized from a melt at pressures >10 kb and equilibrated at temperatures of 1050 to 1100ºC which is consistent with data of Irvine (1974) indicating conditions around 14 kb and 1180ºC.
Garnet websterite indicates excellent evidence for the exsolution of garnet and orthopyroxene from original aluminous clinopyroxene. This formation of garnet is consistent with the relatively low HREE contents of the garnet pyroxenites. The appearance of clinopyroxene and orthopyroxene having very high Mg number (92 to 85) and the absence of plagioclase as early fractionating phases coprecipitating with forsteritic olivine (Fo94-85) point to a crystallization history at high-pressure.
Al-poor phases such as olivine and pyroxene at moderately high temperatures and pressures, has increased the Al contents in the residual basaltic magma. The onset of the crystallization of plagioclase as a separate cumulate phase is reflected in increased Al_2O_3 and CaO and concomitant fall in MgO in garnet gabbro. This represents the product of evolved magma at relatively shallow level. Such processes are common mechanism for island arc magma evolution at depth (e.g., Aleutian arc, Alaska).
Key words: Ultramafics, magmatism, Jijal, Kohistan, Himalaya.

K/43. Kausar, A.B., Picard, C., Takahashi, Y. & Mikoshiba, M.U., 2001. Petrology and platinum group elements group distribution in the Chilas igneous complex, Kohistan island arc, northern Pakistan. Abstracts, 4th Pakistan Geological Congress, Islamabad, 4-7.

The Chilas igneous complex, a large plutonic body extending more than 300 km between Nanga Parbat and western Dir, is composed of several isolated outcrops of u1tramafic-mafic-anorthosite associations (UMA), which are intruded by rocks of "Main Facies Zone" (formerly known as gabbro-norite association). The ultramafic-mafic rocks represent plutonic core of the Chilas igneous complex. The largest mass of UMA is Chilas ultramafic-mafic-anorthosite association, located east of Chilas and described in detail by Khan et al. (1989).

In this study, we will refer the Chilas ultramafic-mafic-anorthosite association of Khan et al (1989) as Thak Gab ultramafic-mafic-association (TGUM). The rock assemblages of the TGUM and as a whole Main Facies Zone (MFZ) do not show the effects of intense regional metamorphism but at few places ductile shear zones are exhibited. These shear zones in the MFZ are typically narrow, ranging from centimetres to tens of metres, and are heterogeneously distributed. These are often anastomosing, separating great masses of relatively undeformed gabbronorite and pyroxene diorite and are more frequently seen in the southern part of the Chilas complex. Most of these shear zones are trending northeast-southwest, with steep northerly dip. East-west trending antiforms and synforms are observed, indicating a folded structure in the Chilas igneous complex.

The TGUM is composed mainly of cyclic units of ultramafic and mafic rocks and crops out in an area as large as 5 km2. The ultramafic cumulate consists of olivine cumulate (dunite), associated with minor amount of olivine-clinopyroxene cumulate (wehrlite) and orthopyroxene-clinopyroxene cumulate (websterite). It occurs as 10 to 100 metres thick layers, alternating with thin layers of plagioclase-dominant cumulate. Plagioclase-dominant cumulate (two pyroxene gabbro) occurs as layered, several metres thick and develops on the olivine cumulate. Phase layering, resulting from the appearance or disappearance of a cumulus phase is a dominant feature of the TGUM. The heterogeneous mafic unit comprises of troctolite, anorthosite, olivine gabbro, gabbro and gabbronorite. This unit has a number of ultramafic xenoblocks. At many places, gabbroic dykes and pockets are also seen in the ultramafic cumulates, whereas in some outcrops ultramafic dykes are seen in the gabbro. All the units from TGUM are enveloped by massive, uniform gabbronorite.

The rock assemblages from the MFZ form at least 85% of the Chilas igneous complex and has a wide range of rock types, ranging from gabbronorite, gabbro, diorite, opx-diorite, qtz-diorite, granodiorite to trondhjemite, with the main lithologies typically being gabbronorite, gabbro and diorite. All these rock units are so complexly mixed that the contact relationship among them is difficult to decipher. Several lines of evidence from the MFZ support a transitional character from tholeiitic to calc-alkaline arc affinity. Major and trace element geochemistry, and MORB-and chondrite-normalized patterns from the Swat- and Indus-Valleys do not differ significantly. The samples are characterized by enrichment of LILE and negative Ta and Nb anomalies, which are similar to modern arc related basaltic to andesitic rocks. Differences between the samples, from the two valleys, occur mainly in the overall REE abundances and not in the shape of the patterns.

Low values in Mg#, Cr and Ni contents, together with rapid decrease in Ni and Cr with decreasing Mg# and increasing Zr abundance, implies that much of the chemical variation in these rocks may be attributed to the crystallization processes. Positive to negative Eu anomalies in the REE profiles for the basic to more evolved rocks indicate that fractionation has taken place during magma evolution.

Another aim of this study is to investigate the platinum-group elements (PGE) and Au distribution in the rocks of the Chilas igneous complex (TGUM & MFZ). The samples have been analysed at the Institute Dolomieu, Grenoble University, France by ICP-MS, after extraction by hydrolysis/reduction using $SnCl_2$ and collection onto Se-Te (Amosse et al., 1986). PGE concentrations are generally associated with chromitite and sulphide occurrences in ultramafic and mafic rocks within large layered intrusions (Stillwater, Bushveld), or in greenstone belts of komatiitic affinity (Naldrett & Duke, 1980). A silicate type environment is also defined, in which no sulphide or oxide is visible to the naked eye. This type of deposit raises new questions on the origin of PGE concentrations and broadens the exploration field in areas insufficiently explored to date. No sulphide phase and no chromite assemblages of large concentrations are known in the ultramafic and mafic rocks of TGUM and MFZ. However, chrome-spinel occurs disseminated throughout the pyroxenite, and in the dunite, where it is an intercumulus phase forming <1 vol. % in dunite of Thak Gab complex. Small concentrations of chromite occur in the form of thin layers (<5 mm thick layer) or streaks in the dunite and may disappear laterally within a few metres, but very rare in the pyroxenites.

In the Chilas complex, dunite from the TGUM, has total PGE concentrations between 14 ppb and 334 ppb, except for some Cr-enriched dunite which has 1002 ppb abundances. Pyroxenite has total PGE concentrations from 13 ppb

to 19 ppb and total concentrations of PGE in gabbro range between 6 ppb and 20 ppb. In Main Facies Zone, gabbronorite shows total PGE concentrations between 8 ppb to 17 ppb. This complex has low PGE concentration that correlate with indicators of magma evolution (Mg/Mg+Fe). So the Chilas igneous complex is not likely prospect for stratiform-sulphide mineralization owing to the failure of these melts to reach saturation and these rocks hold little economic prospects.

To allow comparison between samples, analytical data have been normalized against mantle concentrations. Metal patterns from the TGUM reveal that dunite display slightly positively sloping (Pd/Ir=4 to 7), which exhibits relative enrichment in Ni and IPGE. In contrast, samples from the pyroxenite display more pronounced positively sloping metal patterns from Ir to Pt, which indicates their relative enrichment in PPGE (Pd/Ir=4 to 30). These metal patterns indicate that the PPGE and Cu were preferentially incorporated into more evolved rocks and imply relatively incompatible behaviour for these elements. Such incompatible behaviour of Pt, Pd and Au in these rocks is attested by their increasing abundances in more evolved rocks. An exception to this general trend involves the Pt-enrichment for the dunite sample from the TGUM. The observed enrichment particularly in Pt in dunite rock may be related to the precipitation of isoferroplatinum alloy. The factors responsible for the anomalous high Pt abundances in this sample are however poorly understood. The profiles of mantle-normalized Ni-PGE-Au-Cu values of mafic rocks of MFZ shows that all the curves follow a positive slope from Ni to Cu, disturbed only by a strong negative Pd anomaly in some gabbro and gabbronorite samples. The overall depletion in IPGE and enrichment in PPGE is a pattern typical of fractionation.

The IPGE and Ni were strongly partitioned into the most primitive rock (dunite), which reflects the compatible behaviour of these elements. The good positive correlation between IPGE, Ni and Cr clearly indicates that olivine fractionation in combination with early chromite removal can explain the decrease in Ir and Ni values between primitive and more evolved rocks from the Thak Gab complex. It also accounts for the substantial negative IPGE anomalies on the mantle-normalized diagrams of the complex.

Clear similarities in PGE signature exist between the different lithological units of the Chilas igneous complex and this offers support to hypotheses that similar geochemical processes may have operated on or around these lithologies.

Key words: Petrology, PGE, ultramafics, Chilas, Kohistan, Himalaya.

K/44. Kausar, A.B., Takahashi, Y. & Zafar, M., 1996. Petrological and geochemical observations of the Kohistan batholith with emphasis on REE and their implications for batholith petrogenesis. In: Kausar, A.B. & Yajima, J. (eds.), Geology, Geochemistry, Economic Geology and Rock Magnetism of the Kohistan Arc. Proceedings of Geoscience Colloquium, Geoscience Lab, Geological Survey of Pakistan, Islamabad 15, 37-55.

For further information, consult Kausar (1995).

Key words: Petrology, geochemistry, REE, petrogenesis, Kohistan Batholith.

K/45. Kazmer, C., 1986. The Main Mantle Thrust zone at Jawan Pass area, Swat, Pakistan. M.Sc. Thesis, University, Cincinnati, 79p.

The Main Mantle Thrust (or the Indus suture) zone is a mélange bounded to the north by Kohistan arc and to the south by the Indian plate rocks. This work delineates and describes the lithologies in the fault-bounded mélange. The mélange contains components of the Indian plate, Kohistan, and mafic-ultramafic ophiolitic rocks.

Key words: MMT, Jawan pass, Swat.

K/46. Kazmer, C., Hussain, S.S. & Lawrence, R.D., 1983. The Kohistan-Indian plate suture zone at Jawan Pass, Swat, Pakistan. Geological Society of America, Abstracts with Program 15, p.609.

The suture between the Kohistan Arc (KA) and the Indian Plate (IP) passes near Mingora in Lower Swat. This suture was identified previously as a single thrust fault, the Main Mantle Thrust, where arc-related amphibolites were brought over IP garnet-grade metasediments. In fact, the suture is a complex zone of thrust slices and mélanges bounded by two low-angle thrusts.

The most complete section is exposed SW of Mingora at the Jawan Pass. There, KA amphibolites are thrust over the suture zone. The suture zone consists of two parts: an upper part of imbricate greenstones and meta-volcanics, and a this n band of politic mélange comprising rounded to phacoidal serpentinite, metavolcanic, and exotic carbonate clasts in a sheared pelitic matrix; and a lower part of ultramafic (UM) mélange comprising greenstone, schist, serpentinite, and soapstone clasts in a talc-carbonate matrix. The UM mélange is thrust over the IP metasediments. Retrogressive metamorphism and carbonatization has affected the suture zone rocks and the upper section of the metasediments. The UM mélange is emerald bearing at Swat Emerald Mine in Mingora.
Four phases of folding are recorded in the IP metasediments. The UM mélange is found in F2 troughs. Thrusting of the KA amphibolites and greenstones-metavolcanics, formation of the pelitic mélange, and emplacement of some clasts into the UM mélange post-date F3.
The suture zone at Jawan Pass results from obduction of the KA amphibolites over the IP metasediments. The lower ultramafic part was emplaced as a serpentinite mélange prior to F2. The upper greenstone-metavolcanic part was emplaced concurrently with KA amphibolite emplacement but prior to F4.
Key words: Indus Suture, Kohistan, Indian Plate, Jawan Pass, Swat.

K/47. Kazmi, A.H., 1966. Water supply problems in West Pakistan. Natural Resources 1(2).

Key words: Hydrogeology, water supply, West Pakistan.

K/48. Kazmi, A.H., 1968. Earthquake problems and programme in Pakistan. CENTO Conference on Earthquake Hazards, Turkey. Geonews 2(1).

Key words: Earthquakes, problems, programs, Pakistan.

K/49. Kazmi, A.H., 1972. Earthquakes in Pakistan. Geonews 2(1), 22-30.

Key words: Earthquakes, Pakistan.

K/50. Kazmi, A.H., 1974. Report on the development in studies on Recent Tectonics in Pakistan during 1973-74. Report 3rd Meeting. CENTO Working Group on Recent Tectonics. Unpublished Report, Geological Survey of Pakistan.

Key words: Neotectonics, Pakistan.

K/51. Kazmi, A.H., 1977. Application of ERTS-1 imagery to Recent Tectonic Studies in Pakistan. CENTO Workshop on Application of Remote Sensing Data and Methods, 1975. US Geological Survey Project Report, CENTO Investigation (IR) CENT-10, 140-149.

Key words: Remote sensing, neotectonics, Pakistan.

K/52. Kazmi, A.H., 1978. Mineral resources of Pakistan. Pakistan Mineral Development Corporation, Mineral Review, 11.

Key words: Economic geology, mineral resources, Pakistan.

K/53. Kazmi, A.H., 1979a. Active fault systems in Pakistan. In: Farah, A. & DeJong, K.A. (eds.), Geodynamics of Pakistan. Geological Survey of Pakistan, Quetta, 285-294.

Study of aerial photographs, Landsat imageries and seismological data has revealed a large number of lineaments which appear to be active faults. Recent fault activity is discernible through offsets of the topography, deformation of Late Quaternary deposits, offsets of cultural features, seismicity, and historic records. Fifty three such active

faults and features have been mapped and described briefly. These faults comprise four main types: (a) transform faults that mark the western plate boundary of the Indo-Pakistan subcontinent; (b) strike-slip faults which occur mainly along the inner or eastern margin of the axial fold belt and which are mainly responsible for the formation of syntaxial bends; (c) thrust reverse faults which are commonly arcuate faults and traverse the zone between each set of sterile slip faults, and (d) traces of basement geofractures which appear as lineament of various dimensions.
This study demonstrates the use of Landsat imagery, supplemented by aerial photographs, regional geological maps and seismological data in the delineating active fault systems which would remain otherwise untouched.
Key words: Fault system, Pakistan.

K/54. Kazmi, A.H., 1979b. Preliminary seismotectonic map of Pakistan. Scale 1:200,000 Geological Survey of Pakistan, Quetta.

This is a seismotectonic map of Pakistan at 1: 2,000,000 scale. The map shows the major faults in northern Pakistan, traces of other faults, some of them active, and earthquakes magnitude >3. Depth estimates are also given for the instrumentally recorded earthquakes of northern Pakistan and NE Hindukush in Afghanistan, which have been divided into four groups of magnitude <3, 3-5, 5-7 and >7.
Key words: Mapping, seismology.

K/55. Kazmi, A.H., 1984. Pleistocene ice age cycle in the Himalayas. Kashmir Journal of Geology 2, 79-82.

Extensive and repeated glaciation of the northwestern part of the Himalayas occurred during the Pleistocene. Godwin (1859) was probably the first to record evidence of Pleistocene glaciation in the Himalayas. Further studies have revealed well preserved outcrops of terminal moraines, ground moraines and associated fluvio-glacial cut wash and boulder and gravel deposits in the Jhelum Valley in Kashmir, in the Pir Panjal Range and in Poonch area which indicate that these localities have witnessed a series of four glacial and three interglacial epochs during the Pleistocene. Whereas the glacial moraines and related boulder gravels provide evidence for repeated glaciation, the interglacial periods were characterized by deep erosion and valley down-cutting as indicated by benches and rock terraces in the valley profiles.
Key words: Glaciation, Pleistocene, Himalaya.

K/56. Kazmi, A.H., 1989. A brief review of the geology and metallogenic provenance of Pakistan. In: Kazmi, A.H. & Snee, L.W. (eds.), Emeralds of Pakistan: Geology, Gemology and Genesis, 1-11. Van Nostrand Reinhold, New York.

Key words: Metallogeny, provenance, Pakistan.

K/57. Kazmi, A.H., 1995. Precious stone of Pakistan. Proceedings, International Round Table Conference on Foreign Investment in Exploration and Mining in Pakistan, Islamabad, October 16-18, 1994, 57-70.

This paper gives information on the emerald, ruby, sapphire, pink topaz, etc. found in Pakistan northern part. For further information, consult the following account.
Key words: Gems, precious stones, Pakistan.

K/58. Kazmi, A.H., 1997a. Precious and semi-precious stones of Pakistan. Abstracts, National Symposium on Economic Geology of Pakistan, Islamabad, 1 p.

Gemstones have been intimately linked with the ancient history of Pakistan and since the early civilizations of Mohenjodoro, Harappa, Gandhara and Taxila, they have been used as objects of adornment symbols of power and glory and as exchange in trade. Cutting and polishing of gemstones by traditional methods is an old craft in this subcontinent as evidenced from archaeological remains of these cultures.

During the early years of Pakistan, the gemstone resources in the country remained unexplored. However since 1958 several gemstone discoveries have been made in Pakistan and presently the known occurrences include actinolite, agate. Aquamarine, azurite, emerald, feldspar (moonstone), garnet, onyx marble, pargasite, pink topaz, quartz, rodingite. Peridot, ruby, rutile, serpentinite, spinel, topaz, tourmaline and vesuvianite. Out of these the more significant deposits comprise the Swat emeralds pink topaz of Katlang rubies in Hunza and Azad Kashmir. Hunza spinel peridot from upper Kaghan and mineral specimens from the gem pegmatites of the Karakoram and the High Himalayas. These deposits are briefly described in the paper.
Key words: Gems, precious stones, Pakistan.

K/59. Kazmi, A.H., 1997b. Precious and semi-precious stones of Pakistan. In: Hussain, S.S. & Akbar, H.D. (Eds.), Proceedings, National Symposium on Economic Geology of Pakistan, 1997, Islamabad, 267-284.

For further information, consult the preceding account.
Key words: Gems, precious Stones, semi-precious stones, Pakistan.

K/60. Kazmi, A.H., 2001. Active faults and related high-seismicity zones in Pakistan. Abstracts, 4th Pakistan Geological Congress, Islamabad, 33-34.

Active faults are earthquake generating faults that discernible through offsets of topography, deformation of Late Quaternary deposits, offset of cultural features, seismicity and historic records. Several active faults have been identified in Pakistan. They comprise four main types: (1) transform faults that mark the we3tern boundary of the Indo-Pakistan Shield, (2) strike-slip faults along structural arcs, oroclines and syntaxes, (3) thrust and reverse faults between sets of strike-slip faults, and (4) basement fractures. As may be expected, the active faults overlap high seismicity zones and have caused moderate to severe earthquakes. In this study the major seismotectonic zones have been identified and may be summarised as follows:
Tirich Mir Seismic Zone. It covers a large part of the Hindukush in Pakistan and Afghanistan and is probably linked with the Akbaytal Fault in Afghanistan. Numerous 5-7 magnitude earthquakes with 100-200 km focal depth have occurred in this zone. Yasin Seismic Zone, Located on the M1KT near Yasin town, it has generated several 3-5 magnitude events with focal depths less than 50 kms, Hamran Seismic Zone. In Ghizar Range the Hamran Valley has experienced frequent earthquakes of 3-5 magnitude and <50-100 km deep hypocentres. No active fault has yet been located, though focal mechanism of some events indicates thrusting on NW trending nodal planes.
Indus Kohistan Seismic Zone (IKSZ). It is a NW-SE trending zone between MMT and Hazara- Kashmir Syntaxis. It occurs along a detachment zone and it generated the 1974 Pattan earthquake. Tarbela-Hazara Seismic Zone. Located 60 kms SE of IKSZ, it is characterised by an upper seismic zone (the Tarbela zone) comprising steeply dipping strike faults, and a deeper seismic zone (the Hazara zone), where the hypocentres cluster along a steep basement fault. Cherat-Margalla Seismic Zone. It covers the lesser Himalayan ranges and the southern part of the Peshawar plain. Several 3-5 and a few 6 magnitude events have occurred in this region. The MBT and a number of other active faults are located in this zone.
Sargodha- Shahkot buried ridge. Two portions of this ridge, one SW of Khushab and the other in Lyallpur-Jaranwala area are seismically active and fault-plane solutions indicate extensional faulting. Sulaiman Range Seismic Zone. It is characterised by left lateral active faults along eastern and western margins of the Sulaiman Range. Fault plane solutions suggest strike-slip faulting. Sulaiman Lobe Seismic Zone. Though the entire Sulaiman lobe is seismically active, two regions particularly exhibit high seismicity, contain active faults and have suffered devastating earthquakes. One of these is the Loralai- Mekhtar region where several 3-6 magnitude, shallow (<50 kin) events are attributed to the active Mekhtar Fault. The other is the 25 to 50 kms wide and 250 kms long Harnai-Kingri arc, which has experienced 3-7 magnitude events related to Khalifat, Kohlu, Tatra and Kingri faults. Focal mechanism solutions indicate strike slip faulting. North Kirthar Seismic Zone. It covers the northern part of the Kirthar fold belt. It has been devastated by a few shallow (30-40 kin) earthquakes cantered on the Mach, Johan and Kirthar faults.
Quetta-Kalat Seismic Zone. This is a narrow, 150 kms long, high seismicity zone traversed by the active Bhalla Dor, Ghazaband and Chiltan-Takhatu faults. Several shallow (5-15 kin) events of 5-6 magnitude have occurred in this zone including the devastating 1935 Quetta earthquake. Chaman Fault Seismic Zone. It follows the N-S, 850 kms long, left-lateral, active Chaman Fault and extends from Kharan to Kabul. It produced the destructive earthquakes of 1892, 1975 & 1978.

Makran Coast Seismic Zone. It is a shallow, active subduction zone with high seismicity. Most of the events are offshore, where an earthquake of magnitude 8 occurred in 1945. It uplifted the ocean floor forming small islands and revealed an E-W trending active fault. Inland many 3-6 magnitude events have occurred in the Hoshab- Mashkai Valley, along the Hoshab Fault. Rann of Cutch Seismic Zone. In this zone the frequency of earthquakes is apparently not so high, despite the fact that it has experienced some of the most destructive earthquakes like the one in 1819, which revealed the Allah bund Fault, or the recent Bhuj earthquake. In the remaining areas of Pakistan, the seismicity is relatively low; diffused, and apparently not aligned with ‘any particular tectonic feature. In parts of the Indus Plain, particularly in the fore-deep region several lineaments have been traced and shallow, low-magnitude teleseismic activity has been recorded. These may be related to the bending of the lithosphere or due to active basement faults.
Key words: Active faults, seismicity zones, Pakistan.

K/61. Kazmi, A.H. & Abbas, S.G., 1991. A brief review of the mineral wealth of Pakistan. Geological Survey of Pakistan, 35p.

Consult the following account for further information.
Key words: Mineral resources, Pakistan.

K/62. Kazmi, A.H. & Abbas, S.G., 2001. Metallogeny and mineral deposits of Pakistan. Orient Petroleum Inc., Islamabad, 294p.

This detailed work gives information on the tectonics, metallogenesis, and occurrence of the mineral deposits of Pakistan. Information is provided on the statistics, quality and size of the deposits.
Key words: Metallogeny, mineral deposits.

K/63. Kazmi, A.H., Anwar, J., Hussain, S.S., Khan, T. & Dawood, H., 1987. Emerald deposits of Pakistan. In: Kazmi, A.H. & Snee, L.W. (Eds.), Emeralds of Pakistan, Geology, Gemology and Genesis. Geological Survey Pakistan, & Van Nostrand Company, New York, U.S.A., 39–74.

Key words: Gems, emerald, Pakistan.

K/64. Kazmi, A.H. & Jan, M.Q., (Eds.). 1997. Geology and tectonics of Pakistan. Graphic Publishers, Karachi, 569p.

This is a comprehensive treatise on the geology and tectonics of Pakistan. It is divided into 10 chapters: 1) Introduction, 2) Geomorphology, 3) Regional Geological Setting, 4) Tectonic Framework of Pakistan, 5) Stratigraphy, 6) Magmatism, 7) Metamorphism, 8) Neotectonics, 9) Mineral Deposits, and 10) Mineral Fuels. The work is based on more than 1300 references, followed by an Index of 10 pages. The book is highly illustrated, with hundreds of figures, photographs, and tables.
Key words: Geology, tectonics, Pakistan

K/65. Kazmi, A.H., Lawrence, R.D., Anwar, J., Snee, L.W. & Hussain, S.S., 1986. Mingora emerald deposits (Pakistan): suture associated gem mineralization. Economic Geology 81, 2022-2028.

Emeralds occur disseminated and in veins along fractures and faults in an ophiolitic mélange of the Indus suture zone. Quartz, calcite and limonite are post-emerald fillings; the principal host-rock is talc-chlorite-dolomite schist, the matrix of the mélange. The occurrence is unique; the source of Be is sought in beryl-bearing granite gneiss of the adjacent Indian plate.
Key words: Ophiolites, gems, emerald, Indus Suture, Mingora, Swat.

K/66. Kazmi, A. H., Lawrence, R.D., Dawood, H., Snee, L.W. & Hussain, S.S., 1984. Geology of the Indus Suture Zone in the Mingora-Shangla area of Swat, N Pakistan. Geological Bulletin, University of Peshawar 17, 127-144.

In the Mingora area the Indus suture zone is largely composed of metamorphosed ophiolites and mélanges which have been wedged in between the Indo-Pakistan crustal plate and the Kohistan andesitic arc block. The Indo-Pakistan subcontinental sequence is made up of the twice metamorphosed Manglaur crystalline schists, the intrusive Swat granite gneiss, and the unconformably overlying once metamorphosed Alpurai and Saidu schists. The recognition of this unconformity requires major revision of the stratigraphic correlation of these units which were previously all considered to the Precambrian. Those above the unconformity are probably Phanerozoic, and the Saidu schist may be the local metamorphosed equivalent of the Indus flysch of Ladakh. The ophiolitic and related rocks of the Indus suture mélange group are subdivided into three separate units. The Shangla blueschist mélange is locally present in the north and represents a subduction complex developed adjacent to the Kohistan arc. The Charbagh greenschist mélange crops out in the center of the group and could be of either mid-oceanic island or island arc origin. The Mingora ophiolitic mélange is obduction complex. It is characterized by metamorphism to talc-dolomite schist and emerald mineralization.
Key words: Ophiolites, metamorphism, Indus Suture, Mingora, Shangla, Swat

K/67. Kazmi, A.H. & O'Donoghue, M., 1990. Gemstones of Pakistan. Gemstone Corporation of Pakistan, 146p.

Pakistan is emerging as an important country for occurrence of wide range of gemstones. This nicely produced volume provides a wealth of information supported by 72 coloured photographs, 24 figures, 19 tables and many references. Following introduction the book describes the composition properties and distribution of gemstones.
The gemstones deposits of Pakistan have been divided into those associated with the Indus Suture, the Karakoram Suture, pegmatite-related, hydrothermal veins related and others. Occurrence, physical and chemical data (where available) and other information has been provided for many of the gems.
Key words: Gems, precious stones.

K/68. Kazmi, A.H., Peters, J.J. & Obodda, H.P., 1985. Gem pegmatites of the Shingus-Dusso area, Gilgit Pakistan. The Mineralogical Record 16, 393-411.

Dassu area flanking the eastern margin of the Nanga Parbat-Haramosh massif is invaded by numerous pegmatites, aplites and leucogranite dykes. The pagmatites are locally zoned, others are associated with aplites. Some of the pegmatites are mineralized and contain gem quality tourmaline, aquamarine, topaz, garnet and other minerals.
Key words: Gems, precious stones, Gilgit.

K/69. Kazmi, A.H. & Qureshi, I.H., 1997. A brief review of depositional and deformational history of northern Pakistan during the Neogene. Abstracts, 3rd GEOSAS Workshop on Siwaliks of South Asia, Islamabad. Geological Survey of Pakistan, Records 109, p.34.

Consequent to the India-Eurasia collision, the deformation, magmatism and metamorphism along the Indian Plate margin has occurred intermittently over a period of about 50Ma. The deformation and uplift of the Himalayan region has been most vigorous during the Neogene. The Neogene sedimentary sequence of Northern Pakistan contains clues to several episodes of spasmodic uplift and deformation. Recent sedimentological paleomagnetic and paleontological researches by several workers have provided a wealth of information indicating abrupt changes in lithology and paleocurrents, facies and provenance changes reflected in the mineral and rock fragment assemblages of sedimentary sequences, facies migration, changes in fluvial sedimentation rates, syndepositional unconformities, angular unconformities, tectonic rotation, folding and faulting of relatively young strata and major mammalian fauna turn over events. These are not isolated events. They have occurred in response to the uplift and deformation of the Himalayan region. Based on this data a tentative chronology of the uplift and deformation of the NW Himalayan region since the Early Miocene has been prepared and discussed in this paper.
Key words: Deformation, neogene, Northern areas.

K/70. Kazmi, A.H. & Rana, R.A., 1982. Tectonic map of Pakistan. Geological Survey of Pakistan, Geological Map Series, Scale 1:2,000,000.

This is 1:200,000 scale map of Pakistan and adjacent areas of Kashmir showing major structural features and tectonic stages. The map also shows broader aspects of geology of the country. Four in set map show regional tectonic setting, tectonic zonation, thickness and distribution of Cretaceous and Eocene sedimentary rocks in Pakistan and major fault and lineaments. Also given is chart showing the sequence of tectonic stages, orogeny, magmatism, volcanism and metamorphism in various tectonic zones of the country.
Key words: Mapping, tectonics, Pakistan.

K/71. Kazmi, A.H. & Sabri, A.H., 1970. Status and scope of geological mapping in Pakistan. Proceedings of National Seminar on Mineral Development, Lahore.

This is a generalized account on the geological mapping of Pakistan.
Key words: Mapping, Pakistan.

K/72. Kazmi, A.H. & Safdar, M., 1963. Clay resources of West Pakistan. Proceedings, CENTO Symposium on Industrial Rocks and Minerals, Lahore, 122-128.

Key words: Economic geology, clay, Pakistan.

K/73. Kazmi, A.H. & Siddiqui, R.A. (eds.), 1990. Significance of the Coal Resources of Pakistan. Geological Survey of Pakistan, Quetta, US Geological Survey, 270p.

This is an account of the coal resources of Azad Kashmir, Balochistan, Khyber Pakhtunkhwa, Punjab and Sindh. The huge deposits of Thar in southeastern Sindh are described in detail.
Key words: Economic geology, coal resources, Pakistan

K/74. Kazmi, A.H. & Snee, L.W. (eds.), 1989a. Emeralds of Pakistan: Geology, Gemology and Genesis, Van Nostrand Reinhold, New York, 269p.

This book, a comprehensive study of the geology of major emerald deposits, is the result of a collaborative program among the Geological Survey of Pakistan, the Gemstone Corporation of Pakistan, Oregon State University and the US Geological Survey.
The present volume summarizes the work of the authors. Chapters 1, 2 and 3 describe the geologic settings of the emerald deposits and the geology and tectonics of northern Pakistan. Chapter 4 is a summary of the gemological and physical characteristics of Pakistani emeralds. Chapter 5, 6 and 7 investigate emerald chemistry and fluid inclusion characteristics. The chapter 8 summarizes existing literature on world emerald deposits while chapter 9 gives foundation for the classification of emerald deposits and discussion of the origin of emeralds. A list of selected references is also given at the end of the book.
Key words: Gemology, emeralds.

K/75. Kazmi, A.H. & Snee, L.W., 1989b. Geology of world emerald deposits: A brief review. In: Kazmi, A.H. & Snee, L.W. (Eds.), Emeralds of Pakistan: Geology, Gemology and Genesis, 165-228. Van Nostrand Reinhold, New York.

Key words: Gemology, emeralds.

K/76. Kazmi, A.H., Snee, L.W. & Laurs, M.B., 1998. Himalayan Emeralds: Geology and Genesis. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 93-94.

The known Himalayan emerald-deposits and showing are confined to the NW Himalayas and occur within a narrow, 450 km long belt that largely comprises the Indus suture rock-sequence. Emeralds occur at Gandao, Nawe Kili, Bucha, Pranghar and Kot (Mohmand Agency); Maimola and Mor Darra (Bajaur Agency); Shamozai, Mingora, Char bagh, Makhad and Gujar Kili (Swat District); Allai Kohistan (?); and Khaltaro (Gilgit District). Some of these deposits have been studied by a number of authors, mainly by Jan 1968, Jan et al., 1981, Kazmi et al., 1986, Kazmi and Snee 1989, and Laurs et al,. 1996.
The emeralds occur in a region characterized by three major tectonostratigraphic subdivisions. North to South these are (1) the Kohistan magmatic arc sequence which has been faulted against (2) the Indus suture melange group and the latter had been abducted previously onto (3) the Indo-Pakistan plate sequence. The Kohistan rocks have no bearing on the genesis of emeralds. The Indus suture melange and the Indo-Pakistan hand, directly involved in the formation of the emerald deposits.
The Indus suture melange group comprises tectonic blocks of ophiolites, blueshists, greenschists, metavolcanics and metasediments in a matrix of sheared and variously metamorphosed fine-grained sediments and/or serpentinite. These rocks occupy the MMT zone between the Kohistan andesitic arc and the northern margin of the Indo-Pakistan plate. The latter contains Paleozoic and Mesozoic shelf sediments, unconformably underlain by Precambrian crystalline schists and Paleozoic granitic intrusions. This sequence is intruded by Tertiary granites. The emeralds occur in two distinct geological environments. Except the Khaltaro deposit, all others are suture associated and occur as disseminations or pockets in talc-carbonate-schists. The mineralisation is confined to faults or shear zones. Emeralds formed late in the history of the suture associated rocks after major deformation had been completed as they are nowhere crushed, stretched or otherwise deformed. Emerald mineralisation apparently relates to the final stages of the metasomatic alteration of the ophiolite melange to talc-dolomite melange. The absence of granitic or pegmatitic veins in the melange, presence of beryl pegmatites and tourmaline in the granitic rock near Kot and Pacha Fort and the occurrence of young (tertiary) leucogranits near Karora, Iram and Saidu (close to the suture zone) suggest that the mineralising fluids came from these youngest granitic rocks. Emeralds developed only in the Mingora melange which provided the chromium.
The Swat emeralds are among the most Cr-rich known (up to 2 wt% Cr_2O_3). They have higher Mg and transition metals and lower Al per ^{18}O atoms that the pegmatite Khaltaro emeralds. They contain inclusions of actinolite, chromite, dolomite, enstatite, feldspar, gersdorffite, magnesite, mica and pyrhotite. Fluid inclusions are generally two-phase (brine+CO_2- vapour). Homogenisation temperature ranges from 305o to 349oC and salinity ranges from nil to 20eq.wt% NaCl. The host rocks (talc-carbonate schists) have ultramafic geochemical signatures (930-2520 ppm Cr; 980-2540 ppm Ni). Altered rocks near emerald deposits are locally enriched in Al, Si, Be, and REE reflecting the hydrothermal addition of a continental crust-derived component. Collision of the Indian and Asian plates along the Indus suture zone was an important factor in the genesis of the deposits because it juxtaposed sources of Cr (ophiolitic melange) with sources of Be (continental crust).
South of the Indus suture zone, the Indo-Pakistan plate sequence in the Haramosh Range, comprising Proterozoic schists and layered gneisses, hosts the Khaltaro emeralds. Emeralds occur in thin (0.1-1.0m) hydrothermal veins and granitic pegmatites occurring as sill-like body within garnet-mica schist. The pegmatites give $^{40}Ar/^{39}Ar$ muscovite date of 9.13+0.04 Ma. Emeralds are found mainly within thin (< 30cm) veins of quartz and tourmaline-albite and more rarely in pegmatites, near the contacts with altered amphibolite. The pegmatites are zoned, having ;an inner zone of biotite, tourmaline and fluorite with local albite, muscovite, quartz, and rare beryl, an intermediate zone containing biotite and fluorite with local plagioclase and quartz and an outer zone of amphibolite containing sparse biotite and local quartz. According to Laurs et al. (1996), the inner and intermediate zones experienced gains of K, H, F, B, Li, Rb, Cs, Be, Ta, Nb, As, Y and Sr, and losses of Si, Mg, Ca, Fe, Cr, V and Se. The outer alteration zone has gained F, Li, Rb, Cs, and As. Oxygen isotope analyses of igneous and hydrothermal minerals indicate that a single fluid of magmatic origin produced the pegmatite-vein system and hydrothermal alteration at temperatures between 550º and 400ºC. The emeralds formed due to introduction of HF-rich magmatic-hydrothermal fluids into the amphibolite, which caused hydrogen ion metasomatism and released Cr and Fe into the pegmatite-vein system.
Key words: Gemology, emeralds, Himalaya.

K/77. Kazmi, S.A.T., 1968. Groundwater investigation in Warsak regulating reservoir scheme area. Bulletin 16, Water and Soil Investigation Department Publication 62, WAPDA, Hydrogeology Directorate, North West Frontier Province, Peshawar.

Key words: Groundwater, Warsak.

K/78. Kella, S.C., Qureshi, M.A., Khan, A.B. & Shah, M.Y., 1996. Integrated regional exploration for gold and associated minerals of northern areas of Pakistan. Proceedings, Second SEGMITE International Conference on Export Oriented Development of Mineral Resources and Mineral Based Industries, Karachi, 1994, p.152.

Key words: Gold exploration, minerals, Gilgit-Baltistan.

K/79. Keller, H.M., 1975. The magnetic polarity stratigraphy of an upper Siwalik sequence in the Pabbi Hills of Pakistan. M. A. thesis, Dartmouth College, Hanover, New Hampshire, U. S. A.

Consult the following account for further information.
Key words: Magnetostratigraphy, siwaliks, Potwar.

K/80. Keller, H.M., 1977. Magnetic polarity stratigraphy of the upper Siwalik deposits, Pabbi Hills, Pakistan. Earth and Planetary Science Letters 36, 187-201.

Over 1000 m of fluvial molasse, exhibiting a stable detrital remanent magnetization, is exposed in a mammal-bearing sequence in the Upper Siwalik Group of the Pabbi Hills, Pakistan. The magnetic polarity chronology reveals that the sequence records a time period of 2.6 m.y., extending from the early Gauss Normal Epoch into the Brunhes Normal Epoch. During this period, sedimentation rates increased upward in time from 0.25 m/1000 yr to 0.45 m/1000 yr. The sudden disappearance of red beds and a change in the lithoclastic composition of basal channel sands suggests that about 800,000 years ago the primary source area began shifting from the metamorphic terrane of the Himalayan Orogen to a more local sedimentary terrane on the folded margins of the Himalayan foredeep. About 500,000 years ago the anticlinal Pabbi Hills attained surface expression. Uplift continued at a minimum rate of 1 m/1000 yr.
A local Pliocene/Pleistocene boundary based on the Olduvai Normal Event is clearly recognized. Local fossil finds reveal that *Equus*, diagnostic element of the Pinjor faunal zone, appeared locally about 1.8 m.y. ago and that *Hipparion*, a faunal element of the Tatrot and earlier faunal zones, persisted locally until at least 3.0 m.y. ago.
Key words: Magnetostratigraphy, siwaliks, Pabbi hills, Potwar.

K/81. Kelley, J., 1997. The significance of fossil hominoid discoveries from the upper Nagri Formation, Potwar Plateau, Pakistan. Abstracts, 3rd GEOSAS Workshop on Siwaliks of South Asia, Islamabad. Geological Survey of Pakistan, Records 109, p.68.

Almost all of the fossil hominoid specimens known from the Siwalik Nagri Formation have come from a single locality, Y3 11. Y3 11 lies in the uppermost part of the formation and is dated approximately 10 m.y. based on magnetic polarity stratigraphy. It is the richest hominoid locality in the Siwalik Sequence of the Potwar Plateau; approximately 25% of all fossil hominoid specimens collected from the Potwar Plateau since Dehm's first expedition in 1939 have come from this locality. This total includes fully half of all the hominoid postcramal specimens recovered. All of the hominoid material from Y3 11 has been assigned to a single very large species of Sivapithecus, S. parvada, which is not definitely known from any other Siwalik locality. The S. parvada material has contributed significantly to questions concerning hominoid pbylogeny and paleobiology. Postcramal remains reveal that large individuals of S. parvada were as large as female gorillas or male orangutans, and that body size sexual dimorphism was probably substantial. They also indicate that S. parvada was primarily a quadrupedal rather than a suspensory ape. This has raised questions about the relationship of Sivapithecus to the extinct orangutan, Pongo, established on the basis of cramofacial morphology. Juvenile specimens of S. parvada have permitted an estimation

of the overall rate of maturation in the species, based on the ability to calculate absolute ages at death using growth lines preserved on tooth germs. Maturation rate is one of the most fundamental biological attributes of a species and sharply distinguishes, for example, living monkeys and apes. S. parvada appears to have matured at approximately the same rate as living apes. The paleobiology of S. parvada is now more completely characterized than that of almost any other fossil hominoid.
Key words: Vertebrate palaeontology, hominoid, Nagri Formation, siwaliks.

K/82. Kemp, A.J. & Leak, B.E., 1975. Two hydrous-rich aluminous hornblendes. Mineralogical Magazine 40, 308-311.

Previous studies of aluminous hornblendes rich in alumino-tschermakite, $Ca_2Mg_3Al^{vi}{}_2Si_6Al^{iv}{}_2O_{22}(OH)_2$, have shown that no natural amphiboles are known that closely approach this composition (Leake, I971). From a careful scrutiny of about 1500 analysed amphiboles with at least Ca 1.00 in the half unit cell and from reanalysis of a number of percipiently selected Al-rich samples, it was shown that the maximum possible A1 vi in natural amphiboles increased as A1 iv increased and it was suggested that the maximum possible AIvi value in natural hornblendes when the half unit cell contained $Si6AI^{iv}$ was not above 1.40 although the highest reliably determined A1 v~ value known was only I"35 (Leake, ~97I). Subsequently Bunch and Okrusch (I973) have described a quite extraordinary iron-poor aluminous amphibole (with 22.6 $A1_20_3$), which has $K_{0.16}$ $Na_{0.54}$ $Ca_{1.99}$ $Mg_{3.35}$ $Fe_{0.01}$ $Ti_{0.16}$ Alvi $_{1.47}$ Si $_{5.47}$ $A1^{iv}2.26$ $O_{22.13}(OH, F,C1)_{1.87}$. One of the highly aluminous amphiboles described in this paper is from corundum-bearing amphibolite of timargara, Dir (see Jan et al., 1971).
Key words: Mineralogy, aluminous hornblende, Dir.

K/83. Kempe, D.R.C., 1973a. The petrology of the Warsak alkaline granites, Pakistan, and their relationship to other alkaline rocks of the region. Geological Magazine 110, 385-404 (Corrigendum, 1974, 111, p.450).

A suite of Tertiary alkaline porphyritic microgranites and hybrid and peralkaline granite from northwest Pakistan is described, with six rock analyses (five of them new). The microgranites, an earlier group of which some contain garnet, have undergone metamorphism, lacking in the granites. The microgranites are shown to be precisely similar to those from the Shewa–Shahbazgarhi area, for which four analyses (two of them new) are presented, and related to a third group from Tarbela. The mineralogy of the rocks is discussed, with seven new analyses of aegirine, riebeckite, ferrohastingite and astrophyllite, and X-ray determinations of the feldspar compositions. The granites are considered to be related to the undersaturated syenites and associated rocks of Koga, and a petrogenetic scheme for the alkaline province is presented, with a K/Ar age determination, tentatively deriving the source magma (quartz trachytic) from a Himalayan tholeiite.
Key words: Petrology, petrography, alkaline granites, Warsak, NWFP.

K/84. Kempe, D.R.C., 1973b. Tilloids from N.W. Pakistan. Geological Magazine 110, 373-374.

This article does not have an abstract as it is published as a letter. It gives detail of the tilloid from Warsak area. It’s a metaconglomerate and pebbly quartzite.
Key words: Tilloid, Mullagori, Warsak, Khyber Agency.

K/85. Kempe, D.R.C., 1974. Tilloids from N.W. Pakistan. Geological Magazine 111, 568-569.

Key words: Petrology, Tilloids, alkaline granites, Warsak, NWFP.

K/86. Kempe, D.R.C., 1978. Acicular hornblende schists and associated metabasic rocks from North-West Pakistan. Mineralogical Magazine 42, 405-406.

A suite of unusual acicular hornblende schists is found at Warsak (34° 10′ N. 71°C 23′ E.), some 30 km WNW of Peshawar, North-West Pakistan. The schists occur in association with sill-like masses of amphibolite facies meta-

igneous rocks, possibly a metamorphosed gabbroic and doleritic, dioritic, and granitic calc-alkaline series, and intrusions of alkaline granite and microgranite. These rocks lie within Palaeozoic metasediments and all are folded synclinally. The area was first described by Ahmad et al. (1969).
The rocks of the acicular hornblende schist suite (fig. I) consist essentially of large, idioblastic hornblende crystals—comprising some 30–60 % of the rock—in a fine-grained granoblastic matrix of oligoclase feldspar with minor quartz, iron oxide, biotite, and rutile. The boat-shaped, blue-green hornblendes, twinned on {100}, reach 5 mm in length and are often grouped in sprays or clusters; they are sieved with quartz, ilmenite, and patchy calcite. The groundmass also contains patches and veins of calcite, associated with ragged patchy areas of reddish brown, amorphous iron oxide or hydroxide, perhaps introduced hydrothermally. The schists coarsen in grain size outwards through the sill-form, the hornblendes reaching 4 cm, become rich in chlorite and biotite, and grade into the apparently metagabbroic amphibolitic rocks.
The acicular hornblende schists have a generally basaltic composition, while the hornblendes are tschermakitic. An analysed amphibole has 16·5% Al_2O_3, is slightly zoned with alumina increasing from core to rim, and has the formula: $K_{0\cdot06}Na_{0\cdot50}Ca_{1\cdot90}Mg_{2\cdot13}Fe_{1\cdot49}{}^{2+}Mn_{0\cdot02}Fe^{3+}{}_{0\cdot14}Ti_{0\cdot04}Al^{vi}{}_{1\cdot16}Si_{6\cdot31}Al^{iv}{}_{1\cdot69}O_{21\cdot97}(OH,F)_{2\cdot03}$
Three hypotheses of the origin of the rocks were considered; metamorphism of a suite of basic tufts is the most favoured. Origins involving metamorphism of a lamprophyre-appinite suite or of a gabbroic marginal facies are therefore rejected. Texturally the rocks strongly resemble metatuffs (fig. 2) that occur associated with metagreywackes in the Otago schists of New Zealand (Turner, 1933); like many similar Alpine schists they also contain tschermakitic hornblendes. The Warsak tufts could have formed originally, together with the meta-igneous rocks, possibly as lavas, in an inter-plate tectonic environment; the high A1 content of the hornblende, which is typical of many amphiboles from the surrounding alpine environment in North-West Pakistan, and other mineralogical evidence in the region support a high pressure environment for the metamorphism of the rocks to just within the amphibolite facies, at moderate temperatures of approximately 465 °C.
Key words: Hornblende, schists, metabasic rocks, NW Pakistan.

K/87. Kempe, D.R.C., 1982. Nature and source of the Gandhara sculptural schists. Journal of Archaeological Sciences 9, 25-8.

No definite source localities have been identified for the stones used by the Gandharan sculptors, but it is considered that the predominant rock was alumina-rich chloritoid-paragonite-muscovite-quartz schist, probably from Swat. A chemical analysis of this rock is presented.
Key words: Gandhara, Swat,

K/88. Kempe, D.R.C., 1983. Alkaline granites, syenites, and associated rocks of the Peshawar plain alkaline igneous province, NW Pakistan. In: Shams, F.A. (ed.) Granites of Himalaya, Karakorum, and Hindu Kush. Institute of Geology, Punjab University, Lahore, Pakistan, 143-169.

Alkaline rock complexes are distributed in a semicircle around northern half of the Peshawar plain, NW Pakistan. Stretching west to east for over 200 km, they occur in eastern Afghanistan, Mohmand Agency, Khyber Agency, Warsak, Malakand, Shewa-Shahbazgarhi, Koga-Ambela unit, Tarbela and possibly Mansehra. The rocks, which are described, include alkaline granites and microgranite, albitites, syenites, carbonatites, and silicocarbonitites, intruded generally along fault zones into mainly Early Paleozoic metasediments. They are thought to be associated with rifiting, caused partly by relief tension or compression release perhaps during very Late Cretaceous or Early tertiary times, following contact between the Indo-Pak plate and the island arc(s) or southern continental margin of the Eurasian plate.
Key words: Alkaline granites, syenites, carbonatites, Peshawar plain alkaline province, NWFP.

K/89. Kempe, D.R.C., 1986a. A note on the ages of the alkaline of the Peshawar plain alkaline igneous province, NW Pakistan. Geological Bulletin, University of Peshawar 19, 113-119.

The available ages published for the alkaline rocks and carbonatites of the Peshawar Plain alkaline igneous province are reviewed, with no new data, and briefly discussed. Repeated magmatism has apparently occurred, over the period ca 315 to 31 m.y. ago, due to rifting and the development of thrust planes.
Key words: Alkaline rocks, carbonatites, Peshawar plain, NWFP.

K/90. Kempe, D.R.C., 1986b. Gandhara sculptural schist: Proposed source. Journal of Archaeological Science 13, 79-87.

Previously suggested source localities for the chloritoid-paragonite-muscovite quartz schist, the most widely used Gandharan rock, have been examined and rejected. However, an ancient disused quarry near Sakhakot, south of Dargai, in northern Pakistan, has been located and sampled. Chemical and mineralogical comparisons between two quarry samples and a specimen of artifact schist are very close, leading to the proposal that the quarry is one definite source of Gandhara sculptural schist.
Key words: Gandhara sculpture, schist, petrology, Swat, Buner.

K/91. Kempe, D.R.C., 1986c. The Asota stone circle, Mardan, northern Pakistan. Antiquite 60, 47-48.

This article discusses the petrology of the Asota stone circle in northern Pakistan. Description is given of the stone circle, efforts of several geologists and archeologists to define the Asota stone circle, orphyries recorded by A.L. Coulson, a geologist with the Geological Survey of India, at Shahbazgarhi.
Key words: Gandhara, alkaline granite, Mardan.

K/92. Kempe, D.R.C. & Jan, M.Q., 1970. An alkaline igneous province in the North-West Frontier Province, West Pakistan. Geological Magazine 107, 395-398.

Alkaline microgranites and granites containing aegirine, riebeckite and astrophyllite, from north-west Pakistan, are briefly described, and tentatively correlated with other alkaline rocks in the Peshawar region. It is suggested that the Warsak granites, Shewa-Shahbazgarhi porphyries, Tarbela and Koga alkaline rocks constitute an alkaline igneous province. For more information, consult the following account.
Key words: Alkaline igneous province, NWFP.

K/93. Kempe, D.R.C. & Jan, M.Q., 1980. The Peshawar plain alkaline igneous province, NW Pakistan. Geological Bulletin, University of Peshawar 13, 71-77.

Complexes of alkaline rocks are distributed in a semicircle around the northern half of Peshawar Plain, NW Pakistan. Stretching west to east for over 200 km, they occur in eastern Afghanistan, Mohmand Agency, Khyber Agency, Warsak, Malakand, Shewa-Shahbazgarhi, Koga-Ambela-Utla, Tarbela and possibly, Mansehra; also in Dir. The rocks include alkaline granites and microgranites, syenites, albitites, and carbonatites, intruded generally along fault zones into mainly Early Paleozoic metasediments. It is proposed that they are associated with rifting, caused partly by 'rebound' relief tension or compression release, perhaps during very Late Cretaceous or Early Tertiary times, following contact between the Indian plate and the island arc(s) or southern margin of the Eurasian plate.
Key words: Alkaline igneous province, Peshawar, NWFP.

K/94. Kempe, D.R.C., Jan, M.Q., Jones, G.C. & Din, V.K., 1985. A skarn rock from Dir, northwest Pakistan. Geological Bulletin, University of Peshawar 18, 103-111.

The geology and petrology of a skarn from northwest Pakistan are presented. The chemistry of the rocks and their constituent minerals is discussed briefly and compared with other similar occurrences. The rock chemistry and the abundance of ferrosalite, andradite-rich garnet, and epidote ($Fe3+$ / ($Fe3+$ + al) = 0.30) are considered to be due to metasomatism or, less likely, volcanic rocks by a biotite-two pyroxene tonalite intrusion.
Key words: Petrology, geochemistry, skarn, Dir.

K/95. Kerrick, D.M. & Caldeira, K., 1995. Himalaya-Karakoram metamorphic CO_2 degassing and Cenozoic paleoclimate: Revisited. Abstract Volume, 10th Himalaya-Karakoram-Tibet Workshop, (ETH Zurich) Switzerland.

Kerrick and Caldeira (1993, 1994) proposed that CO_2 generated by metamorphic decarbonation during post-collisional metamorphism in the Himalayan orogenic belt may have contributed to the Eocene greenhouse global warming. The validity of their hypothesis depends upon the timing and duration of prograde metamorphism, the amount of metamorphic CO_2 generated at depth from CO_2 source rocks (i.e., carbonate-bearing protoliths), and the flux of CO_2 to the Earth's surface. Their hypothesis requires that prograde metamorphism was contemporaneous with the late Paleocene-early Eocene warming (ca. 55-45 m.y.).
Recent geochronologic evidence for the timing of prograde metamorphism suggests that early Cenozoic metamorphism was confined to the Himalaya and Karakoram in northern Pakistan (i.e., west of the Nanga Parbat syntaxis). Here, carbonate rocks that enjoyed early Cenozoic metamorphism are abundant in the Swat region, Kaghan Valley and southern Karakoram. Following the methodology outlined by Kerrick and Caldeira (1993, 1994), the amount of metamorphic CO_2 produced from these rocks was estimated from bulk-rock compositions and computed decarbonation reaction progress from modal estimates of calc-silicates. Locally there are tremolite-bearing metacarbonate rocks that produced as much as 20 wt % CO_2. However, in the abundant siliceous carbonate rocks of the Kaghan Valley and- southern Karakoram, the limited average modal amounts of calc-silicates (<5 vol. %) implies that less than 5 wt. % CO_2 was produced from the bulk of the metacarbonate rocks. At the present level of exposure, metacarbonate rocks occupy less than 10 vol. % of the Karakoram range and Pakistan Himalaya. Coupling this volumetric estimate with average reaction progress, and estimates of the duration of prograde metamorphism based on the timing of collision and geochronologic data, the amount of metamorphic CO_2 generated during the Paleocene-Eocene metamorphism was <1018 moles/m.y. Even with a large crustal permeability, this amount of CO_2 would be insufficient to substantially contribute to the atmospheric CO_2 content and thus to Eocene global warming.
Geochronology data suggests that prograde metamorphism in the central and eastern Himalaya (i.e., Zanskar and eastward) coincides with mid-Miocene global warming. The small proportion of metacarbonate rocks in this region (« 5 % of the Higher Himalayan Crystalline Sequence) suggests insignificant 4 metamorphic 002 production from such lithologies. However, in light of the volumetric proportion of metapelitic rocks in this region, coupled with average carbonate and organic carbon contents of pelitic protoliths, the computed amount of CO_2 generated from metamorphism of pelites (>1018 moles) could have contributed to the Miocene paleoclimate. Widespread Miocene metamorphism in the other parts of the Tethyan orogen could have also generated significant metamorphic CO_2.
In Himalayan-Karakoram-Tibet region there were large "pulses" of extrusive and intrusive magmatic activity correlative with the Eocene and Miocene global warming. However, estimates of the volumetric extent of the intrusive and extrusive rocks, coupled with data on the CO_2 contents of magmas, implies that the amount of magmatic CO_2 produced from this region would not have significantly contributed to the atmospheric CO_2 contents during these time periods.
Of all metamorphic belts worldwide, the Cordilleran belt in western North America is the best (and probably only) candidate for climatically significant metamorphic CO_2 degassing during the early Cenozoic. Based on convective hydrothermal circulation modeling, Nesbitt, Mendoza and Kerrick (1995) concluded that Cordilleran metamorphic CO_2 production in the early Cenozoic may have been 1018 -1019 moles/m.y. and thus sufficient to have significantly contributed to paleoatmospheric CO_2 contents at that time.
Based on our preliminary compilation of the volumes of magmatic rocks through time, coupled with estimates of the CO2 contents of magmas, we conclude that magmatic CO2 degassing has been a significant factor in the global carbon cycle and a major contributor to paleoatmospheric CO_2. The global cooling in the last 100 m.y. is compatible with diminished volumes of igneous rocks through this time period.
Key words: Metamorphism, CO_2 degassing, paleoclimate, Cenozoic, Himalaya, Karakoram.

K/96. Kerrick, D.M., Caldeira, K. & Kump, L.R., 1993. Paleoatmospheric consequences of CO_2 released during Tertiary regional metamorphism in the Himalayan orogen. Abstract, Volume, 8th Himalaya-Karakoram-Tibet Workshop, Vienna, 37-38.

Fluxes of metamorphic CO_2 to the atmosphere have been suggested to be climatically important (Fyfe, 1986; Varekamp et al., 1992; Touret, 1992). Using an overly simplified model of decarbonation of a 1 km-thick carbonate layer, Fyfe (1986) concluded that atmospheric CO_2 content could have been significantly affected by the Tertiary Himalayan orogenesis. However, the validity of the suggestion that metamorphic CO_2 has significantly affected the atmosphere critically depends upon a number of factors; i.e., duration of prograde metamorphism, abundance and composition of CO_2 source rocks, and escape of CO_2 to the Earth's surface. The Himalayan orogenic belt affords an excellent case study for analysis of these variables in determining the quantities and fluxes of CO_2 released by metamorphic decarbonation and graphitization.
The Eocene was the warmest epoch of the Cenozoic, with published estimates of Eocene atmospheric CO_2 content ranging from two to six times the current value. The Early Eocene (50-55 Ma) global warming may have been produced by the greenhouse effect arising from elevated CO_2 contents. Our calculations of CO_2 consumption by silicate weathering show that metamorphic CO2 releases of Ca. 1018/Ma could readily account for inferred Eocene atmospheric $C0_2$ contents and, consequently, Eocene warming.
Because of the lack of evidence for Eocene metamorphism in the central and eastern portions of the orogen, we focused on Eocene metamorphism in the western portion of the orogen (i.e., Zanskar and westward). Duration of prograde metamorphism was constrained by the timing of the India-Tibet collision (50-65 Ma) and the peak of prograde regional metamorphism (ca. 40 Ma). Due to lack of published estimates of the proportions and bulk compositions of metacarbonate and graphitic lithologies in the western Himalayan orogen, we coerced selected colleagues (J.A. DiPietro, M.S. Hubbard, K.P. Hodges, and M.P. Searle) into providing "guesstimates" of the proportions of such lithologies. In our computations we assumed marl as the model metacarbonate source rock and that 5wt % of CO_2 was released during prograde metamorphism (Ferry, 1982). With a conservative assumption that carbonate rocks constitute ca. 10% (by volume) of the western Himalayan orogen (J.A. DiPietro, M.P. Searle), and that CO_2 was generated at a constant rate during the prograde event, we estimate that ca. 1019 moles/Ma of metamorphic CO_2 were produced at depth. Assuming 0.5% (by volume) of carbonaceous lithologies, CO_2 released from the graphitization of carbonaceous material is estimated to be Ca. 1018 moles/Ma. These calculations assumed that CO2 was linearly released during prograde metamorphism; however, because extensive devolatilization of mans and carbonaceous lithologies occurs during progradation through the lower greenschist fades (Ferry, 1982; Labotka et al., 1988), $C0_2$ production may have been two to four times more rapid than these estimates.
The possibility of escape of metamorphic CO_2 to the atmosphere is indicated by the global correlation between the distribution of major zones of seismicity and carbon dioxide discharged from hot springs (Barnes et al., 1978). Release of metamorphic CO_2 to the atmosphere would have been impeded by retrograde carbonation and carbonate vein formation in the shallower (lower grade) portions of the orogens. However, in light of large fluid/rock ratios, significant expulsion of CO_2 to the atmosphere may have occurred by focused fluid flow along the Main Central Thrust (MCT) in the Himalayan orogen. Transient expulsion of large amounts of metamorphic volatiles is expected to have accompanied seismic activity along the MCT.
Geochronologic analyses reveal a remarkable similarity in peak metamorphic ages (40-SO Ma) for many areas within the Tethys and Circum-Pacific orogens, thus supporting the concept of a major, world-wide Eocene regional metamorphism. This metamorphic culmination was contemporaneous with increased Eocene atmospheric CO_2 and associated global warming. World-wide Eocene regional metamorphism could well have generated ≥1020 moles CO_2 /Ma at depth. Even if only 1% of the total metamorphic CO_2 produced escaped to the Earth's surface, there would have been significant paleoclimatic consequences.
Key words: Metamorphism, CO_2 degassing, paleoclimate, Cenozoic, Himalaya, Karakoram.

K/97. Khadim, I.M., 1995. Magnetic minerals in red beds of Murree Formation, Barsala area, Azad Kashmir: A preliminary study. In: Khadim, I.M. & Yoshida, M. (eds.), Rock Magnetism and Paleomagnetism. Recent Progress in Pakistan, Proceedings of Geoscience Colloquium, Geoscience Lab, Geological Survey of Pakistan, Islamabad, 13, 43-57.

Ferromagnetic minerals contained in red beds of Murree Formation an examined by optical microscopy, thermomagnetic analysis, dual frequency susceptibility measurement, hysteresis loop analysis, and IRM acquisition experiment. The major carrier mineral for ferromagnetic properties of the rock is hematite but a trace amount of goethite is also identified. The red bed is rather inhomogenous in population of magnetic minerals; some specimens contain iron sulfides, such as pyrite and troilite. Laboratory heating often formed secondary minerals, magnetite (Ti-poor titanomagnetite) and hematite, which are probably decomposed products of the miltide and/or Fe-bearing

minerals by laboratory heating. Goethite is probably a product of weathering. The presence of hematite may prove Murree red bed to possible maintain the primary remanence component which can be used for paleomagnetic study.
Key words: Magnetic minerals, Murree Formation, Azad Kashmir.

K/98. Khadim, I.M., Ahmad, M.N., Yoshida, M. & Hussain, I., 1996. Magnetic susceptibility variation of granitoid in the Kohistan-Ladakh island arcs, northern Pakistan. Extended Abstracts, International Seminar on Paleomagnetic Studies in Himalaya-Karakoram Collision Belt and Surrounding Continents, November 20-21, 1996, Islamabad. Geosciences Lab, Geological Survey of Pakistan, Islamabad, 109-111.

Magnetic susceptibility data of rocks is extremely useable for the interpretation of geomagnetic data, assessing mineral potential and classification of rock type based on magnetic mineralogy. With particular reference to granitic rocks, a classification depending upon constituents magnetic mineral has been suggested by Ishihara (1977) as magnetite-series and ilmenite-series which provide sufficient information on assessment of mineral potential of the host rocks. The present study accomplishes susceptibility data along main traverse of Karakoram Highway in Kohistan island arc and along Gilgit-Skardu road, Satpara-Deosai track, Shigar, Kharmang, and Khaplu valleys in Baltistan area in the Ladakh island arc. The observation points along KKH were located about three kilometers apart but different exposures of geological units were also measured (Ahmad et al., 1995) while in Ladakh arc mainly granitic rocks and other associated rocks were measured.
The northern Pakistan is divided into three major terrains, Indo-Pak subcontinent (Indian Plate), Kohistan (on western side) and Ladakh (on eastern side) island arcs and Karakoram block (a part of Eurasian continent). There are two major collision zones in this area: the northern Main Karakoram Thrust (MKT) zone and southern Main Mantle Trust (MMT) zone.
Kohistan island arc between MKT and MMT is a fragment of Mesozoic intra-oceanic island arc sandwiched between the Eurasian and Indian Plates (Tahirkheli et al., 1980) while the Ladakh terrain is bounded by the Shyok suture zone (MKT) to the north and the Indus suture zone (MMT) to the south. The Ladakh terrain is dominantly composed of granitic rocks of the Ladakh batholith and is variously known as Kohistan batholith in Pakistan (Searle, 1991).
Kohistan arc is divided into four major units from north to south, which has been considered to represent a complete sequence of island arc crust. The northern upper most part of the sequence is comprising metasediments and metavolcanics. Phylitic slates and metavolcanics of this upper most part has very low susceptibilities, O.l – l x 10^{-3} SI. The first horizon in the north is Kohistan batholith, which comprises granites, granodiorite and diorite and susceptibilities of the granitic bodies in the lower part of the batholith show values <1x10" SI except the upper part of the batholith. The next Chilas Complex is consisting of ultramafic to mafic igneous rocks: dunite and gabbro and show high values (2-5 x 10^{2} SI), while gabbro and diorite show low values (<l x 10^{-5} SI). The third is Kamila Amphibolite which mainly comprises of metamorphosed amphibolites situated between Chilas and Jijal Complexes. This expresses quite low susceptibility (8x 10^{-4} SI).
The lower most unit, the Jijal complex consisting of garnet granulite, pyroxene granulite and serpentine facies. The granulites reveal low susceptibilities but serpentine yields highest value (>8x10^{-2} SI). The above results clearly show two values of susceptibilities over the granitoids along Kohistan arc (KKH). This study led to measure the susceptibilities over granitic rocks in Ladakh island arc. Here main six sections were measured. On Satpara-Deosai traverse, metasediments and Kohistan-Ladakh batholith exhibit variable character towards susceptibility. Ladakh batholith, comprising of undifferentiated granites, granodiorite and quartz diorite relatively shows higher susceptibilities (3.5 ~ 1 0 ~ SI) while metasediments show 1.2x102 SI. Metasedimentary rocks include greenschist, slates and phylites. In Shigar valley, rocks of Ladakh batholith and Shyok suture zone show high values to moderate (1.8x10-' SI and 4.0~10" SI). Shyok suture zone rocks include highly deformed, folded and thrusted sequence of greenschist facies volcanic rocks, limestones, shales, conglomerates and quartzite. Recent alluvium exhibits very low susceptibilities.
The Ladakh batholith on Kharmang valley traverse repeats high values (2.3x10^{-2} SI) while Chalt Volcanic group rocks indicate low values (<3.0x10^{-4} SI). The Chalt Volcanic group comprises subaerial and submarine volcanic arc lavas, tuffs and volcaniclastic sediments, metamorphosed to greenschist facies.
The Gol-Saling and Khaplu road profiles were along the Shyok River: the first on the right bank while latter on the left bank. The rocks are almost identical across the river. Ladakh batholith, on the Gol-Saling profile, reflects

generally high values reaching to 2.7 x 10^{-2} SI while on Khaplu road profile, it reaches to a maximum 4.7 x 10^{-2} SI whereas the most of the values range in 4-10 x 10^{-3}SI.
Most of the part of the Skardu-Gilgit Road is covered with low susceptibility rocks such as Iskere gneiss, composed of layered quarts-feldspar-biotite-muscovite gneiss, probably orthogneiss with rare meta-sedimentary hyers, showing very low values (<1.0 x 10^{-3}SI). Similar attitude is observed by Nanga Parbat-Haramosh gneisses. They are Precambrian basement gneisses and Paleozoic sedimentaries intruded by Cambrian granites. There are two high values observed across Ladakh batholith (0.9-3.0 x 10^{-2} SI) and gabbro (-2.4 x 10-3 SI) Metasediments again show very low values (<l.0x 10^{-3} SI).
These results clearly show two major types of granitic rocks in the Ladakh arc. one that carrying high susceptibilities (magnetite-series, values>3.0x 10.' SI) and the other possessing low susceptibilities (ilmenite-series, values<3.0x 10-3 SI). There are two regimes of granitoids in northern Pakistan. Kohistan island arc is abundant in ilmenite-series granites while magnetite-series granites are more common in Ladakh arc. The magnetite-series granites might be produced because of relatively reducing environments related to the subduction along the collision belt. The present study recommends further mineral potential oriented research studies should be taken in these island arc areas.
Key words: Granitoid, magnetic susceptibility, Kohistan, Ladakh, Island arc.

K/99. Khadim, I.M., Yoshida, M. & Ahmad, M.N., 1996. First attempt of VLF-EM survey in Pakistan-temporal change in VLF field and sounding of siderite mineralization zone, Chitral, N.W.F.P. Geologica 2, 171-194.

Key words: Geophysics, mineralization, siderite, Chitral.

K/100. Khadim, I.M., Yoshida, M., Ahmad, M.N. & Shirahase, T., 1997. Magnetic susceptibility variation of granitoids in the Ladakh arc, Baltistan, northern Pakistan, and surrounding terrains: Its implications for mineralization assessment. In: Khadim, I.M., Zaman, H. & Yoshida, M. (eds.), Paleomagnetism of Collision Belts. Geoscience Laboratory, Geological Survey of Pakistan, Islamabad, 73-83.

Low-field magnetic susceptibility was observed for the granitoids and associated rocks in the eastern Ladakh arc, Baltistan area, northern Pakistan. These results were compared with previously reported magnetic susceptibility data of granitoids obtained from the Karakoram block of Asian plate, Kohistan arc, and Indo-Pakistan subcontinent. The granitoids in Karakoram block and IndoPakistan subcontinent generally show low susceptibility values, thus relating to the ilmenite-series. Similarly the granitoids in Kohistan arc mostly give low susceptibility values of ilmenite-series except the northern part of Kohistan batholith which shows high susceptibility values indicating, the effect of magnetite-series. On contrary, the majority of granitoids in Ladakh arc marks considerably high susceptibility values which are related to the magnetite-series. This discrepancy between two terranes is probably related to different type of magmatism for each island arc in the Cretaceous-Tertiary time.
Key words: Granitoid, magnetic susceptibility, Kohistan, Ladakh, island arc.

K/101. Khalid, A., 1981-83. Geology of Northern Hunza. M.Sc. Thesis, Punjab University, Lahore, 94p.

This report describes the results of the geological studies in Passu area Upper Hunza Valley, Gilgit Agency.
A geological map on scale of 1:250,000 is prepared with main outcrops of granodiorite, limestone, dolomite and slates. The micro-paleontological description of the area is brief, as there is no findings of any fossil by us in given area. The petrographic analysis of these rock units is reported in detail. The petrogenesis (Texture, Mineralogy General description) of these rock units have also been discussed.
Along with the petrographic description the tectonic evolution of Karakoram, stratigraphy and structure of the Karakoram, paleogeography is also discussed. Regional (Lower grade) metamorphic has produced slates from shales and fine-grained dolomite as well as limestone. It is assumed that fossils have been crystallized due to metamorphism. Intense tectonic disturbance is evident from the frequent occurrence of strained and crushing effects on the minerals. The area shows the evidence of extensive mountain glaciation in the Quaternary and glacial deposits are common features due to the presence of huge glaciers.

Key words: Micropaleontology, texture, petrography, glaciation, Hunza.

K/102. Khalid, M., Fayaz, A. & Tahir, A., 1975. Geology of Timurgara area, Dir district. M.Sc. Thesis, Punjab University, Lahore.

Key words: Geology, Timargara, Dir.

K/103. Khalid, S. & Bukhari, S.W., 1999. Case history of Meyal Oil Field in Potwar Plateau of upper Indus Basin. M.Sc. Thesis, University of Peshawar, 63p.

Key words: Hydrocarbons, Meyal oilfield, Potwar.

K/104. Khalil, I.U., Khalil, M.J., Zai, J.K.M. & Khalil, I.H., 1988. General geology of Nizampur area, District Peshawar. M.Sc. Thesis, University of Peshawar.

Key words: Geology, Nizampur, Nowshera.

K/105. Khalil, M.A. & Afridi, A.G.K., 1973. Geology of Deshai-Diwangar area, Ushu Gol Valley, Swat Kohistan, NWFP, Pakistan. M.Sc. Thesis Peshawar University, 42p.

For details consult the following account.
Key words: Petrography, metasediments, Usho Gol, Kohistan, Swat.

K/106. Khalil, M.A. & Afridi, A.G.K., 1979. The geology and petrography of Deshai-Diwangar area, Ushu Gol Valley, Swat Kohistan. Geological Bulletin, University of Peshawar 11, 99-111.

This paper presents a geological map, petrography and structure of about 160 sq. km of Deshai-Diwangar area, Swat Kohistan. The area consists of metasedimentary rocks (? Paleozoic to Mesozoic), intruded by Tertiary Plutonic igneous rocks. The plutonic rocks consist of gneissose-quartz diorites, orbicular diorites, and quartz diorites of Early to Middle Tertiary period. The Early Tertiary gneissose quartz diorites are intruded by Diwangar Granite (? Middle Tertiary). Locally, small granitic intrusions and veins of a later age than Diwangar Granite are irregularly distributed in the area. Pegmatites and aplites are associated with all types of rocks.
Structurally the area is not very complex. A main fault runs along the Ushu Valley and is older than the Diwangar granite.
Key words: Petrography, metasediments, Usho Gol, Kohistan, Swat.

K/107. Khaliq, A., 1991. Primary geochemistry and secondary dispersion from gold prospects in the Karakoram and Hindu Kush, northern Pakistan. Ph.D. Thesis, Leicester University.

Key words: Geochemistry, gold prospects, Karakoram, Hindukush.

K/108. Khaliq, A., 1997. Orientation studies for gold and precious metals in Chitral area, Hindu Kush Ranges, Northern Pakistan. Abstracts, National Symposium on Economic Geology of Pakistan, Islamabad, 1p.

To find out the best methods for geochemical exploration of gold and precious metals in Karakorum. Himalaya and Hindu Kush. an orientation study based on different sampling techniques. was conducted around the known gold prospect at Shagor in Chitral, N. Pakistan. This study demonstrates that• panned-concentrates give superior anomaly/background contrast compared to wet-sieved and dry-sieved stream sediments. In the case of gold. panned-concentrates are not very successful in the present situation because of the presence of fine-grained gold. which

cannot be recovered in panning However, for other metallic minerals it is very effective. Wet-sieved stream sediments samples give more useful results.
The effectiveness of panned-concentrates in detecting the mineralization is due to the dominance of' clostic dispersion and insolubility of many metallic minerals in the cold alkaline river waters. Wet and dry sieved sediments suffer from excessive dilution by silicates. Therefore. panned-concentrates should be used for regional surveys in the mentioned and similar terranes. Nevertheless, panned sampling should be accompanied by wet-sieving if fine-grained gold search is involved.
Key words: Geochemistry, exploration, precious metals, Chitral, Hindukush.

K/109. Khaliq, A. & Ahmad, J., 1997. Hydrogeochemical prospecting for uranium in Peshawar Basin. Abstracts, National Symposium on Economic Geology of Pakistan, Islamabad, 1p.

A reconnaissance hydrogeochemical survey for uranium search was carried out in the intramountain Peshawar basin. Stratigraphy of sediments filling this basin is not known due to the Pleistocene alluvial cover. Nevertheless, marginal stratigraphy' indicates that the alluvial cover is underlain by sediments equivalent to the sediments of' Siwalik group since Siwalik group contains sandstone type uranium deposit, a hydrogeochemical survey was under taken in the basin for comparable mineralization.
A total of 683 groundwater samples were collected from tube-wells from the entire basin at an average of one sample per 4 sq.km. Analytical results of these samples reveal hat besides containing high uranium anomalies at Charsadda. Mardan and Swabi the groundwater of Peshawar basin has generally a high uranium (9pph) background value. Moreover, from the close association of uranium with Cu and V. the signature of sandstone type uranium deposits was recognized which probably registers the presence of Siwalik group and/or equivalent sediments beneath the alluvial cover of Peshawar basin.
Key words: Radioactive minerals, hydrogeochemistry, uranium, Peshawar basin.

K/110. Khaliq, A., Butt, K.A. & Ahmad, J., 2000. Hydrogeochemical prospecting for uranium in Peshawar Basin. In: Hussain, S.S. & Akbar, H.D. (eds.), Proceedings, National Symposium on Economic Geology of Pakistan, 1997, Islamabad, 193-209.

For details consult the previous account by the same author.
Key words: Hydrogeochemistry, uranium prospecting, Peshawar basin.

K/111. Khaliq, A. & Moon, C.J., 2000a. Orientation studies for gold and precious metals in Chitral area, Hindu Kush Ranges, Northern Pakistan. In: Hussain, S.S. & Akbar, H.D. (eds.), Proceedings, National Symposium on Economic Geology of Pakistan, 1997, Islamabad, 89-109.

For further information, consult Khaliq (1997).
Key words: Gold, precious metals, Chitral, Hindukush.

K/112. Khaliq, A. & Moon, C.J., 2000b. Survival factor of uraninite in the major rivers of Gilgit Kohistan, Indus Basin, northern Pakistan. Abstracts, 3rd South Asia Geological Congress, Lahore, 138-139.

Key words: Uraninite, Gilgit River, Indus River.

K/113. Khaliq, A., Moon, C.J. & Ahmad, J., 2001. Pyrite-gold-uraninite association in Indus Basin, Gilgit Kohistan, northern Pakistan. Abstracts, 4th Pakistan Geological Congress, Islamabad, 17-18.

The association of pyrite, gold and uraninite is found in Indus basin and most of the major rivers and their tributaries in Gilgit area of Kohistan, including the Hunza valley north of the Indus suture zone. This association is similar to

the mineralization in the Witwatersrand Basin of South Africa, which has been extensively studied and is the best example of paleo-placer gold uraninite deposits (Khaliq, 1991). However, in the Kohistan area of northern Pakistan and in the Indus basin this system has not yet been studied systematically. In this work an attempt has been made to study and examine the factors controlling the dissolution of uraninite and assess its stability as a detrital mineral in recent alluvial sands of the Indus basin. Moreover, the probable sources of pyrite-gold-uraninite assemblage have been discussed.
The distribution of radioactivity, percentage of pyrite and number of gold flakes in different rivers and streams in the region were studied chemically using SEM on panned concentrate samples.
The concentration of pyrite varies in different valleys and some valleys such as Bagrot, Pisan, Shamshal and Hasis valleys (Ishkuman) contain > 45 % pyrite in panned concentrate samples. Pyrite is mostly fresh and occur as euhedral cubes but there are also some grains showing rounded margins, corrosion and alteration. The microprobe study, of pyrite grains from Bagrot valley, shows some high values (several hundred ppm) for gold (Khaliq, 1991).
Gold flakes have different shapes (rounded, tabular, ellipsoidal and irregular) and sizes (<1 mm to >6mm) which probably show probably show different distances they traveled from their sources. Investigations indicate that the radioactive material consists mainly of thorian-uraninite with lesser uraninite, and monazite grains (Khaliq, 1991 and Khaliq & Moon, 2000). Grains of the radioactive minerals are very fresh and show well-defined crystal faces, some have cubic forms with little evidence of corrosion. However, there are few grains which show rounded margins and corrosion. As far as the size is concerned, they are in the very fine-to fine range of the sand size.
Key words: Pyrite, gold, uraninite, Indus basin, Gilgit, Kohistan, Hunza, Indus suture zone.

K/114. Khaliq, A., Moon, C.J. & Khattak, M.U.K., 1997a. Regional geochemical prospection for minerals in Chitral, northern Pakistan. Abstracts, 3rd Pakistan Geological Congress, University of Peshawar, p. 31.

For details consult the following account.
Key words: Geochemical prospecting, stream sediments, Chitral.

K/115. Khaliq, A., Moon, C.J. & Khattak, M.U.K., 1997b. Regional geochemical prospection for minerals in Chitral, northern Pakistan. Geological Bulletin, University of Peshawar 30, 191-207.

A comprehensive regional geochemical survey was carried out in Upper Chitral area. This survey was based on panned concentrates sampling techniques, during which a total of 68 samples were collected from most of major rivers and their tributaries covering an area of more than 1000 km2.
The aim of this geochemical investigation was to determine metals dispersion, their relation to mineralization, and regional distribution in the drainage system of the area. Our research reveals that Chitral area has a high potential for mineralization. Some valleys contain polymettalic anomalies while others have either precious or base metals.
Strong anomalies of precious and base metals, together with As and Sb were detected in the northernmost part (Tirich Gol valley) of the surveyed area in which the respective ranges of Au, Ag, As, Sb, Cu, Pb, and Zn are 20-2500 ppb, 2-22 ppm, 2-1500 ppm, 1-18 ppm, 50-400 ppm, 100-1200 ppm, and 50-550 ppm. The significant mineral occurrences are found north of Reshun Formation. The central part (Barum, Pasti and Shoghor) of the survey area shows polymetallic signature with significant enrichment of precious metals Au=10-200 ppb, Ag=1-12 ppm, As=10-200 ppm and Sb=1-10 ppm). The southern part, mainly Kafiristan valley, is high in Pb (100-1800 ppm) with some anomalies of Au (1-100 ppb) and Ag (2-17 ppm).
New targets for mineral prospecting were located at several localities of Chitral valley. Important regional structures, such as faults and their significance regarding mineralization were also defined during this investigation.
Key words: Geochemical prospecting, metal dispersion, stream sediments, Chitral.

K/116. Khaliq, A., Moon, C. J. & Khattak, M.U.K., 1998. Gold potential of Northern Pakistan, An Assessment Based on the Results of Geochemical Exploration Survey for Gold in Northern Pakistan. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 95.

Northern Pakistan, comprised of three geological units; the Asian Plate, the Kohistan arc and the Indian Plate which are separated by major suture zones, offers a high potential for a variety of mineral deposits occurring in similar geological environments elsewhere in the world. Due to its geotectonic history and associated igneous and metamorphic processes the area seems to be very promising for mineral prospecting. The region is a challenging ground for the mineral prospector because of its complex geological environments and geomorphic features.
Orientation studies based on regional panned-concentrates and geochemical exploration surveys were conducted for gold and precious metals in two geologically different terranes of Northern Pakistan. The Chitral area forms part of the Asian Plate and the Gilgit region is part of Kohistan arc sequence. These two are separated from each other by Northern Suture and from Indian Plate by Main Mantle Thrust (MMT).
Our regional survey in Chitral reveals that the area has a high potential for gold mineralization associated with Ag, As and Sb. Gold anomalies of moderate to high nature were detected in various valleys of the area. The mentioned anomalies contain gold ranging from (10-5000) ppb with an average of 380 ppb. Ag, As, and Sb range between 1-21 ppm, 2- 1500 ppm and 1-16 ppm respectively. As far as zonation of anomalies is concerned the area north of Shoghor limestone and the Reshun Formation is better prospects than that to the south of it. Strong anomalies were located in Tirich, Barum and Past valleys while moderate anomalies were found in Kafiristan valley.
The regional panned-concentrates survey of Gilgit area (Kohistan arc) demonstrates that many of the valleys contain anomalies of precious metals along with Ag and As. In these anomalies gold ranges from 10-7800 ppb with an average of 700 ppb and the concentrations of Ag and As are in the range of 10-25000 ppb and 2-1400 ppm respectively. In Bagrot valley, however, the concentration of gold ranges from 2-14 ppm which is associated with very high concentration (up to 6000 ppm) of As. Highly anomalous valleys, for precious metals along with silver, arsenic and antimony, are Bagrot, Dainyor, Pisan and Minapin in the area of Gilgit town.
Key words: Geochemical exploration, gold potential, Gilgit, Chitral.

K/117. Khan, A., 1966. Geohydrology of Sangau area. Bulletin 12, Water and Soil Investigation Department Report 47, WAPDA Hydrogeology Directorate, North West Frontier Province, Peshawar.

Key words: Hydrology, Sangau area, NWFP.

K/118. Khan, A., 1987-89. The geology and petrography of Jijal and Patan complexes southeast of Indus River in southern Kohistan. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 80p.

The project area lies in some parts of Kohistan and Mansehra districts, covering about 150 sq. kms area, including south castera sides of Jijal and Patan complexes, starting from Karakoram highway spreading up to Pashto village. The work has evolved geological mapping of the area on a scale of 1:50,000. This thesis deals with the geological, petrographical and petrogenetical studies of the Jijal and Patan complexes and their relation with Kayal complex. The project area Lies in the frontal part of the Kohistan island arc which covers about 36,000 sq Km urea, structurally bounded by sutures named as Main Mantle thrust (MMT) and Main Karakorum thrust (MKT) on its southern and northern sides respectively. The Kohistan arc is intruded by a large number of basic complexes starting from a very primitive Dasu complex up to Jijal complex along with a Kohistan batholith which was intruded at last.
Previously, the metamorphosed mafic complexes have been lumped together as an undifferentiated mass called Kamila amphibolite. Now we under the guidance of our supervisors have divided the Kamila amphibolite into three complexes starting from very older Dasu complex down to Kayal complex and last emplaced Patan complex. Dasu complex is the oldest pluton which is highly metamorphosed, intruded in the island arc. Dasu complex is underplated by another pluton the Kayal complex which is metamorphosed.
Key words: Petrography, Jijal, Patan, Kohistan.

K/119. Khan, A., 1992. Origin of abnormal pressure in the Potwar area of northern Pakistan. Abstracts, First South Asia Geological Congress, Islamabad, 21-22.

The occurrence of highly pressured formations in the earth's crust has been well documented in recent years. This geological phenomenon has caused severe problems in most Petroleum areas of the world with Adhi Field in

Northern Pakistan supposedly the most difficult area to accomplish successful drilling. Statistically nearly one half of all land wells have experienced trouble of one type or another by drilling through abnormally pressured formations. In Northern Pakistan the structures where high pressure sands had resulted in premature abandonments of wells are Adhi, Chak Beli Khan and Bains (Bhangali). Abnormal pressure can be formed by any one of a number of developments. These include among others rapid sedimentation rates, tectonic activities, and salt diapirism. The origin of abnormal pressures in the Potwar area of Northern Pakistan on evidence of data collected from Adhi wells shows no indication typical of undercompacted sediments (rapid sedimentation): thus the abnormal pressure appears of tectonic origin which includes faults communication. The origin of abnormal pressures has been summarised, following a brief account of the area's stratigraphy and general geology anomalies of copper, gold, silver and platinum be studied on regional scale.
Key words: Hydrocarbons, high-pressure formations, Potwar.

K/120. Khan, A., 1998. Mineralogy, petrology and geochemistry of manganese mineralization and associated rocks in Saidgi area, north Waziristan. M.Phil. Thesis, University of Peshawar, 119p.

North Waziristan is dominantly composed of rocks of the Waziristan ophiolitic complex, Indian plate and the quaternary deposits. The ophiolite complex is composed of ultramafics, gabbros, sheeted dikes, pillow lavas, pelagic sediments and plagiographites which are overlain by massive sedimentary sequences. The rocks of the Indian plate are mainly limestone, shale and sandstone of Jurassic to Cretaceous age. The quaternary deposits occur as heterogeneous material of variable -size. The Saidgi and Shuidar Mn-deposits are a part of the Waziristan Ophiolitic complex. These deposits are banded and massive in nature and hosted by metachert. In Shuidar area the Mn-ore bodies are generally banded by having Mn-rich layers alternating with the metachert. The Saidgi ore bodies are generally massive in character and are in the form of lenses. The metacherts are finely crystalline, thin to medium bedded hard rocks. These are generally overlying the metavolcanics (pillow basalts) in the study area. Both Saidgi and Shuidar are bodies are having braunite as the Mn-bearing mineral. Braunite and 'cryptocrystalline quartz are the main constituents, however, the Shuidar are bodies have hematite as an additional phase. The chemistry of braunite has similarity with the natural braunite and a/so with that of the Mn-deposits found in ophiolites- else where in the world. The metacherts of both Saidgi and Shuidar areas have similar field and mineralogical characteristics. These are exceedingly microcrystalline aggregates of microcrystalline quartz, chalcedony, and lesser hematite. Chemically the Saidgi Mn-deposits have higher MnO, but lesser Si02 and Fe203 as compared to that of Shuidar Mn-deposits. The Shuidar Mn-deposits, however, have higher amount of trace elements (Cu, Pb, Zn, Ni, Cr, Co) relative to that of Saidgi Mn-deposits. Both these deposits are, characterized by low Fe/Mn ratio. Majority of the major and trace element data fall within the fields defined far hydrothermal Mn-deposits in various discrimination diagrams and, therefore, have no relation with hydrogenous deposits. Metacherts of Saidgi and Shuidar areas are similar in chemical composition. These have Fe/Mn ratio typical of hydrothermal origin. Both Saidgi and Shuidar Mn-deposits are' spatially separated from each other but are cogenetic. These were formed by the submarine hydrothermal solution in an ocean floor spreading environment within the Neo-Tethys Ocean. These deposits are, therefore, originated along sea floor spreading centers (Mid-ocean ridges) and are later on abducted on land alongwith the other ophiolitic rocks of the area. This study also suggest that the Saidgi Mn-deposits (-34000 metric tons) are of greater economic importance as compare to the Shuidar Mn deposits.
Key words: Mineralogy, petrology, geochemistry, manganese, Saidgi, north Waziristan.

K/121. Khan, A., Akhtar, K. & Hussain, I., 1987. Geological map of Chhoi (43 C/14), Attock District, Scale 1:50,000. Geological Survey of Pakistan. Map Series IV; Quetta.

Key words: Geological map, Attock.

K/122. Khan, A., Aslam, M. & Khan, R.N., 1995. Regional Geological Map of Jamrud quadrangle, Khyber Agency (Toposheet No. 38 N/8; Scale 1:50,000), NWFP., Pakistan. New Geoscience No. 933 (Old Sheet No. 90), Geological Survey of Pakistan. NWFP. Geological Map Series, vol. III.

Key words: Geological map, Jamrud, Khyber Agency.

K/123. Khan, A., & Aslam, N., 1974. Emerald deposits of Tora Tigga, Mohmand Agency, North West Frontier Province, Pakistan. Geological Survey of Pakistan, Information Release 71, 13p.

Key words: Emerald, Tora Tigga, Mohmand Agency.

K/124. Khan, A., & Aslam, N., 1981. Interim program on magnetite occurrence in Buni Zom area, Chitral District, North West Frontier Province, Pakistan. Geological Survey of Pakistan, Information Release 111, 15p.

Key words: Magnetite, Economic geology, Buni, Chitral.

K/125. Khan, A., Basir, H.A. & Rehman, S., 1995. Petroleum prospects and hydrocarbon source characterization of Shekhan Formation in Panoba Section, District Kohat. M.Sc. Thesis, University of Peshawar, 50p.

Key words: Hydrocarbons, petroleum prospects, Shekhan Formation, Kohat.

K/126. Khan, A., Din, W. & Shah, M.R., 1982. Preliminary report of the ophiolite occurrences in parts of Waziristan, North West Frontier Province, Pakistan. Geological Survey of Pakistan, Information Release 129, 23p.

This report describes the occurrence of ophiolitic rocks in Waziristan and geological map. The lithologies include peridotites, chromitites, gabbros, sheeted dykes, volcanic rocks and pelagic sediments.
Key words: Ophiolite, ultramafics, Waziristan.

K/127. Khan, A., Kumar S. & Siddique, M., 1971. Magnetic and gravity survey of Swat. M. Sc. Thesis, Punjab University, Lahore.

Key words: Gravity survey, magnetic survey, Swat.

K/128. Khan, A., Rehman, F. & Shah, M.R., 1995. Geological map of Khushalgarh (38 O/15). Geological Survey of Pakistan.

Key words: Geological map, Khushalgarh, Kohat.

K/129. Khan, A., Rehman, F., Shah, M.R., Waliullah & Shah, H., 1995. Coal exploration in Hangu area, Kohat, North West Frontier Province, Pakistan. Geological Survey of Pakistan, Information Release 601.

Key words: Coal, economic geology, Hangu.

K/130. Khan, A. & Salam, M., 1990. Discovery of a normal Paleozoic rock sequence in the Khyber Agency, NWFP, Pakistan. Abstracts, 2nd Pakistan Geological Congress, University of Peshawar, p. 36.

The Khyber Agency, erstwhile considered a very complicated area tectonically, presents a rather simple and undisturbed geological picture in the light of the present study.

A normally folded, Paleozoic rock sequence has been identified for the first time in the area. The sequence is more than 28,000 metres thick. The succession has been established on the basis of the study of contact relationship and the structure of the area.
The prevalent concept of pre-folded thrusts and allochthonous blocks has rather poor and insufficient field evidences. Most of the thrusted contacts of the previous workers are clearly normal transitional contacts. The argillites of the area are not a single unit but rather represent different geological horizons. The sequence can be presented as a type Section for the Paleozoic Rocks of the NWFP as observed of late.
Key words: Tectonics, Paleozoic, Khyber Agency.

K/131. Khan, A., Shah, A. & Haq, I., 1988. General geology of part of Karak Quadrangle, N.W.F.P. M.Sc. Thesis, University of Peshawar, 28p.

Key words: Structure, lithology, Karak.

K/132. Khan, A. & Shakirullah, 1980. Geology of Ilum Granites and a part of Lower Swat-Buner Schistose Group, District Swat, North West Frontier Province, Pakistan. M.Sc. Thesis, Peshawar University. 83p

Key words: Geology, granites, Ilum, Buner, Swat.

K/133. Khan, A.B., Shah, Z.H. & Naeem, S.M., 1970a. Geology of the Ghundai Sar and vicinity, Jamrud. M.Sc. Thesis, Peshawar University. 73p.

For details consult the following account.
Key words: Paleontology, Jamrud, Khyber Agency.

K/134. Khan, A.B., Shah, Z.H. & Naeem, S.M., 1970b. Geology of the Ghundai Sar and vicinity, Jamrud, Khyber Agency. Geological Bulletin, University of Peshawar 5, 115-130.

The area of investigation lying in the eastern part of the Khyber Pass, between Jamrud and Waran Ghundai, is covered by the formations of the Lower and Upper Palaeozoic ages. They are represented by the Landikotal Slate (? Ordovician-Lower Silurian), the Shagai Limestone (? Middle to Upper Silurian) and Ali Masjid Formation (Upper Silurian to? Lower Carboniferous).
All of these are marine, and clastic sedimentary rocks account for more than two-third of the total thickness of the strata exposed in the area. The Landikotal Slate constitutes as much as ± 6000 feet of clastic sedimentary rocks.
Of all the formations the Ali Majid Formation is the only fossilferous formation. It is reefoid, and extensive reef deposits occur in it. Thamnopora, Cladopora, and Favosites are the important tabulate corals. Other fossils present are stromatoporoids, orthoconic cephalopods, byrozoans, brachiopods, and abundant crinoidal stems and columnals. The fossil assemblage indicates an age between Upper Silurian and Lower Devonian. Large-scale metamorphism and dolomitization has occurred, which has resulted in the obliteration of the details of fossils. This has rendered difficult to identify many fossils even at generic level. The effect of metamorphism increases towards north and the reef limestones are converted to marble.
Late Cretaceous and Early Tertiary igneous activity is indicated by the dolerite, gabbro, and (?) microgranite intrusive bodies. Most of these are sills. Dolerite and gabbro sills have mineralized the calcareous phyllites and reef limestones. Extensive and large deposits of soapstone occur within calcareous phyllites and reef limestones (converted to marble). The area is traversed by NS and NW-SE striking thrust faults. In the northeastern part of the area the rocks are folded into a NE plunging syncline. Recent movements have occurred in the area as indicated by elevated terraces and alluvial valleys.
Key words: Stratigraphy, paleontology, Jamrud, Khyber Agency.

K/135. Khan, A.G., Tahirkhelli, T.K. & Altaf, G., 1982. Geology of a section along Main Mantle Thrust, Jijal-Kohistan, Northern Pakistan. M.Sc. Thesis, University of Peshawar, 63p.

Key words: Geology, MMT, Jijal, Kohistan.

K/136. Khan, A.H., 1961. Beneficiation of chromite in West Pakistan. Proceedings, CENTO Symposium on chrome ore, Ankara, 61-72.

Key words: Beneficiation, chromite.

K/137. Khan, A.H., 1992. Phosphate rock exploration in Pakistan. Abstracts, First South Asia Geological Congress, Islamabad, p.22.

Alive to the significance of phosphates in Pakistan's agronomy, Geological Survey of Pakistan in collaboration with United States Geological Survey, launched a program of exploration in 1956. But in 1966 eminent Phosphate geologists concluded that suitable environment for the deposition of marine phosphate rock had not become available in Pakistan. GSP have not taken serious interest in phosphate exploration since then. Team members of Geological and Mining Consultants were not discouraged and Mr. Ikramuddin Ali discovered high grade commercially workable Cambrian phosphate deposits (1970-71) in Hazara which are being currently exploited. This discovery has by no means exhausted the possibility of finding more deposits in Hazara and elsewhere.
In 1989-90 GMC carried out preliminary phosphate rock exploration for Directorate of Mineral Development, Balochistan and identified extensive phosphatization in basal and top horizons of Cretaceous. Scope of work permitted reconnaissance of only 30% of prospective area. Although huge tonnages of phosphate rock exist the grade averages 4 to 5% with some 28% P205 showings. While searching for condensed successions, GMC discovered large deposits of bauxite suitable as feedstock in conventional plants. Although Rs 4 billion worth of phosphates are being imported, little interest is being taken in exploration of indigenous resources.
Key words: Phosphate rocks, exploration, Hazara.

K/138. Khan, A.H., 1994. Phosphate rock exploration in Pakistan. In: Ahmed, R. & Sheikh, A.M. (eds.), Geology in South Asia--I. Proceedings of the First South Asia Geological Congress, Islamabad, 1992. Hydrocarbon Development Institute of Pakistan, Islamabad, 297-299.

Consult the preceding account for more information.
Key words: Phosphates rocks, exploration.

K/139. Khan, A.L., 1965. Geology of lower Batrassi and Mansehra, Hazara. M.Sc. Thesis, Punjab University, Lahore, 90p.

Key words: Mapping, Mansehra.

K/140. Khan, A.L., 1977. Ground water conditions in Paharpur area DI Khan. M.Sc. Thesis, University of Peshawar, 44p.

Key words: Groundwater, Paharpur, D.I. Khan.

K/141. Khan, A.M., 1952. A study of the geological structure of the Lower Himalayas of the Hazara and Mardan districts of the North West Frontier Province. 4th Pakistan Science Conference Proceedings part 3, 125–126.

Key words: Structure, geology, Lower Himalaya, Mardan, Hazara.

K/142. Khan, A.M., 1961. Geological history of the Earth, with particular reference to Pakistan. Natural Resources (Karachi University) 1, 27-31.

Key words: Geological history.

K/143. Khan, A.M., 1962. Construction materials of West Pakistan. Proceedings CENTO Symposium on Industrial Rocks and Minerals, Lahore, 334-342.

Key words: Construction material.

K/144. Khan, A.M., 1965. Sedimentary petrography of Siwalik system exposed in Soan syncline, Sihala, Rawalpindi. M.Sc. Thesis, Sind University, Jamshoro.

Key words: Sedimentology, petrography, Soan syncline, siwaliks.

K/145. Khan, A.M. & Ahmad, A.J., 1988. Groundwater condition in Nizampur area, District Peshawar. M.Sc. Thesis, University of Peshawar, 40p.

Key words: Groundwater, Nizampur, Peshawar.

K/146. Khan, A.M. & Ali, M., 1994. A geo-engineering aspect of Swargali-Bakote Muzaffarabad Road Project. Abstracts, Second SEGMITE International Conference on the Export Oriented Development of Mineral Resources and Mineral Based Industries, p.17.

The Swargali - Bakote - Muzaffarabad road project covers part of Punjab, NWFP and Azad Kashmir areas and lies in the outer Himalayas occupying the western limb of Hazara - Kashmir Syntaxis. The 98 KM long new alignment traverses on highly rugged mountains terrain, linking about 25 villages and crossing two major rivers; Jhelum and Kunhar. It also shows a relief of about 6000 feet between starting and end point. The geological formation of the project area, ranges in age from Cambrian to Recent and includes sedimentary rocks. The major rock units include Hazara Slates (Cambrian) and Murree Formation (Miocene) that composed of shales, clay and sandstone. The two have been juxtaposed against each other by a major thrust known as Murree Fault. While fixing the alignment the highly unstable Murree Formation and Murree fault have been avoided. Geological comparison between the existing road on left bank of river Jehlum and the proposed alignment on the right bank of river Jehlum shows that the latter is more stable and economically viable.
Keeping in view the nature of terrain and geology, the road has been carefully designed in order to meet the required specifications of geometrics, traffic load and construction economics. One of the most modern software system of highway design, known as MOSS has been utilized to attain optimum accuracy and economy. The rock cut slopes and drainage have also been designed in such a way to provide sustainable stability to the road and to control geological hazards including landslide, mudflow and rockfall.
Key words: Geo-engineering, Jehlum, Kunhar, Muzaffarabad, Azad Kashmir.

K/147. Khan, A.M. & Ali, M., 1996. A geo-engineering aspect of Swargali-Bakote Muzaffarabad Road Project, Pakistan. Proceedings, Second SEGMITE International Conference on Export Oriented Development of Mineral Resources and Mineral Based Industries, Karachi, 1994, 163-168.

For details consult the preceding account.
Key words: Geo-engineering, Jehlum, Kunhar, Muzaffarabad.

K/148. Khan, A.M. & Aurangzed, 1991. Gemstone resources of Pakistan. Proceedings, First SEGMITE Symposium, Peshawar, 39-45.

The gem resources of Pakistan are mostly found in the Himalaya-Karakorum-Hindukush region. The paper describes emerald, ruby, topaz, aquamarine, tourmaline, zircon, garnet, moonstone, chalcedony, and apatite. These occur in a variety of tectonic setup and have been attributed to complex processes.
Key words: Mineral resources, gemstones, Pakistan.

K/149. Khan, A.M. & Khan, M.A., 2001. Landslide and foundation: An assessment of the problem in sub-Himalayan regions of Muzaffarabad, Azad Kashmir. Abstracts, 4th Pakistan Geological Congress, Islamabad, p. 46.

Slope stability problems in Sub-Himalayan regions have been investigated for foundation engineering, road construction, abutments, for housing and retaining walls. A survey has been undertaken to investigate slope stability problems during 1985-1995. The stable and unstable slopes were separated on right and left bank of river Neelum and river Jhelum. Mahor landslides in unstable slopes have been marked in Murree Formation of Miocene age from crown to toe due to nearness of active fault (MBT), pore water pressure, sink holes at crown, undercutting for road widening, shale undercutting by differential weathering and undercutting by river currents. A method for remediation has been suggested for foundations in slopes, load-bearing capacity of rocks and soils based on in situ and laboratory investigations. The bearing capacity of foundations on level ground is higher as compared to the slopping surface depending upon the slope angle, composition of the soil, flooding in the river, moisture content of the soil and earthquake intensity which agitate the rocks and soils underlying the foundations. The foundations in such regions depend simply on local conditions, footing size, proximity to the slope, depth of footing and design geometry.
Key words: Slope stability, landslides, Muzaffarabad, Himalaya, Azad Kashmir.

K/150. Khan, A.M. & Mariano, A.N., 1992. Mineralogical characteristics of Katlang pink topaz: Cathodoluminescence analysis. Abstracts, First South Asia Geological Congress, Islamabad, p.24.

The autoclastic limestone of probably Silurian- Devonian age in Katlang district Mardan, NWFP, hosts highly prized, exclusive variety of natural pink topaz. Under Cathodoluminescence (CU) it shows blue and violet red color and sectoral zoning. The colors are attributed to the presence of crystal detect in tetrahedral position and Cr^{3+} as ion impurity activator that has probably substituted Al3+ in the octahedral site. Mass spectrographic analyses, electron microprobe analyses and CL omission spectrum show that cr3+ is directly related to the violet red CL and pink coloratien. Proton induced X-ray excitation (PIXI) analyses indicate that combination of Cr^{3+} V and Ge are diagnostic for Katlang pink topaz. The sectoral zoning is due to F and OH ordering. Variation in color of crystal and co-occurance of brecciated and idioblastic crystals in the same rock indicate several episodes of topaz crystallization.
Key words: Mineralogy, gems, topaz, Katlang, Mardan.

K/151. Khan, A.N., 1993. An evaluation of natural hazard reduction policies in developing countries with special reference to Pakistan. Pakistan Journal of Geography 3, 81-100.

Key words: Natural hazards.

K/152. Khan, A.Q., Jamal, Z., Shah, S.W.A. & Ali, A., 1998. Geology of Kohat, Kotal Pass, N.W.F.P., M.Sc. Thesis, University of Peshawar, 54p.

Key words: Geology, Kohat.

K/153. Khan, A.R., 1992-94. Geotechnical studies and geological mapping of Khan Pur Dam Project area. M.Sc. Thesis, Punjab University, Lahore, 83p.

Key words: Geotechnical, Khanpur dam.

K/154. Khan, A.U., Khan, M.M. & Jadoon, K.G., 1990. Selective floatation of lead from the lead zinc ore of Kohistan, Hazara, Pakistan. Proceedings, First SEGMITE Conference on Industrial Minerals, Peshawar, 79-87.

Flotation studies were carried out to update galena in the lead ore of Besham to make is saleable. The important flotation parameters examined were type and dosage of collector, dosage of the depressant, dispersant and frother, conditioning time for collector and depressant and impeller speed. During step-wise optimization of flotation parameters, lead was upgraded from 3.1% to 16% in the first cycle, and from 16% to 26% in the second cycle of flotation.
Key words: Beneficiation, lead-zinc, Kohistan, Hazara.

K/155. Khan, B., 1983. Lead, Zinc and molybdenite mineralization around Besham, Kohistan, North West Frontier Province. 2nd National Seminar on Development of Mineral Resources, Peshawar 1, 4p.

Key words: Base metals, lead-zinc, Besham, Kohistan.

K/156. Khan, B. & Ahmad, N., 1991. General geology of the Kakul phosphate Deposits, Hazara, Pakistan. Proceedings, First SEGMITE Symposium, Peshawar, 51-60.

Phosphorite in the Kakul area occurs in a folded, thrusted and faulted succession of Cambrian to Jurassic sediments. The succession forms part of the Garhi Habibullah syncline on the western flank of the Hazara-Kashmir syntaxis, a major structural element of the southern part of Himalaya orogenic belt. The geology of the Kakul area has been complicated by thrusts which are approximately parallel to the strike and has divided the succession into a number of discreet thrust sheets, one phosphorite of Kakul mines and the other Kakul west phosphorite. Mineralization extends along a discontinuous belt foe some 2.5 miles to the North West as afar as lambidogi. The depositional environment of the phosphorite at Kakul mine is notably different from that at Kakul west, indicating that large horizontal movements took place along the thrust planes which brought into juxtaposition rocks of widely different facies of phosphorite deposition.
Key words: Geology, phosphate, Kakul, Hazara.

K/157. Khan, B. & Ahmad, W., 1979. Geology of Shewa Shahbaz Garhi area. M.Sc. Thesis, Peshawar University.

Key words: Granite, Shewa Shahbaz Garhi, Mardan.

K/158. Khan, B., Husain, V., Bilqees, R. & Sultan, S., 1992. Correlation of palaeogeography with phosphorites of Pakistan and India. Abstracts, First South Asia Geological Congress, Islamabad, p.21.

The marine phosphorites of Early Cambrian age presently being exploited in Pakistan occur in an area of about 155 km^2 at the foot of Himalaya in Abbottabad, Hazara. The proved reserves for these deposits (Kakul, Lagarban and Tarnawai) are 8 million tonnes with upto 20 million tonnes of resources known in the area. These phosphorites are associated with dolomite, chert, siltstone and black shales occurring in upper part of the Abbottabad Formation.
The presence of Early Cambrian age is characteristic of these phosphate beds. Hazara phosphorites resemble Birmania phosphorites, western Rajasthan and Tal phosphorites, Mussoorie, India, in their composition and origin

due to their close palaeogeographic relationship. All these phosphorites contain carbonate fluorapatite, quartz, dolomite, calcite, clays, pyrite, orthoclase and muscovite. In thin sections, phosphates occur as a variety of nodular clasts, mostly oval, coarse to fine grained, made up of microcrystalline apatite embedded in chertquartz- calcite matrix. All these deposits are of marine origin, occurring in a few inches to several feet thick beds, containing 10-35% P2O5.
The palaeontological, geological and geochemical data support the view that Birmania phosphorites and-Hazara phosphate bearing areas were part of an extensive Palaeozoic (Cambrian-Ordovician) sea with undefined boundaries which came into existence through the subsidence of the old prePalaeozoic land surface. Phosphorites in the areas appear from the stratigraphic and petrologic evidence to have formed authigenically at the sediment - water interface, a common mode of formation in ancient deposits.
Key words: Paleogeography, phosphorite, Abbottabad, India, Pakistan.

K/159. Khan, F., Latif, M., Fayaz, A. & Khan, M.S.Z., 1987. Geology and mineral investigations of Hunza-Nagar area, Northern Areas. Geological Survey of Pakistan, Information Release 291, 32p.

Geological mapping and minerals investigation of Hunza and Nagir areas was carried out in May to June 1985. The mapped area is underlain by maetasedimentary locks of Baltit Group, Chalt ophiolitic mélange zone, and igneous rocks of Karakoram Granodiorite along with veins and dykes of both basic and acidic nature, pegmatites and quaternary deposits.
The area is well known for its ruby deposits in the limesilicate marble of Baltit Group. The Baltit Group mostly consists of gneisses, schists quartzite and marble, The Chalt ophiolitic mélange zone consists of schists, phyllites, marble, dolomitic limestone, slates and Cherty conglomerate. The grade of metamorphism increases from west to east with low grade schists, to limesilicate marble of cata zone. The regional metamorphism is caused by intrusion of Karakoram batholith. The two thrust the main Karakoram thrust and Hispar Hunza thrust are the prominent structural features in the mapped area which both runs in the east-west direction.
The Hispar Hunza thrust is intraformational and separates the high grade rocks from the low grade within the Baltit Group. The area does not possess any other, deposits of economic interest except small pegmatites and an alteration zone near Yal area. A total of 7 samples were analyzed from alteration zone which contains 21-1490 PPM Cu, 32 to 310 PPM Mn, 91-301 PPM Zn and only three samples having Ni values from 177-271 PPM. The higher Cu values are due to malachite veins which are present in the zone. The overall values are not so encouraging to suggest further detail work of the area for Cu mineralization.
Key words: Mineral resources, geology, Hunza, Nagar, Karakoram.

K/160. Khan, F., Latif, M. & Khan, R., 1991. Geology and mineral investigation of the Yasin quadrangle, Northern Areas, Pakistan. Geological Survey of Pakistan, Information Release 494, 19p.

Geological mapping and mineral investigations of Yasin valley were carried out from September to October 1987. The investigated area falls in the Survey of Pakistan topo sheet No. 42 H/7.
The project area is covered by metasedimentary rocks of Darkot group; meta-volcano sedimentary rocks of Yasin group and meta-volcanic rocks of Greenstone complex which were later intruded in multi phases by the Ladakh - Kohistan granitoids. Owing to the presence of the collision boundary zone between the Asiatic Mass and island are, the rocks of the investigated area are severely disturbed thus resulting in a number of folds and faults.
Key words: Geology, mineral resources, Yasin valley, Gilgit.

K/161. Khan, G., 1983-85. Geotechnical studies for slope stability analysis along Muzaffarabad-Kohala Road. M.Sc. Thesis, Punjab University, Lahore, 90p.

The Muzaffarabad-Kohala road is the main way of transportation between Pakistan and Azad Kashmir. A number of landslides occur along this road which damaged and blocked it for hours and sometimes for days. Due to the vital importance of the road this frequent sliding is unbearable. So this field report is prepared with the aim to study the area in detail and to explore the reasons of sliding.

For the present study the area was mapped, and lithological and structural discontinuities are marked. The major structure is the Jhelum Fault, which extends full length of the project area. Attempts have been made to give an idea about the stability conditions prevailing in different zones. On the basis of existing condition in the field, the area along the road is divided into three types of zones i.e., Stable zone, Potentially unstable zones,Unstable zones.
Samples from potentially unstable and unstable zone were collected for laboratory tests. The purpose of this test was to evaluate the strength parameters which are responsible for driving and resisting moments. This report also includes the study of the factors responsible to activate the sliding process and their economical and practical remedies. Conclusion and recommendations are given in the end.
Key words: Geotechnical, slope stability, Muzaffarabad, Azad Kashmir.

K/162. Khan, G., Khan, H. & Shah, S.A.H., 1998. General geology of a part of Kalachitta Hill Range, South of Nizampur, District Nowshera, N.W.F.P. M.Sc. Thesis, University of Peshawar, 52p.

Key words: Geology, Kalachitta Range, Nizampur, Nowshera.

K/163. Khan, H., Husain, V., Qureshi, K., Pasha, K. & Ahmad, N., 1994. Petromineralogical and geochemical studies of Havelian barite, Hazara, NWFP, Pakistan. Pakistan Journal of Scientific and Industrial Research 37, 10, 414-00.

The epigenetic vein type barite deposits occur at several localities near Havelian in limestone and shale sequence belonging to Eocene age. Barite veins varying in thickness from a few inches to several feet occur in gray colored argillaceous limestone and shale. Thin bands of barite and galena are also seen in some samples. Important minerals occurring along with barite are calcite, quartz and magnesite. In polished sections, galena, pyrite and goethite were also identified. Petrographically, barite occurs in several textural types: massive, crystalline, lath or platy shaped ranging from fine to coarse in size. The $BaSO_4$ content in Havelian barite samples ranges from 20 to 92%. Major impurities are SiO_2, CaO, MgO, Fe_2O_3 and Al_2O_3. Barite deposits in Havelian are structurally controlled vein and cavity filling type deposits. These barite deposits have not been developed and mined systematically. Barite deposits of this district are good in quality and need detailed investigations for determining mineable reserves. The physical and chemical characteristics of Havelian barite show their suitability for paint, paper, rubber, petroleum drilling and chemical industries with or without processing.
Key words: Mineralogy, petrology, geochemistry, barite, Hazara.

K/164. Khan, I., 1990-91. The structure, stratigraphy & petrography of the western limb of Hazara-Kashmir Syntaxis, Mansehra-Dalola area, Hazara, Pakistan. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 74p.

The Mansehra-Dalola area lies on the western limb of Hazara-Kashmir syntaxis (HKS) in Attock Hazara foreland fold-and- thrust belt. The Hazara- Kashmir syntaxis is a regional antiformal structure of vital significance in the geological and tectonic framework of the Western Himalayas. A sequence from Late Proterozoic to Mesozoic has been deformed during the pre-Himalayan and Himalayan orogenies. The western limb of the HKS shows a complex juxtaposition of three tectonostratigraphic zones. These are the Garhi Habibullah-Abbottabad zone, the Panjal zone and the Mansehra zone.
Several diverse lines of evidence including the presence of metamorphic clasts in unmetamorphosed Cambrian conglomerates, angular relation of Cambrian rocks to the older cleavages and hornfelsic overprint in contact aureoles of Cambrian granites on older cleavages establish a distinctively pre-Himalayan orogenic event of late Proterozoic age. The D2 deformation event is related to the first phase of the Himalayan orogeny. It produced large scale south verging recumbent folds. A strong S2 folialion is axial planar to these F2 folds.
The D3 deformation event forms F3 folds. The F3 folds in the area are Garhi Habibullah syncline. Tarkot anticline, Doga syncline and Gali Mohri anticline. These are southeast verging open to tight folds. D3 thrusts are the Panjal fault, Garhi Habihullah fault, Naroka thrust, Lagarban fault and Sattu fault. Near surface backsteepening due to oblique thrusting and more resistant strata is also documented as a later phase of the D3 deformation. During D4 deformation earlier thrusts and axial planes of F3 folds are refolded into broad map-scale northwest plunging F4

folds. The F4 folds are synchronous to the development of NNW plunging antiformal structure of the Hazara-Kashmir syntaxis. The major counter-clockwise movement along the western limb of the syntaxis also produced Rheidberg faults in addition to sinistral-slip along major thrusts.
Key words: Structure, stratigraphy, petrography, Hazara-Kashmir Syntaxis, Mansehra, Hazara.

K/165. Khan, I.A., 1968. Northern Chamla and Eastern Buner. M.Sc. Thesis, Punjab University, Lahore, 89p.

Key words: Geology, Chamla, Buner.

K/166. Khan, I.A., 1981. Lithostructural mapping and geology of Murree-Ayubia area, NW Pakistan with special emphasis on sedimentary petrology and petorgenesis. M.Sc. Thesis, Punjab University, Lahore, 217p.

Key words: Lithostructure, sedimentary petrography, petrogenesis, Murre-Ayubia.

K/167. Khan, I.A., 1982-84. Structural studies of Chinar Kot-Galigada Area, District Mansehra. M.Sc. Thesis, Punjab University, Lahore, 87p.

Key words: Structure, Mansehra.

K/168. Khan, I.A., 1991a. Sandstone petrology in relation to provenance, the stratotype Chinji Formation, Siwalik Group, Pakistan. Abstracts, Annual Meeting, Geological Society of America, San Diego, USA, p. A68.

Key words: Petrology, sandstone, Chinji Formation, siwaliks.

K/169. Khan, I.A., 1991b. Patterns of sedimentological variation within the Miocene Siwalik Group, eastern Potwar Plateau, northern Pakistan. Birbal Sahni Birth Centenary Symposium on the Siwalik Basin, Dehradun, India, 23-24.

Key words: Sedimentology, Miocene, Siwaliks, Potwar.

K/170. Khan, I.A., 1992. River systems recorded within the Miocene Siwalik Group, eastern Potwar Plateau, Northern Pakistan. Abstracts, Annual Meeting, Geological Society of America, Cincinnati, USA, p.A352.

Sedimentologic characteristics of paleochannel and overbank deposits are documented in a kilometer-scale coarsening upward succession of the entire Siwalik Group. (Chinji- Nagri- Dhok Pathan and Soan Formations) exposed in Mahesian and Rohtas areas, eastern Potwar plateau, northern Pakistan.
The major channel sandstone bodies are composed of several storeys, stacked both vertically and laterally and represent either singe or superimposed channel-belt deposits. The arrangement and internal characteristics of the storeys indicate deposition as bars and channels hills within low sinosity braided channels. Paleochannel reconstruction from channel-belt deposits, within the Chinji Formation indicate widths of 167-500m, depths of 3.5 to 16 m. bend wavelengths of 1.4-4 km and discharge of 600 – 1300 m^3/s. larger channels form the Nagri Formation show widths of 200-1300 m, depths of 3-21 m, bend wavelength of 0.7 – 6.2 km and discharge of 300 – 6000 m^3/s. relatively smaller channel segments from the Dhok Pathan Formation indicate widths of 114 – 156 m, depths of 3.5 – 6/7 m, bend wavelengths of 0.9 to 1.6 km and discharge of 300 – 1000 m^3/s.
Key words: River systems, Miocene, siwaliks, Potwar.

K/171. Khan, I.A., 1993. Evolution of Miocene-Pliocene fluvial paleo-environments in eastern Potwar Plateau, northern Pakistan. Doctoral Dissertation, State University of New York Binghamton, USA. 188p.

The fluvial Miocene-Pliocene Siwalik Group (Nagri, Dhok Pathan and Soan Formations) in the Mahesian and Rohtas areas, eastern Potwar plateau, northern Pakistan, was studied in order to reconstruct the evolution of depositional environments and the controls on this evolution.
The major sandstone bodies are composed of storeys, stacked both vertically and laterally and represent either single or superimposed channel-belt deposits. Internal characteristics of the storeys indicate deposition as bars and channel fills within low sinuosity (1.1-1.2) braided channels which had a braiding index of at least 2 or 3. Individual channel segments in the Lower Nagri Formation had widths of 167-500m, maximum bankful depths of 7-17m, bend wavelengths of 1.4-4 km and bankfull discharges of 300-1300 m3/s. The discharges of the channel belts in the Nagri Formation were on the order of 1000 m3/s.
Relatively smaller channel segments from the Dhok Pathan Formation had widths of 114-156m,
maximum bankfull depths of 6.7m, bend wavelengths of 0.9 to 1.6km and bankfull discharges of 300-1000m3/s. Overbank sandstone bodies have lenticular, wedge, sheet and channel filling geometries and are interpreted as the deposits of crevasse-splays, levees or floodplain drainage channels. Mudstone sequences consist predominantly of finely laminated to disrupted/bioturbated siltstones which show well developed pedogenic features. Mudstones were deposited from episodic, suspended load deposition from slow moving flood flows on broad, low relief floodplains. Comparison of the Siwalik river systems with modern Himalayan river systems suggests their deposition on large sediment fans and interfan areas.
The following vertical variations are observed within the Siwalik Group: 1) major sandstone bodies coarsen from fine to medium sandstone through the Nagri Formation, there is abrupt fining at the base and top of the Dhok Pathan Formation, followed in the Soan Formation by increasing grainsizes of all facies; 2) the proportion of major sandstone bodies generally increases upwards in the Nagri Formation; however, variation in grainsizes and proportion of major sandstone bodies are not correlated in the Dhok Pathan and Soan Formation; 3) thicknesses of major sandstone bodies increase upwards in the Upper Nagri Formation, due to both thicker storeys and more vertically stacked storeys, and decrease at the base and top of the Dhok Pathan Formation; 4) mean paleocurrent orientations are generally towards the southeast; however, they change to southwest in the Upper Nagri Formation and shift towards the south in the Lower Dhok Pathan and Soan Formations; 5) a decrease in sedimentation rate from 0.34 to 0.25 to 0.21 mm/yr in the Nagri, Dhok Pathan and Soan Formations, respectively, corresponds to a decrease in proportion of major sandstone bodies and increase in proportion of mature paleosols. The association of decrease in sedimentation rates with easterly paleocurrents and increase in sedimentation rates with southerly paleocurrents might be related to periodic regional progradation of wedges or lobes of sediment from the Himalayas. Basin-wide increase in sediment accumulation rate, grainsize and proportion of major sandstone bodies, and changes in their composition in the Nagri Formation are associated with tectonic uplift of the Himalayas, progradation of wedges or lobes of sediment to the south and southeast and increasing depositional slope. Variation in eustatic sea-level had no effect on sedimentation of the Siwaliks. The lack of clear variation in paleochannel geometry through the marked climatic-vegetation change around 7.5-6.5 m.yr suggests river discharges were not affected by climatic change.
Key words: Paleo-environments, Miocene, siwaliks, Potwar.

K/172. Khan, I.A., 1994. Alluvial architecture and sandstone petrology of the stratotype Chinji Formation, Siwalik group, northern Pakistan. Himalayan Geology 15, 123-141.

The stratotype Chinji Formation (14.0-10.8 ma) is composed of alternating sheet sandstones (active channel deposits) and mudstones (lower energy overbank flow deposits). The stratigraphic details of the Chinji Formation are based upon measurement of three complete vertical logs in the stratotype area and lateral tracing of lithofacies for kilometers. On the basis of sandbody geometry, the sandstones are classified as “sheet”, “ribbon”, and “shoestring” types. The mudstones are micaceous and sandy and in the lower part of the formation fine upward into claystones. Thirty-eight sandstone samples in the medium sand range, from the base and top of each sandstone, are analysed by point counting for their modal composition. Quartz (14-36%) is subdivided as monocrystalline non-undulatory (47.12%), monocrystalline undulatory (8.19%), polycrystalline with 2-3 crystals per grain (25.57%) and polycrystalline with > 3 crystals per grain (18.35%). The feldspar (4-16%) consists of plagioclase, orthoclase, microcline and perthite. The lithics are composed of sedimentary (3-29%), metamorphic (7-29%) and volcanic (1-

4%) rock fragments. Calcite (7-36%) occurs as allochems (1-9%), intraclasts (1-7%) and cement (2-26%). The relative percentages of quartz types, plotted on a diamond diagram (Basu et al., 1975), indicate that the sandstones are derived from middle and upper rank metamorphic rocks. The QFL (quartz-feldspars-lithics) triangle after Folk (1968) shows that the sandstones are litharenites to feldspathic litharenites. The LsLmLv triangle after Folk (1968) shows that the sandstone are phyllarenites. The volcanic lithics are mostly pyroclastics. The relative abundance of allochem and intraclast calcite suggests that the rivers drained older limestones during this time. A major uplift of the Kohistan arc began about 15 ma ago and its focus has been Nanga Parbat and Hunza region (Zeitler et al., 1982). Kohistan island arc could be a possible source for metamorphic minerals since the time of deposition of the Chinji Formation**.**

Key words: Sedimentology, Miocene, Chinji Formation, siwaliks, Potwar.

K/173. Khan, I.A., 1995a. Complexity in stratigraphic division of fluvialtile successions. In: Abstract volume (Dissanayake, C. B., Almond, D. C., and Cooray, P. G., eds.), Second South Asia Geological Congress (GEOSAS-II), Colombo, Sri Lanka, p.240.

Key words: Stratigraphy, fluviatile deposits, siwaliks.

K/174. Khan, I.A., 1995b. Controls on evolution of Neogene fluvial environments in the northwestern Himalayan Foreland Basin. In: Abstract volume (Dissanayake, C. B., Almond, D. C., and Cooray, P. G., eds.), Second South Asia Geol. Cong., Colombo, Sri Lanka, p.240.

The Neogene Siwalik Group (Chinji, Nagri, Dhok Pathan and Soan Formations) in the northwestern Himalayan foreland basin consists of two major 100m-scale coarsening upward sequences. The lower sequence (Chinji and Nagri Formations) records coarsening upward from fine to medium sandstone, followed by basin-wide abrupt fining at the Nagri/Dhok Pathan Formations boundary. Upward coarsening is associated with increases in grain size, clast, thickness, lateral extent and proportion of channel-sandstone bodies. The highest proportion of major channel-sandstone bodies (e.g., upper Nagri Formation) is associated with relatively thick, laterally extensive and interconnected channel-sandstone bodies, which have relatively thicker and vertically superimposed sandstone storeys. These are generally interpreted as superimposed channel-belt deposits, The upward increase in mean grain size (e.g., upper Nagri Formation) is probably associated with a regional increase in alluvial slope, possibly due to progradation of a large alluvial cone. A high proportion of sandstone bodies in the Nagri Formation might be related to increasing numbers of channels in the area, either simultaneously or due to frequent channel avulsions (diversions). Increasing avulsion frequency into an area might be related to preferred tectonic subsidence, intrabasinal faulting .(subsurface controls) and/or increased channel-belt deposition rates, possibly related to basin-scale progradation of large active wedges or lobes of sediment to the south and southeast due to orogenic pulses in the orogenic belts. Although the trends in sandstone body proportion over hundreds of meters of strata can be correlated regionally, the local correlation of the 100m cycles suggests a more local cause such as intrabasinal tectonism or fan progradation.

The abrupt fining at the base of the upper 100 m-scale sequence (Dhok Pathan and Soan Formations) is followed by increasing grain sizes of all facies. Basin-wide decrease in sediment accumulation rates from 0.34 to 0.25 to 0.21mrn/yr through the Nagri, Dhok Pathan, and Soan Formations, respectively, corresponds to a decrease in proportion of major sandstone bodies and an increase in proportion of mature paleosols. Abundance of overbank channels is generally associated with increase in proportion of major channel sandstone bodies and deposition rate, which might be due to a greater tendency towards river diversions.

The basin-wide trends in increase in sediment accumulation rate, grain size and proportion of major sandstone bodies, and changes in their composition, are approximately coeval with a major eustatic lowering of the sea-level (Chinji-Nagri Formations boundary) and subsequent rise (Nagri-Dhok Pathan Formations boundary), There is no sedimentological evidence for climatic change through the Chinji to Dhok Pathan Formations.

Key words: Neogene, foreland basin, Himalaya.

K/175. Khan, I.A., 1996a. Facies architecture of the Siwaliks-field guide (Mahesian guide): Field excursion guide book, Introductory Course on Paleomagnetic and Rock Magnetic Applications in Geological Sciences, Geoscience Laboratory, Geological Survey of Pakistan, 16-35.

Key words: Paleomagnetism, field guide, siwaliks.

K/176. Khan, I.A., 1996b. Diachroneity of Miocene strata in Himalayan foreland basin. Extended Abstracts, International Seminar on Paleomagnetic Studies in Himalaya-Karakoram Collision Belt and Surrounding Continents, November 20-21, 1996, Islamabad. Geosciences Lab, Geological Survey of Pakistan, Islamabad, 67-70.

Key words: Miocene, Foreland basin, Himalaya.

K/177. Khan, I.A., 1996c. Evolution of Neogene fluvial environments in Himalayan foreland basin. Abstracts, 30th International Geological Congress, Beijing, p.162.

Key words: Neogene, Foreland basin, Himalaya.

K/178. Khan, I.A., 1997. Causes of evalution of Neogene fluvial environments in Himalayan foreland basin. International Colloquium on Geology and Human Life. Pakistan Academy of Geological Sciences, Lahore, 66-67.

Key words: Neogene, Foreland basin, Himalaya.

K/179. Khan, I.A., 1998. Intra- and extra-basinal controls on sedimentation of neogene fluvial sequence in Himalayan foreland basin. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 95-97.

Molassic, fluvial rocks of the Siwalik Group record changing depositional environments in the Himalayan foreland basin. In the Potwar plateau, Chinji, Nagri, Dhok Pathan and Soan formations of this Group comprise relatively thick (tens of meters) sandstone bodies and mudstones that contain thinner sandstone bodies (meters thick) and palaeosols. Thick sandstone bodies extend for kilometers normal to paleoflow, and are composed of sandstone storeys stacked laterally and vertically adjacent to each other. Sandstone bodies represent single or superimposed braided-channel belts, and storeys represent channel bars and fills. Channel belts had widths of km, bankfull discharges on the order of 103 cumecs and braiding parameter up to about 3. Individual channel segments had bankfull widths, maximum depths, and slopes on the order of 102 m, 101 m and 10-4 respectively, and sinuosities around 1.1. These rivers are comparable to many of those flowing over the magafans of the modern Indo-Gangetic basin, and a similar depositional setting is likely. Thin sandstone bodies within mudstones extend laterally for on the order of 102 m and have lobe, wedge, sheet and channel-form geometries. They represent crevasse splays, levees and floodplain channels. Mudstones are relatively bioturbated/disrupted and represent mainly floodbasin and lacustrine deposition. Mudstones and sandstones are extremely disrupted at places, showing evidence of prolonged pedogenesis. These 'mature' palaeosols are meter-scale thick and extend laterally for kilometers. Lateral and vertical variations in the nature of their horizons apparently depend mainly on deposition rate.
The kilometer scale thick Siwalik Group is comprised of two major 100 m scale coarsening upward megasequences. The lower sequence (Chinji and Nagri Formations, Ca 14-9 Ma) records coarsening upwards from fine to medium sandstones, followed by basin-wide abrupt fining at the base of the upper sequence (Dhok Pathan and Soan Formations, Ca 9-2 Ma). The highest proportion of major channel sandstone bodies (upper Nagri Formation) is associated with laterally extensive and interconnected channel-sandstone bodies, which have relatively thicker and vertically superimposed sandstone storeys. Compacted deposition rates decrease with sandstone proportion (0.53 mm/year for Nagri, 0.24 mm/year for Dhok Pathan and 0.21 mm/year for Soan), and palaeosols are not as well developed where deposition rates are high. Within the Siwalik formations there are 100 m-scale variations (representing on the order of 105 years) in the proportion and thickness of thick sandstone bodies, and tens-of-m-scale alternations of thick sandstone bodies and mudstone-sandstone strata that represent on the order of 104 years. Formation-scale stratal variations extend across the Potwar plateau for at least 100 km, although they may be diachronous: however, 100m and smaller scale variations can only be traced laterally for up to tens of milometers.

Alluvial architecture models indicate that increases in the proportion and thickness of thick 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-m-scale variations in thick sandstone-body proportion and thickness could result from regional shifts in the position of major channels, possibly associated with fan-lobes on a single megafan or with separate megafans. However, such variations could also be related to local changes in subsidence rate or changes in sediment supply to the megafan system.

Formation-scale and 100-m-scale stratal variations are probably associated with interelated changes in tectonic uplift, sediment supply and basin subsidence. Increased rates of hinterland uplift, sediment supply and basin subsidence, recorded by the Nagri Formation, may have resulted in diversion of a relatively large river to the area. Alternatively, changing river sizes and sediment supply rates may be related to climate changes affecting the hinterland (possibly related to tectonic uplift). Climate during deposition of the Siwalik Group was monsoonal. Although the Siwalik sequence contains no direct evidence for climate change, independent evidence indicates global cooling throughout the Miocene, and the possibility of glacial periods (e.g. 10.8 Ma, corresponding to the base of the Nagri Formation). If the Himalayas were periodically glaciated, a mechanism would exist for varying sediment supply to megafans on time scales of 104 105 years. Although eustatic sea-level variations are related to global climatic changes, they are not directly related to Siwalik stratigraphic changes, because the shoreline was around 1000 kilometers away during Miocene.

Key words: Fluvial system, sedimentation, molasse, Siwaliks.

K/180. Khan, I.A., 2000a. Controls on variation in sedimentation rates of fluvial facies. Abstracts, 31st International Geological Congress, Rio de Janero.

For further information, consult the preceding account.

Key words: Sedimentation, fluvial facies.

K/181. Khan, I.A., 2000b. Fluvial facies complexities in Himalayan foreland basin. Abstracts, Third South Asia Geological Congress, Lahore, 33-35.

Detailed sedimentological variations documented through the Siwalik Group (Chinji, Nagri, Dhok Pathan and Soan formations) in northwestern Himalayan Foreland Basin reveal that kilometer-scale thick depositional succession is comprised of two 100 m-scale coarsening upwards megasequences. The lower megasequence (Chinji and Nagri formations, Ca 14-9 Ma) records coarsening upwards from fine to medium grained sandstones, followed by basin-wide abrupt fining at the base of the upper megasequence Dhok Pathan and Soan formations Ca 9-2 Ma). Upward coarsening is associated with increases in clast, thickness, lateral extent and proportion of channel sandstone bodies. The highest proportion of major channel-sandstone bodies (upper Nagri Formation) is associated with relatively thick, laterally extensive and intercohected channel-sandstone bodies, which have relatively thicker and vertically superimposed sandstone storeys. Sandstone bodies represent single or superimposed braided-channel belts, and storeys represent channel bars and fills. Channel belts had widths of km, bankful discharges on the order of lo3 cusecs and braiding parametres up to about 3. Individual channel segments had bankful widths, maximum depths and slopes on the order of 102rn, 10'm and lo4 respectively, and sinuosities around 1 .l. Overbank sandstone bodies have lenticular, sheet and channel filling geometries and are interpreted as deposits of floodplain drainage channels. Mudstone sequences consist predominantly of finely laminated to disrupted/bioturbated siltstones which show evidence of prolonged pedogenesis. These "mature" paleosols are meter-scale thick and extend laterally for kilometres. Lateral and vertical variations in the nature of their horizons depend upon sedimentation rate.

Compacted deposition rates decrease with sandstone proportion (0.53 m/year for Nagri, 0.24 mdyear for Dhok Pathan and 0.21 mdyear for Soan), and paleosols are not as well developed where deposition rates are high. Within the Siwalik formations, there are 100 m-scale variations (representing on the order of lo5 years) in the proportion and thickness of thick sandstone bodies and mudstone-sandstone strata that represent on the order of lo4 years. Formation-scale stratal variations extend across the Potwar plateau for at least 100 km, although they may be diachronous; however, 100 m and smaller scale variations can only be traced laterally for up to tens of kilometres.

Quantitative and qualitative interpretations of the Siwalik depositional environments modeled through: 1) comparison of the sedimentological characteristics of the strata with computer simulated paleochannels and floodplains; 2) sedimentological correlations between time-equivalent rocks; 3) 3-D alluvial stratigraphy models; reveal that upward coarsening (upper Nagri Formation) is associated with a regional increase in alluvial slope, possibly due to progradation of large alluvial fan. A high proportion of sandstone bodies in the Nagri Formation

might be related to increasing number of channels in the area, either simultaneously or due to frequent channel avulsions (diversions). Increasing avulsion frequency into an area might be related to preferred tectonic subsidence, intrabasinal faulting (subsurface controls) and/or increased channel-belt deposition rates, possibly, related to preferred basin-scale progradation of alluvial fans to the South and southeast due to orogenic episodes in the orogenic belts. Formation-scale and 100 m-scale stratal variations are probably associated with interrelated changes in tectonic uplift, sediment supply and basin subsidence. Climate during deposition of the Siwalik Group was monsoonal. Although the Siwalik sequence contains no direct evidence for climate change, independent evidence indicates global cooling throughout the Miocene, and the possibility of glacial periods. If the Himalayas were periodically glaciated, a mechanism would exist for varying sediment supply to megafans on time scales of lo4 to 10' years. Although eustatic sea-level variations are related to global climatic changes, they are not directly related to Siwalik stratigraphic changes, because the shoreline was around 1000 kilometres away during Miocene; however, basin-wide trends in increase in sedimentation rate, grain size, proportion of sandstone bodies and changes in composition of sandstones are coeval with a major eustatic fall of the sea-level (Chinji-Nagri formations boundary) and subsequent rise (Nagri-Dhok Pathan formations boundary).
Key words: Sedimentation, fluvial facies, Siwaliks.

K/182. Khan, I.A., Bridge, J.S., Kappelman, J. & Wilson, R., 1997. Evolution of Miocene fluvial environments, eastern Potwar Plateau, northern Pakistan. Sedimentology 44, 221-251.

The Miocene-Pliocene Siwalik Group records changing fluvial environments in the Himalayan foreland basin. The Nagri and Dhok Pathan Formations of this Group in the eastern Potwar Plateau, northern Pakistan, comprise relatively thick (tens of metres) sandstone bodies and mudstones that contain thinner sandstone bodies (metres thick) and palaeosols. Thick sandstone bodies extend for kilometres normal to palaeoflow, and are composed of large-scale stratasets (storeys) stacked laterally and vertically adjacent to each other. Sandstone bodies represent single or superimposed braided-channel belts, and large-scale stratasets represent channel bars and fills. Channel belts had widths of km, bankfull discharges on the order of 103 cumecs and braiding parameter up to about 3. Individual channel segments had bankfull widths, maximum depths, and slopes on the order of 102 m, 101 m and 10−4 respectively, and sinuosities around 1-1. 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 and floodplain channels. Mudstones are relatively bioturbated/disrupted and represent mainly floodbasin and lacustrine deposition. Mudstones and sandstones are extremely disrupted in places, showing evidence of prolonged pedogenesis. These ‘mature’ palaeosols are m thick and extend laterally for km. Lateral and vertical variations in the nature of their horizons apparently depend mainly on deposition rate.

The 500 m-thick Nagri Formation has a greater proportion and thicker sandstone bodies than the overlying 700 m-thick Dhok Pathan Formation. The thick sandstone bodies and their large-scale stratasets thicken and coarsen through the Nagri Formation, then thin and fine at the base of the Dhok Pathan Formation. Compacted deposition rates increase with sandstone proportion (0-53 mm/year for Nagri, 0-24 mm/year for Dhok Pathan), and palaeosols are not as well developed where deposition rates are high. Within both formations there are 100 m-scale variations (representing on the order of 105 years) in the proportion and thickness of thick sandstone bodies, and tens-of-m-scale alternations of thick sandstone bodies and mudstone-sandstone strata that represent on the order of 104 years. Formation-scale stratal variations extend across the Potwar Plateau for at least 100 km, although they may be diachronous: however, 100-m and smaller scale variations can only be traced laterally for up to tens of km.

Alluvial architecture models indicate that increases in the proportion and thickness of thick 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-m-scale variations in thick sandstone-body proportion and thickness could result from ‘regional’ shifts in the position of major channels, possibly associated with ‘fan lobes’ on a single megafan or with separate megafans. However, such variations could also be related to local changes in subsidence rate or changes in sediment supply to the megafan system.

Formation-scale and 100-m-scale stratal variations are probably associated with interelated changes in tectonic uplift, sediment supply and basin subsidence. Increased rates of hinterland uplift, sediment supply and basin subsidence, recorded by the Nagri Formation, may have resulted in diversion of a relatively large river to the area. Alternatively, changing river sizes and sediment supply rates may be related to climate changes affecting the hinterland (possibly linked to tectonic uplift). Climate during deposition of the Siwalik Group was monsoonal. Although the deposits contain no *direct* evidence for climate change, 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). If the higher Himalayas were periodically glaciated, a mechanism would exist for varying sediment supply to megafans on time scales of 104-105 years. Although eustatic sea-level changes are related to global climatic change, they are not directly related to Siwalik stratigraphic changes, because the shoreline was many 100 km away during the Miocene.
Key words: Fluvial environments, Miocene, siwaliks, Potwar Plateau.

K/183. Khan, I.A. & Dennell, R.W., 1999. Sedimentological context of Plio-Pleistocene vertebrate assemblages in Pabbi Hills, Pakistan. Abstracts, IGCP 421, North Gondwanan mid-Palaeozoic Bioevent/Biogeography Pattern in Relation to Crustal Dynamics, Peshawar Meeting, 14-16.

Key words: Sedimentology, Plio-Pleistocene, vertebrates, siwaliks, Pabbi Hills.

K/184. Khan, I.A., Raza, S.M. & Shah, S.M.I., 1995. Tectonic control on Neogene alluvial architecture in Himalayan foreland basin. Abstracts, International Symposium on Himalayan Suture Zone of Pakistan. Pakistan Museum of Natural History, Islamabad, 19-21.

A detailed sedimentological variation through the Neogene Siwalik group is given in this account. This include Chinji, Nagri, Dhok Pathan and Soan formations. Two major coarsening upward sequences at 100 m scale are described.
Key words: Neogene, Foreland basin, siwaliks, Himalaya.

K/185. Khan, I.A. & Shah, S.M.I., 1997. Evolution of Miocene fluvial environments, eastern Potwar Plateau, northern Pakistan. Abstracts, 3rd GEOSAS Workshop on Siwaliks of South Asia, Islamabad. Geological Survey of Pakistan, Records 109, 27-28.

The Miocene-Pliocene Siwalik Group records changing fluvial environments in the Himalayan foreland basin. The Nagri and Dhok Pathan Formations of this Group in the eastern Potwar Plateau, northern Pakistan, comprise relatively thick (tens of in) sandstone bodies and mudstones that contain thinner sandstone bodies (m thick) and paleosols. Thick sandstone bodies extend for km normal to paleoflow, and are composed of large-scale stratasets (storeys) stacked laterally and vertically adjacent to eachother. Sandstone bodies represent single or superimposed braided-channel belts, and large-scale stratasets represent channel bars and fills. Channel belts had width of km, bankfull discharges on the order of l03 cumecs and braiding parameter up to about 3. Individual channel segments had bankfull widths, maximum depths and slopes on the order of 102 m, 101 m and 104 respectively, and sinuosites around 1.1. 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 and floodplain channels. Mudstones are more-or-less bioturbated/disrupted and represent mainly floodbasin and lacustrine deposition. Mudstones and sandstones are extremely disrupted in places, showing evidence of prolonged pedogenesis. These ‘mature’ paleosols are meters thick and extend laterally for km. Lateral and vertical variations in the nature of their horizons apparently depend mainly on deposition rate.
The 500 m-thick Nagri Formation has a greater proportion and thicker sandstone bodies than the overlying 700 m-thick Dhok Pathan Formation. The thick sandstone bodies and their large-scale stratasets thicken and coarsen through the Nagri Formation, then thin and fine at the base of the Dhok Pathan Formation. Compacted deposition rates increase with sandstone proportion (0.53 mm/yr for Nagri, 0.24 mm/yr for Dhok Pathan), and paleosols are not as well developed where deposition rates are high. Within both formations there are 100 m-scale variations (representing on the order of l05 years) in the proportion and thickness of thick sandstone bodies, and tens-of-m-scale alternations of thick sandstone bodies and mudstone-sandstone strata that represent on the order of l04 years. Formation-scale stratal variations extend across the Potwar Plateau for at least 100 kin, although they may be diachironous: however, 100-m and smaller scale variations can only be traced laterally for up to tens of km.
Alluvial architecture models indicate that increases in the proportion and thickness of thick 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-m-scale variations in thick sandstone-body proportion and thickness could result from 'regional' shifts in the position of major channels, possibly associated with 'fan lobes' on a single mega fan or with separate mega fans. However, such variations could also be related to local changes in subsidence rate or changes in sediment supply to the megafan system.
Formation-scale and 100-m-scale stratal variations are probably associated with interelated changes in tectonic uplift, sediment supply and basin subsidence. Increased rates of hinterland uplift, sediment supply and basin subsidence, recorded by the Nagri Formation, may have resulted in diversion of a relatively large river to the area. Alternatively, changing river sizes and sediment supply rates may be related to climate changes affecting the hinterland (possibly linked to tectonic uplift). Climate during deposition of the Siwalik Group was monsoonal. Although the deposits contain no direct evidence for climate change, independent evident indicates global cooling throughout the Miocene, and the possibility of glacial periods (e.g. around 10.8 Ma, corresponding to base of Nagri Formation). If the higher Himalayas were periodically glaciated, a mechanism would exist for varying sediment supply to megafans on time scales of l04 - l05 years. Although eustatic sea-level changes are related to global climatic change, they are not directly related to Siwalik stratigraphic changes, because the shoreline was many 100 km away during the Miocene.
Key words: Miocene, Foreland basin, Himalaya.

K/186. Khan, I.A., Zaleha, M.J. & Bridge, J.S., 1993. Evalution of Miocene fluvial environments in northern Pakistan. Abstracts, 5th International Conference on Fluvial Sedimentology, Queensland, p.271.

Key words: Miocene, fluvial environments, siwaliks, Potwar Plateau.

K/187. Khan, I.H., Khan, S.R., Kawai, M. & Suzuki, M., 1991. Discovery of scheelite mineralization in Mansehra area, N.W.F.P., Pakistan. Geological Survey of Pakistan, Information Release, 481, 15p.

Key words: Gold mineralization, scheelite, Mansehra.

K/188. Khan, I.H., Khan, S.R. & Nakagawa, M., 1995. Occurrence of platinum-group mineral in sulfide ore from Jijal complex, northern Pakistan. Proceedings of Geoscience Colloquium, Geoscience Lab, Geological Survey of Pakistan, Islamabad 12, 5-21.

The study for platinum-group minerals (PGM) was carried out as a part of training for the exploration of these in Jijal and Dargai areas which included the geochemical sampling by stream sediment panning and rock chip media in the areas already proved anomalous in the previous surveys. The ore microscopy and microprobe analyses were conducted for the identification of PGM. The EPMA work included extensive high-speed qualitative analysis of the panned concentrates and the polished rock samples. The sample JO-2 revealed a strange PGM composition in qualitative analysis with Pt, Pd. Te, Fe. S. & Ni elements in it. The PGM was mapped by H-111 system for four elements (Pd, Te. Fe and S) for homogeneity check and the center of the mineral was analyzed by quantitative method.
The PG mineral discovered after this analytical work is the merenskyite-(Pt. Pd)Te, which is first time dimvmd with the host rock other than Sudbuny deposit i.e. primary-type, massive sulfide vein in ultramafics of the Jijal complex. The significance of this discovery is towards the further work for the exploration of PGE deposits in Jijal area. The discovery and association of merenskyite (PGM) is described through this report.
Key words: PGE, sulfide ore, Jijal, Himalaya.

K/189. Khan, I.H., Leghari, A., Khan, L., Khan, F. & Mujtaba, G., 1989. Geology and mineral investigation of Naltar Punial area, Gilgit district, Northern Areas, Pakistan. Geological Survey of Pakistan, Information Release 405, 13p.

Key words: Geology, structure, mineral resources, Gilgit.

K/190. Khan, I.H., Mahmood, F., Naeem, M. & Mohammad, W., 1994. Processing of emerald bearing rocks of Gujar Kili emerald mine by washing and screening. Pakistan Journal of Scientific and Industrial Research 37(4), 167-00.

The recovery process of talc and emeralds, contained in the emerald bearing altered talcose schists of Gujar Killi were found to be feasible at the bench and pilot plant scale. The various units required for the washing and screening plant were tested. A detailed investigation of size analysis of the head and ground samples, liberation and association of emerald/gangue particles, pulp density, product size analysis and optimization of grinding were undertaken. A tentative block diagram was developed as a result of laboratory tests. The study conducted for the Gem Stone Corporation of Pakistan is encouraging and can be applied to the mechanical recovery of talc and emerald in the Gujar Killi emerald mine.
Key words: Emerald, talc beneficiation, Swat.

K/191. Khan, I.H. & Qazi, M.A., 1983. Mineralogy, chemistry and beneficiation of adit samples of nepheline syenite. 2nd Seminar on Development on Mineral Resources, Peshawar 3, 9p.

Key words: Mineralogy, chemistry, beneficiation, nephline syenite, Buner.

K/192. Khan, I.H., Qazi, M.A. & Rauf, A., 1984. Mineralogical studies of Kumhar magnesite and dolomite using XRD and DTA data. Abstracts, First Geological Congress, Lahore, 39-40.

Key words: Mineralogy, magnesite, dolomite, XRD, DTA, Hazara.

K/193. Khan, I.H. & Yoshida, M., 1995. EPMA and mineral magnetic analyses of Paleocene oolitic iron stone, Hazara area, northern Pakistan. In: Khadim, I.M. & Yoshida, M. (eds.), Rock Magnetism and Paleomagnetism. Recent Progress in Pakistan, Proceedings of Geoscience Colloquium, Geoscience Lab, Geological Survey of Pakistan, Islamabad, 13, 81-98.

For more information, consult the following account.
Key words: EPMA, mineralogy, Paleocene, iron ore, Hazara.

K/194. Khan, I.H. & Yoshida, M., 2000. Mineral magnetic and EPMA analyses of oolitic ironstone, Hazara area, North Pakistan. Abstracts, Third South Asia Geological Congress, Lahore, 35-36.

The oolitic ironstone, known as the Langrial ore (Khan and Ahmed, 1966) Laterite bed (Latif, 1969) underlying the Paleocene Lockhart Limestone as an unconfomity, is distributed widely in Hazara, Kalachita and other areas. This ironstone is investigated by mineral magnetic analyses, mineralogy by XRD and mineral chemistry by EPMA (Electron Probe Micro-Analyzer). Yoshida carried out field sampling in Southern Hazara and mineral magnetic studies. The selected sample collected near Bagnotar village was investigated in detail for mineralogy and chemistry. Two mineral magnetic analysis techniques: TM (therrnomagnetic) and IRM (isothermal remnant magnetization) were used to identify the magnetic minerals. The Curie temperatures by TM indicated the presence of goethite, Ti-poor titanomagnetite or magnetite and hematite. Two IRM has shown the presence of high coercive ferromagnetic minerals, hematite/goethite with trace amounts of maghemite or magnetite.
The XRD analyses showed the presence of chamosite, hematite, quartz, goethite and siderite for untreated specimen whereas in heated specimen hematite quartz and little smectite were identified. The exact distribution of these minerals was checked by 6-elements (Ca, Al, Fe, Si, Ti and Mg) for corresponding Ka X-rays mapping using EPMA. On the basis of relative intensity of these, the oolites are classified into three types i) A-type mainly goethite - hematite - titanomagnetite and siderite ooides with very low charnosite, ii) B-type-considered chamosite- hematite-goethite ooides and iii) C-type with high Si-content and negligible other elements; the matrix of this oolite is

composed of chamosite, siderite, calcite and quartz. The first two are considered primary and later as secondary type- These studies revealed that formation of these oolite has passed from wide range of conditions (oxic to anoxic, non-sulphidic methane type) as drowning to starvation conditions existed during deposition in the southern hemisphere close to 10' South. The matrix minerals are mainly of secondary origin.
Key words: EPMA, mineralogy, Paleocene, iron ore, Hazara.

K/195. Khan, I.U., 1990-91. The geology, stratigraphy, sedimentation and micropaleontology of Jabri area District Haripur Hazara (NWFP), Pakistan. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 106p.

The project area is located in district Haripur (N.W.F.P). It covers about 60 sq. km. It is the part of topographic sheet No.43 G/1 published by Survey of Pakistan at the scale of 1: 50000.
Geological map at the scale 1:12500 of Jabri, Akhora, Faqir Muhammad, Lassan and Dunna Naurl area is presented along with complete record of Pre-Cambrian to Eocene rock units especially, Hazara Formation, Samana Suk Formation, Chichali formation, Lumshiwal Sandstone, Kawagarh Limestone, Margala Hill Limestone, Chorgali Formation, exposed in the area.
On the basis of field observations and petrographic studies the depositional environments of rock units have been interpreted. The formations exhibit varying fauna and lithology and microfacies from bottom to top.
Basal unit i.e. Hazara Formation which is predominantly slates and Samana Suk Formation which is mainly oolitic Limestone and shows shallow marine environment. The Chichali Formation which is dominantly Black slates with Iron Pyrite nodules, is the result of anaerobic conditions (lagoona1 environments) Glauconitic and ferrogenous Sandstone of Lumshiwal Formation shows open marine shelf environment. Kawagarh Formation posses mainly, fine grained micritic Limestone, which show deep sea environment. Hangu Formation having laterite Bauxite, limonite, quartzite, red clays, Oolitic Haematitic sandstone and Carbonaceous shales which represent facies change and shows that the area was eroded during that lime of deposition and marks unconformity between Cretaceous to lower Paleocene which is the result of regression of the sea for long period.
Lockhart Limestone is mainly nodular, Limestone, medium to find grained with bituminous smell having shales and marl at various places which shows shallow marine environment. Patala Formation having Khaki shales with fossiliferous Limestone and marl which shows that the environment is shallow marine (Circa litoral sub zone).
Key words: Stratigraphy, sedimentation, palaeontology, Haripur.

K/196. Khan, I.U. & Said, M., 1997. Study of landforms: Techniques and Methodology. A study in stratigraphy south of River Kabul, Peshawar vale. Abstracts, 9th All Pakistan Geographic Conference, Islamabad, p.15.

Key words: Stratigraphy, sedimentation, landforms, Kabul River, Peshawar.

K/197. Khan, J., 1972. Geology of Baraul valley, Dir District. M.Sc. Thesis, University of Peshawar, 42p.

Consult the following account for details.
Key words: Paleocene-Eocene, volcanics, metasedimentary rocks, Dir.

K/198. Khan, J., 1979. Geology of the Baraul valley, Dir. Geological Bulletin, University of Peshawar 11, 153-162.

Over 520 sq. km of the Baraul Valley has been investigated geologically and mapped on 1:63, 360 scale. Quartzites are the oldest rocks, exposed in the eastern part of the valley, and overlain by the mixed series of Paleocene-Eocene age which covers the central part of the area. The series includes interbedded volcanics (andesite, dacite, rhyolite, tuff and agglomerates) and metasedimentary/sedimentary rocks (pelitic, calcareous and arenaceous) intruded by small post-Eocene dioritic rocks. A large part of the valley, in the north as well as the south, occupied by (?) Creto-

Eocene diorites, quartz diorites, granodiorites and leucodiorites. The northern contact between the diorites and the mixed series is probably faulted.
Key words: Paleocene-Eocene, volcanics, metasedimentary rocks, Baraul, Dir.

K/199. Khan, J.A., 1981. Geology and petrology of southern Dir with special emphasis on Diorites of the area. M.Sc. Thesis, Punjab University, Lahore.

Key words: Petrology, diorite, Dir.

K/200. Khan, J.A., 1997. Impact of Lahore-Islamabad Motorway on natural and human environment. Abstracts, 9th All Pakistan Geographic Conference, Islamabad, 25-26.

Key words: Environment, motorway.

K/201. Khan, K., 1987. Physiography of Pakistan. In: Shams, F.A., Khan, K. & Mrs. Khalida (eds.), Resources Potential of Mountain Regions of Pakistan, Punjab University, Lahore, 1-7.

Kew words: Physiography, Pakistan.

K/202. Khan, K., 1995. Mass erosion in the Central Karakorum Range, northern Pakistan. In: Stellrecht, I. (ed.), Pak-German Workshop on Problems of Comparative High Mountain Research with Regard to the Karakorum, Tubingen, October 12-14, 1992. Tubingen (Culture Area Karakorum, Occasional Papers 2), 44-49.

Key words: Erosion, Karakoram.

K/203. Khan, K. & Ali, T., 1990. Hydrometallurgical method for the recovery of molybdenum from molybdenite ore of Kohistan. Abstracts, First SEGMITE Conference on Industrial Minerals, Peshawar, p.9.

Key words: Molybdenite, ore, beneficiation, Kohistan.

K/204. Khan, K., Mumtaz & Amin, M., 1990. Recovery and separation of lead zinc by acid leaching from Kohistan-Hazara ore. In: Siddiqi, F., Husain, V., Kaifi, Z. & Ghani, A. (eds.), Proceedings, First SEGMITE Conference on Industrial Minerals, March 1990, Peshawar, 92-95.

Different mineral acids were used for the leaching of the Pb-Zn ores. Bench-scale parameters, i.e., effect of acid concentration, temperature and leaching time ere set up. The results obtained were encouraging and about 90% separation as well as recovery of lead-zinc was obtained.
Key words: Acid leaching, Pb-Zn deposits, Kohistan.

K/205. Khan, K.S.A., 1980. Pattan Earthquake of December 28, 1974 and reconstruction programme in the effected areas of Swat, Hazara and Kohistan Districts. Geological Survey of Pakistan, Record 47, 35p.

Geological studies were carried out during the field seasons of 1974-76 in Pattan and other areas of Swat and Hazara Kohistan region, Northwest Frontier Province which have been seriously affected by an earthquake of mode rate intensity on 28th December 1974. The earthquake completely' destroyed the towns of Pattan, Jijal and Dubair and caused large scale destruction in the area. The investigations were aimed at selection of safe and suitable sites for the

construction of model colonies in the region, study of various road alignments to connect the interior regions with the main Karakoram Highway and to examine the suitability of various bridge sites along these roads.
The rock types exposed in the area are Palaeozoic schists, marbles and quartzites, late Cretaceous amphibolites, gabbros, diorites, and early to middle Tertiary granitic rocks and serpentinites. The age of garnet gneiss exposed at Pattan is unknown. From engineering geology point of view, the rocks are heterogenous in texture and composition, and behave ..differently under different atmospheric and ground conditions. The sites for the construction of townships at Pattan and Besham were select4 after a study of the topography, accessibility, availability of space, earthquake intensity and rock and soil conditions of the area.
Road alignment were studies keeping in view landslide problems and slope stability. Rock and soil conditions guided designing of slope. However, as a general rule the ratio of cuts for slopes at 1 horizontal : 3 vertical to 1 horizontal : 4 vertical were recommended in medium hard to hard rocks and 1 horizontal : 5 vertical in very hard rocks. Gentler slopes were recommended in unconsolidated deposits and weak strata. Benches may be provided at each 8 metre interval. The study of bridge sites over the river Indus at Pattan and Besham require detailed surface and sub-surface investigations.
Key words: Earthquake, Pattan, Swat, Kohistan.

K/206. Khan, K.S.A., 1992. Landslide problems and their control along the Karakoram Highway, Northern Areas, Pakistan. Abstracts, First South Asia Geological Congress, Islamabad, p.19.

Key words: Landslides, KKH, Northern Areas..

K/207. Khan, K.S.A., Babar, M.Z., Khan, I.H. & Shakoor, T., 1986. Landslide investigation at the site of Cereal Diseases Research Institute, Pakistan Agriculture Research Centre, Murree. Geological Survey of Pakistan, Information Release 271.

The C.D.R.I. building in faced with the problem of subsidence and development of cracks in the building compound. The cracks have enlarged in magnitude with the passage of time giving rise to small slip circles on the north and northeast slopes. The Murree Formation, consisting of shale and sandstone, is exposed in the area. It is underlain by thick overburden material forming steep slopes.
The initiation and enlargement of the slide is attributed to the excessive infiltration of rain and snow-melt-water, the lithological characteristics of the sediments and the environmental changes in the natural slopes of the area. Based on the site conditions restraining structures such as retaining and crib walls, spur and catch-water drains are recommended to effectively control the problem of slumping and subsidence.
Key words: Landslides, Murree.

K/208. Khan, K.S.A. & Fayaz, A., 1987. Geological appraisal of malam Jabba Ski-Lift and tourists resort site swat, Pakistan. Geological Survey of Pakistan, Information Release 281, 14p.

A geological reconnaissance of the Malam Jabba Tourists Resort site in Swat was carried out in August, 1985 to evaluate the stability of slopes and foundation conditions at various tower positions of the skilift.
The area is underlain by mica and graphitic schists with thick accumulation of overburden material consisting of soil and humus. The bedrock at most of the tower positions is deep and beyond the foundation depth of the towers. The rocks are fractured and highly weathered. The foundations of the towers are designed at a bearing capacity of 1.0 Kg/C m2. However, the foundation conditions may be improved by filling of fractures by grouting. The stability of slopes may also be improved by construction of retaining walls and catch-water drains.
Key words: Reconnaissance, mica, graphite schists, Malam Jabba, Swat.

K/209. Khan, K.S.A., Fayaz, A., Hussain, S.H. & Latif, M., 2001. Landslides and their control along the Karakoram Highway (Gilgit to Khunjerab Pass) Vol. I, Geological Survey Pakistan. Special Publication.

Key words: Landslides, KKH, Khunjerab.

K/210. Khan, K.S.A., Fayaz, A. & Khan, I.H., 1988. Construction of gravity irrigation system for Northang Maidan on Indus River, Skardu, Baltistan. Geological Survey of Pakistan, Information Release 365.

Key words: Gravity irrigation, Indus River, Skardu.

K/211. Khan, K.S.A., Fayaz, A. & Latif, M., 1988a. Road alignment studies along Rakhiot-Astor road, District Diamir, Northern Areas, Pakistan. Geological Survey of Pakistan, Information Release 378, 37p.

On the request of Frontier Works Organization (FWO), road alignment studies were carried out by the Geological Survey of Pakistan along the Rakhiot-Astor Road in 1974 which was followed by detailed geological investigations in 1989. The investigations comprised identification of landslide prone areas and measures for their control and correction, application of slope stabilization techniques and foundation studies for bridge sites. The road passes over a variety of rock and soil material, comprising igneous and metamorphic rocks, loose glasio-fluvial deposits and scree all along its length.
These rock and scree deposits are lying at their critical angle of repose and prone to sliding. Depending upon their angle of repose, stable cutslopes have been proposed. The road crosses three major landslide areas namely Lichar, Shah Pul and Mushkin which need special treatment. Methods for their control and stabilization have been proposed. The road also passes over a number of nullahs which have steep banks and deep channels and need construction of permanent bridges. The foundation conditions for the proposed bridge sites have been studies in detail and recommendations made according to the geological conditions prevailing at each site.
Key words: Road engineering, Raikot, Astor, Nanga Parbat, Diamir.

K/212. Khan, K.S.A., Fayaz, A., Latif, M. & Khan, M.S.Z., 1987. Study of landslide problem along the Rawalpindi–Murree–Kohala Road, (Kashmir Highway). Geological Survey of Pakistan, Information Release 279, 36p.

Landslide Investigations were carried out along the Rawalpindi-Murree-Kohala Road (Kashmir Highway) during the field season of 1984-85 on the request of Highways and Forest Departments, Government of the Punjab. Kashmir Highway **is** an all-weather road and links the Punjab with Azad Kashmir. Landslide activity often blocks the road and hinders the flow of traffic, particularly in the rainy season. The geotechnical problems of the area were thoroughly investigated and classified according to their mode of origin such as landslides, mudflows and bridge abutment problem.
In all, 14 slides have been studied and discussed in this report, Study of slides includes type of rock/material involved in the affected area, reasons of its occurrance and remedial measures to check them. The Koha-la landslide has been studied in detail owing to its critical nature as well as its repeated occurrences involving large amount of falling material and road block. Proper execution and proposed implementation of the recommendations may help a great deal in prompting the stability of the Kashmir Highway.
Key words: Road engineering, landslides, Kashmir highway.

K/213. Khan, K.S.A., Fayaz, A., Latif, M. & Khan, M.S.Z., 1988. Development of cracks in village Danser, Kharmang sub-division, Baltistan. Geological Survey Pakistan. Information Release 276, 14p.

The village of Danser, Kharmang Sub-Division, district Baltistan was badly affected by sliding and slumping during the winter of 1985. The sliding caused heavy damage to the land and property of the people and is still in the process of further enlargement in its area of effectiveness.
Diorite rocks constitute the northern side of the Danser village whereas thick alluvial silt, gravel, and talus compose the southern terrane.

The large scale sliding could be due to the underground caving of terraces as a result of sub-surface flow and channelization of the stream from the Shaheen nulah on the eastern side of the village terraces. The effect of caving accentuates because of the infiltration of surface water from the irrigation “Kouhle” constructed at the contact of loose and porous overburden material and the diorite rock basement.
In view of the active nature of the slide and possibility of its further enlargement, the local people should be evacuated and rehabilitated in safe areas. However, the sliding may partially be controlled by constructing a dyke at the nullah bed level and diverting the flow of Shaheen nullah at its point of entrance under the village terrace. The infiltration from the irrigation “Kouhl” can easily be checked by cementing and lining of the drain.
Key words: Landslides, hazards, cracks, Baltistan.

K/214. Khan, K.S.A., Fayaz, A., Latif, M. & Khan, N.A., 1998. Engineering geological suggestions for improvements of road links in and around Chilas district Diamir, Northern Areas, Pakistan. Geological Survey of Pakistan, Information Release 673, 36p.

Geological investigations were carried out along various side-valley roads in the Diamir district in 1996. These investigations were aimed at improving the present road conditions in relation to their gradient, slope stabilization, bridge locations and excavation problems to be encountered during widening of these roads.
The following road sections were studied ill detail:
I. Chilas-Babusar Pass Road.
2. Nihat Gah Valley Road.
3. Chilas-Buto Gah Road
4. Kiner Gah Valley Road
5. KKH-Gini Gah Road.
The rocks and soils exposed along these roads comprise igneous and metamorphic rocks of vario us types, glacio-fill vial deposits, and unconsolidated materials consisting of boulders gravels and scree. These deposits lie at their critical angle of repose and prone to sliding frequently. The slopes are unstable, road gradients are usually steep and curvatures are difficult to negotiate. All these problems were studied ill detail and remedial measures have been suggested for their improvement and stabilization as the case may be.
Key words: Engineering geology, Chilas.

K/215. Khan, K.S.A., Fayaz, A., Latif, M. & Wazir, A.K., 1986. Rock and debris slides between Khunjerab pass and Gilgit along the Karakoram Highway. Geological Survey of Pakistan, Information Release 272, 56p.

Rock, debris and scree slides from Gilgit to Khunjerab pass along the Karakoram Highway (KKH) are discussed in this report. Study of slides include type of rock/material involved in the affected area, reason of their occurrences and remedial measures to check the mass movement phenomenon. Kafir Pahar slide zone, Notorious killing zone and Shita Pari slide are studies in detail due to their critical position on the KKH; and the magnitude and repeated occurrences involving large amount of material fall. Specific recommendations for the stabilization of slopes have been proposed for each of the affected areas.
Continous maintenance of the KKh requires considerable efforts in terms of time and money. Proper execution and implementation of the recommendations proposed in this report may help a great deal in reducing the manpower and maintenance cost of the KKH.
Key words: Debris slide, Karakoram Highway, Khunjerab Pass, Gilgit, Hunza.

K/216. Khan, K.S.A., Khan, I.H., Leghari, A.L. & Khan, M.S.Z., 1987. Geology along the Karakoram Highway from Hasanabdal to Khunjerab Pass. Geological Survey of Pakistan, Information Release 314, 46p.

Additional information may be seen under the entry KSA Khan et al. (2000b).
Key words: Geology, KKH, Hassanabdal, Khunjerab.

K/217. Khan, K.S.A., Latif, M., Akhtar, J. & Fayaz, A., 1990. River bed erosion problem in Hunza, Ishkuman and Yasin River valleys, Gilgit and Ghizar districts, Northern Areas, Pakistan. Geological Survey Pakistan. Information Release 475, 96p.

Geological investigations for river bed erosion control were carried out during 1989 in Hunza, Ishkuman and Yasin River valleys in the Gilgit and Ghizar districts, Northern Areas Pakistan. The rocks exposed in these valleys comprise mostly metamorphic with small intrusions of igneous rocks and some outcrops of sedimentary rocks especially in the Yasin and Ishkuman valleys. The Hunza valley is characterized by two major Creto-Tertiary granitic belts alternated by metasedimentary rocks and a metavolcanic complex which are known as the Ladakh-Kohistan granitic belt and Karakoram granitic belt. Geomorphologically, these valleys are drained by the Hunza, Ishkoman and Yasin Rivers which are perennial streams and fed by glacial melt waters. These rivers have a general north-south flow direction and are in their youthful stage of development. A much greater length of these rivers are confined by high alluvial/colluvial terraces and valley fill, presumably created by tectonically induced incision during the late Quaternary age. Geomorphologically the main river channels of the area are divided into Straight/Gorge River Channel, Meander River Channel and Braided River channel.
Based on the river capture system and mechanism of meandering 28 plantation sites in the flood plain areas have been identified in Hunza, Ishhkuman and Yasin River valleys for channelising stream flow and reducing the large scale river bed erosion. These plantations may help in stabilising the river beds against erosion and add to the fuel, fodder and timber resources of the area in the future.
Key words: Riverbed erosion, Hunza, Ishkuman, Yasin, Gilgit.

K/218. Khan, K.S.A., Latif, M. & Fayaz, A., 1988. Reconnaissance geology along Kharmong valley road, District Baltistan, Geological Survey of Pakistan, Information Release 377.

Key words: Reconnaissance geology, Baltistan.

K/219. Khan, K.S.A., Latif, M. & Fayaz, A., 2000a. Site appraisal of the proposed Rawalpindi Medical College Campus and Hospital, Takht Pari Forest Land, Rawalpindi. Geological Survey of Pakistan, Information Release 713.

Key words: Engineering geology, Rawalpindi

K/220. Khan, K.S.A., Latif, M., Fayaz, A., Khan, N.A. & Khan, M.S.Z., 2000b. Geological road log along the Karakoram Highway from Islamabad to Khunjerab Pass. Geological Survey of Pakistan, Highways Geological Map Series 1.

This is a 1:250,000 scale geological map of the highway stretching for 875-km from Islamabad to Pak-China Boarder at Khunjerab. There are 25 plates (photographs), including three on the covers, showing various aspects of geology and geomorphology. Further data on geography, regional geology, mineral showings, and seismics risk is contained in seven inset maps and two tables.
Key words: Geomorphology, geology, KKH, Islamabad, Khunjerab.

K/221. Khan, K.S.A., Latif, M., Hussain, H. & Fayaz, A., 1999. Geomorphological mapping and engineering geological appraisal of the road links of Skardu-Shigar area, Northern Areas, Pakistan. Geological Survey of Pakistan, Information Release 693.

Engineering geology investigations for road alignment and geomorphological classification of land forms in the Skardu-Shigar quadrangle was carried out on 1:50,000 scale in 1993.
The Shigar Valley is one of the most picturesque areas in Baltisan and serves as a land route to the K-2, Concordia, Broad Peaks and other famous peaks in the region. The valley is traversed by two roads which run on each side of the Shigar River. These roads are jeepable tracks and pass through a variety of land forms which need slope

correction, improvement of gradients and tackling of engineering geological problems during construction and have been described in detail in the section-wise description of each road.
The rock types ranging in age from Cretaceous to Eocene are exposed in the investigated area and comprise Katzarah formation, Greenstone complex, Deosai Volcanics, and the Yasin Group rocks. The metasediment found in the area are slate, phyllite, schists, gneisses, marble and quartzite. The volcanic rocks are composed of basalt and andesite intersected by felsic and mafic dykes. The main Karakoram Thrust (MKT) is encountered in the vicinity of Tassar village in the upper reaches of Shigar Lungma. Geomorphologically, various types of erosional and depositional land forms are identified and these have been classified into fluvial, aeolian denudational and structural units. This classification may help a great deal in tackling the envisaged problems during construction of the road.
Key words: Geomorphology, geography, engineering geology, Skardu.

K/222. Khan, L.A. & Arif, A.H., 1968. Report on geohydrology investigation in Bannu Basin, West Pakistan. Bulletin 15, Water and Soil Investigation Department, Publication 56, WAPDA, Hydrogeology Directorate, North West Frontier Province, Peshawar.

Key words: Hydrology, geology, Bannu.

K/223. Khan, M., 1995. Engineering properties of some building stones from Peshawar plain, NWFP., Pakistan. M.Phil. Thesis, University of Peshawar, 64p.

Rock types including limestone, marbles, quartzite, granites and basic rocks already in use as building and decorative stones are exposed in the surrounding of Peshawar basin. To ensure their safest use in building and other structure, some important geotechnical properties such as compressive strength, tensile strength, compressive strength/tensile strength, durability, water absorption and specific gravity of the se rocks were carried out. Highest compressive strength values are shown by Misri Banda quartzite and are in the range of 12188 to 18179 PSI, whereas Malakand granite show lowest compressive strength values 4559 to 6422 PSI values. Tensile values are highest in Misri Banda quartzite and Tor Warsak marble. Whereas Tor Warsak marble, Bagh and Malakand granite have lowest tensile strength. Tarako marble and Shewa Shahbaz Garhi granite show highest compressive strength/ tensile strength ratio. All the geotechnical properties of these rocks are found to be within or very close to the recommended values of American Standards of Testing Materials (ASTM).
Key words: Geotechnical, limestone, marble, granite, Malakand, Misri banda, Peshawar basin.

K/224. Khan, M., Haider, S. & Ahmad, A., 1990. Investigation of comprehensive strength of some commonly found rocks of N.W.F.P. M.Sc. Thesis, University of Peshawar, 93.

Key words: Geotechnical investigation.

K/225. Khan, M., Riaz, M. & Khan, K., 1996. Extraction of alumina from Nepheline Syenite by sintering with limestone. Pakistan Journal Scientific and Industrial Research, 39, (1–4), 25–31.

Nepheline Syenite of Koga (Lower Swat Area) Pakistan was sintered at 125^{0}C with suitable quantity of limestone followed by water leaching for the formation of alkali abuminates which are further processed for the extraction of alumina. Parameters such as particle size variation, ratio of nepheline syenite and limestone, time temperature of sintering and sodium hydroxide concentration were optimized to obtained maximum recovery of alumina. The extraction of alumina on the basis of alumina in Nepheline syenite has been found to be about 70%. Such a process may be of vital importance to countries without ready access to supplies of alumina in the form of bauxite.
Key words: Alumina extraction, nephline syenite, Lower Swat.

K/226. Khan, M.A., 1968. The stratigraphic section on the southern slop of Handyside Fort, Kohat, West Pakistan. Geological Bulletin, University of Peshawar 3, 15-18.

The area of investigation, which lies on the southern slope of the Handyside Fort, is formed of formations of Upper Mesozoic and Cenozoic ages.
The formation of Upper Mesozoic ages are represented by Oolitic Limestone-Late Jurassic, Green Shale-lower Cretaceous, Sandy–shale and silt–stone Middle Cretaceous, and Limestone- Middle Cretaceous. The formations of Cenozoic age are represented by Nodular limestone–Palaeocene and Gritstone-Conglomerate-shale–Paleocene. Of all the formations, the Griststone,Conglomerate, and Shale represent deposition under fluviatile, fluvio-lacustine, and lacustrine conditions. The carbonate rocks (mainly limestone) account for more than three-fourth of the total thickness of the strata exposed in the area of investigation. The area is very much disturbed. Intense folding and faulting – which occurred during the Tertiary Era has complicated the stratigraphy and structure of the area.
Key words: Stratigraphy, lithology, Kohat Pass.

K/227. Khan, M.A., 1969. Siluro-Devonian reef complex of Ghundai Sar and vicinity, Jamrud, Khyber Agency. Geological Bulletin, University of Peshawar 4, 79-82.

A Siluro-Devonian ‘reef complex’, striking east-west, and dipping in a northward direction, is exposed to the north of Jamrud Fort along the Warsak Canal. The ‘reef complex’ forms the entire Ghundai Sar hills comprises four distinct units.
Gray and yellowish-gray dolomitized quartzite; Reef Breccia and talus; Reef Core; Phyllites and crinoidal limestone. Unit 2 and 3 represent the characteristics structural layers of reef.
Key words: Sedimentology, reef complex, Jamrud, Khyber Agency.

K/228. Khan, M.A., 1970. The Ali Masjid Group, Jamrud, Khyber Agency. Geological Bulletin, University of Peshawar 5, 90-95.

Of all the formations exposed in the north of Jamrud, the Ali Masjid Formation is the most diverse lithologically. A detailed work revealed that the so-called Ali-Masjid Formation contains many well-defined and stratigraphically valid formations. As such the Ali Masjid Formation is considered here as a group. Evidence for this conclusion consists of: The snowy white and grayish-white quartzites, which form the base of the group, are traceable over most of the Khyber Agency, Mulla Gori, and in Hazara. The Kandar Phyllite, a formation of considerable distribution, ranges in thickness from 600 to 900 feet. Both lithologically and paleontologically, it is distinguishable from the underlying and he overlying rocks. The Ghundai Sur Reef, already recognized as the Nowshera Formation (Siluro-Devonian), forms a part of the Ali Masjid Group.
The Quartzite conformably overlying the Nowshera and other reef carbonates and measuring about 600 feet in thickness is recognized as the Misri Banda Quartzite. The Warran Ghundai Formation, about 1200 feet thick, is both lithologically and palaeontologically different from other formations exposed in the area. It represents varieties of environment of deposition.
Key words: Stratigraphy, lithology, Khyber Agency.

K/229. Khan, M.A., 1979a. Petrography and sedimentology of the Ghundai Sar reef complex, Jamrud Khyber Agency: Pakistan. Geological Bulletin, University of Peshawar 12, 32-40.

A belt of Siluro-Devonian Coralline limestone of pink, yellowish-pink, and grayish-white color is exposed in the hills of Gundai Sar, near Jamrud; Khyber Agency. The entire formation represents deposition on a stable shelf. The environments were conducive for the development of coral reef. The ortho-quartzites associated with dolomite and limestone supports this observation.
In this paper, petrography and sedimentology of the reef limestone is discussed in detail. 101 specimens were collected and 30 sections were cut to describe the petrography. The limestone and dolomite show variations in their mineralogical composition. All variations from arenaceous limestone to calcareous ortho-quartzite occur.
Key words: Petrography, sedimentology, reef complex, Jamrud, Khyber Agency.

K/230. Khan, M.A., 1979b. Report on Lithostructural Mapping of the Paras area, Kaghan valley with special emphasis on structure. M.Sc. Thesis, Punjab University, Lahore, 153p.

Key words: Mapping, lithostructure, Kaghan valley.

K/231. Khan, M.A., 1985a. Geology of the Babusar-Thak valley, and its implications on the configuration of the Kohistan island arc sequence. Abstract Volume, 1st Himalayan Workshop, Department of Geology, University of Leicester.

Most of the stratigraphic and tectono-metamorphic zonation suggests for the Kohistan arc sequence is based on the geological information collected from the Indus- and Swat valleys, the two most accessible traverses across the Kohistan. The Babusar-Thak valley in the SE Kohistan presents an additional section through the southern half of the arc sequence. Unlike the central and western Kohistan, where the southern arc sequence is principally made of amphibolites (together with enclosed isolated zones of blueschist and bodies of ultramafics) and Chilas ultramafic-mafic complex, in the Babusar-Thak valley the sequence is much more varied. Here the sequence principally comprises a thick pile of low-grade metavolcanics and plutons of diorite, granodiorite composition, bounded on the either side (both in the north and south) by amphibolites. The southern of the amphibolite sequence encloses at least one ultramafic body, and amphibolite sequences encloses at least one ultramafic body, and rests tectonically on the Indian plate metasediments. In the northern amphibolites have a banded appearance similar to the ones in the central Kohistan. These amphibolites have a tectonic contact with the Chilas complex in the north, which is marked by 30m thick shear zone.

The stratigraphic succession of gabbroic to metabasaltic amphibolites, island arc type tholeiite-andesite volcanics and calc-alkaline diorite-granodiorite plutons together with the tectonic contacts with the Indian plate metasediments in the south, and with the Chilas Complex in the north, suggest that the southern Kohistan sequence holds a separate entity within the Kohistan sequence, and may represent yet another island arc.

Key words: Tectonics, metamorphism, Babusar, Kohistan arc.

K/232. Khan, M.A., 1985b. Bibliography of the Geological Survey of Pakistan reports on the North West Frontier Province, Pakistan. Geological Survey of Pakistan, Information Release 133, 16p.

This Bibliography lists contributions of the Geological Survey of Pakistan on the geology of the North West Frontier Province. These are included in the more comprehensive Bibliography on the geology of the province prepared by Khan, Karim and Iqbal (1987; given in the following).

Key words: Bibliography, GSP, NWFP.

K/233. Khan, M.A., 1987. One or two island arcs? Petrochemical and structural data from the Chilas-Babusar area, Kohistan. 3rd Himalayan-Karakoram-Tibet Workshop, Imperial College, London.

Key words: Structure, petrology, geochemistry, Babusar, Thak, Chilas, Kohistan island arc.

K/234. Khan, M.A., 1988. Petrology and structure of the Chilas ultramafic-mafic complex, N. Pakistan. Ph.D. Thesis, University of London.

Key words: Structure, petrology, ultramafics, Chilas, Kohistan island arc.

K/235. Khan, M.A., 1988-90. Geology and structure of Kotli-Nikial Khuiratta Area. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 115p.

Geological and structural mapping of Kotli-Nikial-Khuiratta area of about 300 square km was carried on 1:50,000 scale of toposheet No's 43 K/2, 43 K/3, 43 G/11 and 43 G/15 of survey of Pakistan. The lithostratigraphic units described range in age from Pre-Cambrian to Pleistocene and consist mainly of sedimentary rocks. The Pre-Cambrian rock formation is Dogra Slate and Cambrian rock unit is Sirban Formation. In this area apart from Lower Cambrian, all the formations of Paleozoic and Mesozoic are missing. Either they were not deposited or were

weathered to form Bauxite/Fireclay representing an unconformity of a big gap. In the Tertiary period, Patala Formation, Margala Hill Limestone, Murree Formation and rocks of Siwalik Group were deposited. Section measurements were done to establish the stratigraphy. The rocks are folded and faulted comprising the major and minor structures of the area. The major folds of the area are khuiratta-Kohali anticline (11ρρ/325ρρ), Devigarh-Palana anticline (04ρρ/313ρ), Tattapani-Karela anticline (6ρρ/116ρρ) and Khad-Bahni syncline (6ρρ/228ρρ). The major fault is the Himalayan Frontal Thrust with minor thrust like Gala Thrust and Khad Thrust. Deformational events and stereographic projection of the area have been interpreted. The tectonic setup has been also discussed. About eighty five rock samples were taken from the field and carried back to the laboratory for petrographic studies. In the field of economic geology, a number of deposits including Fireclay, Bauxite, Coal, Limestone, Chalk and Dolomite are of economic interest.
Key words: Mapping, structure, Azad Kashmir.

K/236. Khan, M.A., 1991. Economic evaluation of decorative stones of Neelum Valley, Azad Kashmir. Proceedings, First SEGMITE Symposium, Peshawar, 8-16.

Key words: Economic, decorative stones, Neelum valley, Azad Kashmir.

K/237. Khan, M.A., 1990-92. Sedimentary Petrology/sedimentology of Paleocene Hangu Formation and lithostructural mapping of Changla Gali Area in Galiat region, Hazara, Northern Pakistan. M.Sc. Thesis, Punjab University, Lahore, 97p.

A Comprehensive study of Geology and structure of Chhangla Gali area is, presented along with special constraints on the sedimentology of Hangu Formation. Large scale (1: 7000) Geological mapping of a small segment of the Lesser Himalaya in the Chhangla Gali area is presented. The lithostratigraphic unit range from Upper Jurassic to Upper Eocene, Samanasuk Formation being the oldest. Structurally the area comprises NE-SW trending double plunging folds constituting anticlinoria and synclinoria. The folds are tight to isoclinal with a general vergence to the southeast. The folded sequence is disrupted by a number of high angle dip slip strike faults especially within or on the margins of anticlinoria. A detailed petrographic study of a section of Hangu Formation that comprises 18 microfacies. The deposition of Hangu Formation took place in humid, arid, subtropical conditions.
Key words: Sedimentology, Paleocene, lithostructure, Hangu Formation, Changla gali, Abbottabad, Hazara.

K/238. Khan, M.A., 1992. Petrology of metamorphic rocks in the Chakdara and Landakai areas, Dir and Swat districts, NWF-Province, Pakistan. M.S. Thesis. University of Iowa, U.S.A., 191p.

Part of the information in this thesis is provided in Khan and Foster (1998, 2000).
Key words: Petrology, metamorphic rocks, Dir, Swat.

K/239. Khan, M.A., 1994. Himalayan orogeny: impact on global climate. Symposium on Environmental Geology. Department of Geology University of Peshawar, p.19.

Key words: Structure, climate, orogeny, Himalaya.

K/240. Khan, M.A., 1995a. Utilization of Kakul and Hazara phosphate resources, North West Frontier Province. Proceedings, International Round Table Conference on Foreign Investment in Exploration and Mining in Pakistan, Islamabad, October 16-18, 1994, 137-152.

Key words: Phosphates, Kakul, Hazara.

K/241. Khan, M.A., 1995b. Geology and tectonic significance of the Himalayas of N. Pakistan. Published in "Souvenir, International symposium and field workshop on phosphorites and other industrial minerals; SEGMITE-UNESCO joint organization, Abbottabad, Pakistan.

Key words: Tectonics, Himalaya.

K/242. Khan, M.A., 1996a. Kohistan terrain of NW Himalayas of Pakistan: A model for crustal growth through accretion of island arc and back–arc assemblages. Abstract volume 30th International Geological Congress, Beijing, China, Aug. 4-14, 1996. G-2-16 01738 1451, p. 296.

Key words: Crustal growth, Kohistan Island arc, Himalaya.

K/243. Khan, M.A., 1996b. Structural geology of the southern parts of the Nanga Parbat Massif, Higher Himalayas, N. Pakistan. Abstract volume 30th International Geological Congress, Beijing, China.

Key words: Structure, petrology, Nanga Parbat, Himalaya.

K/244. Khan, M.A., 1997a. Bearing capacity of foundations in slopes of sub-Himalaya regions. Abstracts, 3rd Pakistan Geological Congress, University of Peshawar, p. 34.

The foundations of important national buildings, bridges, common houses and roads are mainly on slopes. Most of the slopes are destabilized by road widening, active landslides and the presence of faults. All the civil engineering structures are designed without prior investigation of grave landslides, active faults and level of seismicity in the area. This paper describes a method of designing foundations on slopes of cohesionless material such as clays and normally consolidated sandy clays. The method is based on the results of physical centrifuge tests. In order to extend the centrifuge findings under the slope, the results of other model tests were incorporated into the design procedure which is outlined. The method presented, is based on mechanical tests. The bearing capacity of a footing on or near the slope is rated as percentage of the capacity that the same footing would have on the surface of level ground. The use of local experience can determine the safe bearing capacity of reference level ground footing. The designer needs correct data of the tests run on footing of reasonable scale. The method is simple to use and covers the design geometries that are most likely to be met in practice.
Key words: Geotechnical, landslides, slope stability, Sub-Himalaya.

K/245. Khan, MA., 1997b. Slop stability analysis in Higher and Sub-Himalayan regions of Pakistan. Abstracts, National Symposium on Economic Geology of Pakistan, Islamabad, 1p.

A biplaner shear lies at a depth of 10-25m below the surface affecting the bridge and highway abutment in northern Pakistan. The overlying rocks are highly cracked, sheared, fractured and jointed. Many landslides occur in thick mass on down dip exposures on shear planes in Himalayan regions. An extensive investigation was undertaken to deliniate shear zones and other significant stress creating features such as folds and faults, for further probable slides which would endanger the highway and bridge structures in northern Pakistan. An analysis was made to determine the extent and nature of treatment that would be required to stabilize the rock mass.
Shear nets were used to determine failure modes faced with combinations of joint sets and shear zones. Two dimensional studies were conducted leading to 3d i.e. the wedge angle method. Alternative treatments were conducted on the same slope. A monitoring system was installed to document the initial slope movement and the results obtained from this investigation.
Key words: Slope stability, landslides, Himalaya.

K/246. Khan, M.A., 1997c. Tectonic evolution of southeast Kohistan, Northwest Himalayan Pakistan. Ph.D. Thesis, University of Peshawar, 320p.

The Kohistan island arc terrane in the northwestern Himalayas of N. Pakistan is sandwiched between the Indian and Karakoram plates. Structures related to collision tectonics have exposed more or less a complete crust of the arc terrane from its very base at Moho to its subaerial volcano-sedimentary cover. Within southeastern Kohistan, recent geological mapping along a N-S transect across the lower to middle crustal part of arc terrane, provides new and

important information relating to the magmatic emplacement of the principal units. The base of the arc here, is occupied by a major stratiforrn ultramafic-gabbroic complex (the Sapat-Babusar complex), which overrides the crust of the Indian plate along the Indus suture (i.e., the Main Mantle Thrust; MMT). The complex was intruded into the base of a thick pile of rnetavolcanics (the Kamila belt)l which comprise a tectonic collage of MORB-type tholeiitic basalts (Jal-Niat amphibolites). island-arc tholeiites (Babusar amphibolites) and calc-alkaline andesites (Sumal amphibolites). The Chilas complex comprising ultramafic and gabbronorite rocks is also intrusive into the Kamila belt but unlike the Sapat-Babusar complex, it was emplaced onto the top, rather than the base, of the belt. The Kamila belt is intruded by a suite of [1raniloid rocks (gabbro, gabbro-diorite/tonalite-granodiorite granite and trondhjemite). The first group is closely comparable with the host Jal Niat amphibolites, second group rocks are similar to the subduction-related plutonic rocks from Kohistan (e.g., Kohistan batholith), and the trondhjemites were formed from the partial melting of Jal-Niat amphibolites. The field relations suggest a two-stage history of crustal thickening in lower and middle part of the arc crust. From its initiation at ca. 125-120 Ma until ca. 90 Ma, the arc grew by magmatic emplacement, into its base, of stratiforrn ultramafic-gabbroic plutonic complexes one below the other. In stage two, the focus of crustal growth shifted upwards from the base of the arc with the emplacement of the Chilas complex on top of the Kamila belt. This stage of crustal thickening was accompanied by crustal shortening associated with 90-80 Ma aged Kohistan-Karakoram collision.
Key words: Tectonics, metamorphism, ultramafics, amphibolites, Kohistan.

K/247. Khan, M.A., 2001. Tectonics of north Pakistan: Consensuses and controversies. Abstracts, 4th Pakistan Geological Congress, Islamabad, 35-37.

North Pakistan is a prime example of continent-island arc-continent collision zone resulting in world' s most fascinating mountain ranges of Karakoram, Hindukush and Himalaya. Tectonic evolution of this orogenic belt has remained focus of several national and international research programmes in the past three decades. These studies have greatly enhanced our understanding of orogenic processes and mountain building activity, which in turn, have led to the refinement of metallogenic models. At times, however, detailed studies have revealed several complexities leading to controversies.
Karakoram-Hindukush Block
A consensus has developed regarding plate tectonic position of Karakoram-Hindukush block (KHB) as a microcontinental plate accreted to Eurasia in Late Jurassic. Between Late Jurassic and Middle Cretaceous (- 90 Ma), KHB served as an active margin for the subduction of the northern Neotethys, before it was accreted by the Kohistan island arc at its southern margin. The presence of subduction related granitoids (145-90 Ma) of the Karakoram batholith and an absence of marine sedimentation younger than Middle Cretaceous testifies to this plate tectonic scenario. The pre-Middle Cretaceous history of the KHB is recorded in well-preserved and superbly exposed stratigraphy dating back to Ordovician. A pre-Ordovician basement has first time been recorded in KHB directly below the Ordovician and younger cover sequence. Faunal comparisons testify to Gondwanic affinity of the 11KB, its separation from Gondwana in the Permian together with other micro continents like Afghan block and Lahasa, and finally collision with Eurasia in Late Jurassic at the expense of Palaeotethys. Despite a Middle Cretaceous minimum age of collision at the margin of the 11KB, recent radiometric dating shows that much of metamorphism and deformation in KHB is Late Tertiary in age and thus related with Himalayan orogeny. Some of the world's largest batholiths of crustal-melt derived leucogranites of Late Tertiary age form an interesting element in the geology of Karakoram and Hindukush.
Kohistan Island-arc Block
The discovery of blueshists from Shangla, Swat (1970) and recognition of two sutures, Main Mantle Thrust in the south and the Main Karakoram Thrust (now commonly referred to as the Shyok Suture) in the north (1976) led to discovery of Kohistan island arc block between the Indian plate and the KHB. This interpretation has withstood the test of time spanning about three decades. There are, however, still some differences of opinion on details:
The high pressure-temperature Jijal complex crystallized in a deep-seated magma chamber as such, or in a shallow-seated magma chamber that was subsequently subducted to depths of ~50 km? or alternatively, Jijal complex represents a mantle-crust transition? The same applies to the Chilas complex, which is interpreted as cumulates crystallized in a magma chamber or alternatively, a solid state intrusion of the mantle slab?
Kohistan formed as an island arc just offshore of Karakoram just like current example of Japan offshore of China, or it formed within the Neotethys far away from both India and Karkoram? This, in turn, questions the size of ocean separating Kohistan from Karakoram; was it of the size of Sea of Japan or of that of Pacific? Subduction polarity is

another issue; most workers prefer a northward subduction polarity for the origin of Kohistan while Khan et al. propose a southward subduction to explain boninites in Chalt volcanics.
Indian plate
Detailed work in N. Pakistan in past two decades has greatly resolved mysteries of Himalayas. For instance we now know ages of peak metamorphism, phases of magmatism and events of deformation. There is a consensus however, that there is a considerable difference in the Himalayas of N. Pakistan compared to those of India and Nepal. Despite this, attempts to stretch some boundary faults into Pakistani Himalayas generate interest. Main Central Thrust (MCT) is one such debatable issue. Other interesting points still under debate include:
The discovery of eclogites from Kaghan and recent recognition of coesite from these rocks suggest a pressure of ~30 Kbars (~90 km depth). More importantly what tectonic processes brought these rocks back to the earth's surface (exhumation) from such depths in such a short span of 5-8 Ma? The age of rift-related magmatism? Dating by radiometric methods with high closure temperatures (Rb-Sr, U-Pb on Zircon) clearly manifested a Permo-Carboniferrous age for rift-related magmatism in Peshawar Plain. Is there still a phase of alkaline magmatism as young as Late Tertiary as suggested by some recent data? Compressional tectonics vs transpressional tectonics? In the context of foreland of Pakistan 'Himalaya, some recent work has stressed role of transpressional tectonics in Kohat Plateau. If so how this tectonic style changes to mainly compressional tectonics in the Potwar Plateau, just across the river? This talk is aimed at highlighting some recent advances made in our understanding of the tectonics of N. Pakistan. In this context some unsolved issues are pinpointed to identify the future course of research in this unique orogenic belt.
Key words: Structure, tectonics, Karakoram, Hindukush, Himalaya.

K/248. Khan, M.A., Abbasi, I.A., Khan, S.R., Hadi, S. & Tariq, M., 2001a. Tectonic subdivision of India-Afghan collision zone, Waziristan-Kurram region, NW Pakistan. Abstracts, 4th Pakistan Geological Congress, Islamabad, 37-38.

The India-Afghanistan collision zone exposed in Kurram-Waziristan area of NW Pakistan comprises a stack of-thrust sheets derived from various parts of a continental shelf-ocean floor transition formerly located at the NW margin of the Indian plate (Beck et al., 1996). From SW to NE, these thrust sheets include; Waziristan ophiolite, Khaisora nappe of outer shelf sediments, Shahur Tangi-Kahi nappe of deep-marine olistostromal sequence and Isha nappe of inner continental shelf Late Palaeocene and younger shallow-marine and fluvial sediments unconformably overly the thrust stack and are involved in deformation. Four stages of tectonic evolution are recognized in the Waziristan-Kurram collision zone:
Middle Cretaceous (~90 Ma): An early phase of intraoceanic ophiolite obduction at ~90 Ma gave rise to Shahur Tangi-Kahi group of sediments in a fore-deep setting. This event conforms to a regional Middle Cretaceous orogeny (Semail ophiolites; Kohistan-Karakoram collision; Kamila shear zone, Kohistan).
Early Palaeocene (~65 Ma): A major thrust displaced the extensive nappe of Shahur Tangi-Kahi group eastward onto the entire NW continental shelf of the Indian plate during the Early Palaeocene, contemporaneous with and directly above the syndepositional breccia of Lockhart Formation. A closely following break-back thrusting event involved internal imbrication of the Waziristan ophiolite, thrust emplacement of the Waziristan ophiolite stack eastward onto the outer shelf (Khaisora group) and that of the Khaisora nappe onto the Shahur Tangi-Kahi nappe. This Palaeocene thrust stacking was complete prior to the deposition of Late Palaeocene Patala Formation onto the Shahur Tangi-Kahi group (Thai area), that of the Datakhel Formation on the stacked Waziristan ophiolite, and that of the Ghazij Formation and the younger sediments on the contact between the Isha and Shahur Tangi-Kahi groups (Khajuri Post area).
Post Middle Eocene (~45 Ma): Late Palaeocene-Middle Eocene shallow-marine transgression onto the thrust stack was followed by a major hiatus that marked onset of fluvial sedimentation at the expense of marine sedimentation. Late Miocene Kamlial Formation in the north (near Thai) and the Pliocene Litra Formation (near Bannu) mark the earliest molasse sediments in this region.
Quaternary (<2 Ma): Molasse sediments in Waziristan-Kurram foreland are uplifted, tilted and folded. An extensive sequence of conglomerates overlying the Litra Formations is tilted to high angles in the foreland region near Bannu, suggesting Holocene (<1 Ma) age for this deformation event. A Quaternary transpressional upright fault brings base of the Shahur Tangi-Kahi group in tectonic contact with Ghazij Formation near Shinki Post (Bannu-Miran Shah road section). In the hinterlands, the Quaternary deformation event may be responsible for large structures of Drasmand and Khadimak antiforms together with associated thrust faults.

Whereas the Middle Cretaceous intraoceanic ophiolite obduction event correlates well with documented tectonic events in Kohistan and Oman, the Early Palaeocene thrust stacking is probably related with a second phase of ophiolite obduction similar to that of Spongtang, Ladakh (Searle et al., 1986), rather than with the India-Eurasia collision (Beck et al., 1996). The tectonic event related with Late Eocene termination of marine sedimentation could be the manifestation of India-Afghan collision in this region that continues into Quaternary due to an oblique collision and associated transpressional deformation.
Key words: Structure, tectonics, Kurram, Waziristan, collision zone.

K/249. Khan, M.A., Abbasi, I.A., Khan, S.R., Hadi, S. & Tariq, M., 2001b. Tectonic collage of transitional crust, India-Afghan collision zone, Waziristan-Kurram region, NW Pakistan. Journal of Asian Earth Sciences 19, p.35.

Consult the preceding account for more information.
Key words: Structure, tectonics, Kurram, Waziristan, collision, Cretaceous.

K/250. Khan, M.A., Abdelsalam, M.G. & Stern, R.J., 1997. Polarity of the subduction system for the Cretaceous Kohistan island arc terrain, N. Pakistan. Abstracts, 3rd Pakistan Geological Congress, University of Peshawar, p. 35.

Key words: Polarity, subduction, Cretaceous, Kohistan island arc.

K/251. Khan, M.A., Ahmed, R., Raza, H.A. & Kemal, A., 1986. Geology of petroleum in Kohat-Potwar depression, Pakistan. American Association of Petroleum Geologists Bulletin. 70, 396-414

The 36,000-km^2 Kohat-Potwar depression in northern Pakistan has more than 5,000 m of marine deposition (Precambrian to Eocene, with a major break during Ordovician to Carboniferous). More than 10,000 m of Miocene to Pleistocene alluvial sediments overlies the marine sequence. The tectonic depression formed as a result of continent-to-continent collision at the northwestern margin of the Indian plate. Although the region has been under active petroleum exploration since the mid-nineteenth century, it has been tested by only 60 exploratory wells. Ten oil fields have been discovered; original recoverable reserves total 200 million bbl, of which 112 million bbl has been produced. The region has several attractive features for petroleum generation and accumulation including source-reservoir-trap assemblages and thermal maturity regimes. Total ultimately recoverable hydrocarbon resource of the area is estimated at 2.4 billion bbl of oil equivalent.
Many unexplored surface and subsurface prospects and stratigraphic leads are known. Parts of the region, particularly the Bannu depression and Kohat salt zone, can be regarded as frontier areas; based on the exposed geology and available seismic information, we believe these areas are promising. Recent discoveries of Dakhni field (1983) and Dhurnal field (1984), which were the first discoveries in the northern part of the platform zone of the Potwar plateau, and production from Paleozoic horizons have added new dimension to petroleum prospects of the area. The region needs careful reevaluation of available information, exploratory drilling on selected targets, and detailed exploration in its western part.
Key words: Hydrocarbons, petroleum, geology, Kohat-Potwar.

K/252. Khan, M.A. & Ahmad, W., 1991. Report on SDA mineral activities in NWFP. Directorate of Minerals, Sarhad Development Authority. 64p.

This report gives details of the mineral exploration and mining activities in the subject areas of Sarhad Development Authority.
Key words: Minerals, Sarhad Development Authority.

K/253. Khan, M.A., Ali, K. & Khan, M.A., 1992. Structure in the hanging wall of the Main Boundary Thrust: Examples from the Kohat hill range, N. Pakistan. Abstracts, First South Asia Geological Congress, Islamabad, p.58.

Key words: Structure, tectonics, MBT, Kohat hills.

K/254. Khan, M.A. & Coward, M. P., 1991. Entrapment of an island arc in collision tectonics: A review of the structural history of the Kohistan arc complex, N. W. Himalayas. Physics and Chemistry of the Earth, 17, 1-18.

Key words: Structure, tectonics, Kurram, Waziristan, collision, Cretaceous.

K/255. Khan, M.A. & Din, S.M., 1994. Landslide incidences in western limb of Hazara Kashmir syntaxis. Abstracts, Second SEGMITE International Conference on the Export Oriented Development of Mineral Resources and Mineral Based Industries, Karachi, p.25.

The northwestern limb of Hazara- Kashmir Syntaxis, is an area of high landslide incidences. The valley system is characterized by steep sided river valleys cut into bed rock and river deposits. The steep slopes, undercutting of the Psammatic and Pilitic slates (Hazara Slates), silty and clayey soils, and humid climate of the area. All this area contributes to landsliding in the region. The situation has been further aggravated by road widening, effects of Main Boundary Thrust (MBT), and seismic activities resulting in many major landslides. Slumping, rock-falls, creep and at places earth-flows or combination of these are most common modes of failure.
The dormant and active landslides were investigated in detail because of their large size and proximity to roadways and residential area. Geological and topographic maps were prepared for each site and soil samples were collected to investigate geotechnical properties involved in failure and to establish stratigraphy of the sites.
In addition to the site investigation, a landslide map of the area was prepared using field reconnaissance and aerial photographs. All slope failures were marked on the map according to their damage severity. A high concentration of slope failure occurs on the western limb of Hazara Kashmir Syntaxis and on the eastern side of Kunhar River. The results indicate that slope failure occurs due to high swelling potential of soils, active faults and shear failures.
Key words: Landslides, MBT, Hazara-Kashmir Syntaxis.

K/256. Khan, M.A. & Foster, C.T., 1998. Geothermobarometery in Landakai and Chakdara areas, Swat and Dir Districts NWF Province Pakistan. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, p.98.

The Landakai and Chakdara areas, occupy the northern part of the Indian Plate south of the Main Mantle Thrust. The oldest rock unit in the area is the metamorphosed Swat granite gneiss of Cambrian age. The schists, marble and amphibolite exposed in the region are believed to be continental shelf sediments of Silurian-Devonian age which have a tectonic contact with gneisses. The rocks of the MMT/Mingora ophiolitic melange were tectonically emplaced upon the metasediments of the Indian Plate during late Cretaceous to early Tertiary time.
Metamorphism in the area ranges from low to medium grade at relatively high pressure. The rocks exposed north of the Swat River belong to the greenschist facies, whereas rocks exposed south of the river fall in the Kyanite zone of the amphibolite facies. Retrograde metamorphism has affected the area throughout but is more intense north of the river.
Geothermobarometery was carried out in pelites and amphibolites south of the Swat River. Applications of the garnet-biotite geothermometer and garnet-aluminum silicate-plagioclase geobarometer in metapelites gave a T and P range from 535^o C, 8.3 kb to 662^{o}C, 11kb. In amphibolites, the garnet-hornblende geothemometer and garnet hornblende-plagioclase geobarometer gave a T and P range from 588^{o}C, 10.8 kb to 705^{o}C, 11.9kb.
Key words: Geothermometry, metamorphic rocks, Dir, Swat.

K/257. Khan, M.A. & Foster, C.T., 2000. Pressure-Temperature estimates in rocks around Landakai area, Swat District, NWF-Province, Pakistan. Abstracts, Third South Asia Geological Congress, Lahore, p.67.

Consult the preceding account for further information.
Key words: P-T estimates, metamorphic rocks, Swat.

K/258. Khan, M.A., Habib, M. & Jan, M.Q., 1985. Ultramafic and mafic rocks of Thurly Gah and their relationship to the Chilas complex, N. Pakistan. Geological Bulletin, University of Peshawar 18, 83-102.

Detailed field and petrographic studies in Thurly area substantiate the idea of a two-fold subdivision of the Chilas Complex. Much of the area is occupied by the association of "Main Norites" with subordinate pyroxenites and anorthosites displaying only local layering. Apparently intrusive into these is the association of ultramafic-mafic rocks occurring principally in a 2.5×1 km lensoid body. These possess well-developed sedimentary features, especially layering, and comprise dunite, peridotite, pyroxenites, troctolite, norite, anorthosite, and olivine/pyroxene pegmatites. There are distinct differences in the mineralogy of the two associations, especially in the composition of plagioclase and oxide minerals. It is suggested that the ultramafic-mafic association was derived from a picritic magma emplaced in the floor of a crystallizing (main) noritic magma. There is a strong concordance in the planar structures of the two associations and the crystallization of the ultramafic-mafic rocks apparently preceded all deformational events.
Key words: Ultramafics, Thurley Gah, Chilas complex, Kohistan, Himalaya.

K/259. Khan, M.A., Hamidullah, S., Khattak, M.U.K., Sayab, M. & Jan, M.Q., 1999. Geology and structure of the south-eastern Nanga Parbat Syntaxis, NW Himalaya, Pakistan. Terra Nostra 99, Abstract Volume, 14th Himalaya-Karakoram-Tibet Workshop, Kloster Ettal, Germany, 83-85.

The Nanga Parbat Syntaxes in N. Pakistan marks a crustal-scale structural bend in Himalaya that is companied by an unusually fast exhumation and uplift rate and a phase of Pliocene-Pleistocene regional metamorphism and crustal anatexis that is unique in the tire Himalaya. Despite its significance for understanding collision-related crustal geodyanamics, e region has remained poorly mapped, particularly in southern and south-eastern parts, mainly because of the inaccessibility but also due to the location in proximity to the border with Indian Kashmir. In this paper, we present results of our new mapping in south-eastern parts of the Nanga Parbat region. Our observations are based on traverses along the Astor valley and its eastern tributaries (i.e., Gurikot, Rupal and Maiche) and a 40-km traverse across the 4564 m high Shontargali Pass, between the villages of Rattu in the Astor valley and Kel in the Neelam valley.
The Astor Section: Mapping in the Astor valley shows a continuation of the Iskere and Shengus gneiss units (Madin et al., 1989) from the Indus valley. These gneisses occupy the core of the massif, with the Iskere unit in the west and the Shengus unit in the east. The contact between the two, in the Astor valley, passes to the west of the village Harchu and is faulted. Whereas, the Iskere gneiss unit is a grey orthogneiss (quartz, k-feldspar, biotite ± garnet), that is often weakly porphyroclastic and migmititic, the Shengus unit in Astor is a characteristic pink paragneiss (a reflection of garnet and biotite abundance; kyanite and silliminite locally present) which contains local calc-silicates and quartzite intercalations. The marginal parts of the syntaxis at both sides (east and west) are occupied by a sequence of metasedimentary rocks. The metasedimentary unit at the eastern margin comprises kyanite-silliminite-garnet schists and paragneisses (derived from calc-pelites), marbles and calc.silicates and together with common amphibolites, is classified as the Rattu Unit (Tahirkheli, 1988). The metasedimentary succession at the western margin is highly attenuated and comprises siliceous schists, marbles and amphibolites. A thin slice of the Rattu unit is observed in the core of the syntaxis near Mushkin that is closely associated with a sequence of amphibolites, together forming part of a narrow (faulted) syncline. The Astor section contains at least two sets of mylonitic gneisses derived from granites. The Mongdoian mylonitic gneiss is characteristically grey with medium-grained feldspar porphyroclasts and occurs enclosed in the metasedimentary unit at the western margin of the massif, while the Harchu pink mylonitic gneiss occurs at the contact between the Iskere and Shengus gneisses. Additionally, a

granite gneiss with characteristic feldspar laths and a pink mylonitic matrix (the lath unit) intrudes the contact between the Shengus and Rattu units. Finally, there is a weakly porphyritic granite in the Astor section that is apparently undeformed and intrudes the grey Mongdoian mylonitic gneiss at the western margin. A partly undeformed granite of similar general characteristics but an extensive geographic distribution has been noticed at the SW margin of the syntaxis in Bunar area (the Jalhari granite of Edwards et al., 1997). Structurally, the Astor section comprises at least two major antiformal fold structures, with a narrow faulted syncline at Dichilli confluence. The strata near the two margins is overturned (dipping inward to the core of the syntaxis) at topographic higher parts, suggesting outward “ballooning” of the syntaxis through crustal-scale fold structures. At the eastern Nanga Parbat-Ladakh terrane contact in Astor section, we have noticed ultramafic lenses that confirm preservation of the Indus Suture melange.

Gurikot, Rupal and Maiche Sections: Traverses along these western tributaries of the Astor river show a continuation of the geology observed in the Astor section. The part of the Gurikot section we covered includes Indus-suture melange comprising ultramafic lenses set in a matrix of basic mylonites, Rattu Unit, a very attenuated ‘Lath unit”, Shengus unit (large kyanites in pink-paragneisses) and Harchu pink mylonite gneiss unit. The entire sequence in the Gurikot section dips steeply to the west and is overturned. The Rupal section that gives access to most central parts of the syntax is in the SE comprises, from margin inward, Indus Suture mylonite melange, Rattu unit and an attenuated Shengus unit. The core of the massif here is occupied by the Rupal augen gneiss, which is unique to the southern parts of the massif. The dominant fabric (SI) in the Rupal augen gneiss trends E-W (dips 60-80o N) in the core of the massif but changes to NNE-SSW in the east near Tarshing. Strong stretching lineation associated with this fabric plunges shallowly to the NNW. Edwards et al. (1996) interpret SI to be associated with a major shear zone which they term Rupal-Chhhichi shear zone. A relatively weaker fabric (S2) is superimposed on SI with a constant attitude of NW-SE /~80o SW. The Rupal augen gneiss contains E-W trending screens (several tens of m wide) of low-grade siliceous schists and quartzites at the ridges flanking the Rupal valley to the north and south (Tahirkheli, 1988; this study). The stratigraphic position and contact field relations of these metasediments are not known.

Rattu-Shontargali-Kel Section: The Rattu unit, in the area to the south of Rupal is bifurcated into two, at the limbs of a north-plunging antiform. The eastern limb of this antiform runs along the Indus suture and the western, along the Chhichi valley. The antiform is cored by grey migmatitic gneisses that resemble the Iskere gneiss, followed by a mixture of pink and grey gneisses (the Shengus unit) and finally the Rattu unit at limbs. The traverse along the Mir Malik River crosses obliquely through this antiformal structure. At Rattu, the Indus Suture melange contains abundant lensoid bodies of ultramafic rocks set in greenschist mylonites. The Rattu unit is well exposed at the lower reaches of the Mir Malik valley that is followed by the pink paragneisses in the Shengus unit. Much of the upper reaches of the Mir Malik valley and the Shontargali Pass comprise grey migmatitic gneisses locally intercalated with coarse-grained marbles, calc-silicates and garnetiferrors amphibolite sheets. We correlate these gneisses with the Iskere unit. A thick thrust slice comprising tremolite marbles, calc-silicates, calc-pelitic schists and amphibolites (resembling the Rattu unit) occurs enclosed in the Iskere gneisses in the upper reaches of the Mir Malik valley. The paragneisses resembling Shengus unit reappear on the SW side of the Shontargali Pass in the upper reaches of the Shontar valley. These together with a sequence of tremolite-marble, calcsilicates, calc-pelites and amphibolites (the Rattu unit, locally called Nangimahli Formation; Malik, 1995) dominate the Shontar valley. The NW-verging Shontar thrust (Tahirkheli, 1988) runs along the Shontar valley and thrusts Shengus unit on to the Rattu unit. A tight hangingwall anticline and relatively open syncline that are followed to the NW by another pair of NW-verging anticlines and synclines accompany the Shontar thrust. The Shengus unit is in contact with Rupal augen gneisses both to the NW, in the Sarawali glacier area, and to the SW near Kel.

Discussions: The south-central and southeastern Nanga Parbat syntaxis is divisible into three mappable units, Iskere, Shengus, Rattu, that occur in a “stratigraphic’ order. Of these the Iskere unit of grey orthogneisses (often migmatitic) is clearly an Early Proterozoic basement gneiss (Zeitler et al., 1993) while the Rattu unit is metamorphosed cover either of Palaeozoic (equivalent Abbottabad Group; Latif, 1970) or Permo-Triassic (equivalent Panjal Group) age. The Shengus unit is interpreted here to be predominantly metasedimentary and may be equivalent of the Precambrian pelites widespread in Lesser Himalayas of N. Pakistan (e.g., Salkhala, Hazara, Attock slates). The Rupal augen gneiss, the Harchu pink mylonites, Mongdoian grey mylonites, the Lath unit and the Jalhari granite are newly recognised units that owe their origin to granite magmatism of discrete but unknown ages. Structurally the Astor section is dominated by two large, N-plunging antiforms intervened by a narrow faulted synform. This fault possibly joins the Rupal-Chhhichi sear zone in the south (Edwards et al., 1996). The NW verging Shontar thrust and related fold structures are reworked by SE-verging Rupal-Chhhichi shear zone at the high topographic levels marking the drainage-divide between Rupal and Neelam valleys (Figure 1), which we interpret as the southern limit of the affect of Pliocene-Pleistocene exhumation of Nanga Parbat.

Key words: Mapping, structure, metamorphism, Nanga Parbat, Himalaya.

K/260. Khan, M.A. & Jan, M.Q., 1990. Transition from island arc to intra-arc rift tectonics reflected in successive phases of magmatism in the Chilas Complex, Kohistan. Abstracts, 2nd Pakistan Geological Congress, University of Peshawar, 24-25.

Two distinct phases of magmatic activity indicating differences in tectonic setting of magma generation have been recognized in the Chilas Complex. The first and main phase crystallized mainly into homogeneous or weakly layered non-cumulate ultramafic and anorthosite rocks. Detailed evaluation of these rocks suggests that the calc-alkaline parental magma was generated and emplaced during mature stages of arc building in Kohistan. The remarkable the Chilas Complex through its entire extent (approximately 8 km2) suggests a peculiar mode of emplacement prob rough a plume-like up rise of magma body in the core of the aruation indicating a component of extensional environments in later stages of arc building.
The second and youngest phase of magmatism is represented swarm of basic dykes which cut across all the other lithologies present the Chilas Complex. These basic dykes have a fractionation trend indicating greater iron enrichment than the host main-phase gabronorities. Comparatively tholeiitic magma character is also supported by rare-earth elements.
Magmatism in island arcs is normally tholeiitic in the initial stages building, switching to a calc alkaline composition in the mature stages. The reverse trend in the Chilas Complex i.e., from calc alkaline to tholeiitic composition in the successive phases of magma is suggestive of intra-arc rifting of compressional environments re with Kohistan Arc- Karakoram plate collision.
Key words: Ultramafics, tectonics, Island arc, Chilas complex, Kohistan.

K/261. Khan, M.A. & Jan, M.Q., 1991. An interpretation of the Himalaya-Karakoram region of Pakistan in the light of plate tectonics and rock ages. Pakistan Journal of Geography 1, 1-23.

This paper presents a brief and simplified review of the concept of plate tectonics, continental drift, and methods of radiometric age determination. An attempt has also been made to present the tectonic and magmatic evolution of the NW Himalaya-Karakoram in the light of recent advances in earth sciences. North Pakistan has experienced a complex interplay of continental collision, magnetism, metamorphism, uplift and erosion. The region is envisaged as consisting of the Karakoram and Indo-Pak plates, both of which represent fragments of the Gondwanaland drifted towards north. Sandwiched between these ii the Kohistan- Ladakh tectonic zone, a late Mesozoic to Early Tertiary island arc.
Key words: Plate tectonics, Himalaya, Karakoram.

K/262. Khan, M.A. & Jan, M.Q., 1992a. Some fundamental field and petrographic aspects of the Chilas mafic-ultramafic complex, Kohistan arc, Northern Pakistan. Acta Mineralogica Pakistanica 6, 126-147.

Detailed field and petrographic studies of the Chilas Complex, especially around Chilas, suggest that it is principally made up of gabbronorites with local pyroxenites, anorthosite, quartz diorites and tonalites. These contain, locally, up to 10 km2 lensoid bodies of ultramafic rocks with associated anorthosites, troctolites, olivine gabbros, gabbros and gabbronorites. These latter are commonly layered and contain excellent sedimentary structures. However, the main gabbronorites are mostly uniform with only sporadic presence of igneous layering. The complex is remarkably coherent with rare evidence of multiple intrusions, suggesting that most of the crystallization took place in one or a few large, continuous magma chamber(s). The contact relations show that the Chilas Complex intruded into a basement comprising metavolcanic amphibolites and paragneisses. The close association of the Chilas complex with arc-related rocks both in space and time, details of mineral and whole-rock geochemistry (presented elsewhere) and the absence of cyclically layered successions negate the possibility for the complex to have developed in mid-oceanic ridge conditions. The Chilas complex may represent rocks of the magma chamber to the Kohistan Island Arc, more likely, it developed from a mantle diaper in an intra-arc rift, similar to that documented in a number of recent island arcs, e.g., Mariana, Fiji.
Key words: Ultramafics, petrography, Chilas Complex, Kohistan, Himalaya.

K/263. Khan, M.A. & Jan, M.Q., 1992b. Magmatic evolution of the lower island arc crust, Kohistan, N Pakistan. Abstract Volume, 7th Himalaya-Karakoram Workshop, Deptt. of Earth Sciences, Oxford University, England, 47.

The Eocene obduction of the Kohistan island arc onto the Indian plate exposed a uniquely complete island arc crust in southern Kohistan. Much of the lower arc crust, exposed in the southern Kohist.an, is ultramafic to mafic in composition, and is considered to have formed in an intraoceanic island arc setting. A detailed geochemistry, combined with a limited available radiometric age data, yields a three-stage magmatic evolution of the lower-arc crust in Kohistan.
Tora-Tigga, Jijal, Sapatgali, and Babusar ultramafic-mafic complexes occupy the immediate hangingwall of the Indus suture, and are all characterized by a low-K, high-Mg tholeiite geochemical composition. Rocks of this geochemical character are also encountered in the Kamila amphibolite belt as fine-grained metabasalts, and in the Chalt volcanics in the upper arc crust. This early-arc low-K, high-Mg tholeiitic magmatism took place between 120 to 110 Ma. and marks stage-1 magmatic phase in the Kohistan island arc.
The stage-2 magmatism in Kohistan is typically calc-alkaline and is represented by the Chilas Complex, Pattan garnet-granulites and several smaller plutons intrusive in the Kamila amphibolite belt. Trondhjemitic granites, equivalent to 102 Ma. old Matum Das pluton in Hunza valley intrude the stage-2 basic plutons. Some of the calc-alkaline volcanics in the upper arc crust may be equivalent of this stage-2 magmatic phase. An origin in mature island arc with a component of embryonic stages of intra-arc rifting is envisaged for this phase on the basis of trace-element geochemistry. The stage-3 magmatism in the lower-arc crust in Kohistan marks a reversal back to tholeiitic magmatism. It is represented by the intrusion of ultramafic-mafic-anorthosite association in the Chilas Complex, which is distinctly more depleted in incompatible trace elements than the stage-2 gabbronorite, and is characterised by an enrichment in FeO and TiO2. The later phases of stage-3 magmatism is also tholeiitic in character and is represented by a suite of ~80 Ma tholeiitic basic dykes which intrude both the Chilas Complex and the Kamila amphibolites. These dykes, representing the last phase of intra-oceanic magmatism in Kohistan, intruded immediately after a major deformation phase related with Kohistan-Karakoram collision. A tholeiite-calc-alkaline-tholeiite temporal evolution of magmatism in the lower arc crust in Kohistan suggests changing tectonic setting of magma generation, in an intraoceanic environment, from an early-arc, through mature-arc, to back or intra-arc rifling in a span of 40 Ma (between 120 and 80 Ma.), prior to Kohistan-Karakoram collision.
Key words: Magmatic evolution, ultramafics, Indus suture, Kohistan, Himalaya.

K/264. Khan, M.A., Jan, M.Q., Qazi, M.S., Khan, M.A., Shah, Y. & Sajjad A., 1995. Geology of the drainage divide between Kohistan and Kaghan, N. Pakistan. Geological Bulletin, University of Peshawar 28, 65-77.

This paper describes the geology of an area of about 1200 km2 in the upper Kaghan valley. The area is traversed by Main Mantle Thrust, which juxtaposes the southern part of the Kohistan terrane in tectonic contact with the higher Himalayas of the Indian plate. The Indian-plate sequence in the study area comprises a basement of granitic gneisses (both ortho- and paragneisses) followed by the Domel unit (calcareous schist/paragneisses, garnetiferous marbles, calc silicates and amphibolites) and the Parla Sapat unit (graphitic quartz-mica to garnet staurolite schists). These rocks are in tectonic contact with the mafic-ultramafic rocks of the Sapat complex along the Main Mantle Thrust. The Sapat complex underplates metabasalts of the Kamila amphibolite belts (i.e., Niat metavolcanic unit) and comprises ultramafic cumulates (dunites, peridotites and pyroxenites) at the base, layered gabbros in the middle and isotropic gabbros in the upper levels. The complex is folded through two phases of folding and metamorphosed under greenschist/lower amphibolite facies. The restored thickness of the complex approaches in excess of 2 kms.
The Main Mantle Thrust was mapped at several new locations during this study. Our observations show that the MMT at the base of the Sapat complex is younger than the melange /olistostorm preserved in the upper parts of the Parla Sapat unit. The thrust cuts upsection laterally, and to the east of Babusar, occurs at the base of the Niat metavolcanic unit.
Key words: Tectonics, MMT, Sapat, Kohistan, Himalaya.

K/265. Khan, M.A., Jan, M.Q. & Weaver, B.L., 1993. Evolution of the lower arc crust in Kohistan: temporal arc magmatism through early, mature and intra-arc rift stages. In: Treloar, P.J. and Searle, M.P. (eds.), Himalayan Tectonics. Geological Society of London, Special Publication. 74, 123-138.

The middle to lower island-arc crust in southern Kohistan represents a 40 Ma life-span of subduction-related magmatism in an intraoceanic setting. The Kamila amphibolite belt comprises two varieties of metavolcanic amphibolites. One enriched in high-field strength (HFS) and heavy rare-earth (HRE) elements is transitional in character between N- and E-MORB with a minor subduction-related component, and represents the earliest arc basement in Kohistan. The other variety of the metavolcanic amphibolites, together with deformed and amphibolitised intrusive basic plutons, has a transitional tholeiitic to calc-alkaline nature marked by depleted HFS and HRE elements and a distinct negative anomaly for Nb, suggesting emplacement in the early to mature stages of arc growth. The subsequent magmatism in southern Kohistan took place in two stages. The extensive calc-alkaline gabbronorites of the Chilas complex were derived from partial melting of a mantle diapir emplaced into a mature arc or, more probably, during the initial stages of sub-arc splitting. This intra-arc rifting, at its advanced stages, generated tholeiitic picrite to high-Mg basalts which crystallized the ultramafic-mafic-anorthosite (UMA) association and basic dykes of the Chilas complex. The Late Cretaceous accretion of the Kohistan island arc with the Karakoram plate in the north ceased the intraoceanic history of magmatism in southern Kohistan.
Key words: Magmatism, island arc, amphibolites, Kamila, Kohistan.

K/266. Khan, M.A., Jan, M.Q., Windley, B.F., Tarney, J. & Thirwall, M.F., 1989. The Chilas mafic-ultramafic complex; the root of the Kohistan island arc in the Himalaya of northern Pakistan. Geological Society of America special Paper 232, 75-94.

The Chilas Complex is a large mafic-ultramafic body closely associated with the Kohistan Arc sequence in the western Himalaya of northern Pakistan. The arc and the Chilas Complex occupy an area of 36,000 km2, bounded on the north and south by major sutures. The arc formed close to the margin of Eurasia in response to the northward subduction of neo-Tethyan ocean lithosphere in Late Jurassic to middle Cretaceous time, and consists of intra-arc sediments, calc-alkaline volcanics, and diorite-tonalite-granite plutons. At its base is the Chilas Complex, which extends for more than 300 km and which has a maximum width of 40 km. Most of the complex consists of massive (although locally layered) gabbro-norites, which comprise variable amounts of plagioclase (An 64-40), orthopyroxene (En 76-48), clinopyroxene (mg = 75-55), magnetite, ilmenite, +quartz, tK-feldspar, hornblende, +biotite, +rare scapolite. In the central part of the complex, near the base, there are minor discordant dikes and intrusive bodies as large as 5 km2 of a dunite-peridotite-troctolite-gabbronorite-pyroxenite-anorthosite association that displays excellent layering, graded bedding, slump breccias, and syndepositional faults. These rocks contain olivine (Fo 94-71), relatively Mg-rich orthopyroxene (En 91-65), clinopyroxene (mg = 85-67), and calcic plagioclase (An 98-83), +/- hornblende, +/- chrome spinel, +/-pleonaste, and represent a more primitive magma batch emplaced into the base of the gabbro-norite magma chamber. The mafic complex is not an ophiolite. Rocks of the complex have more petrographic and compositional similarities with plutonic blocks from island arcs and with other major mafic complexes such as the Border Ranges Complex of Alaska and those from the Ivrea Zone in the Alps. Trace-element patterns of the gabbro-norites have marked negative Nb anomalies, positive Sr, Ba, and P anomalies, and high K/Rb ratios, features consistent with melting of a hornblende-bearing sub-arc mantle source. The Chilas Complex either represents the root zone magma chamber of the Kohistan island arc, or magma generated by diapirism in the early stages of intra-arc rifting during formation of a back-arc basin.
Key words: Ultramafics, Chilas complex, Kohistan, Himalaya.

K/267. Khan, M.A., Karim, T. & Iqbal, S., 1987. Bibliography and index of the geology and mineral resources of N.W.F.P., Pakistan. Geological Survey of Pakistan, Record 77, 233p.

This is a detailed document that provides a comprehensive list of contributions to the geology and mineral resources of the North West Frontier Province, now called Khyber Pakhtunkhwa. There is an index for easy access to entries. The document is useful for researchers and those interested in exploration and development of the mineral resources of the province.
Key words: Bibliography, geology, mineral resources, NWFP.

K/268. Khan, M.A. & Khan, A., 1989a. Revised stratigraphy of Paleozoic rocks, Khyber Pass, Khyber Agency, Pakistan. Geological Survey of Pakistan, Information Release 431.

Key words: Stratigraphy, Paleozoic, Khyber Agency.

K/269. Khan, M.A. & Khan, A., 1989b. Geology of Reshun quadrangle, Chitral district, NWFP, Pakistan. Geological Survey of Pakistan, Information Release 430.

Key words: Geology, Reshun, Chitral.

K/270. Khan, M.A., Khan, F.R. & Dawar, A.Y., 1977. Geology of Reshun and Buni area Chitral, N.W.F.P. M.Sc. Thesis, University of Peshawar, 36p.

Key words: Geology, Reshun, Buni, Chitral.

K/271. Khan, M.A. & Khan, I.H., 2001. Geothermobarometry of Oghi area, Mansehra, north Pakistan. Abstracts, 4th Pakistan Geological Congress, Islamabad, p.3.

The Mansehra area occupies the part of Indian plate south of the Main Mantle Thrust (MMT). The oldest rocks exposed belong to Tanawal Formation's schist, marble and quartzite of various grades. The Mansehra granite of Cambrian age has intruded the Tanawal Formation. The granitic gneisses, porphyritic granite and tourmaline granite are part of the Mansehra granite. The diabasic dykes of Siluro-Devonian age are emplaced into granite and rocks of Tanawal Formation. Some of these dikes are metamorphosed to amphibolite grade surrounding Oghi area and are aligned in an east-west direction. The major and trace element composition by XRF analysis have revealed Si02 contents ranging from 45-48% and represent mainly basic compositions.

The metamorphism of these rocks ranges from low to medium grade at relatively high pressure. The exposed lithologies belong to green schist facies and fall in the kyanite zone of the amphibolite grade. The area is affected by retrograde metamorphism and shows sericitized schists of variegated grades. The amphibolitized bodies are aligned east-west parallel to the Oghi shear. The geothermo-barometery was carried out to know the peak metamorphic P-T conditions. The garnet-hornblende-plagioclase geobarometer and garnet-hornblende geothermometer gave 10.8 to 11.9 Kb pressures and 5880C to 7050C temperatures. These amphibolite bodies may have equilibrated at high pressures and low to medium temperatures during the Himalayan collision times (?).

Key words: Metamorphism, geothermobarometry, Mansehra.

K/272. Khan, M.A. & Khan, M.A., & Khan, M.S., 1982. Geology of Gandao quadrangle, Mohmand Agency, North West Frontier Province, Pakistan. Geological Survey of Pakistan, Information Release 130, 24p.

Key words: Geology, Gandao, Mohmand Agency.

K/273. Khan, M.A, Khan, M.A. & Jan, M.Q., 1998. Trondhjemites in the southeastern part of the Kohistan Island-Arc Terrane, Pakistan: A product of partial melting. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 97-98.

The Kohistan terrane in N. Pakistan is sandwiched by two major thrusts, the Main Karakorum Thrust (MKT) in the north and Indus Suture or Main Mantle Thrust (MMT) in the south. Recent geological mapping in southeastern part of the terrane, along a N-S transect, provides new and important information about the geology of the area. Hence, the base of the terrane is occupied by a stratiform mafic-ultramafic complex (the Sapat complex), which overrides the crust of the Indian plate along. The complex was intruded into the base of a thick pile of metavolcanics of different environments (the Kamila belt). The Kamila belt is intruded by a suite of granitoid rocks divisible into three groups. gabbroic association, gabbro-diorite/tonalite-granodiorite-granite association and trondhjemite association.

The trondhiemites occur as thin veins and dykes in the northern part of the Kamila amphibolite belt. Here, the belt is in contact with the Chilas complex along a strong shear zone known as Jal shear zone. Under the microscope the trondhjemites contain feldspar, quartz and amphibole with minor epidote, muscovite, biotite, sphene, garnet and ore, and show parallel alignment of mineral grains in one major direction. They show a very spiked pattern and are depleted in all HFSE, particularly strongly in Ti, P and Nb relative to the other granitoids of the area. The trondhjemites formed by the partial melting are depleted in these elements due to occurrence of amphibole and garnet as the residual phases in the arc basement

Partial melting of a basaltic source material is considered to be the most viable mechanism for the generation of high-AI trondhjemites similar to those of the area studied by Drummond and Defant (1990). Basalts converted to amphibolites and eclogites when involved in subduction-zone setting are partially fused to generate trondhjemites (De Vore, 1983a, b., Windley, 1984; Martin, 1986, 1987). The geochemical modeling and experimental studies (Drummund and Defant, 1990) favour a hot oceanic crust (20-30 Ma old) subducting and melting to produce trondhjemites. The trondhjemites of the present study are probably a product of partial melting of Kamila amphibolites but a direct role of subduction is not observed.

Treloar et al. (1990) considered that the amphibolite-facies metamorphism and deformation in the Kamila belt is related to the Kamila shear zone of 80 Ma, suggesting a similar age for the trondhjemites. The emplacement of Chilas complex (90-80 Ma) might have played an important role in the genesis of the trondhjemites as a heat source. Field evidence, distinctive geochemical signatures and restricted distribution of trondhjemites close to the Jal shear zone and the lower contact of the Chilas complex support the idea but the exact petrogenesis of the trondhiemites cannot be properly evaluated without data on rare-earth elements.

Key words: Tectonics, volcanics, metamorphism, Kohistan, Himalaya.

K/274. Khan, M.A., Khan, M.A., Qazi, M.S., Khan, T. & Jan, M.Q., 1997. Chalt-Babusar transect across the Kohistan island-arc terrane, N. Pakistan. Abstract volume, 12th Himalaya-Karakorum-Tibet International Workshop, Rome, Italy, 157.

Kohistan Island Arc terrane in N. Pakistan is a Creto-Tertiary island-arc complex entrapped between collided Indian and Karakoram plates [1]. Several aspects of the crustal geology of the terrane have been refined in the light of our recent mapping along its eastern margin, i.e., Babusar-Chilas-Chalt transect (Fig. 1).

The base of the arc crust in SE Kohistan is occupied by the 2-km thick Sapat mafic-ultramafic complex [2]. Unlike the garnet-granulite facies Jijal Complex exposed in the Indus valley [3], the Sapat Complex is metamorphosed only to lower-amphibolite facies.

The Sapat complex underplates a sequence of amphibolite-facies metabasalts belonging to the Kamila amphibolite belt (KAB). Two compositional types are identified in the KAB. The volumetrically preponderant Niat metabasalts have a geochemical composition similar to the N-MORB, characterized by enriched HFSE and HREE relative to the LILE and REE [4].

These metavolcanics are locally intercalated with metabasalts, which are calc alkaline and have a composition typical of subduction-related magmas. Unlike the Indus-valley section [5], the part of the KAB in SE Kohistan is devoid of metagabbroic amphibolites.

To the north, the KAB is in tectonic contact with the Chilas complex [4]. Much of the northern contact of the Chilas complex is against the relatively younger Kohistan batholith, which more or less completely separates it from a sequence of metabasalts and metasediments exposed near Jaglot. The Chilas complex carries xenoliths of KAB in its southern marginal parts and those of the metasediments of the Jaglot group in its northern marginal parts, suggesting that it was emplaced at the interface of KAB and Jaglot group.

The Jaglot group [6] comprises Gilgit Formation (paragneises, schists and pillowed metabasalts) at the base, pillowed metavolcanics similar to the Chalt volcanics in the middle and Thelichi Formation (slates, metavolcanics and marble) at the top. There is possibility the Jaglot group is equivalent to the Chalt-Yasin succession exposed adjacent to the Northern Suture, but more geochemical data are needed for evaluation of this aspects.

Key words: Ultramafics, metamorphism, Babusar, Chalt, Sapat, Kohistan, Himalaya.

K/275. Khan, M.A., Khan, M.H., Tahirkheli, T., Treloar, P.J. & Petterson, M.J., 2000. Tectonic Evolution of the Eocene Drosh-volcano-sedimentary basin NW-Kohistan island arc terrane, Hindu Kush, N Pakistan. Abstract Volume, 15th Himalaya-Karakoram-Tibet Workshop, (Chengdu) China, 180-181.

In NW Himalayas, the suture zone between the collided Indian and the Karakoram Plates is occupied by crust the Cretaceous Kohistan Island-Arc Terrane (Tahirkheli et al., 1979). Late Cretaceous (about 90 Ma) accretion with the southern margin of the Karakoram Plate the site of the Shyok Suture Zone turned Kohistan to become an Andean-type margin. The Neotethys was completely subducted at the southern margin of Kohistan by Early Tertiary, leading to collision between Kohistan and continental crust of the Indian Plate at the site of the Main Mantle Thrust.
More than 90% of the Kohistan terrane comprised plutonic rocks of (1) ultramafic to gabbroic composition forming the basal crust of the intra-oceanic stage of the island arc, and (2) tonalite-granodiorite-granite composition belong to the Kohistan Batholith occupying much of the intermediate to shallow crust of the terrane mostly intruded in the Andean-type margin stage (Petterson & Windley, 1985). Both these stages of subduction-related magmatism were associated with volcanic and sedimentary rocks formed in Late Cretaceous and Early Tertiary basins. This study addresses tectonic configuration of Early Tertiary Drosh basin exposed in NW part of the Kohistan terrane, immediately to the south of the Shyok Suture Zone.
Previous studies have shown that Shyok Suture Zone in its immediate southern vicinities comprises a sequence of Late Cretaceous sediments comprising turbidites and subordinate limestone, together constituting the Yasin Group, overlying a sequence of met volcanic rocks called Chalt Group. Recent detailed studies by us confirm that this configuration holds true for the area between the Hunza valley in the east to the Village of Shamran in the west, through the Chalt Volcanic Group increasingly becomes less deformed and more siliceous towards the west. West of Shamran, in the area around the Shandur Pass, there is sporadic presence of rhyolite-rhyodacite dominated green as well as pink volcanic rocks resembling closely with the Eocene Utror Volcanic Group. These rocks, known as the Shamran Volcanic Group. 40Ar-39Ar hornblende dating of the Shamran Volcanic Formation has yielded a 58 Ma age. Further west in the area near Drosh, occurrence of two volcanic units; Gawuch and Drosh formations is known previously (Pudsey, et al., 1985). The Gawuch Formation comprises highly tectonic greenschist metavolcanics, with common intercalation of limestone and marble in its upper (northern) part. The Drosh Formation consists of mildly deformed to slightly metamorphosed basalts of tholeiitic character, similar to the Chalt Volcanic group. Our recent mapping in Drosh area finds a third volcanic unit; this unit is andesite to rhyolite in composition, massive; aphyric to hornblende-and/or pyroxene and/or plagioclase phyric, undeformed and only mildly metamorphosed and is equated with the Eocene Shamran Volcanic Formation in strike to the east. All the volcanic units in the Drosh area are intruded by the Mirkhani granodiorite pluton. A sequence of red conglomerate, sandstone, siltstone, siltstone and shale of fluvial origin, termed Purit Formation is associated with all the volcanic rocks of the area. Previously this unit was considered to have an unconformable stratigraphic position above the Gawuch Formation and the Mirkhani granodiorite pluton but below the Drosh Formation. Detailed mapping and field-relation studies demonstrate that (1) Mirkhani Pluton is intrusive and thus younger than all the volcanic units in the area, implying that the Purit Formation that rests unconformably on top of the Mirkhani Pluton is the youngest in the area, (2) the occurrence of the Purit Formation unconformably on top of the Shamran Formation suggests a post Early Eocene age for the former.
A comparison between the Early Tertiary Drosh basin with the southerly located Dir basin (Sullivan, et al., 1993) of equivalent age shows a close match in the volcanic rocks in terms of composition and Andean-type setting of origin, but contrast in the sedimentary record. Sediments in the Dir basin are deep-water turbidites (the Baraul Banda Slate Formation) and are considered to have formed in an Andean-type fore-arc setting. In contrast the Purit Formation is typically fluvial and is relatively younger than the Early Eocene Shamran Formation. We equate the Drosh basin with the Reshun basin further to the north and suggest an Andean-type back-arc basin origin for these two basins.
Key words: Tectonics, Eocene, volcano-sedimentary basin, Kohistan island arc, Chitral, Hindu Kush.

K/276. Khan, M.A. & Khan, M.R., 1994. Evaluation of geotechnical properties and deformability of Jura granites, Neelum valley Azad Kashmir. Kashmir Journal of Geology 11 & 12, 89-95.

The geotechnical and deformability characteristics of Jura granites are presented. The middle and lower Jura granites are medium textured and takes excellent polish. The upper Jura is coarse textured and also take polish. From geotechnical variations it is apparent that upper coarse textured granites display a behavior markedly different

from lower granites. In the upper weaker rocks, the elastic range is limited to very low stress levels. The sensitivity of the strength to water content has also been discussed.
Microscopic characteristics in particular are outlined, in the areas of grain contact were successfully used to explain strength and deformability of granites: Evaluation of geotechnical properties shows potential as a compliment to the index test of saturated rocks and uniaxial load for weak and strong granites respectively.
The Aggregate Abrasion Value (4%), Aggregate Crushing Value (10%), soundness (1.3 to 6%), porosity (0.1 to 6%), compressive strength (2000-3500 PSI) and slake durability (75% retained) tests were conducted for economic exploitation of the rocks.
Key words: Geotechnical, granites, Neelam valley, Azad Kashmir.

K/277. Khan, M.A. & Khan, M.S., 1989. Engineering characteristics of Nauseri Marble, Azad Kashmir. Kashmir Journal of Geology 6 & 7, 125-132.

White, gray and bluish gray marble and brownish gray to whit and dense marble occur in Nauseri area. The deposits were formed at southwestern margin of Kashmir landmass during Permo-Carboniferous times. They were metamorphosed to varying degrees. White crystalline limestones are calcite marbles of inferior quality comprising of a small part of the deposits. Most of these potential sources are not developed so for mainly for lack of technical information. However, on the basis of range of colors, good textures and quality a large and potential quarries could be developed. This paper describes the engineering characteristics of Nauseri Marbles.
A number of mechanical characteristics were determined and most of them are in confirmation to ASTM specifications.
The compressive strength of the marble varies from 3100 PSI to 8100 PSI. Taber Abrasion Index value range from 8.0 to 15.01. The soundness ranges from 0.1 to 5.0% absorption varies from 0.01 to 8%. Specific gravity ranges from 2.65 to 1.73. The porosity of the marble is 0.5 to 8.3%.
Key words: Engineering characteristics, marble, Azad Kashmir.

K/278. Khan, M.A. & Khan, S., 1979. Geology of Pegmatites of Upper Neelam valley, Azad Kashmir. Geological Survey of Pakistan, Information Release 112, 27p.

Key words: Geology, pegmatite, Neelum, Azad Kashmir.

K/279. Khan, M.A., Khan, S.F. & Islam, F., 1999. Geology of marbles from District Buner, N.W.F.P., M.Sc. Thesis, University of Peshawar, 91p.

This study of marble deposits of the North West Frontier Province has been carried out in order to update the previous work on the commodity and also to investigate some of the new and the little known occurrences.
The project is located at the central part of Buner district which include areas of Yakhdara, Mirdara, Matwanai, Tursak, Bazargai, Nanser and Bampokha. These are the major marble producing deposits in North West Frontier Province, and different mining corporations are working in these areas.
The marble deposits under study are mostly associated with metasedimentary rocks of Paleozoic age. The marble deposits are located in Kashala, Nikanai Ghar and Saidu Formations. Variation in composition, texture, thickness, and structure displaying a wide array of color shades and grain sizes. The present study include general characteristics of the outcrop exposures, physical and chemical characteristics, petrography and geo-technical properties of these marble. The geology, petrography and geo-technical studies shows that the marble from these deposits has a pleasing appearance, take good polish and meet the standard specification for specific gravity, water absorption, flexural strength and other physical properties.
Key words: Marbles, Buner.

K/280. Khan, M.A., Khan, Z.A., Qureshi, M.S. & Nasim, S., 1994. Evaluation of geotechnical properties of Miocene shales of Muzaffarabad Azad Kashmir. Kashmir Journal of Geology 11 & 12, 97-104.

Geotechnical behavior of shale of Murree Formation of Miocene age was observed under static and dynamic tests. It include natural water content, absorption, specific gravity, plasticity, characters, slake durability, point load index, compaction and strength characteristics of mixed samples with varying proportions of shales and sills. This shows improvement in geotechnical behavior of the construction material.
The XRD analysis of the specimens shows montmorillonite and illite as the dominant clay minerals. Generally, the shales tend to have low absorption values, strength after compaction of the samples. Clayey shales showed the best compaction with the lowest void ratio. The void ratio increases with increasing proportions of siltstone in many cases. The unconfined compressive strength decreased with increasing proportions of siltstone (50-65%). The durability seemed to influence by the nature of cementation, degree of lithification and the proportion of silt.
Key words: Geotechnical, shale, Miocene, Muzaffarabad, Azad Kashmir.

K/281. Khan, M.A., Kidd, W.S.F. & Edwards, M.A., 2000. Tectonics of the western margin of the Nanga Parbat-Haramosh syntaxis: Tracing the active Raikot Fault to the SW and modeling its impact on Quaternary exhumation of the massif. Abstracts, Third South Asia Geological Congress, Lahore, 16-17.

Key words: Tectonics, NPHM, Raikot.

K/282. Khan, M.A., Nasir, S. & Malik, I., 1990. Brief geology of the Pegmatites of Jagran area, Neelam valley Muzaffarabad district, Azad Jammu and Kashmir. Geological Survey of Pakistan, Information Release 460.

Key words: Pegmatites, Neelam valley, Azad Kashmir.

K/283. Khan, M.A. & Petterson, M.G., 1992. Magmatic evolution of the Kohistan arc: Geochemical constrains. Abstracts, First South Asia Geological Congress, Islamabad, p.23.

The Kohistan sequence -in N. Pakistan comprises a diverse assemblage of rocks, emplaced during a wide span of time. The recently acquired radiometric ages and whole-rock geochemical data suggest that the sequential magmatism in the Kohistan arc was controlled by changing plate tectonic setting of the region. An early phase of magmatism was exclusively in an intraoceanic island arc setting and was mainly basic in composition (e.g., the Jijal and Chilas Complexes, the Kamila amphibolites, and high-Mg tholeiite volcanics in the Chalt area). The late Cretaceous accretion of the island arc with the Karakoram plate in the north resulted in a major change in the tectonic character of the Kohistan from an intraoceanic island arc to a continental margin. This led to generation of a predominantly acid magmatism which now makes bulk of the Kohistan batholith and volcanics in the upper parts of the arc sequence. Within this broad two-fold division of the arc magmatism, our geochemical data enables us to recognize changes in the tectonic character of the Kohistan arc from an interoceanic early to a mature stage, and from a continental margin to a continent-continent collision zone. In this paper we present geochemical data for these successive phases of magma, and identify changes in the magma character related with changes in the tectonic settings of the Kohistan arc.
Key words: Magmatic evolution, geochemistry, Kohistan arc.

K/284. Khan, M.A., Quddus, A. & Khan, M.F., 1974. Field report on geology of Shakardara area, Swat Pakistan. M.Sc. Thesis., Punjab University, Lahore.

Key words: Geology, mapping, Swat.

K/285. Khan, M.A. & Qureshi, M.S., 1989. Physical characteristics of soil of Muzaffarabad Kohala area Azad Kashmir. Kashmir Journal of Geology 6 & 7, 109-124.

Field and laboratory investigation of physical characteristics related to grades, sediments, water relationship, effect of stress and the amount of strain have been investigate from civil engineering point of view.

The origin of the soils have been studied to summarize the relationship between the soil types and their response to varying condition of moisture, stress response in relation to the grades of the soils.
Key words: Stress, strain, sediments, soil, Muzaffarabad, Azad Kashmir.

K/286. Khan, M.A. & Qureshi, M.S., 1991. Landslide hazards in southern Muzaffarabad Azad Kashmir and southeastern Hazara Pakistan. Kashmir Journal of Geology 8 & 9, 121-on ward.

The Jhelum River Valley in southeast of Hazara and southern part of Muzaffarabad are the areas of high landslide hazards. Steep slope, silty, sandy and clayey soils, heavy rains, water seepages all contribute to the landsliding in the region. The instability of the area has been further increased by road widening and effect of the Main Boundary Thrust (MBT) resulting in the form of many major landslides, such as slumping earthflows, rockfall, sinkholes and combination of these.
The active Kohala and Rara landslides were investigated in detail because of their large size and proximity to roadways. Soil samples were collected to evaluate engineering properties of the materials involved in these failures. The investigated area lies in a structurally complex belt of folded and faulted sedimentary rocks which have been further deformed by the locally important Murree Thrust and regionally significant Main Boundary Thrust (MBT).
In addition landslide map of the area was prepared by performing fieldwork and using Ariel photographs. All slope failures were classified according to their movement and state of activity, with variation and change of water content (6.7-45%), liquid limit (22.6-41.5), plastic limit (6-23.7), swellability (8.9-55), compressive strength (2-15 MPa), shear strength (3-10 MPa) and pore water pressure (4-6 MPa). The results suggest that slope failure occur due to high swelling potential of soils, active faults and shear failures.
Key words: Hazards, landslides, Muzaffarabad, Azad Kashmir, Hazara.

K/287. Khan, M.A. & Qureshi, M.S., 1992. Review of geotechnical characteristics of Neelum granites, Neelum valley, Azad Kashmir. Kashmir Journal of Geology 10, 141-146.

The Neelum granite of Neelum Valley Azad Kashmir has been investigated to evaluate its geotechnical properties. The geotechnical properties like compressive strength shear strength, soundness, porosity, water absorption and slake durability of the granite show their potential to be used as construction raw material. The compressive strength values ranges from 100-350 MPa. The shear strength varies from 150-950 MPa, soundness 0.1-2%, water absorption 14-20%, slake durability 99.5-99.8%, porosity 0.2-15% and degree of polish good excellent.
An evaluation of geotechnical properties of different granites suggest the rational use of the raw material, considering the deformability characters of the rocks.
Key words: Geotechnical, granites, Neelum, Azad Kashmir.

K/288. Khan, M.A., Rehman, I., Rehman, O. & Abbasi, I.A., 1990. Multiple detachment levels and their control on the deformation style of the Kalachitta Hill Range. Abstracts, 2nd Pakistan Geological Congress, University of Peshawar, p.2.

Detailed mapping in a part of the Kalachitta Hill Range, Attock District (I. Rehman, 1990) has shown two distinct styles of deformation, apparently controlled by two detachment levels. The lower detachment occurs at the base of the Mesozoic strata, and the upper in the Patala Formation of Paleocene age. The deformation in the Mesozoic-Paleocene sequence between these two detachment levels is controlled by thrusting, resulting in the formation of a duplex zone, in which the lower detachment is acting as a sole thrust while the upper detachment as roof thrust. The Mesozoic-Paleocene strata in this duplex zone is repeated, at one place, more than four times in the form of south-verging horses. No folding, except for that related with thrusts (open hanging wall anticlines) has been observed in the sequence between the two detachment levels. In contrast deformation in the Cenozoic strata overlying the upper detachment surface in the Patala Formation is controlled by large scale folds verging both to the north and south, in a fashion similar to that outlined by Cotter (1933) while presenting a model for the tectonic evolution of the Kalachitta Hill Range.
Key words: Deformation, Kalachitta range, Attock.

K/289. Khan, M.A. & Ristic, D., 2001. Swelling potential of sandstones and clays in Himalaya regions. Abstracts, 4^{th} Pakistan Geological Congress, Islamabad, p.47.

Swelling potential of rocks in Himalayan regions is a great problem for civil engineers for designing high rise buildings, bridges, highways, viaducts, overpasses, under passes and other civil engineering structures. This paper covers a broad mechanism of swelling potential of rocks and soils. The rocks were classified in different classes for identification and uses for civil engineering structures. The categories involve mudstone, shales, weakly cemented sandstones, and clays. The engineering aspects of swell are described by the influence of density, in-situ stress and availability of water. The identification of swell-shrink susceptible strata includes testing techniques and the design criteria for subsurface and surface structures in the Himalayan regions of Pakistan and are presented here.
Key words: Geotechnical, sandstone, clay, civil engineering, NW Himalaya.

K/290. Khan, M.A. & Stern, R.J., 1996. Polarity of the subduction system responsible for the Cretaceous Kohistan island arc terrane, N. Pakistan: geochemical and structural constraints. Geological Bulletin, University of Peshawar 29, 27-40.

The Kohistan island arc terrane of N. Pakistan has experienced multiple collisions, resulting in obliteration of the subduction system responsible for its creation. Indirect evidence, based on structural vergences and across-the-arc variations in trace elements (Ti, Zr, Nb, and P) have been combined to interpret the nature of the subduction zones responsible for Kohistan in terms of their location and polarity (i.e., dip direction). Geochemical investigations, from north to south, in the Chalt volcanics, the Chilas complex and the Kamila amphibolite belt indicate a systematic increase in high-field strength elements from north to south. These variations indicate an overall decrease in the degree of melting or degree of source-region depletion, which in either case, give a facing direction for the arc terrane towards north. The structural vergences in the northern parts of the Kohistan terrane are also consistent with a south dipping subduction zone located to its north. Using these observations, a tectonic model is proposed for the origin of Kohistan terrane on a south-dipping subduction zone located at its northern margin. The subduction switched to the southern margin of the arc terrane soon after the Kohistan-Karakoram collision with a reverse polarity (i.e., dip direction towards north). The model has been tested in the light of modern examples of arc-continent collisions in SW pacific ocean.
Key words: Geochemistry, structure, subduction, Kohistan arc.

K/291. Khan, M.A. & Stern, R.J., 1997. Isotope composition of Sr, Nd and Pb in the Kohistan Intra-Oceanic Arc Terrane of Northern Pakistan. Abstract volume, 12^{th} Himalaya-Karakorum-Tibet International Workshop, Rome, Italy, 55-56.

The Kohistan terrane of northern Pakistan is a remnant of a Creto-Tertiary island arc crust trapped between collided Indian and Karakoram plates. Two phases of evolution are recognized. Much of the arc crust (i.e., lower-crustal ultramafic-mafic cumulates of Sapat and Jijal complexes, intraoceanic phase. The collision with Karakoram took place at about 90 Ma accompanied by intrusion of the Chilas ultramafic-gabbronorite Complex. Much of the Kohistan batholith was emplaced in the subsequent continental-margin setting.
We report isotopic composition of Sr, Nd and Pb for the principal units of the island arc crust, i.e., Kamila amphibolite belt, Chalt volcanics and the Chilas complex. Sr and Nd isotopic data for the Kohistan batholith has been published. The Kamila amphibolite belt in SE Kohistan comprises predominantly of metavolcanic rocks metamorphosed under lower-amphibolite facies. Two compositional types are recognized.
The predominant variety is E-type amphibolite, characterized by slight to moderate enrichment in HFSE and HREE over LREE, respectively. Overall composition is not far from type N-MORB. The D-type amphibolite are typically calc-alkaline in composition and show major and trace element composition consistent with a genesis involving strong subduction component. The distinction between the two varieties of the Kamila amphibolite is amplified by the isotope data; E-type contains more radiogenic Nd (Nd120Ma=+7.0 to +7.4) and less radiogenic initial Sr (87Sr/86Sr=0.7036-0.7039) than the D-type (Nd120Ma=+2.9-+4.7; 87Sr/86Sr=0.7041-0.7047). Pb isotope composition for the two varieties shows only subtle differences. The Kamila amphibolites, in SE Kohistan (Thak-Babusar valley), are intruded by a syntectonic suite of Gabbrodiorites-tonalites-granodiorites-trondhjemites. Within this suite three subgroups are identified based on geochemical and isotopic composition. The Gabbro-diorite-tonalite

suite is tholeiite to calc-alkaline in composition with race-element characteristics common with subduction related rocks. They have highly radiogenic Nd (143Nd/144dm>0.51290), less radiogenic Sr (mean 87Sr/86Sr=0.71380), comparable to E-type Kamila amphibolites. The granodiorite suite, in contrast, has moderate radiogenic initial Sr and least radiogenic Nd (mean 87Sr/86Sr=0.7037, 143Nd/144Ndm<0.51280). The trondhjemites have low initial Sr (mean 87Sr/86Sr=0.7037) and moderately low Nd (143Nd/144Ndm=0.512840-0.512865). The Chilas Complex comprises ultramafic cumulates, gabbronorites and hypersthene diorites with a typical calc-alkaline composition and a strong subduction component [3]. It is characterized by a homogeneous isotopic composition for Sr, Nd and Pb (87Sr/86Sr=0.70396-0.70414, Nd120Ma=2.8-4.0), which is closely comparable with that of the D-type amphibolites from the Kamial belt. The Chalt volcanics are compositionally heterogeneous comprising basalts, bonninites and rhyodacites. These have homogeneous isotopic compositions for Nd (Nd120Ma=6.3-7.3) and Pb (206Pb/204Pb=18.1-18.4); 208Pb=44-58; 207Pb=5-10, but have highly variable initial Sr (87Sr/86Sr=0.7040-0.7055), probably reflecting alteration accompanying submarine hydrothermal metamorphism. In the Kohistan batholith, Stage I tonalites have radiogenic Nd and low initial Sr (87Sr/86Sr=0.7039; Nd120Ma=+6.9), Stage II granitoids have moderate initial Sr and less radiogenic Nd (87Sr/86Sr=0.7041-0.7042, Nd120Ma=+3.01-4.09), and Stage III leucogranites have variable but high initial Sr and low Nd [2]. The isotopic composition of Sr and Nd for various units of the Kohistan arc terrane, when used together, identify two source types. The E-type Kamila metavolcanic amphibolites, Stage I (Matum Das) plutons of the Kohistan batholith, and Thak valley gabbro-diorite-tonalite suite are all characterized by more radiogenic Nd and less radiogenic Sr. The Chalt volcanics have comparable Nd but higher and variable initial Sr. Assuming that higher initial Sr is due to seawater alteration, the Chalt volcanics appear to have a source common with the above mentioned three suites of rocks. The early-arc crust in Kohistan, comprising these four units (and basal cumulates of Jijal and Sapat complexes), is envisaged to have formed from partial melting a mantle source similar to those of N-MORB, with slight but variable modification by subduction related metasomatism.

The mantle source responsible for the Chilas complex, D-type metavolcanic amphibolite and granodiorite and trondhjemite intrusives in the Kamila belt and the Stage-II Kohistan batholith is characterized by less radiogenic Sr and Nd. These suites of rocks formed in the later stages of intraoceanic phase or during Andean-type continental-margin phase, when the arc was in its mature stages of development. A mantle source with higher degrees of subduction-related metasomatism is considered responsible for this crustal component in the Kohistan arc terrane.

An interesting feature of the Isotopic compositions of Sr and Pb in Kohistan rocks is the presence of DUPAL signature, suggesting that Kohistan formed at or to the south of equator prior to its northward drift and collision with the Karakoram plate. Independently acquired recent paleomagnetic studies confirm this conclusion.

Key words: Geochemistry, isotopes, paleo-position, Kohistan arc.

K/292. Khan, M.A., Stern, R.J., Gribble, R.F. & Windley, B.F., 1997. Geochemical and isotopic constraints on subduction polarity, magma sources and palaeogeography of the Kohistan Arc, northern Pakistan. Journal of the Geological Society, London 154, 935-946.

Geochemical and isotopic data are presented for 18 representative samples from the intraoceanic phase of the Kohistan arc. A restricted range of initial $^{87}Sr/^{86}Sr$ (0.7036–0.7066) and ºNd (+2.8 to +7.4) along with measured $^{206}Pb/^{204}Pb$ (18.0–18.6) are consistent with formation of the arc complex in an intra-oceanic setting. The isotopic data demonstrate the involvement of enriched, DUPAL-type mantle, suggesting that the Kohistan arc formed at or south of the present equator. Subduction polarity inferred from geochemical and isotopic data indicate that the Chalt Volcanics and Kamila Amphibolites represent a forearc and backarc basin sequence, respectively. These inferences are most simply resolved with a tectonic model whereby the intra-oceanic Kohistan arc evolved over a south-dipping subduction zone, implying that Kohistan and India moved northwards on the same plate, although separated, during much of Cretaceous time. Collision of Kohistan with the Karakorum caused a new, north-dipping subduction zone to form on the south side of Kohistan, leading to collision with India in early Tertiary time.

Key words: Geochemistry, isotopes, subduction, polarity, palaeogeography, Kohistan arc.

K/293. Khan, M.A., Stern, R.J., Gribble, R.F. & Windley, B.F., 1998. Discussion on geochemical and isotope constraints on subduction polarity, magma sources, and paleogeography of the Kohistan arc, northern Pakistan. Himalayan Geological Society of London, 155, 893–895.

Key words: Geochemistry, isotopes, subduction, polarity, Kohistan arc.

K/294. Khan, M.A. & Tahirkheli, T., 1980. Petrography and mineralogy of Tarbela alkaline complex. M.Sc. Thesis, University of Peshawar, 132.

The Tarbela complex comprises gabbroic rocks (oldest), dolerites, melteigites, albitites, normal and sodic granites, albite-carbonate rocks / breccia, and carbonatites (youngest), together covering an area of about 4 sq. km. The rocks have been intruded along a fault zone between the Salkhala and Tanawal formation. Some of the gabbroic intrusions display in situ differentiation with one intrusion grading from pyroxenitic outer margin to leucogabbroic/dioritic interior with a core of intrusive albitites.
Key words: Petrology, alkaline complex, Tarbela.

K/295. Khan, M.A. & Thirlwall, M.F., 1988. Babusar amphibolites: arc tholeiites from the southern Kohistan arc, N. Pakistan. Geological Bulletin, University of Peshawar 21, 147-158.

An imbricate sequence of amphibolites, apparently in the form of a linear belt occurs in the hanging wall of the Indus Suture at Babusar Pass (SE Kohistan). Major-, trace- and a limited rare-earth element data classifies them to be arc tholeiite in composition, in contrast to the bulk of the Kohistan arc, which is predominantly calc-alkaline. Models are discussed about their position with respect to the rest of the Kohistan magmatic sequence, whereas there is a possibility that they represent early tholeiite phases of arc magmatism, a model is presented which considers them (together with a conformable basal ultramafic unit) as crust of a tholeiitic island arc, formed as a separate entity from a predominantly calc alkaline Kohistan arc to the north.
Key words: Petrology, amphibolites, tholeiites, Kohistan island arc.

K/296. Khan, M.A., Treloar, P.J., Khan, M.A., Khan, T., Qazi, M.S. & Jan, M.Q., 1997. Chalt-Babusar transect at the eastern margin of the Kohistan terrane: Implications for the constitutions and thickening of island-arc crust. Abstracts, 3rd Pakistan Geological Congress, University of Peshawar, p.36.

For details consult the following account.
Key words: Tectonics, ultramafics, MMT, Indian plate, Karakoram plate, Kohistan island arc.

K/297. Khan, M.A., Treloar, P.J., Khan, M.A., Khan, T., Qazi, M.S. & Jan, M.Q., 1998. Geology of the Chalt-Babusar transect, Kohistan terrane, N Pakistan: implication for the constitution and thickening of island arc crust. Journal of Asian Earth Sciences 16, 253-268.

The Kohistan island arc terrane is sandwiched between the collided Indian and Karakoram plates in the Himalaya of North Pakistan. Structures related to collision, during which the arc was thrust onto the leading edge of continental India along the Main Mantle Thrust, have resulted in exposure of an almost complete section of arc crust. Mapping along a transect across the east end of the arc terrane provides new data concerning the magmatic emplacement of several of the principal units. The base of the arc here is occupied by a major stratiform ultramafic–gabbroic complex, the Sapat complex. This was intruded into the base of a thick pile of meta-volcanic rocks which make up the Kamila amphibolite belt, and which comprise a varied sequence of basalts some with MORB-type tholeiitic affinities and some with island-arc tholeiitic affinities as well as calc-alkaline andesites. Ultramafic and gabbronorite rocks of the Chilas complex are intrusive into the top of the Kamila amphibolite belt. The upper part of the crust comprises meta-sediments and meta-volcanic rocks of the Jaglot and Yasin-Chalt Groups. These were formed in one or more arc-related basins, and host much of the Kohistan batholith. A three-stage history of crustal thickening can be documented for the Kohistan arc. From its initiation at *ca*. 125–120 Ma until *ca*. 90 Ma, the arc grew downward through magmatic emplacement, into its base, of stratiform ultramafic–gabbroic plutonic complexes, and upward through extrusion of volcanic sequences. In Stage 2, the focus of crustal growth shifted upwards from the base of the arc with emplacement of the Chilas complex along the interface between the Kamila amphibolite belt and the overlying volcano-sedimentary cover. This stage of crustal thickening was accompanied by shortening associated

with the 90–80 Ma Kohistan–Karakoram collision. Finally, in Stage 3 (80–45 Ma), the Kohistan batholith was emplaced into deformed cover rocks of the uppermost part of the arc crust.
Key words: Tectonics, MMT, Indian plate, Kohistan island arc.

K/298. Khan, M.A., Treloar, P.J., Searle, M.P. & Jan, M.Q. (eds.), 2000. Tectonics of the Nanga Parbat Syntaxis and the western Himalaya. Geological Society of London Special Publication 170, 485p.

This is a compilation of referee-reviewed contributions on the geology, tectonics, erosion and exhumation of the Nanga Parbat-Haramosh massif, and some other neighbouring areas. Individual papers are presented at appropriate places in the present work.
Key words: Tectonics, Nanga Parbat, NW Himalaya.

K/299. Khan, M.A., Turi, K.A. & Abbassi, I.A., 1990. Structures in the hangingwall of the Main Boundary Thrust: post-folding thrust and normal faults from the Kotal-pass area, Kohat Range, N. Pakistan. Geological Bulletin, University of Peshawar 23, 175-186.

The Main Boundary Thrust is a wide, complexly folded and faulted zone which uplifted the Kohat range, and tectonically emplaced the Mesozoic-Cenozoic shelf carbonate succession over the Tertiary molasse sediments. The MBT zone is characterized mainly by major thrust faults both imbricate and duplex type and tight folds. Tight folding along the MBT zone resulted in the formation of out-of the syncline faulting. Late stage (post folding and thrust faulting) development of normal faults at the base of the Paleocene succession further deformed the MBT zone in the Kohat area. The Paleocene strata in the hanging wall of southward propagating normal faults is subhorizontal to shallowly dipping northward, and lies discordantly over the Mesozoic succession. The normal faults are of localized nature in the MBT zone and are reported for the first time from the Kohat range. The normal faults may have exploited the weaker horizons generated during earlier thrusting such as out-of-syncline faults. Presence of thick fault breccia along the fault plane suggests that these structures may have formed close to near surface conditions during uplift of the Kohat range.
Key words: Structure, tectonics, MBT, Kohat.

K/300. Khan, M.A.R. & Hussain, S.H., 1989. Geology of Mirpur area, Azad Kashmir. Geological Survey of Pakistan, Information Release 445.

Key words: Mapping, Mirpur, Azad Kashmir.

K/301. Khan, M.H., 1952. Investigation of the Khewra, Warchha Mandi, Kala Bagh and Mari salt mines. Geological Survey of Pakistan, Records 6(1), 47-51.

Key words: Salt mines, Khewra, Kala Bagh.

K/302. Khan, M.H., 1992-93. Tectonics and structure of Timargara-Lal Qila-Wari areas District Dir N.W.F.P. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 265p.

Key words: Tectonics, structure, Timargara, Dir.

K/303. Khan, M.I., 1958. A preliminary geological map of Pakistan (scale 1: 500, 000). Geological Survey of Pakistan.

This is one of the earlier attempts of preparing a geological map of Pakistan.
Key words: Geological map, Pakistan

K/304. Khan, M.I., 1989. Ablation on Barpu-Glacier, Karakoram Himalaya, Pakistan. A study of melt processes on faceted debris-covered ice surface. M.A. Thesis, Wilfried-Laurier University, Waterloo, Ontario.

Key words: Glaciers, Barpu, ablation, melting, Karakoram, Himalaya.

K/305. Khan, M.I., 1992. Glacial hazards of Northern areas. Culture Area Karakorum, Newsletter 2, p.10, Tubingen.

Key words: Glaciers, hazards, Karakoram.

K/306. Khan, M.I. & Hammad, M., 1978. Petrology of Utla granite, Gadoon area. M.Sc. Thesis, Peshawar University.

Key words: Petrology, granite, Gadoon, Swabi.

K/307. Khan, M.J., 1974. Geological investigation for graphite in Gangarh Range, southern Hazara, Pakistan. Geological Survey of Pakistan, Quetta, Information Release 82.

Key words: Graphite, Gandghar, Hazara.

K/308. Khan, M.J., 1983. Magnetostratigraphy of the Neogene and Quaternary Siwalik Group of the Trans-Indus Salt Range, Northwestern Pakistan. Ph.D. Thesis, Graduate School of Arts and Sciences, Columbia University, 217p.

Part of the information contained in this thesis is presented in summarized form in the following three papers by M. J. Khan.
Key words: Magnetostratigraphy, sedimentation, Quaternary, Trans-Indus Salt Range, siwalik.

K/309. Khan, M.J., 1984a. Brief results of the paleomagnetic studies of the Siwalik group of the trans-Indus Salt range, Pakistan. Geological Bulletin, University of Peshawar 17, 176-178.

Thirteen stratigraphic sections were measured and sampled, from the Siwalik group rocks of the Trans-Indus Salt Range, for Paleomagnetic studies. After measuring Natural Remnant Magnetization (NRM) of all samples, a few were arbitrarily selected for Progressive Alternation Field (AF) demagnetization and Partial Thermal Demagnetization (PTD). The results of these studies show that AF demagnetization is not sufficient for the successful removal of the secondary component of magnetization particularly in case of samples collected from reddish-brown siltstone / claystone units. However, PTD successfully enables to isolate the stable and primary component of magnetization. Therefore, all samples were subject to PTD at 5000C to 6600C, to obtain the stable component of remnant magnetization. These stable directions of remnant magnetization were used to establish a magnetic-polarity reversal sequence of each section, respectively.
Key words: Paleomagnetism, sedimentation, Trans-Indus Salt Range, Potwar.

K/310. Khan, M.J., 1984b. Sedimentation and tectonics of the Trans-Indus Siwalik Group by paleomagnetic methods. Abstracts, First Pakistan Geological Congress, Lahore, p.11.

Paleomagnetic studies of thirteen stratigraphic sections from the Bhittani, Marwat, Khasor, Shinghar, and Surghar Ranges show that the Siwalik Group rocks in this area range in age from 12 Ma. to 0.5 Ma. The basal part of the Siwalik Group in the Bhittani Range could not be dated due to lack of exposure of lower part of the Siwalik Group.

These studies clearly indicate that onset of the Siwalik sedimentation, in the Trans-Indus area, started much later than in the Potwar Plateau, where basal part of the Siwalik Group is older than 15 Ma. Therefore, the Siwalik Group of the Trans-Indus area indicates westward transgression of the Potwar Plateau molasse facies.

Sediment accumulation rates calculated for the Trans-Indus Siwalik Group are generally higher than those calculated for the similar deposits of the Potwar Plateau. These higher sedimentation rates indicate faster subsidence of the Trans-Indus area, and consistant availability of detrital material. The entire stratigraphic sequence is conformable and suggests a lack of tectonic activity, except general subsidence of the basin of deposition, between 12 Ma. and 0.5 Ma. The Siwalik sedimentation was brought to halt at about 500,000 years BP, when the Trans-Indus area was uplifted during the Pleistocene phase of the Himalayan orogeny. Presence of uplifted recent aluvial deposits indicates that uplift is still an active process in this area.

Key words: Sedimentation, paleomagnetism, Trans-Indus Salt Range, Potwar.

K/311. Khan, M.J., 1987. Sedimentation and tectonics of the Siwalik Group of the Trans-Indus Salt Range, northwestern Pakistan. Geological Bulletin, University of Peshawar 20, 129-141.

Sediment accumulation rates calculated for fluviatile sediments of the Trans-Indus Salt Range in northwestern Pakistan are generally higher than those of the Potwar Plateau. This indicates more rapid subsidence of the Trans-Indus area compared to the eastern Potwar Plateau area, as well as a continued supply of detrital material. The entire stratigraphic sequence, which covers a time span of 12.0-0.5 Ma, is conformable, suggesting that the only tectonic activity in this area over this period consisted of gradual subsidence of the depocenter. However, Siwalik sedimentation ceased at about 500,000 BP when the Trans-Indus region was uplifted during Pleistocene phase of the Himalayan orogeny. The uplift terraces of recent alluvial deposits show that uplift is still an active process in this area.

Key words: Sedimentation, tectonics, Trans-Indus Salt Range, Potwar.

K/312. Khan, M.J. & Ahmad, W., 1987. Clay mineralogy of the Quaternary Lake deposits of Peshawar basin, at Jehangira, district Mardan, NWFP, Pakistan. Geological Bulletin, University of Peshawar 20, 143-152.

X-ray diffraction studies of Post-Siwalik Quaternary lacustrine clay deposits exposed near Jehangira suggest the presence of illite, chlorite and montmorillonite. Illite and chlorite show regular and well-formed structure suggesting detrital origin. Whereas montmorillonite may have detrital and/or authigenic origin, If authegenic the depositional environments were alkaline and “non-aggressive”. Mafic, ultramafic metamorphites of the Kohistan sequence and Main Mantle Thrust (MMT) melange zone and the schists of the Indo-Pakistan plate south of MMT are inferred as the ultimate source for these clay deposits.

Key words: Clay mineralogy, Qauaternary lake deposits, Peshawar basin.

K/313. Khan, M.J., Arif, M., Awais, M. & Iqbal, S., 1987. Depositional environments of the Hissartang Formation Attock-Cherat Range, Peshawar. Geological Bulletin, University of Peshawar 20, 99-110.

Hissartang Formation forms the middle part of Silurian-Devonian stratigraphic sequence exposed in the Attock-Cherat Range. Detailed petrographic, textural and structural studies reveal that this formation consists of two facies described as follows.

Argillite facies:

Lower Argillite (99.12m) thin bedded, grey in color.

Upper Argillite (72.73m) thin bedded variegated in color.

Quartzose Sandstone facies:

Lower Quartzose Sandstone: (88.80m), thin to thick bedded, white to light gray in color.

Upper Quartzose sandstone: (105.99m), medium to thick bedded, white to light gray in color.

Only a few stratigraphic horizons of the upper quartzose sandstone show cross beds. Whereas thin to thick strata and thin laminae are commonly present in both, argillites and quartzose sandstone facies. Lack of various sedimentary and biogenic structures, fine grain size of quartzose sandstone and associations of argillites suggest the supratidal to

subtidal environments. Fine grain size of quartz and absence of barrier ridge sandstone suggest the large distance of transport of quartz particles and lesser amount of terrigenous material available.
Key words: Petrography, structure, depositional environment, Hissartang Formation, Attock-Cherat range, Peshawar.

K/314. Khan, M.J., Beck, R.A. & Burbank, D.W., 1992. Depositional diachronity of the Siwalik group between Potwar and Trans-Indus Ranges, Pakistan. Abstracts, First South Asia Geological Congress, Islamabad, p. 24.

Key words: Depositional diachronity, Potwar, Trans-Indus Salt Range, siwalik.

K/315. Khan, M.J. & Hamidullah, S., 1994. Geochemistry of the seepage water from drain hole 0+53 Down, Adit RAA-2 of Tarbela Dam. Geological Bulletin, University of Peshawar 27, 117-123.

Geochemical parameters of the seepage water from drain hole 0+53 Down, Adit RAA-2 of Terbela Dam are markedly in contrast with the similar parameters of the reservoir water. TDS and EC values are significantly higher and the amount of dissolved oxygen is lower in the drain hole seepage water than those of the reservoir water. The data suggest addition of soluble salts from the rocks of the right abutment into the seepage water while in transit from reservoir to drain hole. This clearly shows removal of soluble material from the country rocks and thus creation of voids in the right abutment. Lower values of dissolved oxygen in seepage water, as compared to those of reservoir water, indicate its consumption for the oxidation of ferruginous minerals during the transit period. Both gypsum and limestone are present in the country rocks with the former having higher oxidation potential and thus considered a preferred target of removal through dissolution, as compared to the latter. Therefore, proper future monitoring of the geochemical parameters of the seepage water in various drains is very important for evaluating the goetechnical hazards being posed by the dissolution of gypsum from the country rocks of right abutment of Tarbela Dam.
Key words: Hydrogeochemistry, seepage, TDS, Tarbela.

K/316. Khan, M.J. & Jan, M.Q., 1986. Last stages in the closing of neotethys and geotectonic evolution along the Indus suture zone. Abstracts, Symposium/Workshop on Plate Tectonics and Crust of Pakistan. Institute of Geology, Punjab University, Lahore, 20-21.

Geology of Himalayan mountain chain has been widely attributed to the closing of Neotethys. Permian rifting along northern margin of “Greater India” resulted in the opening of Neotethys and separation of several small continental blocks. Closure of Neotethys had been affected by Early Eocene. Mechanism and timing of various stages of evolution of the ocean basin are still strongly debated. Recent geological data enables us to constrain the evolution in the western and central Himalayas. The data indicate that subduction began earlier in the western Himalayas than along the southern margin of Tibetan block. This was due to late separation (Jurassic) of Lhasa block from northern margin of Gondwanaland. In conformity with the recent radiometric ages and field observations it is proposed that subduction began during Upper Jurassic-Late Cretaceous in the Kohistan-Ladakh Island arcs and simultaneously along a subduction zone north of Lhasa block, probably along the Bangong-Nujiang suture. The process of subduction continued in the western arcs and shifted to south of Lhasa block during Middle Cretaceous. This was accompanied by the development of Trans-Himalayan batholiths (Kohistan-Ladakh-Gangdese belt), rifting of the Indian plate from Gondwanaland and probably a change from steeply dipping to shallow dipping Benioff zone. During this transition the subducting slab intersected the base of magmatic arc and dragged a fragment of the stratiform Chilas complex to depths of more than 40 km. This resulted in the formation of Jijal garnet granulite complex around 103.9 mybp (Sm/Nd age). Continued spreading in the Indian ocean lead to an accelerated rate of subduction. Consequent compression in the island arcs resulted in the closure of the basins located north of the magmatic arcs between 90-75 mybp. The formation of this northern suture (Main Karakorum Thrust) resulted in a major phase of deformation affecting the early plutons of Kohistan-Ladakh batholith. Subsequent magmatism is due to the northward subduction of Neotethys and later anatexis. Contemporaneous formation of the blueschists of the Indus-Zangbo suture is indicated by available radiometric ages. Rapid northward drift of India between 80-55 mybp resulted in complete closure of the Neotethys. Subsequent thrusts and accompanied obduction of the island arcs

resulted in the formation of melanges and emplacement of the tectonic blocks to their present position along the Indus-Zangbo suture.
Key words: Tectonics, Indus Suture, Himalaya.

K/317. Khan, M.J., Jan, M.Q. & Humayun, M., 1986a. A new Neotethyan closure model in western and central Himalayas. Abstracts with Programs, Geological Society of America 18, p. 656.

Recent geologic data indicate that closure of the Neotethys began earlier in the western Himalayas than along the southern margin of the Tibetan block. The data indicate the subduction began during Upper Jurassic-Early Cretaceous epoch along a zone presently occupied by the Kohistan-Ladakh island arcs and probably the Bangong-Nujiang suture, north of Lhasa block. This was due to late separation (Jurassic) of Lhasa block from Gondwanaland and its middle Cretaceous suturing. This resulted in the shift of subduction to the southern margin of the Lhasa block and emplacement of Trans-Himalayan batholyths. Rifting of the Indian plate caused a change from steeply dipping to shallow dipping Benioff zone. During this transition the subducting slab intersected the base of magmatic arc and dragged a fragment of the stratiform Chilas complex to depths of more than 40 km forming the Jijal garnet granulite complex (103.9 mybp). Continued spreading in the Indian ocean led to an accelerated rate of subduction, compression in the island arcs and closure of the basins located north of the magmatic arcs between 90-75 nybp. The formation of this northern suture (Main Karakoram Thrust) resulted in a major phase of deformation effecting the early plutons of the Kohistan-Ladakh batholith. Subsequent magmatism is due to the northward subduction of the Neotethys and crustal anatexis. Contemporaneous formation of the blueschists of the Indus-Zangbo suture is indicated by 84-75 mybp ages. Rapid northward drift of India between 80-55 mybp resulted in complete closure of the Neotethys. Obduction of the island arcs resulted in the formation of melanges and emplacement of tectonic blocks along the Indus-Zangbo suture.
Key words: Neotethys, Himalaya.

K/318. Khan, M.J., Jan, M.Q. & Humayun, M., 1986b. Last stages in the closing of the Neotethys and geotectonic evolution along the Indus suture zone. "Plate Tectonic and Crust of Pakistan". Geology Department, Punjab University, 20-22.

Recent geologic data indicate that closure of the Neotethys began earlier in the western Himalayas than along the southern margin of the Tibetan block. The data indicate that subduction began during Upper Jurassic-Early Cretaceous epoch along a zone presently occupied by the Kohistan-Ladakh island arcs and probably the Bangong-Nujiang suture, north of Lhasa block. This was due to late separation of Lhasa block from Gondwaland and its middle Cretaceous suturing. This resulted in the shift of subduction to the southern margin of the Lhasa block and emplacement of Trans-Himalayan batholiths. Rifting of the Indian plate caused a change from steeply dipping to shallow dipping of Benioff zone. During this transition the subducting slab intersected the base of magmatic arc and dragged a fragment of the stratiform Chilas complex to depths of more than 40 km forming the Jijal garnet granulite complex (103.9 mybp). Continued spreading in the Indian ocean led to the accelerated rate of subduction, compression in the island arcs and closure of the basins located north of the magmatic arcs between 90-75 mybp. The formation of this northern suture (Main Karakoram thrust) resulted in a major phase of deformation effecting the early plutons of the Kohistan-Ladakh batholith. Subsequent magmatism is due to the northward subduction of the Neotethys and crustal anatexis. Contemporaneous formation of the blueschists of the Indus-Zangpo suture is indicated by 84-75 mybp ages. Rapid northward drift of India between 80-55 mybp resulted in complete closure of the Neotethys. Obduction of the island arcs resulted in the formation of melanges and emplacement of tectonic blocks along the Indus-Zangbo suture.
Key words: Neotethys, tectonics, magmatism, NW Himalaya.

K/319. Khan, M.J. & Opdyke, N.D., 1980. Magnetostratigraphy of the Siwalik sediments in Bhittani-Marwat anticline, Tran-Indus Salt Range, Pakistan. Geological Society of America, Abstracts with Program 12.

Key words: Magnetostratigraphy, Bhittani-Marwat anticline, Trans-Indus Salt Range, Siwaliks.

K/320. Khan, M.J. & Opdyke, N.D., 1981a. Correlation of the Siwalik Group in Trans-Indus Salt Range, Pakistan, based on magnetic polarity stratigraphy. Geological Society of America, Abstracts with Program 13.

Key words: Stratigraphy, magnetic-polarity, Trans-Indus Salt Range, siwaliks.

K/321. Khan, M.J. & Opdyke, N.D., 1981b. The magnetic polarity, stratigraphy, and correlation of the Upper Siwalik Sediments from the Bhittani range, North West Frontier Province, Pakistan. Physics of the Earth and Planetary Interiors 24, 133-141.

Two sections were sampled in Bhittani range, the first at Bain pass consisting of 60 sites through 2200 m of section and the second along the North West Frontier province Road north of Pezu consisting of 25 sites through 100 m/ both sections are in rocks known to range in age from the late Pliocene and Pleistocene based on vertebrate fauna of Pijor age. After partieal thermal magnetization a series of magnetozones were established, ten at Bain Pass and six at Pezu, which can be correlated to each other and to the standard magnetic time scale. The sediments from the long section at Bain Pass span the time from the middle Gauss to the upper most Brunches Chron. The Jaramillo and Olduvai subchrones are present within the Matuyama Chron. A short normal magnetozone is present in the section preceding the Olduvai subchron which correspond in age to the Reunion subchrone. Based on the rate of sedimentation during lower Matuyama time which would be 0.95 m/1000 y for Bain Pass section, the Reunion subchron would span at least 25000 y. the section at Pezu Pass begins within the Olduvai and ends between the Jaramillo and Brunches/Matuyama boundary. The sedimentation rate determined at this section is 0.77m/1000 y. the rate of sedimentation in this region was much higher than over comparable time span previously determined from the eastern Salt Range. The folding of the Bhittani range must have occurred less than 730000 year ago, since Bruchhe age sedimenst have been deformed.
Key words: Stratigraphy, magnetic-polarity, siwaliks.

K/322. Khan, M.J. & Opdyke, N.D., 1987. Magnetic-Polarity stratigraphy of the Siwalik group of the Shinghar and Surghar Ranges, Pakistan. Geological Bulletin, University of Peshawar 20, 111-127.

Four stratigraphic sequence were measured and sampled from the Shinghar and Surghar Ranges, Pakistan, for detailed magneto-stratigraphic studies of the fluviatile Neogene and Quaternary Siwalik Group. The samples were subjected to blanket thermal demagnetization at 500 ^{0}C. Some of the samples, particularly those from the pale brown siltstone/claystone units, were further subjected to 600 ^{0}C to isolate the stable primary component of magnetization used to establish the magnetic-polarity-reversal sequences. This sequence was correlated to the MPTS with the aid of fossils collected from the nearby Dawood Khel area (Hussain et al., 1977) and from the Shinghar Range during paleomagnetic sampling. This correlation suggests that deposition of the Siwalik Group in this area began during basal Chron 11 (11.8 m.y.B.P.) and continued till the late Matuyama Chron (0.85m.y.B.P.). These indicate that the Siwalik sedimentation in this area started later than that of the Potwar Plateau.
Key words: Magnetostratigraphy, Shinghar, Surghar, siwaliks.

K/323. Khan, M.J., Opdyke, N.D. & Shroder, J.F., 1985. Bain diamictite: lithology, age and the origin. Geological Bulletin, University of Peshawar 18, 53-64.

The Bain diamictite is part of the Plio-Pleistocene Siwalik Group of northwest Pakistan. The type section is exposed in the Bhittani Range on the south edge of the Kurram river drainage basin near its confluence with the Indus. A counterpart section, reported here for the first time, occurs in the Shinghar Range north of the Kurram River. The unit in both areas is an unsorted, unstratified deposit that has heterogenous lithology, including significantly large volcanic clasts and basal ash stringers. Cooling or drying cracks occur on the upper surface in at least one locality. Clast lithologies indicate a transport direction from the highlands of Afghanistan in the WNW. Previous workers have considered the Bain diamictite to be a tillite, but the low elevation of about 500m and lack of possible glacial

source area prior to main Himalayan orogenesis rule this out. Instead a debris-flow or volcanic-lahar origin from Dasht-i-Nawar caldera 300-400km away in Afghanistan is most likely. The probable volume of 30x109m^3 of the deposit is compatible with most probable pre-caldera volcano topography and post- eruption caldera size, but is still perhaps the world's largest known lahar.
Key words: Lithology, diamictite, Kurram River, Plio-Pleistocene, Siwaliks.

K/324. Khan, M.J., Opdyke, N.D. & Tahirkheli, R.A.K., 1988. Magnetic stratigraphy of the Siwalik Group, Bhittani, Marwat and Khisor Ranges northwestern Pakistan and the timing of Neogene tectonics of the Trans-Indus. Journal of Geophysical Research 93, 11773-11790.

Nine stratigraphic sections in the Siwalik Group, three from the Bhittani Range, five from the Marwat Range, and one from the Khasor Range, were measured and sampled for magnetostratigraphic studies. Progressive alternating field and partial thermal demagnetization of samples indicated the presence of two components of magnetization. These are a secondary component of low coercivity, which can be removed by alternating field demagnetization in fields up to 40 mT and/or temperatures to 400°6, and a stable primary component of magnetization which has blocking temperatures above 450°C. Therefore all samples were subjected to blanket demagnetization at 450°C and 500°C, and some to temperatures up to 600°C. Positive fold tests from the Bhittani and Marwat ranges indicate the successful isolation of a prefolding characteristic direction of magnetization. A magnetic polarity reversal sequence for each of the sampled sections is determined and correlated to the magnetic polarity time scale utilizing a fission track date and fauna from the sequences which have previously been shown correlated to the magnetic polarity time scale. This correlation shows that the Siwalik Group in the area of study ranges in age from the late Gilbert chron to the early Brunhes chron (about 0.5 m.y. B.P.). Deposition of the thick sandstone units of the Siwalik Group in the Marwat Range began at least by Gauss chron time. The correlation of observed magnetic polarity stratigraphy, of the Khassor Range, with the standard magnetic polarity time scale shows that the Siwalik Group of this area ranges in age from the early Gauss chron (about 3.2 Ma) to the Brunhes chron. The region of this study began to subside prior to 4 Ma and subsided at a rate of from 60 to 100 cm per 1000 years. The tectonism of the region began within the last 1 m.y. and may well be synchronous with folding in the Pabi Hill anticline on the other limb of the syntaxis near Jelum. This orogeny is therefore one of the world's youngest and is undoubtedly still in progress.
Key words: Bhittani, Marwat and Khisor Ranges

K/325. Khan, M.L. & Bangesh, I.H., 1983. Petrography of the Mahak area, Upper Swat. M.Sc. Thesis, University of Peshawar, 71p.

Mahak area in upper Swat lies in the southern amphibolites belt of the Kohistan island arc. The various rock types of Mahak are medium- to coarse-grained amphibolites, hornblendites, hornblende pegmatite, diorites, meta-gabbro, metapyroxenite and quatzo-feldspathic veins and dykes. Amphibolites are most abundant rocks of the area. These are distinguished into epidote amphibolite and plagioclase amphibolite.
Key words: Petrography, amphibolites, hornblendites, Mahak, Swat.

K/326. Khan, M.M., Jadoon, K.G. & Khan, A.U., 1990. Selective flotation of lead from lead zinc ore of Kohistan, Hazara, Pakistan. Abstracts, First SEGMITE Conference on Industrial Minerals, Peshawar, p. 7.

Key words: Lead-zinc ore, floatation, Kohistan, Hazara.

K/327. Khan, M.M., Naseem, T. & Wahid, F., 1994. Beneficiation of North Waziristan copper ore. Abstracts, Second SEGMITE International Conference on the Export Oriented Development of Mineral Resources and Mineral Based Industries, Karachi, 21-22.

Key words: Copper ore, beneficiation, Waziristan.

K/328. Khan, M.R., 1972. Geology and petrology of Taghma area, Swat. M.Sc. Thesis, Peshawar University, 57p.

Key words: Petrology, Taghma, Swat.

K/329. Khan, M.R., 1983. The exploitation of iron deposits of Pakistan; great requirement of the time. 2nd National Seminar on Development of Mineral Resources, Peshawar, 12-25.

Key words: Iron ore, exploitation, Pakistan.

K/330. Khan, M.R. & Ali, M., 1994. Preliminary gravity model of Western Himalayas in Northern Pakistan. Kashmir Journal of Geology 11 & 12, 59.

The gravity modeling in western Himalayas along SW-NE profile from Fatehjang (southwest) to Kundul Shahi has been developed. Gravity model indicates 8-Km thick sedimentary wedge in the Fatehjang, which gradually increases to 20 km at Kundul Shahi. The thin skin metasedimentary wedge. These thrusts have brought in contact the different stratigraphic units of Precambrian to Mesozoic ages in the area of Hazara Kashmir Syntaxis. The stratigraphic units consist of Hazara Formation (mainly slates of Precambrian), Tanol Formation (pelites/psammites Late Cambrian), Panjal volcanics (Permo Carboniferous), Carbonate (Mesozoic-Tertiary) and Molasse (Miocene to Recent).
The western limb of the syntaxis moves southward over the decollement and formed the low angle thrust while in the eastern limb thrust nappes are uplifted in the absence of decollement and form the high angle thrust. Jhelum strike-slip fault developed by the differential movement marks a boundary between salt and salt areas.
The crystalline crust of 38 Km thick extending all the way from Fatehjang to Kundul Shahi is broken into blocks by the basement faults northeast of Taxila and Abbottabad. These faults are the Hazara lower Seismic Zone and the Bagh Basement Fault. The Main Central Thrust is not detected in the study area; it may be passing from the upper Neelum Valley Azad Kashmir. The results indicate that the differential movement because of the presence and absence of salt and anti clockwise rotation of transport direction are responsible for the formation of Hazara Kashmir Syntaxis. The average crustal thickness of 46 Km in Fatehjang gradually increases to 49 Km at Kundul Shahi.
Key words: Geophysics, gravity model, Himalaya.

K/331. Khan, M.R. & Ali, M., 1997a. Tectonic study of the Hazara and its adjoining areas of northern Pakistan based on gravity data. Abstracts, 3rd Pakistan Geological Congress, University of Peshawar, p. 37.

Consult the following account for more information.
Key words: Tectonics, gravity, Hazara, Himalaya.

K/332. Khan, M.R. & Ali, M., 1997b. Tectonics of the Hazara and adjoining areas, based on gravity data, Northwest Himalaya, Pakistan. Geological Bulletin, University of Peshawar 30, 273-283.

Gravity data in the Hazara-Kashmir Syntaxis of northern Pakistan has been incorporated into interpretation of the gross crustal structure of the area. In this area, due to the continued northward migration of Indian plate, the Indian plate has been overridden by slices of its own northern margin and activity has caused the slight thickening of crust in the northeast and northwest of the Hazara-Kashmir Syntaxis. In the sedimentary wedge, the thinskin structures have been developed by the southward migration of the sedimentary wedge. In northern Pakistan, Late Precambrian to Early Cambrian strata constitutes the zone of decollement. It is absent in eastern side in Kashmir and India. In the eastern limb of the Hazara-Kashmir Syntaxis, the Main Boundary Thrust (MBT) and the Panjal Thrust (PT) are developed. Here the strong coupling between sediments and basement occurred due to the absence of decollement which caused the high topography of the Hazara-Kashmir Syntaxis range front. In the western limb the MBT and the Nathiagali Thrust (NT) are developed. These thrust sheets moved southward over this decollement. The thrust

system of eastern and western limbs are converging near the apex of Hazara-Kashmir Syntaxis. The differential movement resulted due to presence and absence of salt in the area developed the Jhelum fault. Jhelum fault cuts the PT, MBT and the Kashmir Boundary Thrust (KBT) in the Kashmir side and the MBT and NT in the western side in northern Pakistan. The sedimentary wedge of the western limb of the Hazara-Kashmir Syntaxis moves southward along this fault.
Key words: Tectonic modelling, gravity, Hazara, Himalaya.

K/333. Khan, M.R. & Ali, M., 1997c. Tectonic modeling of western Himalaya in northern Pakistan based on gravity study. Geological Bulletin, Punjab University 31 & 32, 103-113.

Gravity data in the Hazara and its adjoining areas of northern Pakistan have been incorporated for the interpretation of the gross crustal structure of the Hazara-Kashmir Syntaxis in western Himalayas. In this region two types of deformation have been observed. One is in the crystalline basement and other is in the sedimentary wedge. The crystalline crust of 38 Kms thickness faulted into blocks in the northeast of Taxila and Abbottabad. These faults are Hazara Lower Seismic Zone and Bagh Basement Fault. These predeveloped faults have been reactivated after collision of Indian and Eurasian Plates. Some of the normal faults trending in the NE-SW, also appeared to exist in the upper crystalline basement near Rawalpindi. These faults were developed by the extensional stresses, which are caused by the bending of Indian crystalline basement.
In the sedimentary wedge the thin-skin structures have been developed by the southward migration of the sedimentary wedge. In the area under study the thin-skin structures consist of thrust faults, strike slip faults and the salt/incompetent state (decollement). In the eastern limb of Hazara Kashmir Syntaxis there is strong coupling between sediments and basement consequently the materials is uplifted. In Pakistan Late Precambrian to Early Cambrian age strata constitute the uplifted zone of decollement. Over this decollement the western limb of Hazara-Kashmir Syntaxis move southward between Jhelum and Kalabagh strike slip faults.
Key words: Tectonic modelling, gravity, NW Himalaya.

K/334. Khan, M.R., Ali, M. & Ashraf, M., 1998. Crustal study in lesser and Sub-Himalayas of northern Pakistan based on gravity modelling. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 101.

In lesser and sub-Himalaya in Northern Pakistan the deformations have been observed in crystalline crust and sedimentary and metasedimentary wedge using gravity technique. The crystalline crust of 38-km thickness extended all the way in the study area and faulted into blocks under the western limb of Hazara-Kashmir Syntaxis. These faults are Hazara Lower Seismic Zone (HLSZ) and Bagh Basement Fault (BBF). These predeveloped faults have been reactivated after collision of Indian and Eurasian plate. The HLSZ has been associated with the basement fault under Northern Potwar trending NW-SE. Along this fault 6 Km relative movement of the blocks have been observed. In the gravity modelling best fit of the observed and calculated curves in the northeast of Abbottabad also suggested 4-km relative movement of the blocks. This fault has been named as the Bagh Basement Fault which is existing between HLSZ and Indus Kohistan Seismic Zone (IKSZ).
In the sedimentary and metasedimentary wedge the deformations have been developed by the southward migration of this wedge. The thrust faults have brought in contrast the different stratigraphic units in sedimentary and metasedimentary wedge of the Hazara-Kashmir Syntaxis. From north to south in Lesser Himalaya Nathiagali Thrust (NT) brings the Hazara Slates of Precambrian age over the Eocene to Cretaceous marine rocks. The Main Boundary Thrust (MBT) is the major southern most lineament along which the pre-collisional marine sediments are thrusted over post-collisional molasse in the Sub-Himalaya. The fault plane of MBT is steeper near surface and becomes gentle in depth, and joins the low angle detachment. The fault plane of the NT does not join the MBT, which indicates that NT is not a part of MBT Zone. The MBT at present is active in the north of Kohat and in the eastern limb of Hazara-Kashmir Syntaxis. The present gravity investigations suggested the presence of the Panjal thrust between Panjal volcanics and Tanol Formation in the eastern limb and do not pick the Main Central Thrust up-to the Kundul Shahi. This may exist in the upper Neelum Valley. The thrust system of eastern and western limbs were converging near the apex of Hazara-Kashmir Syntaxis. The Jehlum Fault cuts Panjal Thrust (PT), MBT and the Kashmir Boundary Thrust in the Kashmir side and the Hazara Thrust System in the western side in northern Pakistan. The dips of the Hazara Thrust system increase towards northeast. The differential movement exists in the Hazara-Kashmir Syntaxis due to the presence and absence of decollement (salt). In the western limb thrust nappes

are thrusting southward over the decollement, whereas, in the eastern limb the thrust nappes are uplifted in the absence of decollement. These differential movements developed the Jehlum Fault. The sedimentary and metasedimentary wedge of the western limb of Hazara-Kashmir Syntaxis moves southward along the Jehlum Fault. The Kuldana Shales are acting as a secondary decollement, in the sedimentary wedge. The average crustal thickness or Moho depth in the area seems to vary from 46 km (southwest) in Fatehjang to 59 km in Kundul Shahi (northeast). It seems that the total crustal thickness from Potwar plain (Fatehjang) to the Neelum Valley (Kundul Shahi) Azad Kashmir increases by 13 Km.
Key words: Gravity modelling, deformation, NW Himalaya.

K/335. Khan, M.R. & Khan, M.S., 2001. Study of shallow geological structures in the core of Hazara Kashmir syntaxis based on residual gravity data in Azad and Jammu Kashmir, Pakistan. Abstracts, 4th Pakistan Geological Congress, Islamabad, 69-70.

The residual gravity data has been incorporated for the interpretation of shallow geological structures in the core of Hazara Kashmir Syntaxis. In the western periphery of the area Jhelum fault is running along the river Jhelum. The contours trend on residual granite maps from Muzaffarabad to Tam follows the trend of Jhelum fault. The negative contours closure on the residual gravity map in Bagh area shows the low-density sedimentary basin of recent age. The modelling of residual gravity data indicates 1 .3 km deep sedimentary basin. The contours trend from Bagh to Chikar and from Chikar to Muzaffarabad delineate the Kashmir Boundary Thrust (KBT). The KBT is running from Bagli to Chikar between the Murree Formation and the Siwaliks whereas iii the northeastern side from Chikar to Muzaffarabad the Siwaliks have been eroded and the Murree Formation is exposed. The gravity modelling also envisages the KBT as a shallow thrust, which penetrates upto the depth of the Kuldana Formation. The shales of the Kuldana Formation are acting as decollement for the overlaying sedimentary wedge of the Murree Formation which is thrusting over the Siwaliks along the KBT.
Key words: Structures, tectonics, geotechnical, gravity, Hazara Kashmir syntaxis.

K/336. Khan, M.S., 1986. Pleistocene sediments and chronology of Middle Indus and Lower Gilgit Valleys between Shatial and Dainyar. M.Phil. Thesis, University of Peshawar, 101p.

Thick valley-f ill deposits preserved in deep valleys in Indus, Gilgit and Hunza river areas and a variety of age dates allow new definition of Quaternary events in Karakoram Himalaya. Three glacial stages of Pleistocene are recognized with several advances in Holocene. The early stage is indurated lower Jalipur tillites and hetrogenous upper Jalipur valley - fill sedimentary rock younger than 1 to 2 myr and folded, overturned or overridden by movement of Raikot fault associated with rapid overall uplift rates of Nanga Parbat-Haramosh massif. Middle stage is two tills intercalated with in variable sediments, including thick lacustrine units dipping upto 43' along fault. Indus-Shatial tills record the farest advance down Indus of Pleistocene glacier at this time, Late stage consists of three or more seperate advances that retain moraine topography; the Dianyor moraine near Gilgit was produced by a major longitudinal glacier from Hunza. Downstream a t Jaglot, Nanga Parbat, Shatial and elsewhere, transverse glaciers blocked Indus to produce lake deposits now dipping upto 6' along the fault. Catastrophic breakout floods emplaced some Punjab erratics and sediments that was reworked into loesses in the Himalayan fore land.
Key words: Sedimentology, Quaternary, Pleistocene, Jalipur, Chilas.

K/337. Khan, M.S., 1997. Gold mineralization in the Carboniferous-Permian rocks in the Neelum valley, Azad Kashmir, Lesser Himalayas. Abstracts, National Symposium on Economic Geology of Pakistan, Islamabad, 2p.

The agglomeratic slates and the Panjal volcanics (lava flows) and associated carbonate rocks are sandwiched between the Main Boundary Thrust and the Panjal Thrust in the Neelum valley. Muzaffarabad, the Lesser Himalayas. The Panjal volcanics have been altered and metamorphosed to lower greenschist facies metamorphism. Major alteration minerals are chlorite, epidote, albite. actinolite, quartz and sphene. The Panjal volcanics are mainly tholeiitic to slightly alkalic rocks. They are dominantly basalts to basaltic andesites. The alteration has also been revealed from their high LOI values and high Na_2O and K_2O contents and by other mobile elements.

Reconnaissance geochemical “grab” sampling along two mapping and petrographic traverses across the strike of the volcanic sequence encountered Au and Ag mineralized units. The host rocks are dioritic and andesitic in composition exposed along and within the Panjal volcanics. The Panjal volcanics are closely associated with the Nauseri granite-granite gneiss terrain. The gold mineralization is located at two horizons. The lowest is a dioritic rock which is foliated and mylonitized. This rock is at the contact of the lava flows and chemically consists of SiO_2 60.30. MgO 1.28, CaO 1.04. TiO_2 0.80 Wt.%, Ni l24lppm. Pb l588ppm, Cu 49 ppm, Zn 80ppm and Au 11 ppm. The second horizon is a sulfide zone containing pyrite and chalcopyrite and located within the lava flows of the Panjal volcanics in an andesitic rock. The chemical constituents of this rock are $Si0_2$ 61.69, MgO 2.06, CaO 7.62, $Ti0_2$ 1.4 Wt%, Ni 99ppm, Cu 5639ppm and Ag 8ppm. Both zones represent altered parent lithologies. Rocks have altered to chlorite. sericite, epidote and clay minerals. The foregoing results of only few samples in reconnaissance indicate that a follow-up comprehensive geochemical exploration programme in the areas comprising agglomeratic slates and the Panjal volcanics would be worthwhile.
Key words: Mineralization, gold, carboniferous, Permian, Neelam valley, Azad Kashmir.

K/338. Khan, M.S., 1998. Estimation of contaminants in the groundwater establishment of protection zones in Wah Cantt. Area. Ph.D. Thesis, Punjab University, Lahore.

Key words: Groundwater, contamination, Wah cantt, Attock.

K/339. Khan, M.S., Ahmad, M. & Anwar, M., 1970. Morphological comparison of the heavy minerals of Manki Slate and Attock Shale of the Attock Group. M.Sc. Thesis. Geol. Dept., Peshawar University, 28p.

Key words: Morphology, heavy minerals, Manki slates, Attock shale, Peshawar.

K/340. Khan, M.S. & Ashraf, M., 1989. Panjal volcanics: geochemistry and tectonic setting in Azad Jammu & Kashmir & Kaghan valley NW Himalaya. Kashmir Journal of Geology 6 & 7, 61-80.

Panjal Volcanic rocks, with maximum upto 1400 m thickness, occur within a system of Main Boundary Thrust and Panjal Thrust in the NW Himalayas from Kahuta to Kaghan. The geotectonic evolution of these volcanic have been studied by field investigations, petrography and geochemistry. Petrographic study of the Panjal rocks show that they are basalts to basaltic andesites and are tholeiitic to slightly alkaline in character. They were formed mostly in submarine environments showing alteration of their minerals to epidote, chlorite and sodic Plagioclase.
Major elements data for the Panjal Volcanics are plotted on different tectonomagmatic geochemical discriminate diagrams, to infer their tectonic environment. The data largely plot in the oceanic fields. The geology of the area, geochemistry and inferred tectonic setting show that Panjal Volcanics were erupted in a rift to oceanic, environments.
Key words: Geochemistry, tectonics, Panjal volcanics, Azad Kashmir, Kaghan.

K/341. Khan, M.S., Ashraf, M. & Chaudhry, M.N., 1991. Geochemical evidence for an oceanic affinity of the Panjal volcanics in Kaghan valley, Pakistan. Kashmir Journal of Geology 8 & 9, 1-18.

The Panjal volcanic rocks in Kaghan area have been analyzed for major and trace elements. These rocks have been altered and spilitized considerably because Na_2O varies from 0.38 to 6.4 wt. %. Inspite of alteration of these rocks the whole rock composition retains a strong igneous imprint (TiO_2 1.28 to 2.34 % P_2O_5 0.1 to 0.24 %, Zr 77 to 179 ppm and Y 19 to 39 ppm). The abundance of incompatible and immobile elements when plotted on discrimination diagrams of infer tectonic setting, indicate geochemical signature of ocean floor basalts. These rocks are transitional between within-plate to ocean floor basalts on major and trace element abundance.
Key words: Geochemistry, Panjal volcanics, Azad Kashmir, Kaghan.

K/342. Khan, M.S., Ashraf, M. & Chaudhry, M.N., 1992. Geochemical evidence for an oceanic affinity of the Panjal volcanic in Azad Kashmir and Kaghan area. Abstracts, First South Asia Geological Congress, Islamabad, p. 24.

For more information on the topic, consult M. S. Khan et al. (1991, 1997).
Key words: Geochemistry, tectonics, Panjal volcanics, Azad Kashmir, Kaghan.

K/343. Khan, M.S., Ashraf, M. & Chaudhry, M.N., 1997. Geochemical evidence for the tectonic setting of the Panjal volcanics in Azad Kashmir and Kaghan areas. Geological Bulletin, Punjab University 31 & 32, 43-52.

The Permian to Early Triassic age Panjal volcanics in Azad Kashmir and Kaghan areas are exposed along Main Boundary Thrust. Studies of the major and trace elements in the Panjal volcanic rocks indicate that they formed in a tectonic setting transition from within plate to oceanic conditions. These rocks show TiO_2 contents from.1.08 to l.59 wt. %, SiO_2 from 47.93 to 51.24 wt. %, MgO from 5.05 to 9.07 wt. % and P_20_5 from 0.09 to O.19wt. %. Mg# varies from 59.7 to 66.10 Na_2O contents range from 1.11 to 4.99wt. %, k2O from 0.11 to 2.67wt. %. Major elements especially Na2O and K2O indicate alteration of these rocks.
Trace element contents of the Panjal volcanics also show variation. Zr contents range from 53 to 110 ppm, Ni 56 to 229 ppm and Cr from 54 to 677ppm. Major and trace elements and Mg# of the rocks indicate that the Panjal magma has been evolved as tholeiitic to slightly alkalic in composition $with geochemical characteristics similar to enriched mid ocean ridge (P-type) basalts or ocean island tholeiites. The interbedded chert, limestone and associated turbidite deposits indicate shallow marine environment during the time of eruption of magma. The volcanics represent range of the northern margin of Indian continent and development of shallow marine oceanic conditions during Upper Paleozoic.
Key words: Geochemistry, tectonics, Panjal volcanics, Azad Kashmir, Kaghan.

K/344. Khan, M.S., Ashraf, M. & Raja, M.K.K., 1994. Petrology of the Nauseri granite gneisses in lower Neelum valley state of Azad Jammu and Kashmir. Kashmir Journal of Geology 11 & 12, 29-42.

The Nauseri granite gneisses occur in the lesser Himalaya of Azad Jammu and Kashmir. The granite gneisses are sheared, mylonitized, deformed and occur in the metamorphic assemblages of biotite to kyanite grades. The field relations of these rocks characterized by peraluminous and S-type nature. On the basis of available data i.e. their intrusive character in the field, petrography and major element chemistry, partial melting origin s envisaged and large scale subsequent granitization for the granitic rocks. These rocks have been resulted from the emplacement of the anatectic melt into the low-grade metasediments, which had been uprooted and transported southwards from their original place.
Key words: Petrology, granite, gneisses, Neelam valley, Nauseri, Azad Kashmir.

K/345. Khan, M.S. & Chaudhry, M.N., 1997. Tectonic-magmatic environment of the Panjal volcanics in Azad Kashmir and Kaghan areas, Pakistan. Abstracts, 3rd Pakistan Geological Congress, University of Peshawar, p.37.

For more information on the topic, consult M.S. Khan et al. (1991, 1997).
Key words: Tectonics, Panjal volcanics, Azad Kashmir, Kaghan.

K/346. Khan, M.S., Mateen, A. & Tufail, M., 1997. Investigations of radioactivity in Hazara phosphate deposits for fertilizer applications. Abstracts, National Symposium on Economic Geology of Pakistan, Islamabad, 2p.

Natural radioactivity due to ^{40}K, ^{226}Ra and ^{232}Th has been investigated in the phosphate rock deposits of Hazara division of Pakistan. Gamma measurements of the radionuclides were carried out using a high purity germanium (HPGe) detector. Data acquisition and activity analysis was done by a PC based MCA. A common index, called Radium Equivalent Activity that incorporates ^{40}K, ^{226}Ra and ^{232}Th activity values, was found to be considerably higher than the permissible limit of 370Bq.Kg^{-1}. That can result in significant radiation exposure in the environment of fertilizer making plants and in its storage places where radon is accumulated. Radioactivity is also spread in the agriculture land along with fertilizers. Removal of radioactivity from the phosphate rock and ventilation of storage places of the fertilizers affect the economic value of the phosphate products.
Key words: Radioactivity, fertilizer, phosphates, Hazara.

K/347. Khan, M.S., Shah, H. & Saeed, G., 1995. Geological Map of Thana quadrangle (Toposheet No. 43 B/2, Scale 1:50,000), NWFP, Pakistan. New Geosc. No. 1038 (Old Sheet No. 70), Geological Survey of Pakistan NWFP Geological Map Series, vol. III.

Key words: Mapping, Malakand Agency.

K/348. Khan, M.S.Z., Abdullah, S.K.M. & Offield, T.W., 1966. Reconnaissance geology of the Mansehra quadrangle, Hazara district, West Pakistan. Geological Survey of Pakistan and U.S.G.S Project Report PK (IR)–10, 31p.

Key words: Reconnaissance, Mansehra.

K/349. Khan, M.S.Z., Shah, S.H., Khan, N.A., Latif, M. & Khan, K.S.A., 1999. Geological Map of the Gilgit quadrangle (Toposheet No. 43-I/5; Scale, 1:50,000), Northern Areas, Pakistan. Sheet No. 1310, Geological Survey Pakistan. Geological Map Series.

Key words: Geological map, Gilgit.

K/350. Khan, M.Y., 1974. Geological investigation for graphite in Gandghar Range, southern Hazara, Pakistan. Geological Survey of Pakistan, Information Release 28.

Key words: Exploration, graphite, Gandghar, Hazara.

K/351. Khan, M.Y. & Ahmad, Z., 1974. Geology of Barwa quadrangle (Toposheet No. 38 N/9), Dir State, West Pakistan. Geological Survey Pakistan. Information Release 79.

Key words: Geology, mapping, Dir.

K/352. Khan, M.Y. & Hussain, A., 1974. A note on the occurrence of iron ore near Mazari Tang, Peshawar District, N.W.F.P., Pakistan. Geological Survey of Pakistan, Information Release 72, 8p.

The iron ore occurrence near Mazari Tang Payan village in Peshawar district has been investigated. The ore is hematite and is of sedimentary origin. It occurs in two to three lenticular beds in the lower part of Jurassic limestone. The hematite is good quality and contains more than 50% of Fe_2O_3. The extent of the deposit is limited and its reserves, calculated to a dip depth of 400 feet, are 450000 tons.
Key words: Iron, Mazari Tang, Peshawar.

K/353. Khan, M.Z., 1983-85. Geology and petrology of Burawai area upper Kaghan valley District Mansehra, Pakistan. M.Sc. Thesis, Punjab University, Lahore, 125p.

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

K/354. Khan, M.Z., 1991. Petrology and Geochemistry of melange zone and southern amphibolite belt rocks from Gantar area. Allai-Kohistan, Hazara, N. Pakistan. M.Phil. Thesis, University of Peshawar.

Petrographic and geochemical study was performed for the Kohistan island arc 9KIA) rocks, Main Mantle Thrust (MMT) mélange zone and Indian plate rocks at Gantar and Kalalota, Allai Kohistan, Hazara, in order to envisage the petrogenetic history of these rocks. Field and petrographic data shows that the KIA is composed of amphibolites (mainly epidote amphibolite) together with hornblend pegmatite. The mélange zone include blue schist, green schist, meta-gabbro/norite, ultramafic and pillow lavas while the Indo-Pak plate comprises quartz-muscovite-chlorite-carbonate schist, quartz-actinolite schist calcareous schist graphite schist and siliceous marble.
Amphibolites of the Kohistan arc are derived mainly from the basic magma of non-alkaline characters (transitional between tholeiitic and calc-alkaline) through crystallization differentiation of ferro-magnesian minerals with plagioclase. This protolithic material was the subjected to a metamorphism of amphibolites facies followed by retrogression into epidote amphibolite facies and green schist facies.
Mineral chemistry of amphibolites reflects maximum metamorphic temperature i.e. 600 c for tschermakitic hornblend and 500 c for the actinolite under a metamorphic PH2O of 4-5 kb. The hornblend pegmatite appears to be of possible metasomatic origin.
It is concluded that the mafic/ultramafic rocks, meta-gabbro/norites, blue schist, pillow lavas and other basic rocks (metamorphosed to green schist) envision the normal ophiolitic sequence being offset by intensive multiple episodes of tectonic deformations (subduction and obducting environment).
Key words: Petrology, geochemistry, amphibolite belt, Allai-Kohistan.

K/355. Khan, M.Z. & Khattak, N.N., 1989. Hydraulic characteristics of the aquifers of Haripur area, District Abbottabad. M.Sc. Thesis, University of Peshawar, 67p.

Key words: Groundwater, aquifer, Haripur, Abbottabad.

K/356. Khan, N., 1990-91. Structure, stratigraphy and petrography of the western limb of the Hazara-Kashmir Syntaxis, Abbottabad and Manglaur areas, Northern Pakistan. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 138p.

The Abbottabad and Manglaur area lies along the western extremity of the Hazara-Kashmir syntaxis. The area has been divided into two zones on the basis of structure and stratigraphy. Because the rocks of the blocks belong to different stratigraphic provinces and have become in contact with each other tectonically, these zones are Garhi Habibullah-Abbottabad (east of Panjal thrust) and Mansehra zone (west of Panjal thrust).
Rocks east of Panjal thrust in the area consist predominantly of Precambrian to Paleocene sedimentary and very low-grade metasedimentary rock units (Hazara Formation) that represents the first deformation and metamorphism in the Hazara area. Whereas, in west of Panjal thrust, the area consists of Cambrian granite gneisses and very low to low-grade metasedimentary (Tanol Formation) that represent D2 deformation and metamorphism associated with the Himalayan deformation phases. The grade of metamorphism varies from chlorite-grade in the south to biotite-grade in the north. The Mansehra zone is intruded by the Permian Panjal mafic dykes and sills of dolerite and basalts. These dolerite and basalts are mostly fresh. The sedimentary, metamorphic and intrusive igneous rocks of

these zones are classified and characterized by petrographic studies. The stratigraphy of the area has been developed in which the Abbottabad group has been divided into three formations which are Sobrah, Kakul and Sirban formations. The redivision was marked by an unconformity between Sangargali and Mahmdagali of the Sobrah and Kakul formations.
The rocks have undergone at least three phases of deformation (D1, D2 & D3) and have been metamorphosed to greenschist facies. The first deformation D1 took place as a result of Hazaran orogeny and produced first fabric (S1) in the Hazara Formation which is generally parallel or slightly oblique to the original lithologic layering S0. D2 is associated thrusting and folding phase. Himalayan orogeny folded S1 into open and closed F2 folds that range in size from small kink bands to larger map scale folds. It caused development of penetrative S2 foliation axial planar to F2 folds. D3 deformation phase associated with the formation of Hazara-Kashmir syntaxis and formed F3 cross folds.
Key words: Structure, stratigraphy, petrography, Hazara-Kashmir syntaxis.

K/357. Khan, N. & Ilyas, T., 1995-96. Geometric analysis of mesoscopic shear zones in the Gandghar Range, N.W. Himalaya; Pakistan, M.Sc. Thesis, 66p.

Key words: Structure, Gandghar Range.

K/358. Khan, N.A. & Khan, T., 1998. Geology of the Chilas quadrangle (Toposheet No. 43 I/3), Diamir district, Northern Areas, Pakistan. Geological Survey Pakistan. Information Release 548, 10p.

The mapped area lies within the southern Kohistan island arc terrane. The Kohistan arc terrane has been considered to form due to the northward subduction of the Neo-Tethyan oceanic lithospheric plate under the Eurasian plate during Cretaceous time. Two suture zones delineate the arc from the continental plates, viz., the Main Mantle Thrust (MMT) and the Main Karakoram Thrust (MKT). The Main Mantle Thrust (MMT) passes through the southeastern part whereas the MKT is exposed to the north" of the mapped area.
Rock formations ranging in age from Cretaceous to Recent include Thak amphibolites, Sunal greenstone, metasediments and metavolcanics of the Jaglot group, Chilas complex, Kohistan batholith and glaciofluvium, alluvium and colluvium deposits. Thak amphibolites occupy Jal shear zone which are sheared and deformed. Sunal greenstone include metabasalt and metaandesite with minor dacite and rhyolite, volcanic breccia and tuff Amphibolites, metagabbroic and metadioritic in composition occur in Kiner Gah area. They have intrusive contacts with the Chilas complex and the Kohistan batholith. Metasedimentary and metavolcanic (amphibolites) of the Jaglot group occur as xenoliths within the Chilas complex. The Chilas complex comprises mafic, ultramafic and feldspathic rocks. The complex is dominantly composed of gabbronorite and pyroxene quartz diorite. Dunite, peridotite, pyroxenite, anorthosite (ultramafic-mafic-anorthositic association; cumulates) are also characteristic of the Chilas complex. Blastomylonite diorite and tonalite are also present. Kohistan batholith includes tonalite which intrudes the Thak amphibolites.
Tectonically, the area is characterized by a number of northwest dipping high angle fauns and shear zones which are truncated in the east by the Raikot fault. The ultramafics of Chilas complex have chromite, PGE and copper mineralization. Small patches of the sulphide zones occur within the Chilas complex and the Thak amphibolites.
Key words: Mapping, Chilas Complex, Kohistan Island Arc.

K/359. Khan, N.A., Khan, T., Mujtaba, G., Hussain, H. & Khan, R., 1999. Geology of the Kiner Gah quadrangle (Toposheet No. 43 I/2), Diamir district, Northern Areas, Pakistan. Geological Survey Pakistan. Information Release 684, 13p.

The mapped area lies within the southern Kohistan island arc terrane. The Kohistan arc terrane has been considered to form due to the northward subduction of the Neo- Tethyan oceanic lithospheric plate under the Eurasian plate during Cretaceous time. Two suture zones delineate the arc from the continental plates, viz. the main Mantle
Thrust (MMT) and the Main Karakoram Thrust (MKT). The Main Mantle Thrust (MMT) passes through the southeastern part whereas the MKT is exposed to the north of the island arc.
Rock formations ranging in age from Cretaceous to Recent include Kiner amphibolite, metasediments and metavolcanics of Jaglot group, Chi/as complex, Kohistan batholith and glaciofluvial deposits. Kiner amphibolites

(metagabbro and metadiorite) occur in Kiner and Hadar gah which are sheared and deformed in Dang Phhar area. They have intrusive contact with the Chilas complex and the Kohistan batholith. Metasediment and metavolcanics of the Jaglot group occur as xenoliths within the Chilas complex and Kohistan batholith.
They are schists and paragneisses interlayered with amphibolites. They are hybridized and at places migmatized. The Chilas complex comprises gabbro-norite, pyroxene quartzdiorite, hornblendite with minor ultramafic rocks. This sequence intruded by the Kohistan batholith which occupies about 70% of the northern part of the mapped area. It is composed of multiphases plutons of diorite, tonalite, quartzdiorite, granodiorite, adamellite, granite and leucocratic dykes. The diorite and tonalite show deformation whereas quartzdiorite, granodiorite and granites are partly deformed.
Tectonically, the area is characterized by a number of northeast dipping high angle faults and many shear zones are developed which accommodate the neotectonic uplift of the NPHM
Key words: Geology, Kiner gah, Diamir.

K/360. Khan, N.A., Latif, M., Bakht, M.S. & Fayaz, A., 1999. Geology of the Guner quadrangle (43 I/7), Diamir District, Northern Areas, Pakistan. Geological Survey of Pakistan, Information Release 683.

The investigated area lies on the SSW of the Nanga Parbat Haramosh Massif (NPHM) and southern part of Kohistan island arc. The oldest formation is Nanga Parbat group of paragneisses, schists and orthogneisses of Precambrian age. These are polycyclic metamorphic facies which consist of garnet-micaparagneisses, mica schists, migmatites, augen-gneiss, orthogneiss and retrograde chlorite schists. These rocks are intruded by granitoid of Cambrian age.
These rocks updomed from a cover of thrusted amphibolites/meta volcanic of Kohistan island arc and formed the Nanga Parbat syntaxis.
The Raikot shear zone is mostly amphibolite green schist and actinolite schist having faulted contact with Nanga Parbat group and Kohistan island arc. The Kohistan sequence has the oldest rocks of the Thak and Kiner amphibolites. They were formed from the early volcanics and plutonic rocks of calc-alkaline nature. The Chilas complex is a large mafic-ultramafic body intruded into the arc sediments and amphibolite and represent the root zone of magma chamber of the Kohistan island arc.
All these rocks are intruded by Kohistan batholith. Latest intrusions are tonalite stocks, garnet-tourmaline granitic sheets and granitic pegmatites after the collision during Miocene. Small deposits of molasse occur along the Indus River. However, the unconsolidated sediments are found along the Indus River and its major tributaries which are moraine, terrace and scree. Sulphide veins are associated with the Nanga Parbat gneiss and gneissic-schist, have mineralization of gold and silver. Detailed exploration may be carried out and geochemical studies are further recommended. The Indian plate collided with Kohistan island arc during 55 to 50 Ma along the Main Mantle Thrust (MMT). Later on due to reverse faulting the Raikot shear zone was formed and protruding of NPHM towards north. Many ductile and brittle shear zones are developed which accommodate the neotectonic uplift of the NPHM. The area is characterised by a number of high angle faults which are truncated the Raikot shear zone.
Key words: Geology, NPHM, Kohistan island arc.

K/361. Khan, N.A., Latif, M. & Shah, S.H., 1999. Geology of the Thurgoh-Gol quadrangle (43 M/15), Skardu District, Northern Areas, Pakistan. Geological Survey of Pakistan, Information Release 687.

The mapped area lies within the Kohistan-Ladakh island arc near the Asian mass and separated by the Main Karakoram Thrust (MKT). The rock units are Katzarah formation, Shigar volcanics, Yasin group, mafic and ultramafic rocks, intruded by multiphase diversified plutons of Ladakh batholith. The Katzarah formation of Early Cretaceous age consists of intra-arc flysch deposit of various grade phyllite, schists, hornfels and para-gneiss interlayered with epidote amphibolite and marble lenses. The Shigar volcanics consist of basalt, basaltic andesite, andesite and pyroclastic volcanics which have turbidite beds and green schist. The Yasin group of Early Cretaceous age consists of slate, sandstone, green schist, massive algal limestone, marble and turbidite beds.
The mafic-ultramafic rocks comprise of layers of altered peridotites, changed into serpentinite near northern suture zone and the scattered outcrops of mostly metagabbro with pockets and patches of peridotite, gabbroic monzonite and diorite. Ladakh batholith of early Paleocene to Miocene consists of granodiorite and granite associated with

quartz diorite. It occupies southern and eastern parts of the mapped area. Leuco dykes and sills of aplite and pegmatite are also present.
The unconsolidated sediments consist of low and high altitude moraines and also terraces along the Indus River and its other tributaries. Shigar volcanics have faulted contact with the overlying Yasin group, the folds and faults of varying magnitudes are common in the mapped area, with major fold axis plunging toward west.
The gold showings are present in the quartz veins of Katzarah formation and Shighar volcanics. Some pockets and lenses of serpentinite occur in the remote areas of the Yasin group.
Key words: Geology, tectonics, ultramafics, MKT, Skardu.

K/362. Khan, N.A., Mujtaba, G. & Khan, T., 1998. Geology and mineral investigations of the Gupis quadrangle (Toposheet No. 42 H/8), Northern Areas, Pakistan. Geological Survey Pakistan. Information Release 546.

The Gupis quadrangle 42-H/8 is bounded by latitudes 36° to 36° 15'N and longitudes 31° 4' to 73° 30'E. It comprises mainly the Kohistan batholith which contains xenoliths of Chalt volcanics and the metasediments. The Chalt volcanics are considered to be of early Cretaceous age and consist of basalt, andesite, rhyolite, tuff with marble and quartzite intercalation. It shows metamorphism from amphibolite to greenschist grades. The Kohistan batholith is composed of multiphased plutons of diorite, granodiorite, granite, pegmatite and aplite. The diorite shows deformation whereas granodiorite and granites are mildly deformed and undeformed. Economically the area is not so much promising accept the occurrences of a small sulphide zone and quartz veins which contain at places some transparent to translucent quartz crystals.
Key words: Mapping, minerals, Kohistan.

K/363. Khan, N.A., Shah, S.H., Khan, F. & Laghari, A.L., 1999. Occurrence of gold in Garesh area, Gilgit District, Northern Areas, Pakistan. Geological Survey of Pakistan, Information Release 692.

Key words: Gold, Gilgit.

K/364. Khan, N.A., Shah, S.H., Laghari, A.L. & Mujtaba, G., 1987. A preliminary report on occurrence of sulphide mineralization in Singal area (42 H/16), Gilgit District, Pakistan. Geological Survey of Pakistan, Information Release 288.

Massive sulphide mineralization zone has been found in volcanic and metasedimentary rocks of lower Cretaceous age in Singal area about 50 km northwest of Gilgit (Toposheet No. 42 H/16). The mineralization occurs in Rakaposhi volcanic complex and is exposed in an area of 2.5 sq. km approximately. This sulphide zone can be recognized as ab altered product of original rocks that weathers to pale, brownish, reddish and dark grey material in the superficial part of the outcrop. The mineralization is also observed in the form of dissemination in the volcanics and dolerite dikes mostly along the surface of joints and fractures. During the geological investigations of the area, 15 representative samples were collected and chemically analysed, Majority of samples show encouraging results of anomalous massive sulphide mineralization. The metallic content of analysed samples generally indicate the presence of Fe, Zn, Cu, Mn, Co and Mo in above-average quantities.
This report is based on field investigations and chemical analyses and may be suggested to be followed by a more comprehensive field and laboratory studies to prove the economic potential of sulphide mineralization.
Key words: Sulphide mineralization, Gilgit.

K/365. Khan, N.A., Shah, S.H. & Khan, M.S., 1988. Geology and mineral investigations of the Single quadrangle, Northern Areas, Pakistan. Geological Survey of Pakistan, Information Release 362, 20p.

The investigated area is a part of the Kohistan island arc sequence lying adjacent to the south of the Main Karakoram Thrust (MKT), and falls in the Survey of Pakistan Toposheet No. 42 H/16.

The project area is typified by meta-volcano-sedimentary rocks which are intruded by multi phases intrusions of the Ladakh-Kohistan granitoids with subordinate gabbroic intrusions, acidic and hornblendic pegmatites. Magmatic segregation and differentiation are noted within the granitic rocks. The contact metamorphic effects are more pronounced along the marginal zones of the intrusive bodies thus resulting schist, amphibolite and gneisses. Owing to the presence of the collision boundary between the Asiatic mass and Island are, the rocks of the investigated area are severely disturbed resulting a number of upright tight folds and faults.
Copper showings have been found in the Japuka and Hamuchal areas. Besides, altered massive sulphide mineralization and pyrite crystals as sparse dissemination are also located in the mapped area.
Key words: Volcanics, MKT, Kohistan island arc, Gilgit.

K/366. Khan, N.M., 1950. A survey of coal resources of Pakistan. Geological Survey of Pakistan, Records 2(2), 10p.

Key words: Hydrocarbons, coal, Pakistan.

K/367. Khan, N.M., 1962. Geology of coal fields in Pakistan. CENTO Symposium on Coal, Zonguldak, 1961, 97-102.

Key words: Hydrocarbons, coal, Pakistan.

K/368. Khan, N.M. & Reinemund, J.A., 1962. Industrial rocks and minerals in Pakistan. Proceedings, CENTO Symposium on Industrial Rocks and Minerals, Lahore, 21-27.

Key words: Industrial rocks and minerals.

K/369. Khan, N.M. & Reinemund, J.A., 1963. A cooperative mineral exploration and development program in Pakistan. UN Conference on Application of Science and Technology for the benefit of less developed areas, Genevia. Natural Resources (Karachi University) 2, 71-89.

Key words: Mineral exploration.

K/370. Khan, R., Hussain, H. & Saleem, M., 1984. Cement raw material around Muzaffarabad, Azad Kashmir. Geological Survey of Pakistan, Information Release 225.

During September, October and Novanber,1982, the investigation of cement raw materials around Muzaffarabad was undertaken by the authors on the request of the Government of Azad Kashmir and the Chairman, AKMIDC, to establish a cement plant near Muzaffarad, Azad Kashmir.
In the investigated area the metasedimentary and sedimentary rocks, ranging in age from Precambrian td Quaternary, are exposed. The sedimentary rocks are mainly limestone, shale and sandstone ranging in age from Cambrian to Pliestocene. The metasedimentary rocks of the Hazara formation, probably of Precambrian age, consist of slate, phyllite, shale, limestone with lenticular bodies of gypsum are exposed in t be west of Muzaffarabad.
Although the cement raw materials are available at different places between 2-8 kilometers around Muzaffarabad, but the most suitable deposits on the basis of quality and quantity are the Batmang deposits of the Chhalpani formation located at about 8 kilometers north of Muzaffarabad. During the course .of investigation over sixty limestone, shale and gypsum samples were collected for chemical analysis on the basis of which a deposit was found to be suitable.
Key words: Limestone, cement, Muzaffarabad.

K/371. Khan, R., Shah, S.H. & Khan, N.A., 1999. Investigation of the geothermal springs of the Tatta Pani area, District Kotli, Azad Jummu and Kashmir. Geological Survey of Pakistan, Information Release 701.

Key words: Geothermal springs, Tatta Pani, Azad Kashmir.

K/372. Khan, R.A., 1973. Field report on geology and petrology of Thakot–Shang area, Hazara and Swat. M. Sc. Thesis, Punjab University, Lahore.

Key words: Petrology, Thakot-Shang, Hazara, Swat.

K/373. Khan, R.M.K., 1976-78. The geology and petrology of Jura-Bandi Area Muzaffarabad, Azad Kashmir. M.Sc. Thesis, Punjab University, Lahore, 97.

Jura Bandi, an igneous and metamorphic complex, is a part of Nanga Parbat-Haramosh zone. The area is highly disturbed being in the region of syntaxial influence i.e. involvement in Himalayan orogeny. The metamorphic rocks are the oldest marking of Salkhala series which includes granitic rocks (Quartz-o-feldspathic rocks) along with prominent foliated structure with development of augen gneisses at places. Lithologically the oldest metamorphic rocks present are as following:
i) Chlorite mica schist.
ii) Garnet mica schist.
The metamorphism extends up to garnet grade yet retrograde metamorphism is commonly observed especially in the chlorite mica schist. Among Quartz-o-feldspathic rocks two granites (Granite gneiss and granite porphyritic) lying side by side extending in NE and NW direction. Mineralogically both granites are rich in Potash feldspar. Pegmatites and Aplites are present as dykes. The basic rocks among the minor bodies are diorite and diabases dykes. The report submits a detailed map on scale 1ρρ-789 miles or 1:50.000 of about twenty seven square miles along with details of field and laboratory investigation, the petrogenesis of both the granites (Granite gneiss and granite porphyritic) is derived on the streldeson's triangle method. The Petrography is discussed slide wise.
Key words: Petrology, igneous rocks, Muzaffarabad, Azad Kashmir.

K/374. Khan, R.N., 1987. Feldspar deposits in NWFP. Geological Survey of Pakistan, Information Release 283.

Key words: Minerals, feldspar, NWFP.

K/375. Khan, R.N., Afridi, A.G. & Shah, H., 1986. Geology of Charbagh Quadrangle, Swat. Geological Survey of Pakistan, Quetta. Information Release 132.

Key words: Mapping, geology, Swat.

K/376. Khan, R.N., Iqbal, S., Khan, S. & Khan, M.A., 1995. Geological Map of Murghzar quadrangle (Toposheet No. 43 B/2, Scale 1:50,000), NWFP, Pakistan. New Geoscience No. 1073 (Old Sheet No. 71), Geological Survey Pakistan. NWFP Geological Map Series, vol. III.

Key words: Mapping, Murghuzar.

K/377. Khan, R.N. & Saleemi, B.A., 1972. Geology of Kotegram and Akhagram quadrangle, District Dir and Swat, Pakistan. Geological Survey of Pakistan, Information Release 80, 28p.

Key words: Mapping, geology, Dir, Swat.

K/378. Khan, R.S., 1986-88. Geological studies of Jabri Area with special emphasis on sedimentology of carbonate rocks. M.Sc. Thesis, Punjab University, Lahore, 134p.

Key words: Sedimentary rocks, carbonates, Hazara.

K/379. Khan, R.S., Chaudhry, M.N., Ghazanfar, M. & Sameeni, S.J., 1992. A reconnaissance microfacies studies of Margala Hill Limestone Jabri area, southern Hazara, Pakistan. Abstracts, First South Asia Geological Congress, Islamabad, p.54.

Key words: Metamorphic, limestone, reconnaissance, Margalla Hill, Hazara.

K/380. Khan, S., 1965. Notes on the dolerite dykes in Northern Hazara. Zamaka, Peshawar University Geological Bulletin 2b, 1-4.

The northern regions of Hazara consist mostly of metamorphic and plutonic rocks of Palaeozoic and Mesozoic times. The plutonic rocks consist of granites and gneisses which are part of the great Himalayan batholiths. The metamorphic rocks consist of almost all grades from chlorite schists to staurolite schists passing further north into sillimanite gneisses in Hazara Kohistan. A little south of Oghi, big crystals of kyanite can be seen in a small portion of Susal Gali granite gneiss. These rocks of different metamorphic grades show all sorts of mineralogical, textural, and structural variation. Almost the whole of the region is isoclinally folded. Analysis of the structural data indicates that this area has been subjected to more than two phases of tectonic events. The granites and gneisses are also extremely variable, mostly have faulted contacts, and contain accessary minerals such as andalusite, sillimanite, kyanite, and garnet, etc., all of which are generally of metamorphic affinities. There is ample evidence that they are products of assimilation (Shams, 1961). Some granites are also very rich in tourmaline. These granites are of a later time and are generally very massive. Some of them for example the Hakale granite in Mansehra proper is extremely rich in volatile components and has intrusive relations with Mansehra granite. These rocks are profusely intruded by dolerite dykes and sills at different intervals of geological time. They have a tendency to be more abundant in plutonic than metamorphic rocks. The majority of these dykes and sills occurring in metamorphic rocks are regionally metamorphosed with well developed schistose planes striking parallel to the regional strike. The present notes are a short discussion of the various types of these dolerite veins, their optical characters and a review of their possible relation to the granites.
Key words: Metamorphic rocks, plutonic rocks, dolerite dykes, Hazara.

K/381. Khan, S.A., 1981-83. Geology of Para-Bela-Jared Area Central Kaghan Valley. M.Sc. Thesis, Punjab University, Lahore, 145p.

This report covers a comprehensive study of a part of central Kaghan Valley. The principal emphasis has been on detailed litho-structural mapping of the area of the scale 1:8333. The rocks range in age from Precambrian Salkhalas to Miocene Murrees. Stratigraphically, the geology is in many ways different from that in the Abbottabad-Murree-Tarbela-Attock area further south. Part of the Mesozoic and part of the Tertiary sequence is missing in the project area. Furthermore, the equivalents of Panjal Trap and associated limestone are not found in the above mentioned area southwards. Structurally except for some folding in the blocks and nearly all contacts are faulted. The succession in the area is overturned. A fairly detailed account of the stratigraphy is being given and the report also includes a detailed account of the Petrography of all units based on extensive sampling. Tectonically the area is very interesting and the Panjal Traps appear to represent Ophiolites while the Agglomerate Slates appear to indicate Volcano-sedimentary material with island arc affinities. There is thus some evidence of a Paleozoic subduction zone in this area. Numerous photographs and sketches have also been included to illustrate the geology of the area.
Key words: Geology, petrology, Kaghan valley.

K/382. Khan, S.A.Q. & Munir, A., Undated. Mineralogy and economic geology of Lahor–Pazang area, Swat Kohistan. M.Sc. Thesis, Geology Department, Peshawar University.

Key words: Economic geology, lead-zinc, Lahor-Pazang, Swat Kohistan.

K/383. Khan, S.D., 1973. Stratigraphy of Chail group in Hazara. M.Sc. Thesis, Punjab University, Lahore.

Key words: Stratigraphy, Hazara.

K/384. Khan, S.H., 1997a. Neotectonic Map of Pakistan, 1:5,000,000 scale. Geological Atlas Pakistan. Geological Survey Pakistan.

Key words: Mapping, neotectonics, Pakistan

K/385. Khan, S.H., 1997b. Map showing major faults of Pakistan. Geological Atlas of Pakistan. Geological Survey Pakistan.

Key words: Mapping, fault zones, Pakistan.

K/386. Khan, S.H. & Ahmad, S.A., 1994. Publication Catalogue of Geological Survey of Pakistan. Geological Survey Pakistan. Record 104.

This is a catalogue that lists all publications (Memoirs, Records, Information Releases, etc.) of the Geological Survey of Pakistan (GSP) up to the year 1993.
Key words: GSP.

K/387. Khan, S.N., 1961. Survey of radioactive minerals. Natural Resources (Karachi University) 1, 63-66.

Key words: Radioactive minerals, Pakistan.

K/388. Khan, S.N., 1964. Geology of Rajdhawari pegmatites, Oghi sub-division, Hazara District, West Pakistan. Geological Survey of Pakistan, Information Release 19, 18p.

The detailed study of Rajdhhwari pegmatites was completed on December, 30, 1961. In this study an attempt has been made to classify the pegmatites on the basis of their size, shape, internal structure, and mineralogy. An area covering 21 square miles around Rajdhawari has been geologically mapped. Longitudinal cross sections and radiometric grid maps of two productive pegmatites have also been prepared.
Out of a total of 74 pegmatite bodies studied in Rajdhawari area, less than three per cent contain traces of billibinitc and other unidentified radioactive minerals. Nearly fifteen percent pegmatites contain beryl. The two productive pegmatite bodies have an approximate reserves of 1500 pounds of beryl, 225 tons of mica, and 2500 tons of feldspar. Total reserves of feldspar to a depth ranging from 20 to 50 feet in five bigger pegmatites have been estimated as 6200 tons.
Key words: Pegmatites, beryl, Hazara.

K/389. Khan, S.N., 1970. Search for radioactive minerals in Pakistan. National Seminar on Mineral Development, Lahore.

Key words: Radioactive minerals.

K/390. Khan, S.N., 1985. Publication catalogue, Geological Survey of Pakistan. Geological Survey Pakistan. Records, 48, 57p.

This is a listing of the geological Survey of Pakistan (GSP) publications up to the year 1984.
Key words: Publication catalogue, GSP.

K/391. Khan, S.N., 1995. Mineral resources and metallogenic zonation of Pakistan. Proceedings, International Round Table Conference on Foreign Investment in Exploration and Mining in Pakistan, Islamabad, October 16-18, 1994, 43-45.

Key words: Mineral resources, metallogeny.

K/392. Khan, S.N., Khan, I.A., Abbas, S.G. & Khan, A.L., 1992. Coal resources potential of Pakistan. Geological Survey of Pakistan, Information Release 533.

Per capita power consumption is an indicator of the development stage of a country, and normally developed countries are using vast quantities of coal for power generation. In the USA 63 million tonnes of coal is used annually for power generation. In East Germany 220 million tonnes and in Western Europe 182 million tonnes of coal is used for power production every year. Pakistan, unfortunately has not been able to utilize its coal resources and the share of coal in the energy mix has declined from about 60% at the time of independence to less than 5% at present. Pakistan at present is using imported oil and natural gas for almost total thermal power generation. However, fast depleting gas resources and sharp increase in already scarce foreign exchange bill for import of oil are pressing hard to develop indigenous coal resources for generation of power.
GSP, from its own resources and aided by USAID and USGS, has continued its efforts to explore and establish the coal resources of the country. The efforts of the department have resulted in the recent discovery of two new large coal fields with coal quality suitable for power generation. The coal resources of the country are now projected at 22 billion tonnes.
Out of these 637 million tonnes are measured, 2440 million tonnes indicated 855 million tonnes inferred and 10646 tonnes hypothetical. Over ninety seven percent of these resources occur in Sindh Province, not very far from Karachi, the biggest industrial centre of the country.
The Pakistan coals are lignite A to Hv sub B and generally high in sulphur. However, the latest discovered coal field of Thar desert contains low sulphur coal. with the erection of two power plants of 50 M.W each, based on Lakhra coal, a beginning to utilize indigenous coal for large scale power generation has been made and it is expected that discovery of low sulphur coal in Thar will encourage the investment on development of huge coal resources of the country for power generation.
Key words: Hydrocarbons, coal, Pakistan.

K/393. Khan, S.N., Khattak, M.U.K. & Ahmad, W., 1997. Significant gold base-metal anomalies associated with Tirich Mir Fault zone, Chitral, Northern Pakistan. Abstracts, National Symposium on Economic Geology of Pakistan, Islamabad, 2p.

The Chitral region geographically occupies the eastern terminations of Hindukush ranges and geotectonically the western extremities of the Himalaya sedimentary rocks of Karakoram and Asia to the north and a dominantly Cretaceous volcano-sedimentary sequence of Kohistan arc in the south. The Paleozoic to Mesozoic rocks are strongly sheared, folded and faulted during the Cretaceous-Tertiary orogenesis and are subjected to subduction related ~‘oIcanop1utonic complexes.
This paper describes anomalous concentrations of gold and base-metal in the rock formations north and south of the Tirich fault zone. This research is part of a systematic regional exploration comprising drainage geochemical survey and remote sensing through the study of satellite imageries and aerial photographs together with use of information on ground geology (petrography. petrology and geochemistry) and mineral occurrences. Tirich Mir fault zone is typically associated with mafic-ultramafic rocks and probably represents a suture zone between the Karakorum and the Asian plates.
Key words: Minerals, base metal anomalies, gold, Tirich Mir fault zone, Chitral.

K/394. Khan, S.R., 1989. An introduction to Ophiolites of Waziristan. Geological Survey of Pakistan, Information Release 435.

The Waziristan ophiolite is a prominent feature of the geology of Pakistan and delineates the suture at the northwest edge of the Indian plate. It comprises all the component lithologies of a typical ophiolite. This paper is amongst the earliest descriptions of it. For details, see description under S. R. Khan (2000) and Khan et al. (2001).
Key words: Waziristan ophiolite, Pakistan.

K/395. Khan, S.R., 1992a. Stratigraphy and structural set up of Swabi and adjoining areas, NWFP, Pakistan. M.Phil. Thesis, University of Peshawar, 42p.

The present work has resulted in the recognition of a well developed stratigraphic succession of the Tethyan Himalayas exposed in the mountain ranges fringing the northeastern Peshawar basin (Swabi, Mardan, and Buner districts of the NWFP, Pakistan). The rocks range in age from Precambrian through Paleozoic to Early Mesozoic and are composed of igneous, metamorphic and sedimentary rocks. A Precambrian succession comprising of Salkhala and Tanawal formations makes a basement to about 400 metres thick Paleozoic succession, comprising Ambar Formation (Cambrian), Misri Banda Quartzite (Early to Late Ordovician), Panjpir Formation (Late Silurian), Nowshera Formation (Early Devonian), and Jafar kandao Formation (Early Carboniferous). These metasedimentary rocks provide evidence for Late Paleozoic (Carboniferous Permian) intracontinental rifting, the onset of which is indicated by north derived clasts in the jafar Kandao Formation and together with extrusion of rift related volcanism in the form of alkaline acid porphyries and tholeiitic to alkaline basalt horizons. A much greater variety of hypabyssal and plutonic rocks including carbonatite, ijolite etc., are associated with this phase of magmatism. Post Permian thermal subsidence and marine transgression led to the deposition of the Early Mesozoic carbonate rocks which unconformably overly the Karapa Greenschist. The whole stratigraphic succession is considered to be developed in a northward dipping epicontinental basin while the magmatism is related to the rifting episode. Most of the rocks have yielded fossil evidences regarding their ages, while a few have been dated by radiometric determination. The present work describes some of the new evidences relating to the Paleozoic-Mesozoic rocks of the study area and their interpretation and implication in the reconstruction of the regional geological framework of this part of Tethyan outer Himalayas.
Key words: Stratigraphy, structure, Precambrian, Paleozoic, Swabi.

K/396. Khan, S.R., 1992b. Ophiolites in Pakistan. Abstract volume International Symp. Himalayan Geology, 3–9 Sept., 1992, Shimane, Japan, p.22.

This general account includes ophiolites from the area of this work of ours.
Key words: Ophiolites, Pakistan.

K/397. Khan, S.R., 1992c. Paleozoic stratigraphy and intracontinental magmatism, northern Pakistan. 29th International Geological Congress, Kyoto, Japan. Abstract volume 1 of 3, p.122.

Key words: Magmatism, stratigraphy, Paleozoic.

K/398. Khan, S.R., 1995. A preliminary geological report on part of Waziristan ophiolitic mélange, North Waziristan Agency, NW Pakistan. Abstracts, International Symposium on Himalayan Suture Zone of Pakistan. Pakistan Museum of Natural History, Islamabad, p.4.

The Waziristan ophiolite is a prominent feature of the geology of Pakistan and delineates the suture at the northwest edge of the Indian plate. It comprises all the component lithologies of a typical ophiolite. This paper is amongst the earliest descriptions dealing with the tectonic mélange which contains components of the ophiolite.. For details, see description under S. R. Khan (2000).
Key words: Ophiolite, geology, Waziristan.

K/399. Khan, S.R., 1999a. Stratigraphy of the passive margin of the Indian Plate, Waziristan, N.W. Pakistan. Geologica 4, 47-68.

Key words: Tectonics, stratigraphy, Indian plate.

K/400. Khan, S.R., 1999b. First discovery of Mesozoic fauna from Waziristan and its stratigraphic significance. Abstract book, Peshawar meeting IGCP 421 (8-26 September 1999) – additional abstract. National Centre of Excellence in Geology, University of Peshawar.

Key words: Stratigraphy, fauna, Mesozoic, Waziristan.

K/401. Khan, S.R., 2000. Petrology and geochemistry of part of the Waziristan Ophiolite Complex, Pakistan. Ph.D. Thesis, University of Peshawar, 253p.

This work presents for the first time a detailed geological mapping, petrologic, geochemical and stratigraphic synthesis of a part of the Waziristan Ophiolite Complex and part of shelf-slope sediments of the Indian plate in North Waziristan, northwest. Pakistan. The study area is presently sandwiched between the Afghan block to the west and Indian plate to the east and divisible into two blocks. These blocks from east to west are the shelf-slope sediments and Waziristan Ophiolite Complex. The shelf-slope sediments are thrust over by the Waziristan Ophiolite Complex to the west, whereas a thick pile of Tertiary sediments unconformably overlies the ophiolite complex.

The shelf-slope sediments based on detailed geologic mapping, section measurement and fauna discoveries are divisible into seven stratigraphic units. These units from older to younger are Raghzai formation of Middle Triassic, Kishai formation of Late Triassic, Zehe formation of Early Jurassic, Alexandra formation of Middle Jurassic, Zargar Khel formation of Late Jurassic-Early Cretaceous (?), Sinai formation of Early Cretaceous and Marni Rogha limestone of Late Cretaceous (Campanian) age.

The Waziristan Ophiolite Complex is also divisible into three thrust sheets/ nappes, each characterised by distinct lithologies and style of deformation. These nappes from east to west are the Vezhda Sar, Boya and Datta Khel. The Vezhda Sar nappe forms the eastern edge of the ophiolite complex, is composed entirely of pillow basalts and intermixed with the shelf-slope sediments. It contains exotic blocks of serpentinised ultramafic rocks. The central nappe called the Boya nappe contains an intact normal ophiolite sequence, starting from ultramafic cumulates followed by isotropic/homogeneous gabbros and pillow basalts and is capped by pelagic sediments. The central part of this nappe is strongly deformed and contains fault bounded blocks of all sort of ophiolitic rocks. The Datta Khel nappe forming the western part of the ophiolite complex is characterised by the presence of sheeted dykes and isolated outcrops of ultramafic-mafic cumulates and, pillow basalts. A thick pile of Tertiary sediments unconformably overlies this nappe. The Tertiary sequence is comprised of Ghazij Formation of Early Eocene and Kirthar Formation of Early to Middle Eocene age. The geochemical characteristics, such as LILE enrichment, HFSE depletion, and non-depletion of Nb indicate that the ophiolitic rocks are transitional between island-arc tholeiites and mid-ocean ridge basalts type affinities. Rocks displaying such a transitional characteristics are thought to have involvement of some sort of subduction component brought by fluids along subduction zone to the source region and interpreted to have formed above a subduction zone in a back-arc basin or suprasubduction zone setting.

The pelagic sediments intercalated and stratigraphically overlying the pillow basalts, contain radiolarian fauna of Late Jurassic to Early Cretaceous (TithonianValanginian) age. Based on the age of the radiolarian fauna, the formation age of the ophiolite is interpreted to be Late Jurassic or older. The 40Ar-39 Ar isotopic dates on hornblende of an amphibolitised gabbro from the Waziristan Ophiolite Complex indicate 93.57 ± 1.01 Ma. This - 93 Ma age may represent the first phase intraoceanic obduction of the Waziristan Ophiolite Complex. The ophiolite complex contains exotic blocks of Marni Rogha limestone of Late Cretaceous (Campanian) age and is also thrust over similar limestone, suggesting late Cretaceous or most probably Paleocene secondary obduction of the ophiolite over the shelf-slope sediments of the Indian plate. The K-Ar whole rock radiometric dates (- 75 Ma) of the gabbroic and trondhjemitic rocks further support this interpretation. The K-Ar whole rock radiometric dates ("""' 60 Ma) of the Waziristan volcanics may suggest the accretion of the Indian plate with the Afghan block. The deformation of the Tertiary sediments overlying the Waziristan Ophiolite Complex, those of the Katawaz Basin and thrusting of the Mesozoic rocks of Kirthar and Sulaiman ranges over the foredeep molasse sediments, suggest collision between Indian plate and the Afghan block during Pliocene-Pleistocene.

Key words: Petrology, geochemistry, ophiolite, Waziristan.

K/402. Khan, S.R. & Fatmi, A.N., 1999. Discovery of Mesozoic fauna from Waziristan and its stratigraphic significance. Additional abstracts, IGCP 421 (North Gondwanan mid-Palaeozoic Bioevent/ Biogeography Pattern in Relation to Crustal Dynamics), Peshawar Meeting, 1p.

Key words: Fauna, stratigraphy, Mesozoic, Waziristan.

K/403. Khan, S.R., Jan, M.Q. & Khan, M.A., 2001. Tectonic evolution of the Waziristan ophiolite, NW Pakistan. Abstracts, 4th Pakistan Geological Congress, Islamabad, p.8.

The Waziristan ophiolite is located in the northwest Pakistan, demarcating a suture zone between the Indian plate to the east and Afghan block to the west. It is highly dismembered and divisible into three nappes. These nappes from east to west are: Vezhda Sar nappe entirely comprising of pillow basalts; Boya nappe, made up of ophiolitic mélange with an intact sequence in the basal part; and Datta Khel nappe, consisting of sheeted dykes along with variable proportions of other components. The intact Ophiolite sequence from bottom to top consists of i) the ultramafics (harzburgite, wehrlite and dunite), ii) the mafics (isotropic gabbros), and iii) the volcanics (pillow basalts), capped by pelagic sediments (limestone, shale and chert). The layered gabbros, sheeted dykes and trondhjemites are found as isolated fault bounded bodies in the highly dismembered central and western parts of the ophiolite suite. The ophiolite is unconformably overlain by sedimentary rocks of Early to Middle Eocene age to the west and thrust over the Mesozoic shelf-slope sedimentary rocks of the Indian plate to the east.
Major and trace elements geochemistry is used in specifying the petrogenetic and tectonic evolution of the Waziristan ophiolite. All the ophiolitic rocks are of N-MORB type and give a similar geochemical characteristics indicating to be comagmatic. These rocks are characterized by higher LLLE/HFSE ratios and non-depletion of Nb. The various geochemical parameters based on high-field strength elements reveal that the ophiolitic rocks are transitional between island-arc tholeiites and mid-ocean ridge basalts. Their transitional characteristics, non-depletion of Nb, higher LILE/HFSE ratios and presence of sheeted dykes suggest that the Waziristan ophiolite may have originated in back-arc basin environment.
Based on the age of radiolarian fauna (Tithonian±Valanginian) recovered from the pelagic sediments (chert), the age of the Waziristan ophiolite is interpreted as Late Jurassic or older. The presence of tectonic blocks of Campanian limestone (Mami Rogha Limestone) in the ophiolite and thrusting of the ophiolite onto Maastrichtian shale, suggest post-Maastrichtian, most probably Paleocene, emplacement of the ophiolite.
Key words: Tectonics, ophiolites, Waziristan.

K/404. Khan, S.R., Jan, M.Q., Khan, M.A. & Khan, T., 2001. Geochemistry and petrogenesis of the sheeted dykes in Waziristan Ophiolite, NW Pakistan and their tectonic implications. 16th Himalaya Karakoram Tibet International workshop, Journal of Asian Earth Sciences 19, p.36.

This paper presents the petrologic and geochemical aspects of the sheeted dykes as well as isolated mafic dykes from the Waziristan Ophiolite, northwest Pakistan. The ophiolite occurs in the suture zone between the Indian plate to the east and Afghan block to the west. It is divisible into three main sheets or nappes which, from east to west are: Vezhda Sar nappe entirely comprising of pillow basalts; Boya nappe made up of ophiolitic melange with an intact sequence in the basal part; and Datta Khel nappe consisting of sheeted dykes along with small proportions of other components. The sheeted dykes are an important component of the Waziristan Ophiolite and their excellent exposure is found in the hanging wall of the Datta Khel Thrust, ENE of Datta Khel. The ophiolite is thrust over the Mesozoic shelf-slope sediments of the Indian plate to the east and unconformably overlain by sedimentary rocks of Early to Middle Eocene age to the west. Major and trace element geochemistry indicate that the dykes (both sheeted and isolated) contain higher contents of Na_2O, $FeOt/MgO$ and LILLE/HFSE ratios, and lower TiO_2 (,0.1 wt%) and K_2O (Figs. 1 and 2). Non-depletion of Nb and high LILE/HFSE ratio negate an island-arc or mid-ocean ridge settings for these dykes, respectively. The enrichment of LILE rather suggests involvement of crustal components driven by fluids along a subduction zone. The various geochemical parameters used in specifying the tectonomagmatic setting of the Waziristan dykes reveal a transitional characteristic between mid-ocean ridge basalt and island-arc tholeiite. It is suggested that the Waziristan dykes may have originated in a back-arc basin tectonic set-up. Based on the age of the radiolarian fauna (Tithonian±Valanginian) recovered from the pelagic sediments (cherts), the age of the Waziristan Ophiolite is interpreted as Late Jurassic or older. The presence of exotic blocks of

the Campanian limestone in the ophiolite coupled with overthrusting of the ophiolite onto Maastrichtian rocks suggest post-Maastrichtian, most probably Paleocene, emplacement of the Waziristan Ophiolite.
Key words: Geochemistry, sheeted dykes, sea floor spreading, ophiolites, Waziristan.

K/405. Khan, S.R. & Karim, T., 1989. Geological map of Drazinda. US Geological Survey, Geological Map Series 775, 170A (39 I/2).

Key words: Mapping, Drazinda, D.I. Khan.

K/406. Khan, S.R. & Khan, M.A., 1994. Late Proterozoic stratigraphy of Swabi area, NWFP, N. Pakistan. Geological Bulletin, Peshawar University 27, 57–68.

A succession of weakly metamorphosed unfossiliferous sedimentary rocks has been described in terns of lithostratigraphy from an area north of Swabi. The succession unconformably underlies the Cambrian Ambar (Dolomite) Formation (=Abbottabad Formation) and represents the supra-crustal sediments of a probable Late Proterozoic age from the Indian- Plate basement. A WNW plunging cylindrical anticline controls the disposition of stratigraphic units. The succession is divisible into two formations; Salkhala and Tanawal. The basal part of the Sulkhala Formation, exposed at the west bank of the Tarbela dam, is classified as the Gandaf unit and comprises pelitic and graphitic schists, brown dolomite and white and grey-black marble. The upper part, exposed at the apex of the Kundal anticline, is predominantly argillaceous and contains black mud- and siltstone which grade upward into pebbly green phyllite. The overlying Tanawal Formation is conglomeratic at its base and comprises three units, two of which are quartzitic, while the one, in the middle, is argillaceous. It is suggested that the Tanawal Formation may be a time-equivalent facies change of the Hazara, Manki and Landikotal Slate formations, rather than being younger as suggested in the existing literature. This may explain some of the discrepancies in the existing regional tectonic framework of the Indian plate in northern Pakistan.
Key words: Stratigraphy, Proterozoic, Swabi.

K/407. Khan, S.R., Khan, M.A., Jan, M.Q. & Khan, T., 1998. Trondhjemites from the Waziristan ophiolitic melange, NW, Pakistan. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 98-99.

Small amounts of leucocratic intrusions composed of quartz, feldspar, and accessory ferromagnesian minerals are associated with most ophiolites, These, commonly called trondhjemite or plagiogranite, are soda-rich and potash-deficient as compared with normal granite. These rocks are generally found in the upper part of mafic cumulates of the ophiolite sequences, but the trondhjemites in the Waziristan Ophiolitic Melange are associated mostly with ultramafic cumulates and only locally with mafic cumulates. In both the cases they have sharp intrusive contacts with the host rocks. They occur in the form of veins, pods and plugs, ranging from a few centimetres to four metres in width and six to ten metres in length. The rocks are light-grey to milky-white, medium-to coarse-grained, equigranular, non-foliated, and composed of quartz, albite (An8-lo) and minor biotite and hornblende. The constituent minerals, espatially plagioclase, show alteration to chlorite, calcite, sericite, epidote and muscovite.
The rocks are characterized by relatively high SiO2 (60.47 - 79.70 wt.%), Na2O (3.04 - 6.06 wt.%), CaO (0.52 - 6.95 wt.%), and low K2O (< 1 wt.%), TiO2 (< 1 wt.%), P2O5 (< 1 wt.%) and MgO (0.23 - 2.82 wt.%). They are sub-alkaline in composition and classify as trondhjemite on the basis of normative albite, orthoclase and anorthite contents [I]. The Rock/Primordial Mantle spider diagram pattern (Fig. 1) shows enrichment in LIL elements (K, Rb, Ba, Sr) relative to HFS (Ti, Y, Nb) elements [2]. The geochemical pattern for the trondhjemites is transitional between those of island arc and mid-oceanic ridge granites.
K/Ar whole rock ages of trondhjemites (77 ± 2 - 70 ± I Ma) are much younger than the overlying radiolaria (Late Jurassic to Early Cretaceous) found in the pelagic sediments lying on top of the ophiolite [3]. From these dates we conclude that the ophiolite was generated by the Late Jurassic and emplaced during the Latest Cretaceous-Paleocene.
Key words: Ophiolites, geochemistry, Waziristan.

K/408. Khan, S.R., Khan, M.A., Jan, M.Q. & Khan, T., 1998. Tectonic implications of major and trace elements geochemistry of volcanic rocks from the Waziristan ophiolitic melange, NW. Pakistan. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, p.100.

Volcanic rocks are the most voluminous component of the ophiolite segments in the Waziristan Ophiolitic Melange (WOM). They are divided into two-groups, i) Vizhda Sar Complex volcanics (VSCV), and ii) Waziristan Ophiolitic Melange Volcanics (WOMV). The VSCV are erupted along the western periphery of the Mesozoic shelf sediments of the Indian plate, in Waziristan, Pakistan. Their most excellent outcrops are found between Vizhda Sar to the south and Baba shaga to the north. The name Vizhda Sar Complex is proposed after Vizhda Sar, the second highest peak in the area and is composed entirely of pillow basalts. The VSCV contain exotic blocks of limestone and shale ranging in age from Lower-Middle Triassic to Late Cretaceous. They are basaltic in composition, and are not associated with dykes. To the west they are obducted by the Waziristan Ophiolitic Melange (WOM). The WONW form the uppermost segment of the ophiolite sequence overlying the mafic cumulate and underlying the pelagic sediments, respectively. In the normal ophiolite sequence they found as pillow lavas, while in the ophiolitic melange part, they are sporadically distributed over a considerable area and found as pillow lavas, sheet flows, agglomerates and breccias. Contrary to the VSCV, the WOMV are intruded by dolerite dykes, showing chilled margins. The WOMV have a wide range in composition varying from basalt to rhyolite. Geochemically, the VSCV are more primitve as evidenced by their higher content of MgO, Cr, and Ni than the WOMV, which are more fertile in LIL (K, Rb, Ba, Sr) elements. Both types are soda-rich, potash deficient, sub-alkaline and tholeiitic in composition. The VSCV are mid-ocean ridge basalt, whereas the WOMV are transitional between mid-oceanic ridge basalt and island arc tholeiite. Field and geochemical data suggest back-arc basin affinity for the formation of WOMV.
The radiolaria found in the cherts lying on top of the ophiolite sequence are of Late Jurassic to Early Cretaceous age, suggesting Late Jurassic age for the generation of WOM. The presence of tectonic blocks of Globotruncana-bearing limestone of Late Cretaceous age in the WOM, the K/Ar radiometric dates of gabbroic rocks (77 ± 2 - 75 ±1 Ma) and trondhjemites (77 ± 2 - 70 ± I Ma) and Early-Middle Eocene strata unconformably overlying the ophiolite sequence, suggest Latest Cretaceous-Paleocene as the time of emplacement of the WOM. This is consistent with the emplacement of Khost ophiolite to the north in Afghanistan and Muslim Bagh ophiolite to the southwest in Pakistan. The high scale deformation of the Tertiary (Early to Middle Eocene) sequence unconformably overlying the ophiolite sequence and the serpentinite splinters cross-cutting the Oligocene-Miocene flysch sediments of the Katawaz basin west of Muslim Bagh propose Pliocene age as the time of India-Afghanistan collision.
Key words: Tectonics, geochemistry, volcanics, Waziristan.

K/409. Khan, S.R., Khan, M.A., Nawaz, R. & Karim, T., 1990. Stratigraphic control for the age of Peshawar-Plain magmatism, northern Pakistan. Geological Bulletin, University of Peshawar 23, 253-263.

Recent mapping and stratigraphic analyses in the area at the north-eastern edge of the Peshawar plain has resulted in the recognition of a bimodal suite of basic and acidic volcanics. These volcanics occupy specify stratigraphic horizons in the Jafar Kandao Formation, whose age is well constrained between Carboniferous and Early Permian, on the basis of conodont studies. It is suggested that the basic volcanics are extrusive equivalents of the extensive suite of basic dykes and sills found in the internal zone of the Indian plate, while the acid volcanics are counterpart of the A-type granites of Warsak, Ambela, and Shewa-Shahbazgarhi. This study provides a stratigraphic control for the age of the Peshawar-plain magmatism.
Key words: Mapping, stratigraphy, magmatism, Peshawar Plain.

K/410. Khan, S.R., Khan, M.S., Afridi, A.J. & Nasir, S., 1976. Petrographic study of Samana Suk Formation, Kohat. M.Sc. Thesis, Peshawar University.

Key words: Petrography, Samana Suk Formation, Kohat.

K/411. Khan, S.R., Khan, R.N. & Shah, H., 1989. Geology of Rustam quadrangle, Mardan and Swat districts, NWFP., Pakistan. Geological Survey of Pakistan, Information Release 443.

Key words: Geology, stratigraphy, petrography, Rustam, Mardan.

K/412. Khan, S.R., Khan, R.N., Shah, H. & Saeed, G., 2000. Geology of the Rustam quadrangle, Mardan district, NWFP., Pakistan. Geological Map Series, vol. III

Key words: Geological map, Rustam, Mardan.

K/413. Khan, S.R., Khan, R.N. & Karim, T., 1990. Field relationship: Stratigraphic and structural position of the Shewa-Shabaz Garhi "porphyritic microgranite". Abstracts, 2nd Pakistan Geological Congress, University of Peshawar, 36-37.

Recent field studies carried out by the GSP in and around Rustam area in the Mardan District, NWFP, have shown, contrary to the previously thought structurally restricted extent (Martin 1962 & Kemp 1973)), that the "Porphyritic Microgranite" of the Shewa-Shahbaz Garhi area has a much larger areal extent showing cyclic intercalations with the host rocks.
The emplacement of the "Porphyritic Microgranite" and the deposition of the enclosing sediments seem to have taken place contemporaneously in an oscillating basin. The whole sequence is now treated as a separate, distinct and mappable time-rock unit. The name 'Jafar Kandao Formation' is proposed after the surveyed type locally at Jafar Kandao, about 5 km southeast of the Rustam village. In addition to the type locality and the better known Shewa-Shahbaz Garhi areas, the formation is also exposed in the Banda-Buner areas of the lower part of the Swat District. In most of these areas, it is found in the cores of the anticlines where the younger strata have been eroded.
The 'Jafar Kandao Formation' consists of argillites, limestone, quartzite, amphibolite, and "Porphyritic Microgranite". The formation has been assigned Early Carboniferous age on the basis of conodonts found in the limestone lenses (Pogue, Pers. Commun.).
Key words: Stratigraphy, field relations, granite, Shewa Shahbaz Garhi, Mardan.

K/414. Khan, S.R., Nakagawa, M., Khan, I.H., Kausar, A.B. & Shirahase, T., 1996. PGE mineralization in the Jijal complex, Kohistan, north Pakistan. In: Kausar, A.B. & Yajima, J. (eds.), Geology, Geochemistry, Economic Geology and Rock Magnetism of the Kohistan Arc. Proceedings of Geoscience Colloquium, Geoscience Lab, Geological Survey of Pakistan, Islamabad, 15, 103-125.

A GSP-JICA joint collaborative project for the investigation of PGE mineralization in the Jijal mafic-ultramafic complex, north Pakistan had been initiated in 1991, and carried out geochemical exploration, mineralogical and petrochemical investigations During the course of works, restricted areas showing remarkable positive anomaly of Pt and Pd were found, and also merenskyite; (Pd,Pt)Te2 hosted by pyrrhotite was discovered from massive sulfide ore of the Kolai stream which showed a considerable content of Pd (> 22 glt). Follow-up petrochemical analysis revealed that the disseminated sulfide mineralization in the garnet pyroxenite and/or hornblendite of the Kolai area contained 1.4 g/t of Pt + Pd which is more than thousand times concentration compared to the host rock background. However, from the comparative study with sub-economical occurrence of PGE in the Ivrea-Verbano Complex, Italy, the tectonic setting of which is similar to that of the Jijal Complex representing a root of paleo-island arc, high grade (> 10 g/t) PGE mineralization would not be expected in the complex except the massive sulfide ore presumably in the garnet hornblendite located close to the Kolai stream.
Key words: PGE, Jijal, Kohistan.

K/415. Khan, S.R., Pogue, K.R., Hussain, A., Saeed, G. & Babar, F., 1995. Geological Map of Topi quadrangle (Toposheet No. 43 B/12, Scale 1:50,000), NWFP., Pakistan. New Geosc. No. 1142 (Old Sheet No. 95), Geological Survey Pakistan. NWFP. Geol. Map Ser., vol. III.

Key words: Geological map, Topi, Swabi.

K/416. Khan, S.R., Saeed, G. & Khan, F., 1984. Geological map of Tarbela (43 B/12), Hazara District, Sheet No. 94, Scale 1:50,000. Geological Survey of Pakistan, Quetta. Map Series.

Key words: Mapping, Tarbela.

K/417. Khan, S.R. & Sano, S., 1994. Geology and petrography of the Landi Raud chromite deposits: A part of the Malakand ultramafic complex, N.W.F.P., Pakistan. Proceedings of Geoscience Colloquium, Geoscience Lab, Geological Survey of Pakistan, Islamabad, 9, 5-16.

Key words: Petrography, ultramafics, chromite, Malakand.

K/418. Khan, S.R. & Suzuki, M., 1997. Geochemical exploration for gold mineralization in northern Pakistan. Abstracts, National Symposium on Economic Geology of Pakistan, Islamabad, 1p.

The study area includes part of the Karakoram plate and the Kohistan arc terrane, which are separated from each other by the Main Karakoram Thrust (MKT). The Karakoram plate to the north of the MKT consists mainly of Paleozoic-Cenozoic sedimentary rocks, which are further intruded by Jurassic to Tertiary plutonic rocks. The island arc terrane contains metavolcanic and metasedimentary rocks intruded by Kohistan Batholith ranging in age from 102 to 30 Ma.

Detailed geochemical exploration, including stream sediments and panned concentrates as media, was conducted along the main streams of the Hunza and Gilgit rivers and their major tributaries. Sampling density was slightly enhanced in the neighbourhood. of Gilgit. where a number of alteration zones have been found. 120 samples of stream sediments were analyzed for gold, whereas 92 samples of panned concentrates underwent chemical assays for Au, Ag, As. Bi. Cu, Mo, Pb. Sb, and Zn in Chemex Laboratories, Canada. Gold contents in the study area are generally higher than the average of the earth crust, implying a high probability of some gold mineralization in this area. The univariate analysis demonstrates high concentrations along the MKT and on the northern side as a whole, except Cu and Mo. Gold shows particularly high concentrations along the MKT.

Factor analyses have led to the extract of the following two factors related to gold mineralization: i) a factor represented by a combination of Au-Ag-As-Sb (Factor I)~ their high factor scores are found along the MKT and ii) a factor represented by a combination of Bi-As-Ag-Au (Factor 2). High-scored points for the Factor 2 are distributed mainly around the glacier areas. The present survey succeeded in demarking areas showing high content of 11 ppm and 50.5 ppm Au as well as high scores for Factor I that suggest a follow-up survey' on priority basis in these areas.

Key words: Geochemistry, gold, Karakoram, Kohistan arc.

K/419. Khan, S.R., Suzuki, M. & Khan, T., 1996. Gold mineralization in the Kohistan arc terrane and Karakoram continental plate, Gilgit and Ghizar areas, northern Pakistan. Geologica 3, 23-67.

Key words: Gold mineralization, Kohistan arc, Karakoram.

K/420. Khan, S.U., 1995-96. Structure, stratigraphy, micropaleontology and petrography of Darthian, Narota & Karwali areas District Haripur Hazara (NWFP), Pakistan. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 89p.

The Darthian, Narota and Karwali area are part of Attock-Hazara fold-and-thrust belt of the northwest Himalaya of Pakistan. The lithographic units exposed in the area are mainly sedimentary in nature and range in age from Mesozoic to Cenozoic. The area is deformed by folding and faulting during the Tertiary-Himalayan collision. The Early Cretaceous Lumshiwal Formation has diconformable contact with the overlying Late Cretaceous Kawagarh Formation. The presence of glauconite in the Lumshiwal Formation reveals that the formation was deposited in marine condition during regressive as well as transgressive phases. The Late Cretaceous subduction of the Indian plate below the Kohistan Island arc caused the deepening of the Tethyan shelf in the subduction zone and initiated

the deep marine deposition of the Kawagarh Formation. The contact between Kawagarh Formation and Early Paleocene Hangu Formation is marked by break in deposition which is evidenced by the presence of laterite/haematite and sandstone. The abrupt change in facies from deep water marine environment of Kawagarh Formation to terrestrial deposition of Hangu Formation indicates the initial Early Paleocene collision of the Indian Plate and Kohistan Island arc.
The Lower Tertiary sequence exposed in the area is Early to Late Paleocene Lockhart limestone, Late Paleocene Patala Formation, Early Eocene Margala Hill Limestone, Early Eocene Chorgali Formation and Early to Middle Eocene Kuldana Formation. The Lower Tertiary sequence marks the complete cycle of transgression and regression of the Tethyan Sea. The presence of early Paleocene to Late Eocene foraminiferal assemblage like globorotalia, globogorina, lockhartia, 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 Kuldana Formation is composed of marine limestone, continental variegated clay, shales and evaporitic gypsiferrous bands. These variegated lithologies show that the Early to Middle Eocene Kuldana Formation deposited in transitional environment. The Kuldana Formation marks the end of transgressive cycle and initiation of regression of the Tethyan ocean. The Paleocene-Eocene boundary cannot be marked due to the lack of microfossils in Patala Formation. However, a tentative Paleocene-Eocene boundary marked at the base of Margala Hill Limestone on the basis of first appearance of Early Eocene fossils in the Margala Hill Limestone. Two sets of folds have been recorded which indicate two separate phases of deformation. These deformation phases are D_1 and D_2 which are related to Himalayan orogeny. D_{1a} is associated with the southeast-directed thrusts and southeast vergent F1 folds. D_{1b} is related with the backsteepening of the major thrusts and northwest overturning of the major F1 folds. This phase is well documented by the northwest vergent Chak Jabbi syncline and Khui-Marl syncline. D_{1b} is also related with backsteepening of MBT due to folding. The D_2 deformation phase is related with the folding of earlier northeast-southwest trending D_1 structures along northwest plunging F_2 cross folds. The F_2 cross folds are antiforms and synforms. These F_2 cross folds are related with the development of the Hazara-Kashmir syntaxis.
Key words: Structure, stratigraphy, micropaleontology, petrography, Haripur, Hazara.

K/421. Khan, S.Z., Shah, S.H., Khan, N.A. & Khan, K.S.A., 1999. Geological map of Gilgit quadrangle (43-I/5) northern areas, Pakistan. Geological map series no. 1310, Geological Survey of Pakistan Quetta.

Key words: Maps, Gilgit.

K/422. Khan, T., 1986. Geology of the Pegmatite Belt in Chitral, North West Frontier Province, Pakistan. Geological Survey of Pakistan, Information Release 266, 16p.

The rock units of the investigated area are the metamorphites and granitoids, which range in age from Devonian to Tertiary. The pegmatite belt comprising simple and complex pegmatites, trending in northeast and southwest direction are the youngest intrusions (85-20 Ma) within the granites. Gemstone mineralization confined to the complex pegmatites has been found at several localities in the high altitudes. Beryl/ aquamarine, schorlite, indicolite, garnet, and mica may get economic significance. Sulphide mineral association, scheelite, graphite and fluorite mineralization has also been observed.
Key words: Pegmatites, Chitral.

K/423. Khan, T., 1991. Geochemistry of the Warsak igneous complex, N. Pakistan. M.Phil. Thesis, University of Peshawar, 103p.

The Warsak Igneous Complex (WIG) is a bimodal suite of granite and basic rocks, with no or little intermediate compositions. The field relations are ambiguous because of shearing and metamorphism, however, there are indications that the basic rocks are older than the granites. The granites, occurring in three petrographic varieties are closely similar in geochemical composition, in particular, in terms of incompatible trace elements. They have all the characteristics of A-type within-plate granites. The basic rocks are typically tholeiitic formed in intracontinental setting, probably in the initial stages of rifting event. The close similarity of the Warsak granites with Ambela and

Koga, suggests a Palaeozoic age of the WIC. The magmatism in the Warsak area (including both basic and alkaline acidic) was probably related with the Paleozoic fragmentation of the Gondwanaland and the separation of India.
Key words: Geochemistry, granite, alkaline complex, Warsak.

K/424. Khan, T., 1992. Geology and tectonics of the Hindukush Range in the north Pakistan. Proceedings of Geoscience Colloquium, Geoscience Lab, Geological Survey of Pakistan, Islamabad 3, 84-90.

Hindukush (also called Nuristan) is a NE-SW striking range straddling parts of the countries including Pakistan, Afghanistan and the former U. S. S.R. The range is bounded by major faults except for in the NE where it may continue with the Karakoram Range (Figure 1: After Desio, 1979). The southern boundary of the Hindukush range is defined by the Main Karakoram Thrust (MKT) which separates the Hindukush range from the Kohistan arc. To the west the Hindukush range is bounded by the Sarobi fault which separates it from the Kabul block in the west. To the north the boundary of the Hindukush is defined by the Herat Fault that separates it from the Badakhshan block in the north. The Hindukush or the Noristan block is itself divisible into two structural domains, separated by the Reshun fault. The Reshun fault is a northward dipping thrust fault, which is locally defined along the Yarkhun River by a narrow belt of metavolcanics with (?) ophiolitic affinity (Pudsey et al., 1985). Thus there is a possibility that the Reshun fault is a palaeosuture between two continental blocks within the Hindukush range.
Key words: Tectonics, Hindukush.

K/425. Khan, T., 1994. Evolution of the “upper and middle crust in Kohistan island arc”, northern Pakistan. Ph.D. Thesis, Peshawar University, 225p.

This thesis presents a geological map of 4,000 km2 area between Chi las and Gilgit on a scale of l:250,000, together with details of geochemistry and petrology. The area is occupied by > 1 km thick basal turbiditic sediments (the Gilgit paragneisses), followed upward by > 0.5 km thick Chait metavolcanics and, finally the Thelichi formation = Yasin group comprising a volcanic base and > 1 km thick overlying turbidites with local intercalations of marble volcanoclastics and lava flows. Other lithologies in the area include, Chilas mafic ultramafic complex (8,000 km2), and the Kamila amphibolites. The Kohistan batholith of mostly Paleocenc·Eocene age, consists of quartz diorites, tonalities, trondhjemites, gabbroic, diorites, quartz n1cmzodiorites, granodiorites, granites, aplites and pegmatites. The batholith contains tholeiitic and calcalkaline mafic dykes; such dykes in the Chilas complex are tholeiitic. Metamorphism up to sillimanite grade has been recorded in the Gilgit paragneisses. The rocks of the Chalt volcanic group, mafic dykes of the Chilas complex and early phases of the Kohistan batholith show amphibolite facies metamorphism. The Thelichi formation contains greenschist facies mineral assemblages. The geochemical signatures of the Gilgit paragneisses support passive continental margin setting for their deposition. The Chalt volcanics demonstrate island are and back arc type affinities, whereas the Maine volcanics resemble back-arc tholeiites and mid ocean ridge basalts. These volcanics show transition from arc volcanism to back-arc spreading. The Kohistan batholith is calcalkaline, and gives island arc and continental margin types configurations.
The 36,000 km2 Kohistan terrane is divisible in three tectonic zones, (i) the southern (Kamila) zone comprises principally amphibolitised basalts, underplated by cumulate mafic-ultramafic plutons which occupy the hangingwall of the Indus suture, (ii) the central zone comprises the Chilas complex, and (iii) the northern (Gilgit) zone, the Gilgit paragneisses and the overlying rocks. The Gilgit zone was welded to the Karakoram plate 90 Ma ago along the Shyok suture. The northern two zones are complexly folded and faulted (in a divergent pop up structure), while the southern zone is folded and imbricated with a persistent southward vergence. Much of the Kohistan batholith cuts across these structures in the Gilgit zone. Previous tectonic models for Kohistan consider the southern two zones as the basal crust and the northern as the upper crust of a Cretacem1s island arc. The present investigation shows that in the Gilgit zone there are two stages of turbidite deposition intervened by basaltic volcanism, an assemblage probably formed in a back-arc basin. These findings have resulted in a completely new interpretation for the Kohistan terrane. It is suggested that only the southern or the Kamila zone represents an island arc crust, while the assemblage to the north of the Kamila-Jal shear zone, including the Chilas complex and the overlying sequence of metamorphosed turbidites and basaltic volcanics, represents a folded and imbricated back-arc basin.
Key words: Ultramafics, metamorphism, volcanics, Chilas.

K/426. Khan, T., 1996. Geological excursion guide along the Karakoram Highway, North Pakistan. In: Geo-traverse along Karakoram Highway, Field Excursion Guide, Geological Survey Pakistan. Proceeding Geoscience Colloquium 15, 1–19.

Key words: Field geology, KKH.

K/427. Khan, T., 1998. Geochemistry, mineralogy and petrology of the sulfide mineralization and associated rocks in the area around Drosh, north Pakistan. Ph.D. Thesis, University of Peshawar.

Copper mineralization in the Drosh-Shishi area is localized in the upper crust of the Kohistan arc terrane in Chitral, northern Pakistan. It is confined to the Gawuch Formation in the area, comprising variably metamorphosed volcanics and sediments intruded by the plutons of diorite and granodiorite composition. The metavolcanics of the Gawuch Formation and the diorite-granodiorite minor plutons have calcalkaline compositional characteristics. In comparison, the metavolcanics of the Drosh Formation, occupying the top of the succession, are island-arc tholeiites. Copper mineralization in the area is related to hydrothermal activity and is mainly associated with altered diorites and quartz veins. It occurs in different forms; in the quartz veins, along the foliation planes, in dissemination and as supergene enrichment. Tetrahedrite, chalcopyrite, pyrite and galena are the dominant ore minerals along with subordinate amounts of sphalerite, magnetite, malachite and azurite. Fluid inclusion studies indicate that the salinity of the hydrothermal solution is <26 equivalent wt% NaCl and the homogenization temperature is in the range of 160 to 350°C. Oxygen isotope data suggest that the quartz in the mineralized quartz veins has 8180 values ranging from 14.49 to 18.32 per mil. with mean value of 16.63 %0. This, when combined with the homogenization temperature obtained from the fluid-inclusion studies, indicates involvement of magmatic fluids (ots0=5.79-q.h2 %0) in the formation of quartz veins and associated copper mineralization. The lead isotopic compositions of three galena samples suggest that $^{206}Pb/^{204}Pb$ ranges from 18.728 to 18.793, $^{207}Pb/^{204}Pb$ from 15.658 to 15.72fluid
20BPb/204Pb from 39.040 to 39.285. These Pb-isotope ratios yield model ages of 42 – 142 Ma with the M values of 9.86 to 10.01. The minimum age (i.e., 42 Ma) is in close agreement with 40Ar-39Ar age of the Lowari pluton, which is considered to be the source of hydrothermal solutions. The lead isotopic composition of studied galena samples indicate involvement of lead derived from older sources. These sources could be the arc volcanics or pelagic sediments of oceanic crust of Neotethys or the continental crust of the subducting Indian plate. It is concluded from these studies that the copper mineralization in Drosh- Shishi area was produced by the hydrothermal activity related with syntectonic dioritic magmatism.
Key words: Geochemistry, mineralogy, petrology, sulphides, Drosh, Dir.

K/428. Khan, T., Ali, I., Siddiqui, R.H. & Kamal, H., 1987a. Occurrence of Pink zoisite at Nomal, Gilgit District, Pakistan. Acta Mineralogica Pakistanica 3, 159-160.

Key words: Zoisite, Gilgit.

K/429. Khan, T., Ali, I., Siddiqui, R.H. & Kamal, H., 1987b. Pink zoisite (thulite) occurrence at Nomal, Gilgit District, Pakistan. Abstract with Programs, Mineral Resources and Geology of Pakistan, Quetta, Pakistan.

Key words: Zoisite, Gilgit.

K/430. Khan, T. & Humayun, M., 1980. Geology of the Shangla-Alpurai area. M.Sc. Thesis, University of Peshawar, 68p.

The Shangla area is a mélange between the Kohistan island arc and the Indian Plate. It contains politic and psammitic rocks, and components of ophiolite, including the main Alpurai ultramafic body. The rocks are described in this thesis.
Key words: Ultramafics, Shangla-Alpurai, Swat.

K/431. Khan, T., Karim, T., Rehman, H., Haider, N. & Naseem, M., 2000. The sheeted dykes: An evidence of sea floor spreading in the Kohistan arc terrain, Northwestern Himalaya, Pakistan. Abstracts, Third South Asia Geological Congress, Lahore, 168-170.

Key words: Sheeted dykes, sea floor spreading, Kohistan Island arc.

K/432. Khan, T., Karim, T., Yoshida, M. & Khan, S.R., 1997a. Petrochemistry of the Ambela–Koga–Naranji Kandao Granite–Syenite Complex, northern Pakistan–Petrogenesis with reference to trace and rare–earth elements. In: Rare–Earth Elements Exploration of alkaline Rocks in Koga Area, Peshawar basin, NWFP, Pakistan. Karim, T. and Yoshida, M. (Eds.), Geological Survey Pakistan. Proceedings Geoscience Colloquium, Geoscience, Special Issue, 17, 11-30.

Key words: Petrogenesis, granite, syenite, carbonatite, Buner, Swat.

K/433. Khan, T., Karim, T., Yoshida, M. & Khan, S.R., 1997b. Petrogenesis of the Ambela–Koga–Naranji Kandao Granite–Syenite–Carbonatite Complex, North Pakistan. Geologica 5, 1–19.

Key words: Petrogenesis, granite, syenite, carbonatite, Buner, Swat.

K/434. Khan, T. & Kausar, A.B., 1996. Peridot occurrence with ferromagnetic mineral in the dunite of the Spat ultramafics sequence, Naran-Kohistan, Pakistan. Extended Abstracts, International Seminar on Paleomagnetic Studies in Himalaya-Karakoram Collision Belt and Surrounding Continents, November 20-21, 1996, Islamabad. Geosciences Lab, Geological Survey of Pakistan, Islamabad, p.130.

We report for the first time the pridot occurrence associated with a ferromagnetic mineral in the sheared dunite body of the Sapat ultramafic sequence, Naran-Kohistan (Survey of Pakistan toposheet Nos. 43E and 43F). The Sapat ultramafic sequence comprises dunite-pyroxenite-gabbro- (anorthosite), thinly layered dunite pyroxenite, dunite with thin chromite layers, homogeneous dunite and serpentinized dunite. It is part of the Sapat layered complex, making the tectonic base of the Kohistan island arc. The ultramafic sequence occupies the Indus suture or the Main Mantle Thrust, with the Indian plate in the south. Peridot-magnetite-bearing dunite is sheared cataclastically, and as a result, the dunite is randomly and intensely jointed. Peridot occurs in the joints, and the cavities. Other minerals associated with the peridot include talc, serpentine, magnesite, chromite and ferromagnetic opaque mineral of which Curie temperature marks 585"C, and the specific gravity up to 5.08. The ferromagnetic mineral occurs as subhedral grains, black-coloured with metallic luster. Talc and/or magnesite is the host and cementing material for the peridot and the ferromagnetic mineral. Peridots of the Sapat area are green, and yellowish green. They are euhedral to subhedral, and transparent but translucent and opaque peridots are also mineralized. Hydrothermal activity is responsible for the mineralization of peridot, ferromagnetic and the associated minerals. Magnetic method is applicable for prospecting the peridot. The association of ferromagnetic mineral with peridot may indicate path finder signatures of the former with the latter. Due to the brilliance and green colour, the peridots of the Sapat ultramafic sequence can be used as gemstones.
Key words: Mafic-ultramafics, peridot, Sapat, Kohistan.

K/435. Khan, T., Kausar, A.B. & Khan, I.H., 1997a. Peridot mineralization in the dunite of the Sapat ultramafic sequence, Naran-Kohistan, Pakistan. Abstracts, National Symposium on Economic Geology of Pakistan, Islamabad, 2p.

For details consult the following account.

Key words: Geochemistry, mafic-ultramafics, peridot, Sapat, Kohistan.

K/436. Khan, T., Kausar, A.B. & Khan, I.H., 1997b. Peridot mineralization in the Sapat ultramafic sequence of the Indus suture zone, Naran-Kohistan area, Northern Pakistan. Abstract volume, 12th Himalaya-Karakorum-Tibet International Workshop, Rome, Italy, 159-164.

The Sapat mafic-ultramafic complex of Jan et al. (1993) lies north of the Kaghan valley and to the northeast of Naran (N 34° 54′ 17″ and E 73° 38′ 51″) and north of Sochch village (N 34° 56′ 29″ and E 73° 42′ 40″) along the Naran-Babusar road. It comprises layered gabbro, gabbronorite and massive to layered ultramafics with basal serpentinitic mylonites (Fig. 1). The layered ultramafics include dunite-pyroxenite-gabbro- (anorthosite) layers, thinly layered dunite pyroxenite, dunite with thin chromite layers, homogeneous dunite and serpentinized dunite (Fig. 2). The Sapat ultramafic sequence is part of the Sapat mafic-ultramafic complex, making the tectonic base of the Kohistan island arc, and marks the boundary, the Indus Suture with the Indian Plate to the south. Peridot mineralization has been spotted for the first time in the serpentinized dunite (minor), homogeneous dunite and the dunite with thin chromite layers (Fig. 2). Peridot occurrence has also been reported at the Zeberget, Island of St. John, in the Red Sea where the host rock is serpentinite dunite (Mclintock, 1951; Reed, 1991), and Fo90 (Strunz, 1962; Wilson, 1976). In the Ross Island Antarctica the peridots occur in nodules in basalt with Fo92 (Wilson et al., 1974). Other localities where the peridot mineralization is known include Upper Myanmar (Burma), Australia, Brazil, China, Mexico (light green peridot, Fo91, and a more iron rich light greenish-brown variety, Fo88.6, Dunn, 1978), Norway (Fo90.6; Bank et al., 1970) and USA (Deer et al., 1982; Reed, 1991).

Peridots (Fo91 at the average, and occasionally Fo92 and Fo95) of the Sapat are green to yellowish green in color. They are euhedral to subhedral and 0.5 cm to 4 cm long. They are generally transparent, translucent, and occasionally opaque. The green-colored, transparent, and fracture-free varieties are used as good-quality gemstones.

In the Sapat area peridot mineralization occurs in 250-m wide zone, bounded by a 3-m thick mylonite zone in the lower part towards the Indus Suture. They are mineralized in the crosscutting joints, joint cavities, and veinlets. The width of the cavities range up to about 7 cm (Fig. 3). Other minerals associated with peridots include clinochrysotile, antigorite, talc and magnetite (Curie temperature 585°C in heating curve and 595°C in cooling curve). Clinochrysotile is the main mineral wrapping the peridot crystals and magnetite grains (Fig. 4). As evident from the antigorite inclusions in peridots and the mode of occurrence of peridots, it seems that they are developed from antigorite, and the magnetite grains associated with peridots are inherited from the serpentinite, indicating high oxygen fugacity conditions during the progressive metamorphism of serpentinites or deserpentinization (Deer et al., 1982), and the processes related to the shearing along the Indus Suture.

Key words: Geochemistry, mafic-ultramafics, peridot, Sapat, Kohistan.

K/437. Khan, T., Kausar, A.B. & Khan, I.H., 2000. Peridots of the Sapat, Naran-Kohistan areas, Himalaya, Pakistan: An evidence of mantel thrust sheet deposit. Abstracts, Third South Asia Geological Congress, Lahore, 167-168.

Consult the preceding account.

Key words: Geochemistry, mafic-ultramafics, peridot, Sapat, Kohistan.

K/438. Khan, T., Kausar, A.B., Takahashi, Y. & Takahasi, Y., 1993. Geochemistry of the mafic and ultramafics rocks of Chilas complex, Chilas, northern Pakistan. Proceedings of Geoscience Colloquium, Geoscience Lab, Geological Survey of Pakistan, Islamabad 4, 51-61.

Chilas Complex is a layered magmatic complex of the Kohistan island arc which is 300 km long and 40 km wide. It comprises pyroxene quartz diorites, tonalites, gabbros, gabbronorites, layered dunites, peridotites and amphibolites. Geochemical studies conducted on the ultramafic and basic to intermediate plutonic rocks of the complex reveal their island arc affinities. Various discrimination diagrams have been used to define these rocks. These are mainly gabbros and pyroxene quartz diorites, tonalites and peridotites. The basic and intermediate rocks are low-K to medium-K and calc-alkaline. The geochemical patterns identify the rocks as developed in the island arc environments. These rocks are depleted in Nb giving typical "V" shape pattern. Positive anomalies at Sr and Zr (in more acidic ones) are also significant. The geochemical pattern support the compatible behaviour of the HFS

elements in olivine, pyroxene and spinel. High degree of partial melting of the metasomatised mantle peridotite is considered the source for the Chilas Complex.
Key words: Geochemistry, mafic-ultramafics, Chilas complex, Kohistan.

K/439. Khan, T., Khan, M.A. & Aziz, A., 1992. Petrogenetic comparison between the mafic dykes of Chilas complex and Kohistan batholith, Northern Pakistan. Acta Mineralogica Pakistanica 6, 118-125.

Kohistan Island Arc is formed due the northward subduction of oceanic plate in Cretaceous. The arc sequence contains two major magmatic complexes: the layered mafic and ultramafic Chilas Complex at the base, and the Kohistan Batholith in the middle part. Mafic dykes intrude the gabbronorite and pyroxene diorites of the Chilas Complex, north of Chilas and the diorites of the Kohistan Batholith west and south of Gilgit. Petrography and geochemistry divided the mafic dykes into three distinct groups. The mafic dykes of the Chilas Complex are rich in plagioclase, hornblende and ilmenite and/or magnetite. These are metamorphosed to amphibolites except the dykes intruding the batholith at shallower part. The Chilas Complex dykes are picrobasalt and basalt whilst in the batholith they are basaltic andesite and trachyandesite. Trace element geochemical patterns are similar for all the three type of dykes but the Chilas Complex dykes are more depleted in LIL elements with marked negative Nb and positive Sr anomalies. The Kohistan batholith dykes are comparatively enriched in the LIL elements and the trachyandesites are more enriched. The former is considered “D-type” and the later “E-type” dykes. They all show island arc affinities but the trachyandesite shows continental margin signatures. The three groups also reflect three different magmatic episodes, derived from the partial melting of less and more heterogeneous mantle sources, respectively.
Key words: Petrogenesis, mafic dykes, Chilas complex, Kohistan batholith.

K/440. Khan, T., Khan, M.A. & Jan, M.Q., 1993. Kohistan, a collage of island arc and back-arc basin assemblages in the Himalaya of Pakistan. Geological Society of America, Abstract Program, A-122.

Trapped between the collided Indian and Karakoram Plates, the 38000 km^2 Kohistan terrain in N. Pakistan is divisible into three tectonic zones. The southern (Kamila) zone comprises principally amphibolitized basalts, underplated by cumulate ultramafic-mafic plutons, which occupy the hangingwall of the Indus suture. The central zone comprises gabbronorites, pyroxene diorites and ultramafics, forming a ~ 8000 km^2 coherent plutonic body. The northern (Gilgit) zone comprises > 1 km thick basal (turbiditic) sediments (the Gilgit paragneisses) metamorphosed up to sillimanite grade, followed by > 0.6 km thick Chalt (meta)volcanics (commonly pillowed) and finally > 1 km thick turbidites locally interbedded with marble of Albian-Aptian age (Yasin group). The Gilgit zone was welded to the Karakoram plate - 90 Ma ago along the Shyok suture characterized by up to 4 km thick olistostrome. The northern two zones are complexly folded and faulted in a divergent pop-up structure, while the southern zone is folded and imbricated with a persistant southward vergence. The Kohistan batholith of mainly Palaeocene-Eocene age cuts across the structures in the Gilgit zone.
Previous tectonic models for Kohistan consider the southern two zones as the basal crust and the northern zone as the upper crust of a Cretaceous island arc. Subsequently we suggested that the Chilas complex was probably emplaced during an episode of back arc rifting. Recent mapping, stratigraphic reconstruction and geochemistry in the Gilgit zone has resulted in the recognition of two stages of turbidite deposition intarvened by basaltic volcanism, an assemblage probably formed in a back-arc basin. These findings have resulted in a completely new interpretation for the Kohistan terrane. We suggest that only the southern or the Kamila zone represents an inland arc crust, while the assemblages to the north of the Kamila-Jal shear zone, including the Chilas complex and the overlying sequence of metamorphosed turbidites and basaltic volcanics, represents a folded and imbricated back-arc basin
Key words: Kohistan, Island arc, Back arc basin.

K/441. Khan, T., Khan, M.A. & Jan, M.Q., 1994. Geology of a part of the Kohistan terrane between Gilgit and Chilas, northern areas, Pakistan. Geological Bulletin, University of Peshawar 27, 99-112.

More than 4000 Km2 area of Kohistan terrane, exposed between Gilgit and Chilas, is mapped and described in this paper. A variety of plutonic and metamorphosed volcanic and sedimentary rocks are encountered in the mapped area, which have been classified into Kamila amphibolite, Chilas complex, Kohistan batholith and Jaglot Group. The Jaglot Group, comprising a succession of metasediments and metavolcanics, is divided into three stratigraphic units, which, from base to top, include Gilgit Formation [~ 1 Km thick succession of schists, paragneisses, calc-silicates and amphibolites (some derived from the pillowed basalts) and Thelichi Formation (comprising a volcanic basal part, overlain by >1km thick turbidites with a thick marble unit in the middle). The rocks of the Jaglot Group are regionally metamorphosed in amphibolite-and greenschist facies; the highest grade is depicted by the occurrence of silliminite in the paragneisses of the Gilgit Formation. A pair of crustal-scale anticline (the Gilgit anticline) and syncline (Jaglot syncline) control the structure of the area. These, together with their parasitic folds, repeat the stratigraphy of the area several times. The Jaglot Group is regionally correlated with the succession of metasediments and metavolcanics exposed along the Northern Suture (i.e., Yasin Group Sediments and Chalt Volcanics) and is considered to have been deposited in an oceanic basin (probably of a back-arc affinity) on the basis of the predominance of tubidites in the metasediments and pillowed basalts in the volcanics.
Key words: Kohistan island arc, Gilgit, Chilas, Himalaya.

K/442. Khan, T., Khan, M.A. & Jan, M.Q., 1995. Back-arc basin assemblages in Kohistan, Himalaya, north Pakistan. Spec. issue, Mitt. Geol. Inst., Zurich, 4p.

The 36,000 km^2 Kohistan sandwiches between the Karakoram and Indian continental plates in the north and south, respectively. In the north the contact is defined by the Shyoke suture or Main Karakoram Thrust and in the south by the Indus suture or Main Mantle Thrust. The whole rock sequence of Kohistan is considered to represent an intra-oceanic island arc with a narrow marginal sea in the north (Petterson & Windley 1985; Pudsey 1986). It was formed due to northward subduction of the Neo-tethyan Lithospheric plate (Coward et al. 1987; Honneger et al., 1982; Tahirkheli & Jan, 1979).
This manuscript includes a geological map of the investigated area together with a brief description of petrology and geochemistry. The area is occupied by >1-km thick basal turbiditic sediments (the Gilgit paragneisses), followed upward by >0.5-km thick Chalt volcanics and, finally the Thelichi formation = Yasin group of lvanac et al. (1956), comprising a volcanic base and >1-km thick turbidites with local intercalations of marble, volcaniclastics and lava flows. Other lithologies in the area include, Chilas mafic-ultramafic complex (~8000 km^2), and the Kamila amphibolites (Bard et al. 1980; Jan et al. 1984; Jan 1988; Khan & Coward, 1990; Khan et al., 1993). The Kohistan batholith (Petterson & Windley, 1985) mostly Paleocene-Eocene cuts across the structure in the Gilgit zone The batholith contains tholeiitic and calc-alkaline mafic dykes; such dykes in the Chilas complex are tholeiitic.
Metamorphism up to sillimanite grade has been recorded in the Gilgit paragneisses. The rocks of the Chalt volcanic group, mafic dykes of the Chilas Complex, and early phases of the Kohistan batholith show amphibolite facies metamorphism. The Thelichi Formation contains greenschist mineral assemblages.
The geochemical signatures of the Gilgit paragneisses support igneous provenance, derived from mainly the oceanic island arc (Roser & Korsch 1988; Condie et al. 1992). Evidences for the existence of the continental basement and fore-arc basin are lacking for the Gilgit paragneisses. The metavolcanic rocks namely the Chalt, and the Majne volcanics are tholeiitic basalts, which show a composite trace elements geochemical signatures. The Chalt volcanics are mainly HFS elements depleted with Nb trough where as the Majne volcanics are HFS elements enriched with positive Nb anomaly. Both the island arc-and MORB-like signatures are found in these two volcanic formations (Alabaster & Storey, 1990). As evident from the stratigraphical setup the Chalt volcanics are older than the Majne volcanics, and enriched in the incompatible elements derived from the subducting lithospheric plate during the initial stages of back-arc rifting (Pearce et al. 1984; Saunders & Tarney, 1991). The Majne volcanics are MORB-like back-arc basin tholeiitic basalts, and are low in MgO and high in TiO_2 contents and FeO(total) / MgO ratio where as the Chalt volcanics are high-Mg tholeiitic basalts with low TiO_2 content and FeO(total)/MgO ratio at a given SiO_2 concentrations. Fractional crystallization and low degree of partial melting of the enriched mantle, and high degree of partial melting of the subduction modified mantle are the possible sources for the Majne and Chalt volcanics, respectively (Pearce & Norry, 1979; Wilson 1989). Moreover, these volcanic formations show transition between arc-like and MORB-like magmatism during back-arc rifting.
The establishment of a new stratigraphy in the middle Indus valley of Kohistan and the recognition of the sillimanite-bearing metasedimentary rocks and the back-arc basin tholeiitic basalts for the first time, divides the Kohistan in three tectonic zones. The southern (Kamila) zone comprises principally amphibolitised basalts, underplated by cumulate mafic-ultramafic plutons, which occupy the hanging wall of the Indus suture. The central

zone comprises the Chilas complex, and the northern (Gilgit) zone, the Gilgit paragneisses and the overlying rocks. The Gilgit zone was welded to the Karakoram plate-90 Ma ago along the Shyoke suture. The northern two zones are folded and faulted (in a divergent pop-up structure), while the southern zone is folded and imbricated with a persistent southward vergence. Much of the Kohistan batholith cuts across these structures in the Gilgit zone.
Previous tectonic models for Kohistan consider the southern two zones as the basal crust of a Cretaceous island arc. The present investigation shows that in the Gilgit zone there are two stages of turbidite deposition intervened by basaltic volcanism, an assemblage formed in a back-arc basin. These findings have resulted in a completely new interpretation for Kohistan. It is suggested that only the southern or Kamila zone represents an island arc crust, while the assemblage to the north of the Kamila-Jal shear zone, including the Chilas complex and the overlying sequence of the metamorphosed turbidites and basaltic volcanics represents a folded and imbricated back-arc basin.
Key words: Back arc basin, Kohistan arc, Karakoram, Himalaya.

K/443. Khan, T., Khan, M.A., Jan, M.Q. & Latif, M., 1996. The Kohistan between Gilgit and Chilas, northern Pakistan: regional tectonic implications. Journal of Nepal Geological Society 14, 1-10.

In this paper, we present geological description of an area located between Gilgit and Chilas within the Kohistan terrane. This terrane has been considered an intra-oceanic island arc, formed due to northward subduction of the Neo-tethyan lithospheric plate. At present, it is squeezed between the Karakoram-Asia and Indian continent plates. Both the contacts are marked by suture zones, that is, Shyok (MKT) in the north and Indus (MMT) suture in the south, respectively. The investigated area consists of plutonic, metamorphosed volcanic and sedimentary rocks, the Chilas Complex, and the Kamila Amphibolite. The metamorphosed volcanic and sedimentary rocks are packaged into the Jaglot Group. This group comprises basal turbiditic sediments, intercalated with amphibolites and calc-silicates (the Gilgit Formation), followed upward by the Gashu-Confluence Volcanic=Chalt Volcanic Group, and finally the Thelichi Formation=Yasin Group of Aptian-Albian age. The Thelichi Formation comprises a volcanic base (Majine volcanics) and overlying turbidites, local intercalation of marble, volcaniclastics and lava flows. Greenschist and amphibolite facies are common in the Jaglot Group, and particularly the sillimanite in the Gilgit Formation. A pair of anticline (the Gilgit anticline) and syncline (the Jaglot syncline) make up the structural scenario. On the basis of field geology, we conclude that the entire Jaglot Group and its equivalent, Yasin Group, Chalt Volcanic Group in Kohistan, and Burjila Formation, Bauma Harel Formation and Katzarah Formation in Ladakh show intra-oceanic back-arc basin rather than island arc affinities as suggested in the past.
Key words: Tectonics, Kohistan island arc, MKT, MMT, Himalaya.

K/444. Khan, T., Khan, M.A., Jan, M.Q. & Naseem, M., 1996. Back-arc basin assemblages in Kohistan, northern Pakistan. Geodynamica acta 9, 30-40.

The east central part of the Kohistan magmatic arc is made up principally of the Jaglot Group. From bottom to top it consists of I) paragneisses and schists intercalated with amphibolites and calc-silicates (Gilgit Formation), II) Gashu-Confluence Volcanics (GCV) and III) the Thelichi Formation comprising a volcanic base (Majne volcanics) and turbidites, marble, volcanoclastic sediments and lava flows. Metamorphic grade varies up to the sillimanite zone. The GCV are correlated with the Chalt volcanics and the Thelichi Formation with the Yasin Group. Other lithologies include the Chilas Complex, the Kohistan Batholith and part of the Kamila Amphibolite. Metavolcanics show a broad range in chemical composition. Geochemical parameters used to specify the tectonomagmatic regime suggest affinities of both island arc and MORB-like back-arc basin basalts. Kohistan can be divided into three tectonic zones, I) the southern (Kamila) zone comprises amphibolitized basalts, and mafic and ultramafic rocks, II) the central Chilas Complex, and III) the northern (Gilgit) zone i.e., the Jaglot Group. Previous tectonic models considered the southern two zones as the crust of a Cretaceous island arc. This investigation concludes that only the southern zone represents a true island arc. The Jaglot Group derives from back-arc basin assemblages and the Chilas Complex is a magmatic diapir emplaced in the back-arc basin.
Key-words: Island arc, back arc, geochemistry, Kohistan.

K/445. Khan, T., Khan, N.A. & Khan, M.S., 1988. A short note on the occurrence of turbidite at Sikanderabad, along Karakoram Highway, Northern Areas of Pakistan. Geological Survey of Pakistan, Information Release 387, 5(+8)p.

In the Hunza valley, rock units belonging to Kohistan Island are, Main Karakoram Thrust zone and Eurasian continent are exposed along the Karakoram Highway. A turbidite unit has been identified at Sikandarabad in the melange zone of the MKT alongwith slates, phyllitic schist, calcareous schist, limestone, green schist pyroclasts, talc carbonate, serpentinite, peridotite, andesite/basalt and rhyolite as the melange constituents. The turbidite of the area is composed of interlayered siltstone, sandstone and mudstone. The mudstone is changed into schist, containing upto 25 cm long pebbles of sandstone, siltstone, limestone, quartz, slate and andesite. These pebbles are flattened and oriented in the northwestern directions. This turbidite of the melange zone may represent deep-seated sedimentary origin in the oceanic island arc environments.
Key words: Turbidites, Hunza, Shyoke suture, Karakoram.

K/446. Khan, T., Khan, N.A. & Shirahase, T., 1998. Geology of the Kohistan batholith in Kar Gah and Gor sectors, Kohistan are terrane, Gilgit, North Pakistan. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 102-103.

Kohistan arc terrane lies between the Asian and Indian continental plates (Fig. 1). Both the northern and southern contacts of the arc are marked by suture zones commonly known as Main Karakoram Thrust (MKT) and Main Mantle Thrust (MMT). The Kohistan batholith which is one of the major rock components of the arc and the Trans-Himalayan batholith extends for more than 2700 km along the length of Himalaya and Karakoram. The Kohistan batholith in Kohistan arc extends for 300x50 km between the Afghan border on the west and the western flank of the Nanga Parbat massif on the east (Fig. 1). The batholith is an ENE-SSW elongated body consisting of many plutons which intrude the Jaglot group and Chilas complex of the Kohistan arc. The Kohistan batholith, south of Gilgit, in Kar Gah and Gor sectors comprises multiphase plutons forming Shinghai and Gor plutonic belts. The Shinghai plutonic belt is basic to intermediate in composition comprising gabbro, gabbroic-diorite and diorite along with younger intrusions of granodiorite and granite (minor). The belt also contains serpentinite, pyroxenite? and paragneiss as xenoliths. The Gor plutonic belt is the principal occurrence of the Kohistan batholith along the drainage divide between the Indus and Gilgit Rivers. It is a coherent body of mainly quartz diorite composition but also contains intrusions of tonalite, granodiorite, adamellite and granite along with ample aplite and subordinate pegmatite. The main pluton contains abundant xenoliths and/or autoliths of basic composition. Both the northern and southern contacts of the Gor pluton are intrusive into the metasedimentary succession of the Jaglot group and the Chilas complex, respectively.
Major and trace element geochemical patterns and petrological characteristics of the Kohistan batholith in the study area reveal that (i) chemical variation seen in the batholith is not due to high level differentiation but can be better explained by partial melting, (ii) much of the Kohistan batholith appears to be the product of mantle wedge above the subduction zone, (iii) some of the leucogranite and aplite seem to be derived by partial melting of the crust of the Kohistan arc, and (iv) there are certain plutons which are alkaline in nature and contain a higher amount of K20 over Na2O which may be derived from crustal material such as Gilgit paragneisses and/or from a possible basement of the Indian plate crust underplating the arc. The Frequency of C twins in the Kohistan batholith is mostly 10 to 20% showing igneous features and shallow depth of emplacement for the batholith.
Key words: Kohistan batholiths, petrography, Gilgit, Kohistan arc.

K/447. Khan, T., Latif, M., Khan, N.A. & Shah, S.H., 1989. Geology and petrography of the rock outcrops in Shinghai Gah and Kiner Gah, Gilgit-Chilas Districts, Northern Areas, Pakistan. Geological Survey of Pakistan, Information Release 446, 15p.

Reconnaissance geological investigation and petrographic study on the rocks of the Shinghai gah and Kiner Gah have revealed that the Kohistan Island arc in these nallahs is composed of plutonic, metavolcanic and metasedimentary rocks belonging to Ladakh-Kohistan granitic belt, greenstone complex, Chilas complex and Thelichi beds. Granodiorites and diorites are the dominant plutonic rocks with granite, pegmatite and aplite as minor associates with norite the bottom most unit exposed at Thak area in Kiner gah. The older granitoids are metamorphosed and mylonitized along the sheared contacts. Volcanics (greenstone/greenschist) occur in an elongated belt underlain by the marble beds, schists, andalusite slate and micaceous sandstone at Shinghai gah. The metasediments have sheared contacts. The older volcanics are metamorphosed into amphibolites and occur as

xenoliths and screens within the intrusive rocks. All the rocks units exposed in Shinghai gah and Kiner gah range in age from Recent to Jurassic and trend mostly in NW-SE direction.
Key words: Petrography, Central east Kohistan, Gilgit-Chilas districts.

K/448. Khan, T., Nakajima, T., Khan, S.R. & Sano, S., 1994. Occurrence of blueschists at Tuwa near Charbagh, NWFP, Pakistan. Proceedings of Geoscience Colloquium (Geoscience Lab, Geological Survey of Pakistan, Islamabad) 8, 94-99.

A new occurrence of blueschists within the Indus Suture near Charbagh has been reported. There is intermixing of blueschists and greenschists, representing single lithology. The coexistence of glaucophane- crosstie, actinolite/tremolite and epidote may suggest high pressure intermediate series metamorphism of the rocks. Thus, blueshists melange and greenschists melange represent a coherent melange group extending from Shangla towards Tuwa.
Key words: Blueschists, greenschists, Indus suture, melange, Charbagh, Swat.

K/449. Khan, T., Nakajima, T., Seki, Y., Khan, N.A. & Khan, S.Z., 2001. Turbidite occurrence at Sikandarabad (Chalt) along the Karakoram Highway, Northern areas of Pakistan. Abstracts, 4th Pakistan Geological Congress, Islamabad, p.70.

In Hunza valley, rock units belonging to Kohistan island arc, Main Karakoram Thrust zone and Karakoram-Asian continent, are, exposed along the Karakoram Highway. A turbidite unit resembling conglomerate has been identified at Sikandarabad (Chalt) in the mélange zone of the Main Karakoram Thrust along with slates, phyllitic schist, calcareous schist, limestone, greenschist pyroclastics, talc-carbonate, serpentinite, peridotite, andesite/basalt and rhyolite as the mélange constituents. The turbidite of the area is composed of interlayered siltstone, sandstone and mudstone. The mudstone is changed into schist, containing up to 25 cm long pebbles of sandstone, siltstone, limestone, quartz, slate and andesite. These pebbles are flattened and oriented. This turbidite of the melange zone may represent deep-seated sedimentary origin in the ocean basin.
Key words: Turbidite, Karakoram thrust zone, KKH.

K/450. Khan, T., Ogasawara, M. & Oeta, E., 1992. Electron probe study of pink zoisite of Nomal, Gilgit District, Pakistan. Abstracts, First South Asia Geological Congress, Islamabad, p.23.

Key words: Mineralogy, zoisite, Nomal, Gilgit.

K/451. Khan, T. & Shirahase, T., 1996. Evolution of the Kohistan terrane with reference to the Jaglot Group and the Chilas complex, Gilgit-Chilas, northern Pakistan. In: Kausar, A.B. & Yajima, J. (eds.), Geology, Geochemistry, Economic Geology and Rock Magnetism of the Kohistan Arc. Proceedings of Geoscience Colloquium, Geoscience Lab, Geological Survey of Pakistan, Islamabad, 15, 15-36.

In this manuscript, we present geological description of an area located between Gilgit and Chilas within the Kohistan terrane. This terrane has been considered an intra- oceanic island arc, formed due to northward subduction of the Neo-tethyan lithospheric plate. At present, it is squeezed between Karakoram-Asian and Indian continental plates. Both the contacts are marked by suture zones, that is, Shyok (MKT) in the north and Indus (MMT) sutures in the south, respectively. The investigated area consists of plutonic, metamorphosed volcanic and sedimentary rocks (Jaglot Group), the Chilas Complex, and the Kamila Amphibolite. The Jaglot Group comprises basal turbiditic sediments, intercalated with amphibolite and calc-silicate (Gilgit Formation), followed upward by Gashu-Confluence Volcanics which is the equivalent of the Chalt Volcanic Group, and finally the Thelichi Formation, equivalent of the Yasin Group of Aptian-Albian age. The Thelichi Formation comprises a volcanic base (Majne volcanics) and the overlying turbidites, local intercalation of marble, volcaniclastics and lava flows.

Greenschist and amphibolite facies metamorphism are common in the Jaglot Group. A pair of anticline (Gilgit anticline) and syncline (Jaglot syncline) makes up the structural scenario. On the basis of field geology and petrology, we conclude that the entire Jaglot Group and its equivalents, the Yasin Group, the Chalt Volcanic Group in Kohistan, and the Burjila Formation, Bauma Harel Formation and the Katzarah Formation in Ladakh show intra-oceanic back-arc basin rather than island arc affinities as suggested in the past. The Chilas Complex exhibits a mantle diapir which ensued during the subduction related back-arc rifting processes.
Key words: Geology, ultramafics, Jaglot group, Chilas complex, Gilgit.

K/452. Khan, T.M., 1992. Uranium distribution in graphitic metapelites in the Pre-Cambrian Formation of Azad Kashmir and NW Pakistan. M.Phil. Thesis, University of Peshawar, 133p.

The graphitic metapelites of NW Pakistan and Azad Kashmir are exposed in a zone of thrust tectonics, and are scattered in the farm cf 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. This form of negative disequillibrium is produced due to the presence 6f daughter products of U, Th and K40. The chemical composition of the graphitic metapelites indicates that the rocks from Tarbela area are more siliceous and contain more organic carbon 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 the classification of Stribrny et al. 1988, the graphitic metapelites from Tarbela area are siliceous and those from other area are dominantly argillaceous, siliceous with high normative quartz, Uranium associated with other elements is concentrated in the upper part of the graphitic metapelites and unlike typical black shale deposits, do not indicate any correlation with organic carbon. The absence of relationship is primarily caused by the dissolution of some of the elements in ground water circulating freely in the otherwise impermeable rock made permeable by the structural movements in the region. Compared to metal rich black shale deposits these rock are enriched in U, V, Ba and Pb, The enrichment of one of the elements took place in association with the detrital fraction of the rock while the rest of the enriched elements were concentrated from normal seawater in oxygenated transitional environment close to the continent. The graphitic metapelites were probably deposited in a basin fed by different source material.
Key words: Radioactive minerals, Precambrian, Azad Kashmir.

K/453. Khan T.M. & Shah, M.S., 1979. Petrography of the Shilman Carbonatite Complex, Khyber Agency. M.Sc. Thesis, Peshawar University, 72p.

This is a description of the field and petrographic aspects of the Shilman carbonatite. The rock-types of the complex include altered (meta) gabbros / dolerite, followed by amphibole-apatite-, biotite/phlogopite-, and dolomitic carbonatites, syenites and lamprophyric rocks, and Fe-rich hydrothermal veins.
Key words: Petrography, carbonatite, Shilman, Khyber Agency.

K/454. Khan, T.N., Khan, M.M. & Mohammad, N., 1994. Upgradation of Kakul rock phosphate by reverse flotation. Abstracts, Second SEGMITE International Conference on the Export Oriented Development of Mineral Resources and Mineral Based Industries, Karachi, p.21.

Laboratory scale flotation studies were conducted on North Waziristan Copper Ore to enhance the copper content in die final concentrate product. Process parameters such as type of collector effect of activator/depressent, effect of pH were investigated. In the final product copper content was enhanced from 0.386% (in feed) to nearly 20 percent (in the concentrate) in a single stage flotation process.
Key words: Phosphate, Kakul, Hazara.

K/455. Khan, W., 1986. Geology and petrography of the metamorphic and ultramafic rocks of Shergarh Sar area, Allai Kohistan, Hazara Division, N.W.F.P. Geological Survey of Pakistan. Information Release 254, 29p.

The area investigated, lies along the main Mantle Thrust and constitutes the southernmost obducted part of Kohistan Island Arc sequence, which developed due to the collision of the northward moving Indo-Pakistan continent with Eurasian plate. The area is occupied mostly by metamorphic and ultramafic rocks. The metamorphic rocks consist of epidote amphibolites, garnet-epidote amphibolite and garnet amphibolites. The ultramafics are peridotite, pyroxenite, dunite and their equivalent serpentinite. The amphibolites are the part of north east trending southern amphibolite belt of Kohistan and represent the metamorphosed Tethyan oceanic crust, while the ultramafics are considered to be the pieces of the underlying upper mantle and show the chromium mineralization.
Key words: Geology, petrography, metamorphic rocks, ultramafics, Shergarh Sar, Alai Kohistan.

K/456. Khan, W., Aslam, M., Begum, I. & Shah, A., 1982. Geology of Shergarh Sar complex Alai Kohistan, Hazara. M.Sc. Thesis, University of Peshawar, 55p.

Key words: Geology, Shergarh Sar, Alai Kohistan.

K/457. Khan, W.M., 1965. The main Malakand granite. Geological Bulletin, University of Peshawar 2, 8-10.

The best exposures of this beautiful rock are seen along the main road from Malakand to Bat Khela. It is a dazzeling white, coarse grained rock, mainly composed of quartz, biotite and alkali feldspar, but there are local variation in color, texture and composition. It is without foliation in the main part but where traced to the surrounding rocks, gneissic structures come in. the country rocks surrounding it are mainly slates and gneisses, but various kinds of schist may also be seen. Quartz, aplite and pegmatite veins are common, especially, where the adjacent rocks are slates. Rafts and xenoliths of slates are common in the granites.
Key words: Granite, Malakand.

K/458. Khan, Z.A., 1997. Nature and Genesis of India-Asia Suture. Abstract volume, 12th Himalaya-Karakorum-Tibet International Workshop, Rome, Italy, 165-166.

The paper reviews the field data from the Chaman and the Indus-Tsangpo regions and points out that currently available evidence does not support the plate tectonic concept that these are sutures zones of the Indian and northern landmasses. Instead, it is suggested that the Indus-Tsangpo is a rift valley. Presumably it came into being in Triassic, which continue to deepen and receive sediments, became dormant in the Cretaceous after a spurt of volcanic activity long before the supposed suturing in the Eocene.
Attention is drawn on the occurrence of extensive Carboniferous fluvioglacial deposits in northern Tibet, and the presence of typical Gondwana flora and fauna bespeak unequivocally that there was a continuity from Peninsular India to northern Tibet in Carboniferous times. Tapponnier et al., (1980) and Acharyya (1990) admitted the existence of Carboniferous tillite with distinct Gondwana affinities underlying Permo—Carboniferous beds in the Lhasa block, but later, the former committed a somersault calling it a rift in—fill to continent to support plate tectonic data. Furthermore, consistent palaeocurrent-directions towards the northwest in Peninsular India, Lesser, and Tethys Himalayas (Sakai, 1991) indicate a continuity from Peninsular India to northern Tibet and may be beyond.
The ophiolite eruptions along the Indus-Tsangpo suture have yielded two different ages of emplacements i.e. implacement took place about 100 Ma before the supposed collision in the Eocene-Miocene. Whereas, the Tibetan glacial indicate that India and Tibet were together in Carboniferous, Lystrasaurus fauna suggests for the Lower Triassic and the ophiolites for the Jurassic-Cretaceous. Thus, India and Tibet were together all the time.
Also, Indian plate is believed to have underthrust the Tibetan plate by about 500 kin, however, if this is correct and if 500 km of shortening along the Himalaya is added to it there should be a displacement of about 1000 km on the Baluchistan coast. Instead, the coast is straight. Similarly, there is no explanation for the fact that, if this underthrusting has taken place, why did Himalayan uplift occur some 500 km from the Indus-Tsangpo suture instead of being along Collision zone itself The collision of suture is therefore, a consequence of misinterpreted evidence and distorted arguments offered by supporter of plate tectonic hypothesis. Likewise, the double thickness of crust in Tibet, is not unique in that it continue south of the so-called suture, as also in Pamir. It is of about the same order in Andes available evidence strongly suggests that the Tethys was entirely epi-continental. It may be noted that the

rivers flowing out of the Tibet area onto the Indian plate must have existed before the Himalaya rising, which means that India-Tibet area was a landmass, and Tethys did not exist. Evidence in support of the points indicated above is discussed in this study.
Key words: Tectonics, Indus-Zangbo suture.

K/459. Khan, Z.A., Dawar, N.A. & Ahmad, M., 1997. Geology of area south of Bahadur Khel District Karak, N.W.F.P. M.Sc. Thesis, University of Peshawar, 43p.

Key words: Geology, Bahadurkhel, Karak.

K/460. Khan, Z.K., 1978. Study of landslide problem along the Murree Kohala road, District Rawalpindi, Punjab. Part 1: General Study. Geological Bulletin, University of Punjab 15, 52-61.

Along 10 miles long stretch of road, from lower Topa to Phagwari village has been surveyed to study the major landslides in detail, namely the so called Kasseri. Norgali, Seher Bagla and Aliot slides. The landslides have been mapped on contour map of scale 1:2400 and 1:4800 on basis of surface geology, characteristics of the slop, types of movement and the material involved. Majority of the failures mainly occurs due to lack of proper drainage facilities all along the road. Engineering properties like Atterberg’s limit, specific gravity, density, cohesive strength, angle of friction and grain size analysis of the soil present on unstable slops are tested to know behavior of the soil under different conditions. Suggestion for improving present conditions of the road and to minimize possibility of its failure are purposed.
Key words: Landslides, Murre-Kohala, Rawalpindi.

K/461. Khan, Z.K., 1991. A Geologic Study of Basha Dam and its appurtenance in Diamir District, Northern area, Pakistan. Kashmir Journal of Geology 8 & 9, 181-184.

The Basha dam site is situated on the Indus River about 45 km downstream of the town of Chilas. This is purely meant for hydel power. Rocks exposed at the dam site are predominantly igneous complex, comprised of norite with subordinate peridotite, hornblendite and quaternary deposits. Geological map is presented with the possible location of main dam and its essential appurtenances. The locations of appurtenances are essentially examined and discussed.
Key words: Geology, igneous complex, Basha, Chilas.

K/462. Khattak, A., Nawaz, A. & Khattak, M.T., 1996. Soils and materials testing for road construction; Indus Highway Project Phase II (Karappa-Karak Section), N.W.F.P. M.Sc. Thesis, University of Peshawar, 55p.

Key words: Geotechnical, material testing, Indus Highway.

K/463. Khattak, A.K. & Aslam, M., 1974. Emeralds deposits of Tora Tigga, Mohmand Agency, N.W.F.P., Pakistan. Geological Survey of Pakistan, Quetta. Information Release, 71, 13p.

Key words: Gems, emerald, Tora Tigga, Mohmand Agency.

K/464. Khattak, A.S.K., Yousafzai, A.S. & Khan, N.A., 1977. Geology and structure geology of part of the area North of Kohat District. North West Frontier Province. M.Sc. Thesis, Peshawar University, 91p.

Key words: Structure, stratigraphy, Kohat.

K/465. Khattak, G.A., 1997. Sedimentological and environmental studies of loess deposits, Nowshera area, Peshawar basin, N.W.F.P. M.Sc. Thesis, University of Peshawar, 114p.

Key words: Sedimentology, environment, loess deposits, Nowshera.

K/466. Khattak, M.A., Aziz, S. & Shah, R.A., 1979. Exploration, beneficiation and utilization of Hazara rock phosphate. International Seminar on Mineral Exploration and Technology, 1979, 59p.

Key words: Exploration, beneficiation, phosphate, Hazara.

K/467. Khattak, M.A., Husain, V. & Qureshi, K.M., 1990. Prospects for development and utilization of some industrial minerals of N.W.F.P. Proceedings, First SEGMITE Conference on Industrial Minerals, Peshawar, 62-67.

The province is endowed with rich reserves of industrial minerals such as rock phosphate, magnesite, gypsum, limestone, soapstone, silica sand, etc. Selected minerals are discussed in terms of reserves and grade. Large deposits of silica sand occur in Pezu, Paniala in DI Khan contain iron, but it can be reduced to use the sand in colorless container glass. At Munda Kucha near Mansehra, 53 million tons of silica sand has been estimated. Very large deposits of limestone occur in the province. Large deposits of gypsum Karak-Kohat belt, and sizable deposits of barite, rock phosphate and magnesite occur in several places.
Key words: Industrial mineral, prospects, NWFP.

K/468. Khattak, M.U.K., Ahmed, I., Ahmed, J. & Ahmed, A., 1984. A note on the occurrence of blue quartz in Rustam, Mardan District, Pakistan. Geological Bulletin, University of Peshawar 17, 174-175.

The Swabi-Chamla sedimentary group of Martin et al. (1962) is generally borders the Ambela granite along its western and southern margin. The main lithologies include shales, quartzites, limestones and dolomites. The low grade regionally metamorphosed phyllitic rocks of Chamla are pelitic to semi pelitic in composition and contain the so-called quartzitic and graywacke layers and zones of elongate pebbles of generally psammitic composition (Martin et al., 1962). The rocks are locally schistose in character. We report here an occurrence of blue quartz in quartz-rich shaly lenses enclosed in the Chamla phyllitic shales. The lenses represent either a layer in the phyllitic country rocks as described by Martin et al. (1962), or quartz veins associated with the Ambela granite. Further data on detailed petrography, tectonic setting and correlation of the rocks in the area and the origin of the quartz will be given elsewhere.
Key words: Ambela granite, metasediments, blue quartz, Mardan.

K/469. Khattak, M.U.K., Ahmed, I., Parvez, M.K., Ahmed, J. & Ahmed, A., 1984. Carbonatite body near Khungai, Rustam area, District Mardan, north Pakistan. Geological Bulletin, University of Peshawar 17, 175-176.

A small carbonatite body is located on the eastern edge of the Ambela granitic complex at Khungai village in Rustam area of Mardan District. The Carbonatite is medium-coarse-grained and has a sharp contact with the Ambela granite. The granite is commonly medium-grained and is generally gneissose at the contact with the carbonatite. The granite is sheared along the contact with the carbonatite, however, in one occasion the contact between the granite and carbonatite contains enrichments of pyroxenes, pyrite, tourmaline, and garnet. At the eastern contact of the carbonatite the granite is very fine-grained and seems more felsic due to metasomatism. Fenetization seems to accompany the emplacement of carbonatite body.
Key words: Carbonatite, granite complex, Rustam, Mardan.

K/470. Khattak, M.U.K., Jan., M.Q. & Khan, M.A., 1998. Nature of Indus suture (MMT) and Astak Fault east of Nanga Parbat-Haramosh Massif. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 103-104.

Recent studies have shown that in much of the Himalaya the Indus suture (IS) demarcates the boundary between the Indian plate and the "Asiatic" mass with local occurrences of ultramafic rocks and ophiolitic melanges. In the northwestern Himalaya, however, a more complicated scenario has been documented due to the presence of an extensive zone, the Kohistan-Ladakh island arc (KLIA), between the Indian plate and Asia. The contact between the Indian plate and the KLIA is an extension of the IS and locally (i.e. within Pakistan) named as the Main Mantle Thrust (MMT).

The MMT is quite variable in nature. It is razor sharp in some places (e.g. Sapat; Jijal; Timargara), consists of ophiolitic melanges (e.g. Shangla; Alai; N of Peshawar), or of melanges containing elements of the Kohistan arc and Indian plate with or without components of the neo-Tethyan crust-mantle (e.g. Babusar; E of NPHM). In some places high-P rocks have been reported in the MMT zone (Patan; Kaghan; N of Astak; Le Fort et al., 1997).

The IS on the eastern margin of the NP is a good example of a melange zone containing all three components. The Indian plate is represented by metasediments and gneisses, the KLIA by amphibolites, and the neo-Tethyan oceanic crust by mafic-ultramafic assemblages. Individual blocks range from a few to hundreds of meters in dimension and show varying degree of deformation and alteration.

West of the Astak river confluence with the Indus river (~3 km W of Astak police station), a series of pelitic and possibly some psammitic rocks, variably deformed and boudinaged, contain lenses of amphibolite (meta-gabbros), semi-pelites, calc-silicate and ultramafic rocks. The mafic-ultramafic assemblages include meta-gabbros (now garnet amphibolite), altered chromite-bearing dunite, peridotite and pyroxenite, and are enclosed in biotite-rich matrix. This biotite-rich matrix probably formed from a mud-rock. The pelites are garnetiferous and have streaky bands and veins of quartz and feldspathic material. Some muscovite pegmatite are highly boudinaged (upto 15 cm thick). Some amphibolite occurs in cm-scale bands. Amphibolite lens may contain 1/2 mm garnet porphyroblasts. The mafic-ultramafic lithologies are highly altered and mostly consist of ?tremolitic green amphibole with or without talc, boudinaged within biotite-rich band. The biotite-rich 'beds' are also boudinaged and in rare cases, reach ~1.4 m in width. These 'beds' consist of abundant biotite and subordinate green amphibole, with possibly a small amount of quartz. These green amphibole-bearing pockets in biotite-rich matrices, normally not more than a few meters across probably represent olistostromes formed at the surface of the neo-tethyan oceanic crust. The mafic-ultramafic lenses are upto a third of a meter in length and some 10-13 cm thick. One ultramafic lens (1/2 m x 20 cm) contains poorly defined layers as well as disseminated grains of chromite in an altered green ultramafic matrix. The outermost 1-2 cm crust of the 'nodule' is very dark, rich in amphibole, possibly some olivine and some orthopyroxene.

Also contained in the zone are lenses of a dense rock consisting of garnet, ?opx, ?cpx, and qtz. One disc shaped, 2 x 3/4 m in size, ultramafic lens contains, from core outward, talc, talc+tremolitic amphibole, and ~1 cm rim of tremolitic green amphibole, enclosed in biotite-rich band. The largest ultramafic lens (~20 m broad), consists of grey/brown material in a greenish to yellowish serpentinitic matrix. In the interior of this lens, there is a biotite-rich zone ~½ m across which contains altered nodules of the ultramafic. These nodules may have talcose interiors surrounded by colorless and/or green fibrous amphibole. Adjacent to the ~20 m ultramafic lens, the biotite band passes into grey to white fibrous amphibole ± talc-bearing band with a green inner and a grey outer zone. Locally this ultramafic lens is grey serpentinitic. Alteration zones in the ultramafic main lens contain upto ~3 cm long green mica, prisms of upto ~2 cm long green amphibole, and ?magnetite. The ultramafic lithologies are hosted by metasedimentary rock which gets more and more gritty to conglomeratic westwards. Well-bedded siltstone and sandstone lithologies are exposed ~250-300 meters west of the eastern-most ultramafic lens. Some of these gritty rocks contain over 1 cm rotated garnet porphyroblasts. Local biotite-rich bands with greenish material continue westwards for at least several 100s of meters. This melange zone extends over ~2 km to the west from the Astak River confluence with the Indus river. Further west, associated with these rocks are greyish orthogneisses, garnet-kyanite gneisses and banded amphibolites and granitic sheets, all intruded by deformed quartzo-feldspathic material (aplites and pegmatite dikes). Similar melange zone has been found some 25-30 km to the south along Astore river east of Harchu, although the scale of the mafic-ultramafic 'pockets' here is several orders of magnitude smaller. Geochemistry is in progress to sort out details and tectonic locale of the various mafic-ultramafic lithologies.

Key words: Indus Suture, melange, petrography, Astak fault, NPHM.

K/471. Khattak, M.U.K., Khan, M.L., Bangash, M.I. & Jan, M.Q., 1985. Petrography of hornblendites and associated rocks at Mahak, upper Swat. Acta Mineralogica Pakistanica 1, 78-82.

An 8-km2 area around Mahak consists of amphibolites, metamorphosed gabbros and pyroxenite, hornblendites, and minor dykes and veins of hornblende-plagioclase pegmatite and quartzo-feldspathic rocks. These are described here petrographically, with a brief discussion on their origin. The amphibolites are meta-igneous and essentially composed of amphibole, plagioclase and /or epidote; the gabbros and pyroxenites are relictual and partially amphibolitized; the hornblendites are essentially monomineralic, variable in grain size and may grade into amphibolites through a plagioclase-bearing variety.
Key words: Petrography, hornblendites, pyroxenites, amphibolites, Mahak, Swat.

K/472. Khattak, M.U.K., Khan, S. & Ahmed, W., 1997. Tirich Mir Fault zone of Chitral. Northern Pakistan. Abstract volume, 12th Himalaya-Karakorum-Tibet International Workshop, Rome, Italy, p. 167.

This paper describes geology of the Tirich Mir fault zone of Chitral in northern Pakistan. The fault zone follows a NE-SW direction from Arkari towards Tirich Gol, passes through Rich and Shah Jinali and enters Afghanistan. The fault zone is typically associated with mafic-ultramafic rocks and probably represents a suture zone between the Hindukush-Karakoram and the Asian plates. The mafic-ultramafic rocks form thin to thick lenticular bodies of fine to coarse grained, locally foliated to banded, gabbro-diorite. homogenous to banded amphibolites, hornblendite, and serpentinite. The serpentinite is strongly shattered, has a typical tectonized appearance and commonly contains veins of asbestos and locally pseudomorphs of pyroxene recognizable in hand specimen. The largest of the mafic-ultramafic bodies is ~20 km long and up to ~2 km thick and is exposed in the Arkari valley. To the northwest, the Wakhan Formation consists of Permian to Jurassic terrigenous sequence of dark gray slate to siltstone with less common fine grained quartzite and intercalations of calcareous schist, dolomite and marble. Drainage geochemical exploration along the Tirich Mir fault zone shows significant gold, nickel, zinc, cobalt, lead, copper, iron, and molybdenum values. Complex mesoscopic scale deformation (folding and faulting) is common along the fault. The fault zone is intruded by hornblende-biotite-granodiorite pluton of Tirich Mir and Kafiristan. No blueschists or eclogitic rocks have been found associated with the fault. To the southeast of the Tirich Mir fault zone is a thick sequence of dark gray slate-siltstone with minor gray argillaceous-arenaceous-calcareous schist, fine grained quartzite, and green metavolcanic and volcano-sedimentary rocks.
The occurrence of the typical alpine-type (as opposed to stratiform-type) mafic-ultramafic rocks along the fault zone on a regional scale probably indicates the existence of a major tectonic contact i.e. a suture between the Asian and Karakoram plates. This is supported by the fact that geochemical signature of the Tirich Mir fault zone resembles that of the Main Karakoram Thrust which is a well established suture between the Kohistan arc and the Karakoram plate in northern Pakistan. Another possibility is that the fault zone may have originated as an intraplate rift zone which probably developed as a result of extensional regime generated within the Hindukush-Karakoram plate and then gave way to a fault (suture) during the compressional phase developed by the northward subduction along the MKT and by the southward subduction along the Reshun Pshart suture in the Pamirs.
Key words: Tirich Mir fault zone, mafic-ultramafics, Chitral.

K/473. Khattak, M.U.K. & Parvez, M.K., 1980. A petrographic account of the east-central part of the Chilas complex, Northern Pakistan. M.Sc. Thesis, University of Peshawar, 83p.

The Chilas complex is mainly composed of gabbronorites. In the eastern part (Astor-Chilas section), it contains many bodies of ultramafic-mafic-anorthosite association. Olivine gabbros and troctolites associated with the later display excellent reaction coronas between olivine and calcic plagioclase. This work presents details of field aspects and petrography of the rocks.
Key words: Petrography, gabbronorites, ultramafics, Chilas complex, Kohistan.

K/474. Khattak, M.U.K., Shervais, J.W. & Jan, M.Q., 1999. Petrology of the layered mafic-ultramafic lenses from the Nanga Parbat-Haramosh massif. Terra Nostra 99, Abstract Volume, 14th Himalaya-Karakoram-Tibet Workshop, Kloster Ettal, Germany, 85-86.

Recent studies have shown that in much of the Himalaya the Indus suture (IS) demarcates the boundary between the Indian plate and the "Asiatic" mass characterized by local occurrences of ultramafic rocks, ophiolitic melanges, and high-P metamorphism. In the northwestern Himalaya, however, a more complicated scenario has been documented due to the presence of an extensive zone, the Kohistan-Ladakh magmatic arc (KLMA), between the Indian plate and Asia. The contact between the Indian plate and the KLMA is an extension of the IS and locally (i.e. within Pakistan) named as the Main Mantle Thrust (MMT). The MNIT is quite variable in nature. It (a) is razor sharp at some places (e.g. Sapat, Jijal, Timargara), (b) consists of ophiolitic melanges (e.g. Dargai-Harichand, Shangla, and Alai, north of Peshawar), or (c) consists of melanges containing elements of the Kohistan arc and Indian plate with or without components of the neo-Tethyan crust-mantle (e.g. Babusar, E of NPHM). In some places high-P rocks have been reported in the MMT zone (Shangla, Allai, Kaghan, N of Stak). The IS on the eastern margin of the NPHM is a good example of a melange zone containing all three components. The Indian plate is represented by metasediments and gneisses, the KLMA by ortho-amphibolites and tonalites, and the neo-Tethyan sediments by biotite-rich gneisses containing lenses of rocks, which contain mafic-ultramafic assemblages. Individual blocks range from a few to hundred of meters in dimension and show varying degree of deformation and alteration/metamorphism (Fig. 1). This article presents data on the mafic-ultramafic assemblages along the eastern margin of the NPHM, which probably represent Tethyan shelf sediments caught up during subduction of the oceanic crust, subjected to elevated pressures and metasomatic changes, and finally thrust upward alongwith the rest ci' the sequence of the NPHM.
At the eastern margin of the NPHM, west of the Stak river confluence with the Indus River, there occurs a melange zone of strongly deformed and boudinaged biotite-rich bands with highly altered mafic-ultramafic lenses (Fig. 1). The mafic-ultramafic lenses consist of amphibolite, garnet amphibolite, pyroxenite, serpentinite, and carbonate- and talc-bearing ultramafic rock. The biotite-rich matrix probably formed from a mudstone, whereas the mafic-ultramafic lenses probably represent carbonate enclaves or portions of carbonate interlayers incorporated within the muds, which were later metasomatized and metamorphosed to their present state. Microprobe analyses of clinopyroxene from one banded pyroxenite lens show almost pure diopsides, characteristically impoverished in Ti02 (<0.03 wt.%) Al_20_3 (0.3 wt.%) Na_20 (0.3 wt.%), Cr_2O_3 (nil) and NiO (<0.06 wt.%) and enriched in MnO (0.4-0.6 wt.%), MgO (15.55-16.44 wt.%), and CaO (23.72-24.46 wt.%). The low Cr and high Mn content of Mg-Ca rich diopsides may be a consequence of metasomatic metamorphism. An iron oxide (hematite or magnetite) analysis contains appreciable amount of TiO_2 (0.8 wt.%), Cr_2O_3 (0.4 wt.%), and Al_2O_3 (0.4 wt.%), whereas an ilmenite analysis contains 2.5 wt.% MgO and 0.5 wt.% Al_2O_3, (Table I). The absence of chromite, the presence of Fe-Ti oxides and the occurrence of carbonate in some lenses further supports the view that the rocks may have been chemically modified during metamorphism.
Key words: Petrology, layered ultramafics, NPHM.

K/475. Khattak, M.U.K., Shervais, J.W. & Stakes, D.S., 1996. Counter-Clockwise P-T-t paths in garnets from the Nanga Parbat-Haramosh Massif and the Ladakh island arc terrane, Northern Pakistan. Abstract volume, 11th Himalaya-Karakoram-Tibet Workshop, Flagstaff, Arizona (USA), 79.

High pressure, upper amphibolite facies metamorphic rocks of the Nanga Parbat-Haramosh Massif (NPHM) in northern Pakistan record the Tertiary metamorphism and dynamics of the Himalayan collision, and subsequent overthrusting of the Kohistan-Ladakh island arc terrane onto the Indo-Pakistan plate. At the time of collision, the Kohistan-Ladakh island arc may have formed the southern margin of the Asia, or may have formed a separate terrane. In our study area, the NPHM is separated from rocks of the Ladakh island arc by the Astak Fault Zone, a NNE-trending high-angle fault that forms the eastern margin of the NPHM.
Metamorphic rocks of the NPHM are represented by an intercalated sequence of para- and orthogneisses, with minor metabasics, calc-silicate rocks, and post-metamorphic pegmatite dikes. Garnets from two gt-bi-sill paragneisses in the NPHM are characterized by three distinct textural zones: (1) an inclusion-free core (2) an inclusion-filled intermediate zone, and (3) inclusion-free rims. These garnets are characterized by distinct chemical zoning profiles from core to rim (Figure 1). Equilibration temperatures for these garnets, calculated with the garnet-biotite geothermometer, are ~650ºC in the inclusion-free core, ~725ºC in the inclusion-filled intermediate zone, and ~500ºC

in the inclusion-free rim. Garnets in a paragneiss adjacent to the Astak Fault Zone and the Ladakh arc terrane are inclusion-free throughout, and have nearly flat, unzoned chemical profiles. Equilibration temperatures for these annealed garnets are ~700-684ºC. The dominance of relatively high equilibration temperatures in all of these garnets is confirmed by oxygen isotope partitioning studies, which show that most grant-quartz, feldspar-quartz, biotite-quartz mineral pairs equilibrated at ~700ºC in the NPHM (Khattak, 1995).
The Ladakh arc terrane, east of the Astak Fault Zone, consists largely of meta-volcanic rocks, but also contains minor paragneiss horizons. Garnets found in gt-bi-sill paragneisses from the Ladakh arc terrane contains minor inclusions in the core but have inclusion-free rims. These show a sharp step-like change in chemistry at the boundary between core and rim (Figure 1), with relatively high temperatures in the inclusion-filled cores (~720-650ºC) and lower temperature rims (~580ºC).
The chemical zoning, P-T estimates, and the textural features of these garnets are interpreted as indicative of the tectonic history of the area. The flat chemical zoning indicates annealing (re-equilibration) of the garnets during or after the peak of upper amphibolite facies metamorphism. The occurrence of inclusion coincides with the preservation of the original growth zoning under dynamic, rapid growth conditions. The following tectonic history is proposed: (1) the inclusion-free core of the NPHM garnets may represent collision of the Indian plate with the Ladakh arc; (2) the higher temperature inclusion-filled intermediate zone in the NPHM garnets and the inclusion-filled core of the Ladakh garnets indicates growth during collision of the India-Ladakh package with the Asian plate; (3) the outermost inclusion-free zones in garnets from both the terrains probably formed during unroofing/cooling. Annealed garnets of the NPHM adjacent to the Astak Fault Zone probably reflect heating by hot base of the over-riding Ladakh arc.
Key words: Garnets, metamorphism, NPHM, Ladakh island arc, Himalaya.

K/476. Khattak, M.U.K. & Stakes, D.S., 1993. New data on the metamorphism of the Nanga Parbat-Haramosh massif, and the adjoining Ladakh island arc terrain, northern Pakistan. Geological Bulletin, University of Peshawar 26, 1-16.

The Nanga Parbat-Haramosh Massif in northern Pakistan records the Tertiary metamorphism and dynamics of the Himalayan collision and subsequent overthrusting of the Asian plate onto the Indian plate. The massif consists of an intercalated sequence of paragneisses derived from the Precambrian Salkhala series, of orthogneisses from Precambrian and early-Paleozoic granites, of minor metabasites and calc-silicate rocks, and of post-metamorphic pegmatite dikes. The adjacent part of the Ladakh arc consists of metasediments intruded by younger massive tonalites. The massif and the Ladakh arc are metamorphosed under high pressure, upper amphibolite facies condition. P – T estimates and P – T paths have been determined for the metapelitic samples from the massif and from the adjacent areas of the Ladakh arc along two cross-strike transects (Indus and Astore rives) through the massif. Results show that the massif followed a compressional (counter-clockwise) and the Ladakh arc a decompressional (clockwise) P – T path, consistent with the tectonic history of the Himalaya of northern Pakistan.
Geothermobarometry on garnet-biotite and garnet-plagioclase pairs from pelites in the massif indicates that the rocks started their metamorphic history at ~ 5.5 kb and ~ 625ºC. During collision, the pressure and temperature rose ~ 9kb and about 725ºC. The Ladakh garnets started to grow at ~ 10 kb and ~725ºC with subsequent decrease in metamorphic pressure and temperature to ~8.5 kb and ~650ºC. After the collision, the massif and the adjacent areas equilibrated at ~ 8 kb and ~ 700ºC.
Key words: Metamorphism, P-T data, NPHM, Himalaya.

K/477. Khattak, M.U.K., Stakes, D.S. & Khaliq, A., 1997. Late stage isotopic resetting in the Nanga Parbat-Haramosh massif. Abstracts, 3rd Pakistan Geological Congress, University of Peshawar, p. 38.

Consult Khattak et al. (1997) for further information.
Key words: Isotopes, NPHM.

K/478. Khattak, M.U.K., Stakes, D.S. & Shervais, J.W., 1995. P-T-t paths of garnets from the Nanga Parbat – Haramosh massif, the Kohistan and the Ladakh island arc terranes, northern Pakistan. Geological Bulletin, University of Peshawar 28, 97-108.

Metamorphic rocks of the Nanga Parbat-Haramosh Massif (NPHM) are represented by an intercalated sequence of para- and orthogneisses, with minor metabasites, calc-silicate rocks, and post-metamorphic pegmatite dikes. Garnets from two gar-bio-sill paragneisses in the NPHM are characterized by three distinct textural zones: (1) an inclusion-free core, (2) an inclusion-filled intermediate zone, and (3) inclusion-free rims. These garnets are characterized by distinct chemical zoning profiles from core to rim. Equilibration temperatures for these garnets, calculated with the garnet – biotite geothermometer, are ~ 650ºC in the inclusion-free core, ~725oC in the inclusion-filled intermediate zone, and ~500ºC in the inclusion-free rim. Garnets in a paragneiss adjacent to the Astak Fault Zone and the Ladakh arc terrane are inclusion-free throughout, and have nearly flat, unzoned chemical profiles. Equilibration temperature for these annealed garnets are ~ 700-684ºC, with thin rims ~ 610oC. The dominance of relatively high equilibration temperature in all of these garnets is confirmed by oxygen isotope partitioning studies, which show that most garnet-quartz, feldspar-quartz, biotite-quartz mineral pairs equilibrated at ~700ºC in the NPHM (Khattak, 1995).
The Ladakh arc terrane, east of the Astak Fault Zone, consists largely of meta-volcanic rocks, but also contains minor paragneiss horizons. Garnets found in gar-bio-sill paragneisses from the Ladakh arc terrane contains minor inclusions in the core but have inclusion-free rims. These show a sharp step-like change in chemistry at the boundary between core and rim, with relatively high temperature in the inclusion-filled cores (~ 720-650ºC) and lower temperature rims (~580ºC).
The chemical zoning, P-T estimates, and the textural features of these garnets are interpreted as indicative of the tectonic history of the area. The flat chemical zoning indicates annealing (re-equilibration) of the garnets during or after the peak of upper amphibolite facies metamorphism. The occurrence of inclusion coincides with the preservation of the original growth zoning under dynamic, rapid growth conditions. The following tectonic history is proposed: (1) the inclusion- free core of NPHM garnets may represent collision of the Indian plate with the Ladakh arc; (2) the higher temperature inclusion-filled intermediate zone is the NPHM garnets and the inclusion-filled core of the Ladakh garnets indicates growth during collision of the India-Ladakh package with the Asian plate; and (3) the outermost inclusion-free zones in garnets from both the terranes probably formed during unroofing /cooling. Annealed garnets of the NPHM adjacent to the Astak Fault Zone probably reflect heating by the hot base of the over-riding Ladakh arc.
Key words: P-T-t path, garnets, metamorphism, collision, NPHM.

K/479. Khattak, M.U.K., Stakes, D.S. & Shervais, J.W., 1997a. Metamorphism of the Nanga Parbat - Haramosh massif - I: Stable isotope thermometry. Abstract volume, 12th Himalaya-Karakorum-Tibet International Workshop, Rome, Italy, 169-170.

The Nanga Parbat-Haramosh Massif in northern Pakistan represents the northernmost exposure of the Indian plate that have been metamorphosed in the Late Tertiary subsequent to the Himalayan collision and overthrusting of the Asian plate onto the Indian plate. The massif is a complex mixture of para- and orthogneisses, of minor metabasics and calc-silicate rocks, and of post-metamorphic pegmatite dikes. The 180 geothermometry results indicate that these gneisses are metamorphosed under peak temperatures of upper amphibolite to granulite facies conditions (< 7000C).
The 180 isotopic compositions of the rocks and their constituent minerals in the massif and adjacent areas of the Kohistan and Ladakh arc along the Indus and Astore Rivers varies as following (Table 1): whole rock d180SM0W=7-15.3%; quartz =7.4-16.4%; feldspar =7-16. 10/ac; garnet 5.3-13.7%; biotite =3.9-12.6%; muscovite =6.7-12.7%; and hornblendic amphibole =4.4-7.256g. 180 thermometry results were calculated from 180 fractionations among quartz, garnet, feldspar, biotite, muscovite and amphibole. Fifteen of the sixteen fractionations of Qtz-Gar pairs (aQG) vary from 2.89Gm to 3.8% giving a range of temperatures from 764°C to 599°C respectively. The 1.00/ac variation in fractionation is greater than the expected error and thus indicates a real variation in the maximum temperatures. Among the analyzed minerals, the feldspars, which are isotopically least stable, indicate isotopic resetting during a later metamorphic event.
Key words: Thermometery, metamorphism, stable isotopes, NPHM, Indian plate.

K/480. Khattak, M.U.K., Stakes, D.S. & Shervais, J.W., 1997b. ^{18}O fractionation in feldspars from the Nanga Parbat-Haramosh massif, Northern Pakistan. Geological Bulletin, University of Peshawar 30, 219-225.

The Nanga Parbat-Haramosh Massif in northern Pakistan represents the northernmost exposure of the Indian plate that has been juxtaposed against the Kohistan-Ladakh island arc along Raikot-Sassi and Astak faults. The massif is a complex mixture of paragneisses, orthogneisses, minor metabasics, calc-silicate rocks, and post-metamorphic pegmatite dikes. These gneisses are metamorphosed under high pressure upper amphibolite facies conditions (5.5-10 kb, 650-750°C; Khattak, 1990).
The ^{18}OSMOW isotopic compositions of the rocks and their constituent minerals in the massif and adjacent areas of the Kohistan-Ladakh arc along the Indus and Astore Rivers varies as following: whole rock δ18OSMOW = 7-15.3%o; quartz = 7.4-16.4%o; feldspar = 7-16.l%o; garnet = 5.3-13.7%o; biotite = 3.9-12.6%o; muscovite = 6.7-12.7%o; and hornblendic amphibole = 4.4-7.2%o (Khattak, 1994). Feldspars isotopic compositions show maximum scatter indicating refractory nature of the minerals. 18O thermometry results based on coexisting quartz-feldspar fractionation curves show disequilibrium in some of the samples. Calculation of the 18O composition of fluids that were in equilibrium with different minerals in the temperature range of 500-700°C reveals that there is one pre-metamorphic and one post-metamorphic fluid activity affecting the isotopic composition of the rocks of the massif. The pre-metamorphic fluids probably originated from an igneous parent, depleting the rocks in -2%o, especially along the major faults. The post-metamorphic fluids probably originated from prograde metamorphic reactions and were heavy enough to enrich the feldspars up to~1 8%o. Retrograde paths indicate that the massif was probably quick in its upward flight from depths of around 35 kms as shown by pressure estimates of Khattak and Stakes (1993).
Key words: ^{18}O fractionation, feldspar, metamorphism, NPHM.

K/481. Khattak, M.U.K., Stakes, D.S., Shervais, J.W., Arif, M. & Shah, M.T., 1995. Stable isotope thermometry of the Nanga Parbat-Haramosh Massif and the Kohistan-Ladakh arc, northern Pakistan. Geological Bulletin, University Peshawar 28, 109-126.

The Nanga Parbat-Haramosh Massif in northern Pakistan represents the northernmost exposure of the Indian plate that have been metamorphosed in the Late Tertiary subsequent to the Himalayan collision and overthrusting of the Asian plate onto the Indian plate. The massif a complex mixture of para- and orthogneisses, of minor metabasics and calc-silicate rocks and of post-metamorphic pegmatite dikes. The 18O geothermometry results indicate that these gneisses are metamorphosed under peak temperature of 700°C.
The 18O isotope compositions of the rocks and their constituent minerals in the massif and adjacent areas of the Kohistan and Ladakh arc along the Indus and Astor Rivers vary as following: whole rock δ18OSMOW= 7-15.3%o; quartz=7.4-16.4%o; feldspar=7-16.1%o; garnet=5.3-13.7%o; biotite=3.9-12.6%o; muscovite=6.7-12.7%o; and hornblendic amphibole=4.4-7.2%o. The majority of the mineral δ-values follow the "normal" sequence. 18O thermometry results were calculated from 18O fractionations among quartz, garnet, feldspar, biotite, muscovite and amphibole. Fifteen of the sixteen fractionations of Qtz-Gar-pairs (αQG) vary from 2.8 %o to 3.8 %o giving a range of temperature from 764oC respectively. The 1.0- %o variation in fractionations is greater than the expected error and thus indicates a real variation in the maximum temperatures. Among the analyzed minerals, the feldspar, which are isotopically least stable, indicate isotopic resetting during a later event.
Key words: Thermometery, metamorphism, NPHM, Indian plate.

K/482. Khattak, N.U., Qureshi, A.A., Akram, M., Hussain, S.S. & Mehmood, K., 2001. Classification and petrogenesis of the Loe-Shilman carbonatite complex Khyber Agency, North West Pakistan. Abstracts, 4th Pakistan Geological Congress, Islamabad, p.4.

The Loe-Shilman Carbonatite Complex is the western extension of a 200 km long belt of alkaline rocks. The alkaline belt is situated on the northern side of the Peshawar Plain in an arcuate fashion. It consists of sills-like bodies of carbonatite and related alkaline rocks. These sill-like bodies have been emplaced along a fault zone in metasedimentary rocks of Palaeozoic to Precambrian age.
Using petrographic techniques the sedimentary and metasedimentary carbonate country rocks of the Loe-Shilman carbonatite were classified as dolomite and dolomitic limestone, while the carbonatites were classified into (a) calcite-carbonatites and (b) dolomite-carbonatites. The carbonatites were also classified into (a) calcio-carbonatites, (b) magnesio-carbonatites and (c) ferro- carbonatites on the basis of geochemical data. Field relationships, petrography and geochemical data indicate that the carbonatite magma originated by direct melting of the partly carbonated, metasomatized mantle peridotites. Calcite-carbonatite, the most widespread variety of the carbonatites

in the complex, appears to represent the first phase of carbonatitic magmatic activity, followed by dolomite (and ferroan dolomite)-carbonatite as a separate intrusion. Fission track dating on apatite crystals indicates that emplacement of the carbonatites took place prior to about 20 Ma, probably in the Oligocene (31 ±2Ma).
Key words: Carbonatite, petrogenesis, Loe Shalman, Khyber Agency.

K/483. Khattak, N.U., Qureshi, A.A., Hussain, S.S., Akram, M., Mehmood, K. & Khan, H.A., 1998. Emplacement time and tectono metamorphic history of the Sillai Patti granite gneiss using fission track dating technique. The Nucleus 35, 159-162.

The Peshawar Plain Alkaline Igneous Province (PAIP) consist of a group of alkaline rocks. It occurs in the north of Peshawar from Tarbela in the east through Koga-Ambela, Shewa-Shahbazgarhi, Malakand, Sillai Patti, and Warsak up to Loe Shilman in the west. The alkaline rocks mainly consist of granites, syenites, gabbros, ijolites, carbonatites etc. The granitic rocks cover a major part of the Alkaline Province. This paper presents an account of fission track age data on zircon as a paleotemperature indicator, recognition of the emplacement time and tectonic uplift history of the Sillai Patti Granite Gneiss in combination with the other radiometric ages. The field relationships show that the Malakand Granite and Sillai Patti Carbonatites are younger than the Sillai Patti Granite Gneiss. However, our fission track age of the Sillai Patti Granite Gneiss is less than absolute ages of Malakand granite (U - Pb age approx. equal to 270 Ma) and Sillai Patti Carbonatite (K - Ar age approx. equal to 31 -+ 2.00 Ma). Therefore, the fission track age of 24.32 -+ 2.80 Ma on zircon from Sillai Patti Granite Gneiss, based on present work, represents a time of post metamorphic uplift history of the area, when these rocks past through the 210 deg. C isotherm, corresponding to depth of about 6.7 km inside the earth crust from their present position
Key words: Metamorphism, tectonics, carbonatite, granite gneiss, fission track dating, Sillai Patti.

K/484. Khattak, R., Inamullah, Ahmad, S. & Ahmad, J., Undated. Geology of western part of Attock-Cherat Range north of Nizampur District Nowshera. M.Sc. Thesis, University of Peshawar, 51p.

Key words: Attock-Cherat Range, Nizampur, Nowshera.

K/485. Khawaja, I.A., 1979. Geology of Khaki area, Mansehra and Hazara. M.Sc. Thesis, Punjab University, Lahore.

Key words: Geology, Khaki, Mansehra.

K/486. Khawaja, M.I., 1978-80. Bangang-Palana Area, District Kotli Azad Jammu Kashmir. M.Sc. Thesis, Punjab University, Lahore, 84p.

The project area has been mapped on 1:9000 scale and covers about 20 miles2. Stratigraphic units from Dogra Slates to Siwalik Group have been identified studied and described. Micropaleontological identification reveals the presence of 18 species of foraminefera. Some invertebrate fossil encountered has also been recorded. It has been noted that unlike Hazara the unconformity has enlarged to bring Paleocene rocks in contact with Cambrian rocks. In this process some of the Lower Paleocene rocks are also absent with the result a new unit representing unconformity has been introduced. On the structural side, Main Boundary Thrust has been noticed passing through the southwestern part of the area. On the economic side minerals like fireclay, bauxite, soapstone, dolomite and coal have been recorded.
Key words: Mapping, stratigraphy, palaeontology, foraminifera, Azad Kashmir.

K/487. Khizr, K.M., 1979-81. Geology of Sawni Sheringal Area, Dir District, NWFP. M.Sc. Thesis, Punjab University, Lahore, 92p.

Sawni-Sheringal area is mainly composed of metamorphic rocks of sedimentary origin, with igneous intrusions. The main rock units in the area are calcareous quartzites, chlorite schists, biotite schists and amphibolites.
Calcareous quartzites are believed to be the oldest rock unit of the area. Chlorite schists, biotite schistose and amphibolites have formed as a result of progressive regional metamorphism of calcareous quartzites. The contacts of calcareous quartzites with the schistose and the contacts between chlorite and biotite schistose are gradational. Amphibolites are developed as formless patches in the schistose.
The area is tectonically highly disturbed being involved in Himalayan Orogeny. The report presents a detailed geological and petrological investigation of about 40-km2 area. A detailed map of the investigated area on a scale of f1: 10,000 are presented, along with its cross-section along X-Y line. Succession of Rocks of the area has been worked out. Detailed petrography of all the major units of the area is described. Petrogenesis of the rocks of the area is interpreted. Major and minor structures of the area are discussed in brief. Economic minerals found in the area are listed.
Key words: Amphibolites, metasediments, Sheringal, Dir.

K/488. Khosa, F.M., 1983-85. Engineering geological mapping and site investigations of Kohala Hydal Project with special reference to appertinances fitness. M.Sc. Thesis, Punjab University, Lahore, 104p.

The detailed geological map of the Kohala damsites No. 1 and No. 2 have been prepared. This field report consists of two Parts. Part "A" deals with the General Geology of the Area. Introduction, Physiography, Stratigraphy, Structure, Tectonics and Economic Geology of the area has been discussed in this part. In Part "B" various Engineering Geological Aspects have been discussed in detail. In this part, different factors of site investigation have been discussed. Recommendations and conclusions have been given at the end.
Key words: Engineering geology, mapping, hydel power, Kohala.

K/489. Khurshid, A., Yeilding, G., Ahmad, S., Davidson, I., Jackson, J.A., King, G.C.P. & Zuo, L.B., 1984. The seismicity of northernmost Pakistan. Tectonophysics, 109, 209–226.

A portable seismic network was operated in the Karakoram area of northern Pakistan for over two months during the summer of 1980. The principal objectives were to record possible subcrustal earthquakes beneath the Karakoram Range, and to monitor crustal activity throughout northernmost Pakistan. We confirm the existence of intermediate-depth seismicity (at a depth of about 140 km) beneath the Karakoram Mountains. Shallow crustal activity also occurs in the Karakoram Range, with events recorded from near the northwest end of the Karakoram Fault and near a number of smaller lineaments in Baltistan. Seismicity in Kohistan appears to be largely confined to the upper crust, though occasional earthquakes at 65 km depth (approximately the base of the crust) occur beneath areas of higher topography (Nanga Parbat, Rakaposhi). An area close to the Hamran (1972) and Darel (1981) earthquakes showed intense activity in the depth range 0–25 km, similar to that involved in the mainshocks themselves. Focal mechanisms for events in this area show thrusting on NW-trending planes, indicating NE-SW compression.
Key words: Seismicity, earthquake, Karakoram, Northern Pakistan.

K/490. Khwaja, A.A., 1987. Natural resources potential of Pakistan. Earthview, 14–45.

Key words: Natural resources.

K/491. Khwaja, A.A. & Anwar, J., 1969. Stratigraphic studies of the Nowshera reef complex, Nowshera Tehsil, West Pakistan. Geological Bulletin, University of Peshawar 4, 33-43.

A belt of Siluro-Devonian limestone and quartzite, pink or yellowish-pink in color is exposed on either side of the Nowshera-Risalpur road. This belt was identified as a 'Reef Complex' in 1965, and is the first of its kind to be discovered in the Indo-Pak sub-continent. Prior to this discovery, the limestone belt had been erroneously assigned a Precambrian age and regarded as part of the Attock Slates.
The entire belt unconformably overlies the Kandar Phyllite and is divisible into four definite units: 1. Carbonate Rocks, 2. Reef Core, 3. Reef Breccia, and 4. The Misri Banda Quartzite. The first three collectively are known as the

Nowshera Formation. With the exception of the last, these units represent the characteristics structural layers of a reef.
The age of the reef complex on the basis of its fossil assemblage ranges between Upper Silurian and Devonian. However, there is no fossil present which may pinpoint an exact age. The uncertainty about the precise age of the reef is largely due to the destruction of many organisms by the process of dolomitization. In the opinion of the writers, the Nowshera Formation and the Misri Banda Quartzite were deposited in the southernmost extremities of the basin in which the Muth Quartzite, of Siluro-Devonian age, was formed. In their opinion, the Nowshera formation and the Misri Banda Quartzite, can be correlated with the middle and upper parts of the Muth Quartzite.
Key words: Stratigraphy, reef complex, Nowshera.

K/492. Khwaja, A.A., Jadoon, I.A.K., Ghazi, G.R., MonaLisa & Hashmi, S., 1997. Nature of faults and focal mechanism solutions of a part of northern Pakistan. Abstracts, 3rd Pakistan Geological Congress, University of Peshawar, p.39.

Key words: Structure, focal mechanism, Northern Pakistan.

K/493. Khwaja, I., 1959-61. Mansehra, Susal Gali (Hazara District). M.Sc. Thesis, Punjab University, Lahore.

Key words: Geology, Mansehra.

K/494. Khwaja, S.A., Murtaza, G., Masood, M.T. & Musa, S., 1976. Petrographic study of Kawagarh Formation, Kohat, North West Frontier Province. M.Sc. Thesis, Peshawar University, 97p.

Key words: Petrography, geology, Kawagarh Formation, Kohat.

K/495. Kichi, E.M.K., 1988-90. Petrography and geology of Fatehpur-Shin Area (District Swat). M.Sc. Thesis, Punjab University, Lahore, 93p.

Rocks of Fatehpur Shin area (Lower Swat) are part of metamorphic hornblende complex. The area lies within the Southern portion of Lower Swat. These rocks are probably the extensions of rocks of Dir in the form of belt running approximately in East-West direction. The area given fieldwork comprises 30 miles in the North-West of Saidu Sharif. The area mainly comprises the main rock units are amphibolite, Norite, Diorite, Quartz-O-feldspar and pegmatite veins. Amphibolites have been metamorphosed basic rocks probably Norite gabbro. As the field evidences, and the laboratory study shows that the amphibolites were formed from basic magma, which has undergone regional metamorphism under the intense orogenic conditions. Quartz-O-feldspathic and pegmatite veins are extensively distributed all over the area indicating the evidence of Diorite magma. Major minerals are plagioclase, Hornblende, epidote and quartz with accessories as sphene and magnetite. These are products of regionally metamorphosed igneous rocks.
Key words: Petrography, Fatehpur, Kohistan.

K/496. Kick, W., 1956. Chogo Lungma Glacier, Karakoram. Geographical Journal 122, 93-96.

I was expecting in the autumn of 1954 to accompany as topographer the expedition of Dr. K. Herrligkoffer, which had for its objective Broad Peak in the upper Baltoro region. But during the summer months of that year the scientists of Professor Desio's successful K2 expedition had been at work on the Baltoro glacier, and I decided to go to another region of the Karakoram. I chose the Chogo Lungma glacier, which had only once before been investigated, and that half a century ago.
Although it is one of the very big valley-glaciers, Chogo Lungma is not situated in the zone of the main crest, but southwards at the bifurcation of the Rakaposhi and Haramosh ranges in the Lesser Karakoram. From Skardu on the Indus, it self only four days by air from Europe, the valley can now be reached by a further four days journey. The

ease and relatively low cost of access may promote more activity by mountaineers and scientists in this region: last summer a Frankforr Himalayan Expedition went to Chogo Lungma, accompanied by the meteorologist Dr. Untersteiner.

Easy access was also the reason that this glacier was the first of all the big Karakoram glaciers to be discovered by a European, G. T. Vigne in 1835. He found the lower end "a short distance from the village Arindo," the height of the ice wall there being nearly 100 feet. The next explorer was Godwin Austen in 1861 who wrote from the small village of “Arundu at its (the 'Chogo Loombah’s) termination, its fields touching the ice." As these statements are still roughly accurate, it would seem that the length of the Chogo Lungma has not changed much during the last 120 years.

However, although the glacier may not have changed much in its length, the thickness of the ice has varied greatly at different times. Godwin Austen carried out the first plane_table survey of this area in the space of only two days. But the result, a part of his "Sketch map of the glaciers of the Mustakh Range" on a scale of 1 /506,880 (1 inch = 8 miles), shows the form of “Chogo Ganse” much better than the map on 1 / 150,000 of the Workman expedition of 1903. This second map was based on a "theodolite survey by B. H. Hewett, corrected and supplemented by the authors (Fanny B. and William H. Workman) from actual observation and photographs:' They supposed, erroneously, that the given highest intersected point "Indus-Nagar-Watershed-Peak No.2" (= Peak 46/42L =Malubiting) was fixed wrong during the Kashmir triangulation, as they thought Pyramid Peak, which they had almost climbed to the top, was at least 300 feet higher than Malubiting. Meanwhile, during the triangulation of the Indo-Russian Connection Series in 1912/13 Malubiting (24,470 feet) was checked and found correct and a new point was intersected: this was Peak 68/42L (23,056 feet) for which the Karakoram Conference Report suggests the name Yengutz Har, because of the glacier with this name on the northern side. The peak which the Workman a tried to climb is really Yengutz Har. Oestreich had already made this suggestion, and last year's triangulation confirmed it. The Workmans' mistake was quite understandable; it is very easy to be wildly out when comparing the height of peaks without instruments. In fact "Pyramid" is 1400 feet lower than Malubiting, not 300 feet higher. Indeed many sketeh_maps of this region are wrong, some even make 2 Siebentausender (peaks over 7000 metres or about 23,000 feet) out of one, partly as a result of the many names existing for this mountain: Yenguta Har or Pyramid is the same as "Ghenish Chish" (Burushaski for "Gold Mountain”) of the official quarter-inch map, and is the top of the ridge shown on Conway's map (1894) as the Golden Parri. The people of Arandu showed me the same peak as "Spantik ," probably because of a highest single spot with grass at the foot of the south-eastern ridge of it (in Balti, spang = meadow, grass, tik = spot).

Key words: Glaciers, Chogo-Lungma, Karakoram.

K/497. Kick, W., 1956 Der Chogo-Lungma Gletscher im Karakoram. Zeitschrift für Gletscherkunde und Glazialgie 3, 335-347.

Consult the preceding account for further information.

Key words: Glaciers, Chogo-Lungma, Karakoram.

K/498. Kick, W., 1956/57. The people of Arandu and their Chogo Lungma Glacier. The Mountain World 4, 163-172.

Key words: Glaciers, People of Arandu, Chogo-Lungma, Karakoram.

K/499. Kick, W., 1958a. Exceptional glacier advances in the Karakoram. Journal of Glaciology, 3(23): 229.

Key words: Glaciers, Karakoram.

K/500. Kick, W., 1958b. An Nanga-Parbat Gletschern. Mitteilungen des Deutschen Alpenvereins, 12, 194.

Key words: Glaciers, Nanga Parbat.

K/501. Kick, W., 1960. 100 jahre Nanga Parbat-gletscher. Urania-Universum 6, 42-50.

Key words: Glaciers, Nanga Parbat.

K/502. Kick, W., 1962. Variations of some Central Asiatic glaciers. In: Proceedings of the Symposium of Obergurgl, September 1962. IAHS Publication 58, 223-229.

Key words: Glaciers, Central Asia.

K/503. Kick, W., 1964. The Chogo-Lungma Glacier, Karakoram. Zeitschriff Gletscherkunde udn Glazialgeologie 5, 1-59.

Key words: Glaciers, Chogo-Lungma, Karakoram.

K/504. Kick, W., 1967. Experiences in comparing geometric elements of glacier variations. Abstracts of the Commission of Snow and Ice Journal Assembly of Bern, September – October, 1967, 173-180.

Key words: Glaciers.

K/505. Kick, W., 1977. Eisgeschwindikeitsmessungen an Gletschern Hochaisens: Geschichte-Technik-Ergebnisse. Zeitschrift für Gletscherkunde 13, 7-22.

Key words: Glaciers, ice measurements.

K/506. Kick, W., 1980. Material for a glacier inventory of the Indus drainage basin - the Nanga Parbat massif. In: Clarke, R.T., (ed.), International Workshop on the World Glacier Inventory, Aletsch Ecological Centre, Riederalp, Ct. Valais, Switzerland, 17-22 September 1978. Proceedings. International Association of Hydrological Sciences. IAHS/AISH Publication, 126, 105-109.

Key words: Glaciers, Indus, drainage, Nanga Parbat.

K/507. Kick, W., 1985. Geomorpohlogie und rezente gletscheranderungen in Hochasien. In: Hartl, M. & Engelschalk, W. (eds.), Geographie-Naturewissenschaft und Geisteswissenschaft. Regensburger Georaphsche Schriften 19/20, 53-78.

Key words: Glaciers, geomorphology, High Asia.

K/508. Kick, W., 1986a. Glacier mapping for an inventory of the Indus drainage basin: current state and future possibilities. In: Richardson, E.L. (ed.), *Symposium on Glacier Mapping and Surveying*, University of Iceland, Reykjavik, 26-29 August 1985. Proceedings. Annals of Glaciology, 8, 102-105.

Key words: Mapping, glaciers, Indus, Drainage basin.

K/509. Kick, W., 1986b. Hundert jahre sachengletscher am Nanga Parbat-Kein ausnahmeverhalten? In: Kuhle, M. (ed.), Internationales Symposium uber Tibet und Hochasien vom 8. bis 11. Oktober 1985. Gottingen Geographische Abhandlungen 81, 11-17.

Key words: Glaciers, Nanga Parbat.

K/510. Kick, W., 1989a. Bericht 1989 uber das Chogo-Lungma-Gletscherende im Karakorum. Zeitschrift fur Gletscherkunde und Glazialgeologie 25, 139-145.

Key words: Glaciers, Karakoram.

K/511. Kick, W., 1989b. The decline of the Last Little Ice Age in High Asia compared with that in the Alps. In: Oerlemans, J. (ed.), Glacier Fluctuations and Climatic Changes. Kluwer Academic Publisher, Dordrecht, 129-142.

Key words: Ice age, Alps, Asia.

K/512. Kick, W., 1994. Gletscherforschung am Nanga Parbat 1856-1990. Munchen: Deutcher Alpenverein (=Wissenschaftliche Alpenvereinschefte 30).

Key words: Glaciers, Nanaga Parbat.

K/513. Kick, W., 1997. Forschung am Nanga Parbat-Geschichte und ergebnisse. Beitrage und Materliene zur Regionalen Geographie 8.

Key words: Nanga Parbat, Tectonics.

K/514. Kidd, W.S., Edwards, M.A., Khan, M.A., Schneider, D.A., Zeitler, P.K. et al., 1998. Structure and chronology of Nanga Parbat Haramosh Massif. 1998 Fall meeting EOS, 79(45), suppl., F909.

Consult the following account for further information.
Key words: Structure, geochronology, uplift, Nanga Parbat.

K/515. Kidd, W.S., Edwards, M.A., Schneider, D.A. & Khan, M.A., 2001. New geological map of the Nanga Parbat-Haramosh massif. Journal of Asian Earth Sciences 19, p.36.

We present a newly compiled detailed geological map (1:100 000 scale) of the Nanga Parbat±Haramosh massif based on our field work during the 1995-8 continental dynamics collaborative project, building from previous work by others (references on the map, and below), and supplemented by interpretation from an excellent cloud-free Landsat thematic mapper image taken in October 1995. Major geological features relevant to the young rapid uplift and denudation of the NPHM include the Raikhot fault and its precursor shear zone, first identified by Madin (1986), which is the main structure developed by the W- to WNW- directed thrusting and exhumation of the NPHM over the past 5±10 Ma. Our work has extended the identification and location of this fault and shear zone from Raikhot Bridge to the southwest through the Diamir valley, and shown the coincidence of this zone with the young Jalhari granite from the Diamir valley southwards (Edwards et al., 2000). Our work also documents the extent and shear sense of ductile shear associated with the Diamir± Raikhot shear zone (DRSZ) and distinguishes older ductile shear and mylonite zones, originally developed by S- to SW-directed thrusting, and some subsequent N-directed low angle normal sense motion, during the earlier `Himalayan' events. The map also documents that the eastern NPHM-Kohistan contact is in most places only folded by the NPHM event, with local young faults in this zone being much

less abundant and not a continuous 36 Abstracts: 16th Himalaya-Karakorum-Tibet Workshop, Austria Fig. 1. N MORB-normalized spider diagram for the Waziristan dykes (after Pearce, 1983). Fig. 2. Primordial mantle-normalized spider diagram for the Waziristan dykes (after Wood et al., 1979) zone, unlike the Raikhot fault on the western margin. Our mapping shows that there is significant E- to NE- directed, mainly ductile displacement on the eastern margin of the main antiform of the Nanga Parbat part of the NPHM, expressed by a wide S/C ductile shear zone in the Chhichi and central Rupal valleys, which continues northwards as a narrower tightly pinched synclinal/ shear zone structure at least to Shengus village in the Indus gorge (Schneider et al., 1999b). This Rupal±Chhichi shear zone (RCSZ) and its northward continuation is well within the NPHM, and does not directly affect the eastern NPHM-Kohistan contact. Some younger brittle faulting is associated with this zone in the Rupal valley, but it is not nearly as prominent as that associated with and defining the Raikhot fault on the western margin of the massif. The RCSZ forms the secondary part of a crustal-scale popup structure conjugate to the DRSZ and Raikhot fault. Besides the quaternary fault along surface trace of the Raikhot fault, some other active fault traces are developed in the Kohistan block to the west, up to as much as 15 km from the Raikhot fault. The map includes the newly discovered Himalayan leucogranite of Miocene age in southernmost Chhichi Nullah (Schneider et al., 1999a).
Key words: Mapping, NPHM.

K/516. Kidwai, A.H. & Immam, A., 1958. Magnetite deposits of Dammer Nissar, Chitral state, West Pakistan geological Survey of Pakistan, Information Release 7.

Large bodes of magnetite are present three to four miles southeast of Dammer Nissar, Chitral state. The magnetite is massive, it is found in lenses ranging from 20 to 425 in length and from 5 and 75 feet in width.
A total reserve of 3.7 million tons of magnetite ore has been calculated on the basis of dimensions measured on the surface and on estimated extensions of ore to depths averaging 150 feet below outcrops of individual lenses.
The grade of the ore in general is high; near the contacts of the ore bodies iron content ranges from 45 to 55 per cent whereas main bodies contain 55 to 65 per cent. An alternate route of ore transport through Afghan territory is suggested.
Key words: Magnetite, Dammer Nisssar, Chitral.

K/517. King, B.H., 1961. A new fossil locality in Swat. Geological Bulletin, Punjab University 1, p. 65.

The author has been engaged on the detailed mapping of the granitic gneisses, schists, amphibolites, and marbles of the Lower Swat Valley and adjoining area of Buner. It was *in* this latter area that, in November 1960, fossil remains were discovered in two outcrops on Nikanai (one of the two synclinal island mountain masses which rise abruptly from the Buner Plain) near the village of Tursak (34°31'; 72°22'). This is the first known .discovery of fossils in the crystallines of the region. The ·fossils occur in the marbles which are wholly crystalline, usually well bedded, and with bluish-grey and white bands. Some parts, however, are more massive and bedding is obscure, or absent; here the marble tends to be lenticular in form, although often several hundred feet thick and up to one mile in length.
The fossils were found at the following two localities:-
1. on the crest of the spur directly above Tursak (43 *B/6* grid 373533). They occur in several discontinuous bands which conform to the bedding of the well bedded marbles. Most of the fossils are highly distorted and only identifiable as such when referred to the few less distorted specimens.
Three types can be recognized;
(a) A small low-spired gastropod up to 1 cm. in diameter.
(b) A small pelecypod up to 2 cm. in diameter, with an oval valve.
(c) A larger pelecypod up to 10 cm. in diameter, with a more symmetrical valve than *(b).*
2. Just north of the summit of Nikanai (43 *B/6* grid 346548). The fossils are less distorted than at the first outcrop, and are seen on a relatively small weathered surface. They display a coralline type of structure.
Thin sections of the collected material show only a mosaic of calcite crystals of two grain sizes and 110 internal structures, although the main outlines are fairly clear. No identification, even on a generic level, can be made of the available specimens. Therefore, it is only possible to put a very questionable Upper Palaeozoic (or possibly younger) age to the rocks. The evidence does, however, show that their age is not Pre-Cambrian, as had been generally assumed, previously.
Key words: Paleontology, fossils, Swat.

K/518. King, B.H., 1964. The structure and petrology of part of Lower Swat, West Pakistan, with special reference to the origin of the granite gneisses. Ph.D. Thesis, University of London.

This Thesis concerns the structure and stratigraphy of Lower Swat, Buner and adjacent area of Swabi, northern Pakistan. There is a considerable discussion on the primary (igneous) versus secondary origin of the granitic gneisses of Lower Swat. Much of the details of stratigraphy and structure are similar to those given in Martin et al. (1962).
Key words: Structure, petrology, Buner, Swat.

K/519. King, G. & Jackson, J., 1984. Tectonic studies in the Alpine-Himalayan belt. In: Miller, K.J. (ed.), The International Karakoram Project, 1, 215-220. Cambridge University Press.

Plate tectonics has successfully explained the behaviour of the major ocean Basins. However, it has proved to be less successful in describing the processes of continental collision and its associated deformation. Seismic studies proved crucial in providing information on which plate tectonics was established. Recent developments in the study of seismic signals recorded on distant instruments and on portable seismographs temporarily installed in the Alpine-Himalayan belt are beginning to reveal the relation between extension, sedimentation, compression and major strike slip faulting such as the Karakoram fault.
Key words: Tectonics, Alpine-Himalaya.

K/520. Kinniburgh, W., 1969. Technical feasibility of producing light-weight aggregates from clays of West Pakistan. Building Research Station, London, K264, 1-9.

Key words: Feasibility, light weight aggregate, Clay.

K/521. Klebelsberg, R. von, 1938. Visser's Karakorum-glaziologie. Zeitschrift fur Gletscherkunde 26, 307-320.

Key words: Glaciers, Karakoram.

K/522. Klinger, F.L., Reinemund, J.A. & White, M.G., 1963a. Status of information concerning indigenous raw materials and process for making iron and steel in Pakistan. Proceedings, Symposium on Industrial Rocks and Minerals, Lahore, 1962, 101-111.

Key words: Economic minerals, iron ore, steel.

K/523. Klinger, F.L., Reinemund, J.A. & White, M.G., 1963b. Status of information concerning indigenous raw materials and process for making iron and steel in Pakistan. US Geological Survey/Geological Survey of Pakistan, (IR) PK-52, 113p.

Key words: Economic minerals, iron ore, Steel.

K/524. Klinger, F.L., Reinemund, J.A. & White, M.G., 1963c. Geology of the iron ore deposits of Pakistan. Symposium on Iron Ore. CENTO, Iran, 101-110.

Key words: Economic minerals, iron ore.

K/525. Klootwijk, C.T. & Conaghan, P.J., 1979. The extent of greater India, 1. preliminary palaeomagnetic data from the Upper Devonian of the Eastern Hindukush, Chitral (Pakistan). Earth and Planetary Science Letters 42, 167-182.

Samples of Upper Devonian sedimentary ironstones from the eastern Hindukush, Chitral (Pakistan), give a characteristic palaeomagnetic direction: declination D = 318°, inclination I = -6.5°; believed to represent the primary magnetization direction. The samples come from an area which lies north of a major ophiolite zone that recent workers suggest is the southwestern continuation of the Indus Suture. As the present palaeomagnetic results are in fair agreement with palaeomagnetic data from the Siberian platform but not with data from Gondwanaland they can be taken as additional evidence that this suture does indeed constitute the main collision zone between the Gondwanic Indian subcontinent and Asia. The palaeomagnetic data presented here from the Devonian of Chitral suggests additionally: (1) in excess of 100° of counterclockwise rotation of the area, associated most likely with the formation of the regional Hindukush-Pamir-Karakoram syntaxial bend; (2) more than 2000 km of crustal shortening between Chitral and the Siberian platform due to the northward indentation of the Indian Gondwanaland fragment subsequent to collision.
Key words: Paleomagnetism, Devonian, Hindukush, Chitral.

K/526. Klootwijk, C.T., Conaghan, P.J., Nazirullah, R. & DeJong. K.A., 1994. Further paleomagnetic data from Chitral (Eastern Hindu Kush): Evidence for an early India Asia contact. Tectonophysics, 237, 1–25.

The Eastern Hindukush forms part of an elongate belt ("Central Domain", collage of Cimmerian microcontinents) that encircles the northern part of the Indian subcontinent. A Gondwanan origin is commonly assumed for this belt, but a "Laurasian" origin for the Chitral region has been argued on palaeontological (Talent and Mawson, 1979) and palaeomagnetic (Klootwijk and Conaghan, 1979) grounds. The "Laurasian" view was based on a pilot study we undertook of Upper Devonian pisolitic ironstones from a thrust sheet at Kurāgh Spur in Chitral. Preliminary results showed a characteristic magnetization component [D = 318°, I= −6.5°, N = 7 (block samples), k = 14, α95 = 16.5°] indicating an equatorial palaeoposition. This component was thought to be of primary origin and was interpreted in terms of a Late Devonian "Laurasian" affinity of the Kurāgh Spur rocks. This controversial conclusion has been tested in the present more comprehensive study of the thrust pile of sedimentary rocks in the Reshūn-Kurāgh-Būni region of Chitral and the primary origin of the characteristic magnetization component refuted. Thermal demagnetization of 333 block samples from Middle to Upper Devonian variegated sediments, Permian quartz flysch, Permo-Triassic carbonates, and mid-Cretaceous redbeds showed two interpretable components. A softer component of recent origin (A); and a harder characteristic component (B) of both normal and reverse polarity whose mean direction [D = 314.1°, I = 6.0°, N = 4 (thrust sheets), k = 198.2, α95 = 6.5°] is comparable to the characteristic component observed in our preliminary study. However, the universal presence of this component throughout the thrust pile proves its overprint origin, which we attribute to initial India-Asia contact. Palaeomagnetic information pertinent to the controversy of a "Laurasian" versus a Gondwanan origin of the Chitral region has not been obtained in this further study because primary magnetizations could not be identified beyond doubt. Hence, we retract herewith our original conclusion of a Late Devonian "Laurasian" affinity of the Chitral region on the basis of the palaeomagnetic evidence. The secondary component (B) comprises a suite of secondary magnetizations, acquired at equatorial-to-low-northern palaeolatitudes, and is attributed to initial contact between Greater India and southern Asia. Component B has been observed previously in the Himalayan-Tibetan region, both north and south of the Indus-Tsangpo Suture zone. Identification is herein extended to the Hindukush region north of the Northern Kohistan (or Shyok) Suture zone, which is a western continuation of the Indus-Tsangpo Suture. Comparison of this suite of collision-attributed equatorial palaeolatitude data from the India-Asia convergence zone with new palaeolatitude constraints from the Ninetyeast Ridge on the northward movement of the Indian plate, constrained additionally by a recent minimal estimate of the palaeogeographic northern extent of Greater India, indicates that initial contact between northwestern Greater India and southern Asia was established at, or before, the Cretaceous-Tertiary boundary. The overprint origin of component B at about this time is further supported by observations by Zeitler (1985) on rocks from the sampled area in Chitral of partially reset zircon fission-track ages around 68-55 Ma. The NW-SE declination axis of component B indicates a 60–70° counterclockwise rotation of the sampled thrust pile with respect to Eurasia and a counterclockwise rotation between 10 and 30° with respect to India. Some of the

recent field components (A) show a comparable rotation and indicate that the tectonic activity that led to the formation of the Hindukush-Pamir-Karakorum syntaxial zone has continued into recent times.
Key words: Paleomagnetic data, collision, India-Asia, Chitral.

K/527. Kneneu, Ph.H., 1929. Petrographic description of the rock from the Hunza valley in the Karakorum. Leidsce Geologie Mededeelingen 3.

During his second Karakoram expedition in 1925 Mr. Ph. C. Visser collected some 70 rock specimens from the valley of the Hunza and its tributaries. The following is a petrographic description of these specimens and I gladly take this opportunity of thanking Mr. Visser for entrusting me with his valuable material. Geologists are much endebted to this energetic explorer for bringing together such a considerable number of samples under circumstances in which all carriage had to be reduced to a minimum and when so many other calls were being made on his time and energy. A collection made by a layman and therefore taken without many observations on mode of occurrence, must naturally be of limited value. When, however, it concerns a region that is almost terra incognita from a geological as well as from a geographical point of view, it may serve to give us an insight into the more salient features, especially petrographic and to some extent structural as well, and therefore constitute an important contribution to geological knowledge. Geologists will all hope that Mr. Visser will soon be in a position to add to the collections he has already made.
Key words: Petrography, Hunza, Karakorum.

K/528. Knowlton, E., 1933. Nanga Parbat 1932. The American Alpine Journal 2, 18-31.

Key words: Geology, geomorphology, Nanga Parbat.

K/529. Koivula, J.I. & Fryer, C.W., 1986. Blue-green zircon in Pakistani beryl. Zeitschrift der Gemmologischen Gesellschaft 35(3-4), 101-103.

Key words: Gemmology, zircon, beryl.

K/530. Koivula, J.I., Kammerling, R.C. & Fritsch, E., 1992. Gem news. Gems & Gemology 28, 268-279.

Key words: Gemology.

K/531. Koivula, J.I., Kammerling, R.C. & Fritsch, E., 1994a. Gem news. Gems & Gemology 30, 191-201.

Key words: Gemology.

K/532. Koivula, J.I., Kammerling, R.C. & Fritsch, E., 1994b. Gem news. Gems & Gemology 30, 271-280.

Key words: Gemology.

K/533. Kojima, J., 1965. Metamorphic and plutonic rocks of the Karakorum and Hindu Kush. In: Geology of the Karakorum and Hindu Kush. Results of the Kyoto University Science. Exped. 1955, VII, 93–119.

The specimens of metamorphic and plutonic rocks collected through the Japanese Expeditions of 1955, 1956 and 1957 have been studied petrographically. The results for 250 samples from Swat, Ghizar, Yasin, Ishkuman, lower

Hunza, Indus gorge east of NPHM and Braldu are listed in a useful and informative petrographic table in the Appendix. The principal rock types include acid to intermediate plutonic rocks, gneiss, basic igneous rocks, impure calcareous rocks, calcareous rocks, siliceous rocks, and psammitic and politic rocks. Based on petrography, the charts showing the metamorphic facies, type of anatexis, preservation of basemental crystalline rocks in the area concerned have been constructed. From these charts the zonal arrangement of the terrains with different characters in the NW-Karakoram and East Hindu Kush, together with the northern extension of the Nanga Parbat gneiss dome, has been discussed. The distribution and the petrographic characteristics of the plutonic rocks show intimate relationship with the geotectonic division of the basement. The Nanga Parbat basement is considered to have passed through polymetamorphism.
Key words: Metamorphism, metasediments, granitoids, Nanga Parbat, Hindu Kush, Karakoram.

K/534. Kolati, T., Ali, S. & Muhammad, H.M., 1986. Groundwater conditions of Sangau area Mardan. M.Sc. Thesis, University of Peshawar, 60p.

Key words: Groundwater, Mardan.

K/535. Kordos, L., 1997. A comparative environmental and hominoid history in the Neogene of Carpathian basin and Siwalik. Abstracts, 3rd GEOSAS Workshop on Siwaliks of South Asia, Islamabad. Geological Survey of Pakistan, Records 109, p.56.

Both Carpathian Basin and Siwalik region rich in Late Miocene Hominoid remains and have a great importance on the early phase of human evolution. The range of Hominoids in the Carpathian Basin 15-9 Ma, and in the Siwalik 12-7 Ma.
At the same time significant global and local environmental changes happened in the two areas, a transition from wet tropical-subtropical to dry temperate climate. However, the Late Miocene geological history of Carpatluan Basin and Siwalik region are basically different. During the Early and Middle Miocene the Carpathian Basin was a member of the Paratethys (Central Paratethys) and separated as a large lake system (Pannonian Lake) during the early Late Miocene (11-10 Ma). The Pannonian lake and swamp gradually disappeared until the Mio-Pliocene boundary. The large body of water caused a long, generally warm and wet permanent environment. During this process the palynological data are showing two cooling periods during the Late Neogene. First is between 11 and 10 Ma, and the second between 8 and 7 Ma. Carbon isotopic analyses of 10 Ma old sediment of Rudabanya Hominoid site indicate purely C3 ecosystem. These climatic and ecological data are showing similar global environmental events at 7-8 Ma, both in Kenya, in Pakistan, and in the Carpathian Basin.
Comparative palaeoecology of Neogene terrestrial mammal faunas of the Carpathian Basin generally support previous analyses and help to answer one of the most interesting question, why Hominoids disappeared during Late Miocene from Eurasia?
Key words: Environment, neogene, hominoid history, Carpathian, siwaliks.

K/536. Kothe, A., Khan, A.M. & Ashraf, M., 1988. Biostratigraphy of the Surghar Range, Salt Range, Sulaiman Range and the Kohat area, Pakistan, according to Jurassic through Paleogene calcareous monnofossils and Paleogene dinoflagellates. Geologie Jahrbusch 71: 3-87, 32 figs., tabs., 17 plts.; Hannover.

Key words: Biostratigraphy, Jurassic-Paleogene, Surghar Range, Salt Range, Sulaiman Range, Kohat.

K/537. Kovak, C., 1986. Minerals and gemstones of Pakistan. The Australian Gemmologist 16, 57-59.

Key words: Economic geology, gems, Pakistan.

K/538. Kravchenko, K.N., 1964. Soan formation - upper unit of Siwalik group in Potwar. Science & Industry 2(3), 230-233.

Key words: Soan Formation, siwalik, Potwar.

K/539. Kravchenko, K.N., 1979. Tectonic evolution of the Tien Shan, Pamir and Karakoram. In: Farah, A. & DeJong, K. A., (Eds.), Geodynamics of Pakistan, Geological Survey Pakistan, Quetta, 25-40.

In the Tien Shan, Pamir and Karakorum the southward migration of the mobile belts reflects the growth of the Eurasian continent during the Phanerozoic. Geosynclinal development in the mobile belts began with rifting and drifting of Pre-Baikalian continental crust during five periods: 1) in the Middle Tien Shan during the Proterozoic (Pre-Late Rifean); 2) in the North Tien Shan during the Late Proterozoic-Early Cambrian; 3) in the South Tien Shan during the Cambrian-Early Carboniferous; 4) in South Ghissar and North Pamir during the Early Carboniferous; and 5) during the Early Carboniferous-Triassic in Central and Southeast Pamir. The I Caledonian orogeny occurred in the North Tien Shan, the Hercynian orogeny in the Middle Tien Shan, South Tien Shan, South Ghissar and North Pamir, and the Alpine orogeny during the Mesozoic and the Cenozoic in Central and Southeast Pamir and the Karakorum. The latest orogenic phase, which began in the Late Oligocene, is very widespread and is the result of the collision between the Eurasian and Indian plates.
Key words: tectonics, Tien Shan, Pamir, Karakoram.

K/540. Krishnan, M.S., 1936. A look at marble samples from Swabi Tehsil, North West Frontier Province. Geological Survey of India, Record 70, p.414.

Key words: Marble, Swabi, India.

K/541. Krishnan, M.S., 1960. Geology of India and Burma, 604 p. Higginbothams, Madras.

This is a revised edition of the geology of the sub-continental India and Burma by the same author. Like the Geology of India by Wadia, this book also covers all aspects of geology, stratigraphy and mineral deposits, etc., of the region stretching from western margin of Pakistan to eastern Burma..
Key words: Geology, Burma, India, Pakistan.

K/542. Krol, M.A., Zeitler, P.K. & Copeland, P., 1994. Temporal and spatial variations in the cooling history of the Kohistan island arc terrane, Pakistan: Implications from Ar/Ar K–feldspar thermo chronology. Geological Society of America, Annual Meeting, A–136, p.7.

Consult krol et al., 1996, for further information.
Key words: Ar-Ar thermochronology, cooling history, Kohistan island arc.

K/543. Krol, M.A., Zeitler, P.K. & Copeland, P., 1996. Episodic unroofing of the Kohistan batholith, Pakistan: implications from K-feldspar thermochronology. Journal of Geophysical Research 101, 18149-18164.

New $^{40}Ar/^{39}Ar$ and U-Pb mineral ages from plutonic rocks help constrain the thermal and tectonic evolution of the Kohistan island arc terrane following its collision with India in early Tertiary time. Kohistan has experienced a prolonged tectonomagmatic history extending from the Early Cretaceous through the Tertiary. Thermal histories derived from multi diffusion domain analyses of K-feldspar within the Kohistan batholith reveal rapid cooling events (70–140°C/m.y.) distributed through space and time. The cooling histories show a systematic variation along the length of the batholith suggesting that Kohistan experienced differential unroofing. An episode of rapid cooling in the middle Eocene is recognized in western Kohistan, whereas rapid cooling occurs substantially later, during the middle and late Miocene, in eastern Kohistan. Rapid cooling in western Kohistan might have been caused by postemplacement cooling of hot magma against cold country rocks at relatively shallow crustal levels. Within the NW region of eastern Kohistan, rapid cooling at 13–12 Ma is recorded in K-feldspars ~60 km from the contact with

the Nanga Parbat-Haramosh Massif (NPHM), whereas cooling does not occur until 11 Ma only 2.5 km from the contact. This temporal and spatial variation in cooling histories may record differential unroofing in response to the development and propagation of the NPHM structure beneath Kohistan. The NPHM has experienced rapid cooling and unroofing over the last 10 m.y., and our results are consistent with this mid–late Miocene event.
Key words: Tectonics, Kohistan batholith.

K/544. Krol, M.A., Zeitler, P.K., Poupeau, G. & Pecher, A., 1996. Temporal variations in the cooling and denudation history of the Hunza plutonic complex, Karakoram Batholith, revealed by 40Ar/39Ar thermochronology. Tectonics, 15 (2), 403–415.

The 40Ar/39Ar thermochronology of the Late Cretaceous Hunza plutonic complex reveals an episodic cooling and denudation history for this regional-scale pluton. The $^{40}Ar/^{39}Ar$ analyses of biotites from a vertical relief section of >3200 m reveal a pulse of rapid cooling at ∼20 Ma. In the interval of 110–27 Ma, age-elevation distributions suggest denudation rates of the order of 0.02 ± 0.003 mm/yr. At ∼20 Ma, denudation rates increased significantly to 2.7 ± 0.7 mm/yr, then returned to much slower rates until 12 Ma. A second pulse of rapid cooling beginning at 12 Ma is revealed by inverse numerical modeling of multidiffusion domain alkali feldspars from a vertical section of 1700 m. Decreasing in elevation, these samples record the onset of rapid cooling at 12, 9, and 7 Ma, respectively. All of the alkali feldspars record a period of nearly isothermal conditions prior to the onset of rapid cooling when rates increased to 30°C/m.y. Assuming a geothermal gradient of 30°C/km, these cooling rates translate into denudation rates of 1.0 mm/yr. Apatite fission track analysis indicates denudation rates of 0.7 ± 0.1 mm/yr over the interval of 6.6 Ma to 2.4 Ma in agreement with the alkali feldspar data. These data suggest denudation of 2.9 ± 0.4 km since the Plio-Pleistocene. Together, the alkali feldspar and apatite data indicate that a minimum of 10 km of overburden has been removed since the mid-late Miocene.
Key words: Ar-Ar thermochronology, cooling history, Kohistan island arc.

K/545. Kruseman, G.P. & Naqavi, S.A.H., 1988. Hdrogeology and groundwater resources of the North West Frontier Province, Pakistan. WAPDA Hydrogeology Directorate, Peshawar, Pakistan/Institute of Applied Geosciences, DELFT, The Netherlands.191p.

This account gives details of the water resources of NWFP. It comprises 1. Introduction, 2. Hydrogeology, 3. Groundwater behaviour, 4. Groundwater investigations, 5. Groundwater development, 6. Groundwater development potential, 7. Groundwater management: a look ahead, 8. The regional groundwater resources, which include 9. the intermontane basins of Dir, Swat and Chitral districts, 10. The left bank areas, 11. the intermontane basins of Peshawar and Mardan districts, 12. the intermontane basins of Kohat and Karak districts, 13. the Bannu basin, 14. The Dera Ismail Khan district, and 15. Groundwater in the Federally Administered Tribal Areas. At the end, references and glossary are given. The document is supported by 32 tables and 88 figures.
Key words: Groundwater, hydrogeology NWFP.

K/546. Kubo, K., Khan, T., Kausar, A.B., Sawada, Y., Takahashi, Y. & Takahashi, Y., 1998. Origin of ultramafic-felsic association in the Chilas Igneous Complex, Kohistan Arc, North Pakistan. Exotic block derived from oceanic crust. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 107-108.

The Chilas Igneous Complex is one of the major geologic units in the Kohistan Arc region, located in the western Himalaya of northern Pakistan. It is a huge gabbroic body, 300 km long, intruding the Kamila amphibolites which occur widely in the southern half of the Kohistan Arc region. The Chilas Igneous Complex is composed mainly of gabbronorite with minor two- pyroxene quartz diorite and two pyroxene granodiorite. The complex contains several small xenolithic bodies of ultramafic-felsic association (UFA), layered two pyroxene gabbro and amphibolites. The layered two pyroxene gabbro is the cumulus facies of the gabbronorite (Kubo et al., 1997).
Within the Chilas Igneous Complex, several bodies of UFA exist. Of these, the body cropping out along the Karakoram Highway (KKH) to the east of Chilas village (named as Thak body) is described in detail. The Thak body extends 2.8 km along the KKH, enclosed and intruded by gabbronorite of Chilas Igneous Complex. The Thak body consists of cyclic units of layered cumulate rocks. The layered rock units are younging from west to east

throughout the body. The cummulates are classified into olivine cumulate and pyroxene-dominant cumulate. Olivine- dominant cumulate consists mainly of olivine cumulate (dunite), associated with minor amount of olivine-clinopyroxene cumulate (wehrlite). It occurs as 10 to 400 m thick layers, alternating with thin layers of plagioclase dominant cumulate. Plagioclase-dominant cumulate occurs as layers several meters to several tens of meters thick. It consists of plagioclase olivine-clinopyroxene cumulate, though the modal ratio of each mineral changes greatly within a layer. The amount of clinopyroxene occurring as primocryst is very low. At the basal part of plagioclase dominant cumulate, a trough structure develops. It crosscuts the underlying olivine dominant cumulate. The boundary between the top of the plagioclase-dominant cumulate layer and the overlying olivine dominant cumulate layer is generally straight, and is parallel to the rhythmic layering or lamina in the upper part of plagioclase-dominant cumulate. This suggests that the plagioclase-dominant cumulate was covered conformably by the olivine-dominant cumulate and the boundary plane represents a horizontal plane during the crystal accumulation.
Under the microscope, the plagioclase-dominant cumulate shows adcumulus texture. Plagioclase, olivine and clinopyroxene occur as granular primocrysts. Olivine is sometimes partly rimmed by clinopyroxene, orthopyroxene and/ or hornblende embedded by vermicular spinel. A similar texture is also recognized rarely in the olivine-dominant cumulate. The characteristics are as follows, i) frequently, olivine is in direct contact with plagioclase without the interception of other crystals, and ii) the rock has an igneous texture and keeps the normal compositional zoning of primocrysts though very weak. Effects of regional metamorphism are not recognized. These characteristics and mineral chemistry data indicate that the vermicular spinel within clinopyroxene, orthopyroxene or hornblende was formed by the reaction between olivine and plagioclase, under the condition of the inconstant existence of a liquid phase among the primocrysts, i.e., the reaction between plagioclase and olivine proceeded during the magmatic stage, instead of during the metamorphic stage.
Pyroxene-dominant cumulate occurs as a layer 18 m in thickness. The upper boundary of the layer is straight and covered concordantly by olivine-dominant cumulate, and the lower boundary is cut by gabbronorite. It consists of orthopyroxene-clinopyroxene cumulate (websterite) and clinopyroxene cumulate (clinopyroxenite). Pyroxene-dominant cumulate occurs also near the eastern margin of the Thak body as platy blocks, 20 m in thickness, intruded by gabbronorite. EPMA data show that the compositional variation of each mineral is very small within and among the layers, and systematic changes through the Thak body are not recognized, i.e., cryptic layering does not exist. The Thak body and gabbronorite of the Chilas Igneous Complex are very different in petrologic and mineralogical characteristics, indicating that these rocks have different origin. The crystallization process of UFA is summarized into, i) olivine and small amounts of clinopyroxene crystallized continuously near the central part of a magma reservoir and settled on the bottom. The settled crystals made up the homogeneous accumulate (olivine-dominant cumulate). During this process, the chemical composition of crystallizing minerals and the magma (liquid) above the cumulate was kept constant,, ii) at the same time, crystallization of pyroxenes and plagioclase occurred at other portions of the same magma reservoir. Some accumulated plagioclase and pyroxenes flew down along the bottom of magma chamber (like a mudflow in water) toward the place where olivine was accumulating. Thus the plagioclase-dominant and pyroxene-channeled or eroded olivine dominant cumulate, iii) plagioclase, olivine and interstitial liquid could not coexist stably, and a reaction rim was formed between plagioclase and olivine, and iv) as the downward flow of plagioclase and pyroxene occurred intermittently, plagioclase dominant and pyroxene-dominant cumulates were covered by olivine-dominant cumulates conformably until the next flow arrived. This magma reservoir is characterized by open system crystallization. That is, primitive magma is continuously supplied into the magma reservoir and differentiation proceeds from the center to margin of the reservoir. Such a magma reservoir is not known except for that supposed for the generation of oceanic crust. Therefore, the ultramafic-felsic association is considered to be derived from the oceanic crust.
Key words: Ultramafic-felsic association, oceanic crust, Chilas complex, Kohistan.

K/547. Kubo, K., Sawada, Y., Takahashi, Y., Kausar, A.B. & Khan, T., 1992. Geological survey of the Chilas igneous complex in 1991 (short note). Proceedings of Geoscience Colloquium, Geoscience Lab, Geological Survey of Pakistan, Islamabad 3, 92-94.

This report describes the mafic-ultramafic rocks of the Chilas complex, which range from dunite, wehrlite, pyroxinite to norite and gabbro. Also given is columnar lithological section of the complex.
Key words: Petrology, Chilas complex, Kohistan.

K/548. Kubo, K., Sawada, Y., Takahashi, Y., Kausar, A.B., Seki, Y., Khan, I.H., Khan, T., Khan, N.A. & Takahasi, Y., 1992. The Chilas igneous complex in the western Himalaya of northern Pakistan. Abstracts of Symposium on Himalayan Geology, Shimane ’92.

This is a summarised account of the field aspects, petrography and petrology of the Chilas complex.
Key words: Petrology, Chilas complex, Kohistan.

K/549. Kubo, K., Sawada, Y., Takahashi, Y., Kausar, A.B., Seki, Y., Khan, I.H., Khan, T., Khan, N.A. & Takahasi, Y., 1996. The Chilas igneous complex in the western Himalaya of northern Pakistan. Proceedings of Geoscience Colloquium, Geoscience Lab, Geological Survey of Pakistan, Islamabad 14, 63-68.

This note describes briefly the occurrence of the Chilas complex and gives a columnar section across the mafic-ultramafic body near Chilas. It is assumed that the complex represents a part of subducted oceanic plate that was obducted during the collision and captured by the norite magma as a xenolith.
Key words: Chilas complex, oceanic crust, Kohistan arc.

K/550. Kuhle, M., 1986a. Die obergrenze der glet cher hohenstufe-oberflachentemperaturen un vergletscherung der Himalayaflanken von 5000, bis 8000m. Zeitschrift fur Gletscherkunde und Glazialgeologie 22, 149-162.

Key words: Glaciers, surface-temperatures, Himalaya.

K/551. Kuhle, M., 1986b. Schneegrenze Berechnung und topologische klassifikation von glet chem anhand spezifischer reliefparameter. Petermanns Geographische Mitteilungen, 41-51.

Key words: Topography, relief,

K/552. Kuhle, M., 1988. Letzt eiszeitliche gletscherausdehnung vom NW-Karakorum bis zum Nanga Parbat (Hunza-, Gilgit- und Indusgletschersystem). In: Tagungsbericht und Wissenschaftliche Abhandlungen des 46. Deutschen Geographentages 1987 in Munchen. Franz Steiner, Stuttgart, 606-607.

Key words: Ice age, glacier expansion, Karakoram, Nanga Parbat, Hunza, Gilgit, Indus glacier system.

K/553. Kummel, B., 1966. The Lower Triassic Formations of the Salt and Trans-Indus Ranges, West Pakistan. Museum of Comparative Zoology, Harvard University, Bulletin 134(19), 161-429.

The Triassic formations in the Salt Range of West Pakistan have played a particularly important role in the development of our Triassic zonal scheme, especially for the Scythian stage. In addition, interest in these formations is heightened because they conformably overlie late Permian formations, and the Triassic formations in the Salt Range have occupied the attention of nearly every student of the causes of abrupt faunal breaks. This great interest has not been matched by many modern detailed stratigraphic or paleontologic studies of these Permo-Triassic formations, Waagens (1895) great monograph on the Fossils of the Ceratit Formation was the first large scale report on a Triassic fauna from the eastern region of Tethys. In the same year Mojsisovics, Waagen, and Diener (1895) published their proposal for a classification of the Triassic System. In that paper the name Scythian was introduced for the lower series of the Triassic and the Salt Range sequence of zones presented as the type section. Later, Noetling 1901) reaffirmed the Pre-eminent importance of the Salt Range sequence in Scythian chronology, at the same time modifying somewhat the scheme of zones proposed by Waagen. It was not until 30 years later that it was

generally recognized that the Triassic fossilbearing formations in the Salt Range studied by Wynne (1878), Waagen (1895), and Noetling (1901, 1905) encompassed only the lower half or so of the Scythian. Waagen's Salt Range ammonites, however, have continued to play a dominant role in our interpretation of the evolution and systematics of Scythian ammonoids.
Key words: Stratigraphy, Lower Triassic, Salt Range, Trans-Indus Ranges.

K/554. Kummel, B. & Teichert, C., 1966. Relation between the Permian and Triassic Formations in the Salt Range and Trans-Indus Ranges, West Pakistan. Neues Jahrbusch Geologica Palaeontologia, Abhandluagen 125, 297-333.

Key words: Permian, Triassic, Salt Range, Trans-Indus Ranges.

K/555. Kummel, B. & Teichert, C., 1970. Stratigraphy and Paleontology of the Permian- Triassic boundary beds, Salt Range and Trans-Indus Ranges, 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, 1-110.

It has been known for about a hundred years that the sedimentary series of the Salt Range and some of the Trans-Indus ranges of West Pakistan encompass a concordant succession of marine, fossiliferous rocks of Late Permian and Early Triassic age. After a brief introduction to geology and geography of the area, the history of research on this sequence and on the problem of the Permian-Triassic boundary is reviewed.
The detailed stratigraphy of the beds immediately above and below the Permian-Triassic boundary is described from nine localities in the Salt Range, two in the Surghar Range, and two in the Khisor Range. The uppermost lithological unit of the Permian Chhidru Formation ("Upper Productus limestone") is a white sandstone unit which is as much as 17 feet thick and in the Khisor Range has yielded brachiopods indicating a Late Permian age. It also contains conodonts, a rich palynological assemblage, and acritarchs.
The white sandstone unit is conformably overlain by a dolomite unit, about *5* to 14 feet thick, containing *Ophiceras, Glyptophiceras, Miocidaris,* and few other megafossils associated with rich assemblages of conodonts, acritarchs, and spores and pollen. This unit forms the base of the Triassic System. It is gradational with an overlying limestone unit that also contains *Ophiceras* and other fossils, including conodonts and palynomorphs. The dolomite and limestone units together form the Kathwai Member which represents the *Ophiceras* Zone, the lowest ammonoid zone of the Triassic System. This is overlain by thin-bedded limestone containing *Gyronites* and other ammonoids (the "Gyronitan" assemblage of Spath) the "Lower Ceratite limestone" of Waagen, which most previous observers believed to form the base of the Triassic System in the Salt Range.
The nature of the boundary between the Permian and Triassic systems in the Salt Range and the Trans-Indus ranges is discussed from the point of view of lithology, diagenesis, sedimentary structures, and fossil content. The abrupt litho-facies change indicates a sharp change of sedimentary environment. Sedimentary structures, such as mudcracks and capped ripple marks, in combination with dolomitization and dedolomitization patterns, suggest that a period of emergence intervened between the deposition of the white sandstone unit and the dolomite unit, and that the co11tact between the Permian and Triassic systems in the Salt Range and Trans-Indus ranges, therefore, is a paraconformity which may represent a gap equivalent to as much as, or more than, a stratigraphic stage.
Key words: Stratigraphy, palaeontology, Permian, Triassic, Salt Range, Trans-Indus Ranges.

K/556. Kummel, B. & Teichert, C., 1973. The Permian-Triassic boundary beds in Central Tethys. In: Logen, A. & Hills, L.V. (Eds), The Permian and Triassic system and their mutual boundary. Canadian Society of Petroleum Geology, Memoir 2, 17-34.

The classical and most important areas for the study of Permian-Triassic boundary beds, with the exception of that at Kap Stosch, East Greenland, are in central Tethys. This report discusses the stratigraphy and paleontology of these boundary beds in the Salt Range and Trans-Indus ranges of West Pakistan, the Julfa region of northwest Iran, and at Guryul Ravine near Srinagar, Kashmir.
The Permian-Triassic contact in the Salt Range and Trans-Indus ranges is interpreted as a paraconformity reflecting a recession of the sea and an emergent condition in latest Permian time followed by a transgression in the earliest

Triassic as defined by the first appearance of *Ophiceras.* These earliest Triassic strata also contain a variety of Permian-type brachiopods which are interpreted as short-lived survivors from the underlying Permian.
The controversial strata of the Dzhulfa region of Soviet Armenia, and now known from the adjacent region of northwest Iran that contains the so-called mixed faunas, are considered to be of Late Permian age. New finds of ammonites, especially genera known previously only from the Changhsing Limestone of Kwangsi, China, are part of the basis for this interpretation. In Guryul Ravine are strata with *Claraia* that contain Permian-type brachiopods. We interpret these beds as of Early Triassic age.
Key words: Permian, Triassic, Tethys.

K/557. Kureshy, A.A., 1970. The larger Foraminifera of lower Eocene of Azad Kashmir. Pakistan Journal of Science 22, 164-165.

Key words: Paleontology, foraminifera, Eocene, Azad Kashmir..

K/558. Kureshy, A.A., 1975/77. Texanomic studies of Tertiary larger foraminifera of Pakistan. Geological Survey of Pakistan, Record 38, 47p.

Key words: Paleontology, foraminifera, Tertiary.

K/559. Kureshy, A.A., 1977a. The Cretaceous planktonic foraminiferal biostratigraphy of Pakistan. Paleontological Society of Japan, Special Paper 21, 223-231.

Key words: Paleontology, foraminifera, Cretaceous.

K/560. Kureshy, A.A., 1977b. The Cretaceous larger foraminiferal biostratigraphy of Pakistan. Journal of the Geological Society of India 18, 662-667.

Key words: Biostratigraphy, palaeontology, foraminifera, Cretaceous.

K/561. Kureshy, A.A., 1978. Tertiary larger foraminiferal zones of Pakistan. Revista Espanola de Micropaleontologia 10, 467-483.

Key words: Palaeontology, foraminifera, Tertiary.

K/562. Kureshy, A.A., 1979. The Cretaceous/Tertiary boundary in Pakistan. Proceedings of Cretaceous/Tertiary Symposium, Copenhagen, 1, 214-221.

Key words: Palaeontology**,** Cretaceous-Tertiary boundary, Foraminifera.

K/563. Kureshy, A.A., 1980a. Foraminifera of Belemnite Formation (Early Cretaceous) of Pakistan. Geology and Palaeontology of Southeast Asia, University of Tokyo Press, 21, 101-108.

Key words: Foraminifera, Early Cretaceous, belemnite.

K/564. Kureshy, A.A., 1980b. The Miocene-Pliocene boundary in Pakistan. Revista Espanola de Micropaleontologia 12, 41-46.

Key words: Palaeontology, Miocene-Pliocene boundary.

K/565. Kureshy, A.A., 1981. The Plio-Pleistocene boundary in Pakistan. Revista Espanola de Micropaleontologia 13, 267-272.

Key words: Palaeontology, Pliocene-Pleistocene boundary.

K/566. Kureshy, A.A., 1982a. The Paleogene-Neogene boundary of Pakistan. Revista Espanola de Micropaleontologia 14, 221-229.

Key words: Palaeontology, Paleogene-Neogene boundary.

K/567. Kureshy, A.A., 1982b. Paleobiogeography of Tertiary larger foraminifera of Tethys region. Proceedings of the North American Paleontological Convention, 3:16.

Key words: Palaeontology, forminifera, Tethys.

K/568. Kureshy, A.A., 1983. Pakistan. In: Moullade, M. & Nairn, A.E.M. (eds.), The Phanerozoic Geology of the World II: The Mesozoic B. Elsevier, New York, 353-374.

Key words: Geology, Phanerozoic.

K/569. Kureshy, A.A., 1984. Quaternary palaeobiogeography and biostratigraphy of Pakistan. Mezhdunarodnyj Geologicheskij Kongress 27, Mascow, 1, 380-381.

Important contributions have been made on paleontology and biostratigraphy of Pakistan (including the area of this monograph) in series of papers by A.A. Kureshi. Unfortunately, we have not been able to access these papers, therefore, no annotation is given for these except the key words.
Key words: Paleontology, biostratigraphy, Quaternary, Pakistan.

K/570. Kureshy, K.U., 1986. Geography of Pakistan. National Book Service, Lahore, 263p.

This is a detailed account of the geography of Pakistan. It covers nicely the varied physiography of the country as well as other geographic subjects with the help of maps and statistical detail.
Key words: Geography.