C/1. Cai, Xiangxing, Li, Nienjie, & Li, J., 1980. The mudrock flows in the vicinity of the Batura Glacier. Professional Papers on the Batura Glacier, Karakoram Mountains, Science Press, Beijing, China, 146–152.

Key words: Glaciers, mudrock, Batura, Karakoram.

C/2. Calciati, C., 1910. Les fronts des glaciers de Yengutsa et d'Hispar. La Geographie 22, 241-246.

This paper reports the fronts of the great Hispar glacier and the Yengutsa glacier. The Hispar is one of the longest glaciers outside the polar region.
Key words: Glaciers, Hispar, Central Karakoram.

C/3. Calciati, C., 1914. Esplorazione delle valle Kondus e Hushee nel Caracorum sub-orientale. Bollettino delle Reale Societa Geograpica Italiana 51(9), 995-1014 & 51(10), 1076-1093.

Key words: Karakoram.

C/4. Calciati, C., 1923. Il piu grande ghiacciaio delle terra. Il Siascen nel Caracorum. Emporium 58, 105-115.

This is a report on the Siachin glaciers, one of the greatest glaciers of the world, in central Karakoram. It gives some details of the geography and geology of the area.
Key words: Glaciers, Siachin, Karakoram.

C/5. Calciati, C., 1928. Il Karakorum secondo le ultime esplorazioni con special riguardo al contributo degli italiani. Instituto Geografico Militare, Firenze.

This is a map of the Karakorum according to the latest explorations with special regard to the contribution of Italian workers.
Key words: Italian expedition, Karakoram.

C/6. Calciati, C., 1928-29. Nel Caracorum. L'assaltoalle piu alte vette del mondo. Le Vie d'Italia, 1928: 976-987; 1929: 57-64, Milano.

Key words: Karakoram.

C/7. Calciati, C., 1930. Al Caracorum. Diario di due esplorazioni. Bemporad, Firenzi.

Key words: Glaciers, Siachin, Karakoram.

C/8. Calciati, C. & Koncza, M., 1910. The basin of the Hispar Glacier. In: Workman, W.H. (Ed.), The call of the snowy Hispar. Appendix 1. Constable, London, 245-282.

Key words: Glaciers, Hispar, Karakoram.

C/9. Caldeira, K. & Kerrick, D.M., 1995. Uplift and chemical weathering in south-central Asia, the carbon cycle and Cenozoic climate. Abstract Volume, 10th Himalaya-Karakoram-Tibet Workshop, (ETH Zurich) Switzerland.

It has been proposed that the general cooling trend through the Cenozoic has been largely due to the enhancement of silicate-rock weathering rates associated with continental uplift in south-central Asia (i.e., the Himalayan and related orogens, and the Tibetan Plateau). One of the primary pieces of evidence cited to support this proposal is the Cenozoic strontium isotope curve, which has been interpreted as indicating progressively increasing silicate-rock weathering rates associated with continental uplift in this region.
Uplift, by increasing the exposed surface area of fresh rock exposed to chemical weathering, may enhance the ease with which rock is weathered, and hence may have an impact on atmospheric CO_2 content and climate. However, if this mechanically weathered rock is rapidly transported to and buried in river deltas, enhanced mechanical erosion need not induce enhanced chemical weathering. Enhanced silicate-rock weathering on a global scale requires an enhanced supply of CO_2, else the atmospheric and oceanic reservoirs of CO_2 would be rapidly depleted. We have constructed a preliminary carbon budget for the Cenozoic, and have shown that the interpretation of the strontium isotope curve in terms of enhanced chemical weathering rates is inconsistent with both inferred rates of CO_2 degassing from the solid Earth and the inferred timing of uplift in Tibet, Himalayas and related orogens. Furthermore, the strontium in rivers draining the Tibetan plateau and the Himalayas is insufficient to account for the observed Cenozoic change in oceanic $^{87}Sr/^{86}Sr$ ratios.
Furthermore, we have conducted a preliminary field study examining the Himalayan and Karakorum orogens as a potential metamorphic CO_2 source to the atmosphere. Our initial results indicate that metamorphic CO_2 releases associated with the India-Asia collision would not have been sufficient to supply the CO_2 required to account for proposed increases in chemical weathering rates.
Key words: Weathering, climate, carbon cycle, uplift, Asia.

C/10. Calkins, J.A., 1966. The geology of the western limb of the Hazara-Kashmir Syntaxis, West Pakistan and Kashmir. Ph.D. Thesis, University of Massachusetts.

The Hazara-Kashmir Syntaxis is one of the most prominent structural features of the Himalayan Range. Forming a hair-pin bend, this structure has been studied in detail in this work. Some of the information from the thesis was published in several papers by Calkins and his co-authors.
Key words: Hazara-Kashmir Syntaxes, Himalaya.

C/11. Calkins, J.A. & Ahmad, M., 1969. Geology of the Tarbela damsite area, Peshawar Division, West Pakistan. USGS/GSP, Information Release PK-47, 17p.

About 80 square miles in the vicinity of the Tarbela damsite was mapped in order to relate the geology of the damsite proper to larger regional geologic features. The rocks in the area are chlorite-mics-quartz schist, marble and calcareous schists, and calcareous graphite schists of the Salkhala Formation (Precambrian); slate and phyllite schists of the Hazara Formation (Precambrian to Early Paleozoic); quartzite of the Tanawal Formation (Silurian or Devonian); dolomite of the Abbottabad Formation (Carboniferous to Permian); and small intrusive bodies of Tertiary age. Unconsolidated surficial deposits include reworked loess, river alluvium, and terrace deposits.
The main structural feature is a strike-slip fault, called the Darband fault, which passes down the Indus River through the damsite, and separates the Salkhala and Tanawal Formation on the west bank from Hazara and younger formations on the east bank. East of the Darband fault large northeast-trending folds plunge northeast. On the west bank, west of the Darband fault, large folds are not evident in the Salkhala Formation, but most small-scale folds are parallel to the large folds east of the fault.
In the northern part of the mapped area quartzite of the Tanawal Formation forms a large east-trending anticline overturned to the south. The southern overturned limb has moved relatively southward over the
Salkhala rocks along a north-dipping thrust fault. The geological feature of greatest potential concern relative to the Tarbela dam is the Darband fault, which passes through the damsite. This fault is considered to be inactive, however, and may be too deeply buried by river alluvium to promote leakage. The schistose rocks in the west abutment area are weak, permeable, and cut by numerous shear zones.

The dolomite rocks of the Abbottabad Formation in the east abutment area, although much jointed. Are rigid and relatively impermeable in comparison with the rocks in the west abutment area.
Key words: Dams, Tarbela, Peshawar

C/12. Calkins, J.A., Ali, S.T. & Offield, T.W., 1967. Soapstone deposits of the Sherwan area, Hazara District, West Pakistan. USGS/GSP. Information Release PK-25, 13p.

Key words: Economic geology, soapstone, Sherwan, Hazara.

C/13. Calkins, J.A., Jamiluddin, S., Bhuiyan, K. & Hussain, A., 1981. Geology and mineral resources of the Chitral-Partsan area, Hindukush Range, northern Pakistan. USGS Professional Paper 716-G, 33p.

This report is based upon field investigations covering an area of about 1,400 square miles (3,626 sq km) in the Hindu Kush Mountains of Chitral State in northern Pakistan and also includes a discussion of geological questions relating to an area of about 8,000 square miles (20, 720 sq km) in the Chitral-Gilgit area. The area is extremely rugged; local relief is more than 8,000 feet (2,438 meters) over most of the area and commonly reaches 10,000 feet (3,048 meters). Many peaks are higher than 17,000 feet (5,182 meters), and Tirich Mir, 8 miles (12.9 km) north of the mapped area, is 25,263 feet (7,700 meters) high. The mapped area includes the following units: Devonian unit; Sarikol Shale (Devonian to Carboniferous); a broad belt of metamorphic rocks of Devonian to Jurassic age; Reshun Formation, a volcanic greenstone unit, a limestone and phyllite unit, a greenschist unit, and the Chitral Slate-all of Cretaceous age. Elongate bodies of granite (Cretaceous) underlie large parts of the area. Of stratigraphic interest are (1) the lateral facies change of the Reshun Formation from fossiliferous conglomeratic red shale and phyllite at Reshun, to marble in the Kafiristan area, and (2) the determination of a Cretaceous age for the Chitral Slate, which formerly was considered to be of Paleozoic age.
Structurally, the mapped area is characterized by a system of folds overturned toward the east and south. This fold pattern marks the regional trend of the Hindu Kush Range, from north in the southwestern part of the area to east-northeast in the eastern part. Several reverse and thrust faults separate belts of rocks of Cretaceous age from belts of older rocks. Metallic deposits in the area include (1) veins containing antimony, lead, and copper with associated gold, silver, and tin; (2) copper localities in mafic rocks and greenschist; and (3) miscellaneous showings, mainly of copper. Antimony has been mined on a small scale at Krinj since 1939. The places of high mineral potential are the vein-type deposits along the fault zones in the Awireth Gol-Shoghot-Madashil area, the Krinj mine area, and in the Shishi Valley area. Along these faults the largest showings of copper, lead, and antimony are found, and in the Awireth Gol locality the lead ore contains large amounts of gold and silver.
Nonmetallic mineral deposits include limestone, marble, dolomite, granite, pegmatite, and talc. No commercial limestone industry exists in the Chitral area. However, limestone and marble are used locally for building stone. Granite is also used locally for building stone. Mica and beryl are mined on a small scale from pegmatites 15 miles (24 km) northwest of the mapped area.
The work also includes a geological map of the area at a scale of 1:96000 along with two cross-sections, a regional geological map of the Gilgit-Chitral area at a scale 1:250,000 scale and a table of chemical analyses for metallic minerals.
Key words: Mineral resources, Chitral, Hindukush.

C/14. Calkins, J.A. & Matin, A.S.A., 1968. The geology and mineral resources of the Garhi Habibullah quadrangle and Kakul area, Hazara district, West Pakistan. Geological Survey of Pakistan/USGS Project Report, Information Release PK 38, 55p.

The mapped area occupies about 250 square miles in the southern Himalayas of norther Pakistan and western Kashmir, rugged mountainous country characterizes the area; maximum topographic relief is about 7500 feet between Lachi Khan (9473 ft) and the lowest elevation of 2000 feet.
The oldest rocks are the slates and phyllites of the Hazara Formation, considered to be of Precambrian (?) age. Quartzose schists of the Tanawal Formation (Silurian? Or Devonian?) overlies the Hazara Formation. Succeeding rock units in the area include: dolomite of the Abbottabad Formation (Carboniferous to Permian), red shales of the

Galadanian Formation (early Jurassic), Daulatmar Limestone (Jurassic), Spiti shale and Glumal sandstone (Upper Jurassic and lower Cretaceous), Sattu Limestone (Upper Cretaceous), chhalpani Formation (Paleocene and Eocene), and the Murree Formation (Miocene). Correlation of the Carboniferous to Eocene sequence of rocks in this area has been established with rocks of the Kala Chitta hills west of Rawalpindi, and with rocks of the Kohat area south of Peshawar.
Key words: Mineral resources, Hazara.

C/15. Calkins, J.A., Offield, T.W., Abdullah, S.K.M. & Ali, S.T., 1969. Geology and mineral resources of southern Hazara District, West Pakistan and parts of western Azad Kashmir. USGS Project Report, Information Release PK-43, 92p.

Key words: Mineral resources, Hazara.

C/16. Calkins, J.A., Offield, T.W., Abdullah, S.K.M. & Ali, S.T., 1975. Geology of the southern Himalaya in Hazara, Pakistan and adjacent areas. USGS Professional Paper 716–C, 29p.

Geologic mapping and mineral investigations were conducted from 1961 to 1965 by the Geological Survey of Pakistan and the U.S. Geological Survey in the Hazara district, Pakistan, and part of western Kashmir, as part of a cooperative mineral exploration and development program. The area covers 2,000 square miles in the southern foothills of the Himalaya between the Jhelum River on the east and the Indus River on the west. Rugged mountains and deep canyons characterize most of the area. Altitudes range from 1,100 feet on the Indus River near Tarbela to more than 16,000 feet on the Kashmir divide; the Indus, Siran, Kunhar, Kishanganga, and Jhelum Rivers all flow in deep gorges through the area. The geologic formations range in age from Precambrian to Quaternary and include sedimentary, igneous, and metamorphic rocks and unconsolidated material. The oldest rocks belong to the Salkhala Formation of Precambrian age. Above it are the Hazara Formation (Precambrian(?) and possibly lower Paleozoic), Tanawal Formation (Upper Ordovician(?) to Devonian (?)), Panjal and Kingriali Formations and "Agglomeratic Slate" (Carboniferous to Triassic), Datta Formation (Lower Jurassic), Samana Suk Limestone (Jurassic), Chichali Formation (Upper Jurassic), Lumshiwal Sandstone (Upper Jurassic to Lower Cretaceous), Kawagarh Limestone (Upper Cretaceous), Kala Chitta Group (Paleocene to Eocene), and the Murree Formation (Oligocene(?) to Miocene). The Mansehra Granite was intruded in Late Cretaceous to early Tertiary time, apparently in the form of one or more sheetlike bodies. Contact-metamorphic effects around the granite generally are not pronounced; however, wollastonite occurs at one locality. Regional metamorphism and accompanying penetrative deformation increase in intensity northward. The regional metamorphism was synchronous with or postdates the granite, because the granite itself is involved in the deformation. The structural pattern in the mapped area consists of two northward-projecting loops or reentrants the larger Hazara-Kashmir syntaxis and the smaller Indus reentrant connected by a broad arcuate belt, called the western arc. The Hazara- Kashmir syntaxis, which is the pivot point of the great regional arc of the northwest Himalaya, is oriented slightly west of north and contains younger rocks in its core or axial zone; successively older rocks wrap around the periphery. A system of boundary faults also wraps around the syntaxis and helps to define it. The southern part of the western limb of the syntaxis is divided into three structural blocks separated by major faults which show combined strike-slip and vertical displacement.
The structural development of the Hazara-Kashmir syntaxis is believed to be related to the great regional arc of the Himalaya 150 miles to the north. Southward tectonic transport moving perpendicular to this great arc would converge on the axial zone of the Hazara-Kashmir syntaxis, which is at the pivot point of the arc. The present syntaxial structure would be the natural result of such movement. Late-stage westward countermovement of the rocks in the axial zone resulted in the present westward overturning of the folds along the southern segment of the western limb of the syntaxis.
The Indus reentrant, as with the Hazara-Kashmir syntaxis, also is interpreted to be the result of smaller scale tectonic convergence towards its present axial zone. Between the Hazara-Kashmir syntaxis and the Indus reentrant, the rocks moved south to form the southward bulge of the western arc. In terms of large-scale tectonics the Himalayan mountain system has southward asymmetry, which has been interpreted in two ways: (1) radial spreading out southward of middle Asia and (2) continental drift of India against Asia. The latter view has gained credibility recently as a result of new data and ideas on global tectonics. The earliest known indications of the Himalayan

orogeny are found at Hindubagh, near Quetta, where ultramafic rocks were emplaced after Cretaceous but before Eocene time. The widespread episode of folding and mountain building began in Miocene time in the mapped area.
Key words: Mapping, Hazara, Himalaya.

C/17. Callegari, E. & Zanettin, B., 1960. Chimismo di rocce vulcaniche plutoniche del Karakorum centro meridionale. Memoir Institute of Geology and Mineralogy, University of Padova, Mem., vol. xxi, 38p.

The Karakoram Range contains large number of plutonic rocks, as well as volcanic rocks along its southern margin. This is a report of the geochemistry of the rocks collected during the Italian expeditions led by Ardito Desio.
Key words: Geochemistry, volcanic, plutonic rocks, Central Karakoram

C/18. Campbell, E., 1917. Notes on the rock specimens collected by the Bullock Workman Expedition 1911–12 in the Bilaphond and Kondus basins, and on the Khondokoto and Masherbrum Glaciers. Appendix. In: Two Summers in the Ice–Wilds of Eastern Karakorum. Workman, F. Bullol and Workman, W.H. (Eds.), Fisher Unwin, London.

Three specimens were collected in the Ghyari nala below the Bilaphond glacier: two of these are white crystalline limestone containing a little tremolite; the third is a serpentine (chrysotile). These were the only specimens actually collected. Dr. Longstaff had previously recorded granite as abundant in the moraines.
Some interesting material was collected at the head of the Dong-Dong glacier. One is a coarse white crystalline limestone like those collected in the Ghyari nala. Another is a fairly coarse- grained white biotite-granite, with garnets reaching 4 mm in diameter; it is very poor in ferromagnesian minerals, containing only a little biotite and a trace of muscovite. Quite the most interesting specimen from this locality is a fragment showing large plates of pale green actinolite: some of these show rough crystal outlines, the outer zone of the crystal being brown. They are associated with portions of finer grain consisting of diopside and tremolite, and some fragments of aplite are also adhering to the specimen. This rock is evidently a product of contact metamorphism due to a granitic intrusion.
Several specimens were collected on the central moraine of the north-east branch of the Kaberi glacier. Here occurred white, pink, and purple limestones similar in texture to those of the Siachen; while a light coloured moraine at the head of the glacier yielded abundant slabs of white marble similar to that collected on the Tarim Shehr.
With the limestones of the central moraine occur masses of tetrahedrite, with malachite and azurite, and a curious mass of black pisolitic concretions cemented and impregnated with pyrites and apparently passing into a kind of pisolitic ironstone.
The east wall of the Khondokoro glacier yielded a fine-grained hornblende-biotite-gneiss and also a typical felspar-amphibolite. From the moraines of the same glacier came a muscovite-biotite- granite containing small garnets and showing a tendency towards granulitic structure. This rock occurs as a fine-grained granite, but in some specimens the plates of muscovite may measure half an inch across. The garnets never seem to exceed 1 mm. in diameter. This type was also found by Sir Martin Conway in the Astor valley.
The Masherbrum glacier yielded four specimens: two are white fine-grained dolomite, one is serpentine, the other is an augen of quartz, apparently from a chlorite schist. An interesting rock was collected at the junction of the Khondokoro and Masherbrum nalas. It is a fine-grained granite- gneiss consisting of quartz, stained yellowish brown, oligoclase and some microcline, with fairly abundant patches of biotite. Sphene and epidote occur as accessories. The oligoclase frequently shows patches of inclusions of biotite and sphene, and also a secondary development of muscovite and epidote. There is some micrographic intergrowth with quartz at the borders of the felspar crystals, and in places a marked tendency towards granulitic structure.
Key words: Glaciers, Masherbrum, Karakoram.

C/19. Campbell, J.F., 1877. On Himalayan glaciations. Journal of the Asiatic Society of Bengal 46.

Key words: Glaciation, Himalaya.

C/20. Caporali, A., 1992. Recent gravity measurements in Karakoram. Abstract Volume, 7th Himalaya-Karakoram Workshop, Department of Earth Sciences, Oxford University, England, 11.

Two new gravimetric profiles have been observed in Karakorum as part of the activities of the Ev K2 CNR Project led by prof. Ardito Desio. One profile, established in 1988, starts from Bazar Dara (China), north of the Aghil range, and covers the portion of the Shaksgam valley between the confluence of the Urdok-Gasherbrum glaciers to the SE and, along the Shaksgam River, Tek ri-Sughet Jangal to the NW. The second profile, done in 1990, starts from Skardu and ends in Gilgit via the Biafo Hispar glaciers. During both expeditions we established a number of astrogeodetic stations for the measurement of the deflection of the vertical, using the satellites of the Global Positioning System to determine reference geodetic coordinates. Two astronomic stations were done in 1988 and fourteen in 1990,

The geographic location and overall quality of the observations indicate that they provide an interesting addition to the collected by Marussi and coworkers from 1964 to 1979. In the course of our surveys a number of the Marussi points were checked to ensure consistency.

The paper contains a preliminary analysis of the Marussi plus our 1988-1990 data. To remove low frequency trends in the anomalous gravity field we make use of predictions based on the spherical harmonics expansion of the global earth gravity field produced by the Ohio State University (model OSU91A). This representation is complete to degree and order 360 and is particularly interesting as it includes for the first time Chinese gravimetry.

Key words: Geophysics, gravity, GPS, Karakoram.

C/21. Caporali, A., 1993. Recent gravity measurements in the Karakoram. In: Treloar, P.J. & Searle, M.P. (Eds.), Himalayan Tectonics. Geological Society of London, Special Publication 74, 9-20.

Two new gravimetric profiles have been obtained in the Karakoram as part of the activities of the Ev-K2-CNR Project. One profile, established in 1988, starts from Bazar Dara (China), north of the Aghil range, and covers the portion of the Shaksgam valley between the confluence of the Urdok-Gasherbrum glaciers to the SE and, along the Shaksgam river, Tek ri-Sughet Jangal to the NW. The second profile, carried out in 1990, starts from Skardu and ends in Gilgit via the Biafo Hispar glaciers. During both expeditions a number of astrogeodetic stations were established for the measurement of the deflection of the vertical, using the satellites of the Global Positioning System (GPS) to determine geodetic reference coordinates. Two astronomic stations were established in 1988 and fourteen in 1990. The new data, when added to those collected by Marussi and co-workers from 1954 to 1979, improve the coverage north of the Main Karakoram Thrust, where the Bouguer anomalies attain their largest negative values. For all available data Bouguer and Airy isostatic corrections have been computed using the ETOPO5 height grid. A mean crust density of 2.85 g cm−3, a density contrast of 0.3 g cm−3 and a normal thickness T = 30 km have been assumed, so that the surface of isostatic compensation locally best fits the Moho. Two profiles have been selected, one continuing northward of the Nanga Parbat - Haramosh massif the deep seismic sounding profiles done in the 1970s. The other is such that it crosses the Indus Suture Zone, the Main Karakoram Thrust and the Karakoram Fault nearly at right angles. In both profiles, from Pakistan to China, the horizontal gradients of the Bouguer anomalies are in the interval −1.5 to −2 mgal km−1, comparable to gradients found in the region between the Indo-Gangetic Plains and the Himalaya. A marked steepening of the Moho is implied here with increased detail. Isostatic anomalies underneath the Karakoram are found to be more negative than those computed in the earlier work of Marussi, who made different assumptions of density and density contrast. Clearly the new data do not uniquely constrain the local structure of the lithosphere but may be of help in better understanding non-negligible deviations from isostatic equilibrium.

Key words: Geophysics, gravity, GPS, Karakoram.

C/22. Caporali, A., 1995. Gravity anomalies and the flexure of the lithosphere in the Karakoram, Pakistan. Journal of Geophysical Research 100 B(8), 15075-15085.

The negative correlation between gravity anomalies in mountain regions and the topographic height implies a mass deficiency beneath the range and adjacent regions. Classical compensation schemes in which roots of constant

density form at a depth proportional to the topographic height (Airy scheme) or individual columns of laterally variable density develop to a constant depth (Pratt scheme) enable only part of the anomalies to be modeled and provide a “static” description of the structure of the crust and upper mantle, regardless of the vertical and horizontal motions associated with the origin and evolution of mountain belts. Early studies of isostatic anomalies across the Karakoram range, in northern Pakistan, have shown that the region is not in isostatic equilibrium in the Airy sense and have pointed to the need of a more refined model of the forces and stresses shaping the lithosphere than classical isostasy. The concept that the lithosphere should respond by flexure to applied loads as a thin, elastic, semi-infinite plate buoyant on a denser, inviscid fluid is used here as the basis to compute model Bouguer anomalies, estimate by least squares the deformation of the plate, and constrain some of the plate's elastic parameters. It is assumed that the forces responsible for the deformation are the topographic load, the hydrostatic response, and the elastic stresses within the plate. The plate itself is assumed to be separated into an Indian and an Asian portion, each with its own equivalent elastic thickness. At the border between the two portions an empirical infracrustal point load is assumed to act vertically. Gravity anomalies are then computed along five profiles crossing the range, as a function of the abscissa of the border point, the load acting at this point, the elastic thicknesses of the Indian and Asian portions of the plate, and the density contrast across the median section of the plate. The corresponding numerical values and associated formal uncertainties are determined by a least squares fit of the model anomalies to the observed Bouguer anomalies, along each of the five independent profiles. The postfit residuals are found to have essentially zero mean and an rms (root mean square) dispersion of the order of 20 mGal, which is consistent with the expected overall accuracy of the “observed” Bouguer anomalies interpolated to the profiles. The distribution of the post fit residuals still shows systematic components at the level of a few tens of mGal, that are likely to be caused by local, shallow geological structures. Overall the peak-to-peak excursion of the residual anomalies is considerably smaller than the classical isostatic anomalies for the same region. It is found that (1) the line connecting the estimated abscissas of the border points on each profile follows closely suture lines which have been independently identified from geological data and could be associated with the center of mass of the Kohistan-Ladakh island arc considered as a buried load; (2) for all profiles the elastic thickness of the Indian plate is systematically less than for the Asian plate, typically 80–100 km for India and 100–120 km for Asia; (3) there is a tendency of the elastic thickness of both portions to increase moving NW, towards the Pamirs. The gravity data are thus consistent with a relatively rigid Asian plate in the Tarim basin, unlike the Central Himalaya where Tibet, being indented by India, has zero strength.
Key words: Topography, gravity, lithosphere, Karakoram.

C/23. Caporali, A., 2000. The gravity field of the Karakoram Mountain Range and surrounding areas. In: Khan, M.A., Treloar, P.J., Searle, M.P. & Jan, M.Q. (Eds.), Tectonics of the Nanga Parbat Syntaxis and the Western Himalaya. Geological Society of London, Special Publication 170, 7-23.

A ‘blank on the map’ only 60 year ago, the Karakoram Range has been explored and surveyed with greater difficulty than the Himalaya and Tibet due to its rugged terrain and extensive glaciation. In the past ten years we have succeeded in doubling the number of gravity stations. A substantial improvement in coverage and overall quality was obtained by concentrating on previously unsurveyed areas and by validating older data with more accurate measurements. Our data were merged with earlier data, converted to full Bouguer anomalies and gridded. The resulting Bouguer anomaly map defines very precisely the gravimetric low associated with the Nanga Parbat-Haramosh Syntaxis, and the huge negative values are now visible also in the Ghujerab-Khunjerab areas. Correlation of the topography and Bouguer anomaly shows that a plate of flexural rigidity with D=2*102 Nm fits the coherence data in the Karakoram at all but two distinct frequency ranges centered at wavelengths of 80 and 300 km. In a rheologically layered lithosphere developing a buckling instability under horizontal compression, the observed spectral features of the topography and Bouguer gravity anomalies constrain the depth of the competent layers to be in the range 13-20 km and 50-75 km respectively.
Key words: Geophysics, gravity, Karakoram,

C/24. Caporali, A., Marzari, F. & Palmieri, F., 1991. Geodetic and geophysical report. In: Geodesy, Geophysics and Geology of the Upper Shaksgam Valley, North East Karakoram and South Sinkiang. Scientific Report of the Italian Expedition to Karakoram 1988 (A. Desio leader). Consiglio Nazionale delle Ricerche-Milano, 11-92.

Key words: Geophysics, geodesy, Karakoram.

C/25. Caputo, M., 1958a. La profondita del Ghiacciaio Baltoro ad Urdukas determinata con metodo gravimetrico, e per mezzo della sua velocita superficiale metodo di 50 migli, Geofisica e Meterologia, Geneva, 6(3-4). Lst. Topografia Geodesia Univ. Triesta; publication series A-39.

This account describes the details of the work conducted by the authors around Baltoro glacier. The depth of the Baltoro Glacier to Urdukas was determined by gravimetric method, and by means of its surface speed of 50 nautical miles, using geodetic and geophysical methods.
Key words: Glaciers, gravimetry, Baltoro.

C/26. Caputo, M., 1958b. Ein graphisches verfahren fur die berechnung der vertikalen komponente der anziehungskraft zylindrischer korper unter dessen anwendung fur die bestimmung der gestalt von gletscherbetten. Zeitschrift fur Geophysik 24.

Key words: Glaciers, geophysics.

C/27. Caputo, M., 1964. Glaciology. In: Geophysics of the Karakoram, Italian Expeditions to the Karakoram (K2) and Hindu Kush (Prof. A. Desio leader), II-Geophysics, 1, 147-162. Brill, Leiden.

Key words: Glaciology, geophysics.

C/28. Carpena, J., 1988. Traces de fission au sommet du K2 (8611 metres). Abstracts, 4th Himalayan-Karakoram-Tibet Workshop, Lausanne, Switzerland, p.14.

Consult the following account for additional information.
Key words: Dating, fission track, Karakoram.

C/29. Carpena, J. & Rutkiewicz, W., 1989. Ages traces de fission des apatites et des zircons du sommet du K2 (8611 m), Pakistan. Eclogae Geologae Halvetae 82, 735-742.

A paragneiss from the top of K2 (8611 m) in Karakoram chain (Pakistan) yields apatites and zircons. Fission Track dating of zircons indicates an age of 63.6±6.0 Myrs (Paleocene). Apatites, a more sensitive Fission Track chronometer, give an age of 8.8±1.0 Myrs (Upper Miocene). These ages let us constrain the thermal history of the K2 massif.
Key words: Dating, fission track, Karakoram.

C/30. Carrel, R.P., 1974. Les pierres precieuses du Pakistan. Bulletin Assciation France Gemmologie 41, p7.

This account gives details of the gemstones of Pakistan till the date of publication.
Key words: Gems, Pakistan.

C/31. Carter, S., 1983. Petrology and structure of the Swat granite gneisses near Manglaur, southern Swat, Pakistan. M.S. Thesis. Geology Department, Oregon State University, Carvalis, U.S.A.

The granite gneiss at Manglaur to the north of Mingora is one of a series of granitic intrusions in Swat. This biotite granite is quite fresh and contains large crystals of alkali feldspar. Much of the rocks is sheared and strongly gneissose with porphyroclasts of the feldspar in medium-grained matrix, but some parts are not so deformed.
Key words: Petrology, structure, granite, gneiss, Swat.

C/32. Casati, P., Spadia, P., et al., 1980. Studi geologici idrologici e floristico vegetazionali nel buchino del Ghiacciaio Biafo e nella valle del F. Brauldu (Karakorum occidental, Pakistan). Natura 71, 121-164, Milano.

This is a multi-disciplinary study of the Biafo Glacier and Brauldu valley in the eastern Karakorum. It relates geology and hydrology of the area with flora and vegetation.
Key words: Geology, hydrology, vegetation, Biafo Glacier, Brauldu valley, Karakorum.

C/33. Casnedi, R., 1976a. Geological reconnaissance in the Yasin valley, NW Pakistan. Rend. Accademy Nazionale Lincei, Series 8, 59, 792-799.

Key words: Reconnaissance geology, Yasin valley.

C/34. Casnedi, R., 1976b. Geological notes on the junction between the Haramosh–Nanga Parbat structure and the Karakoram Range. Rendiconti Accad. Accademy Nazionale Lincei 16, 631–633.

Key words: Structure, tectonics, Nanga Parbat, Haramosh, Karakoram.

C/35. Casnedi, R., 1976c. The ophiolites of the Indus suture line Dras and Astor zones-Kashmir. Ophioliti 1, 365-371.

The ophiolites of the Dras zone outcropping along the Suture between Indian and Eurasian continents are mostly made-up of lherzolite, gabbro and basalt. These are associated with Jurrasic-Cretaceous sedimentary rocks (jaspers-radiolarite-shales-brechias), with the northern fault covering (Deosai plateau) and southern tectonic overthrust of the Tethyan calcareous dolomitic Triassic series. Amphibolitic prasinitic formations influenced by the nanga Parbat Massif metamorphism and basic igneous masses developed near Astore on the western slope Deosai. They could represent the northern continuation of this Suture line. The ophiolitiferous series and the metabasites are briefly described, and hypotheses as to their origin are presented.
Key words: Ophiolites, Indus Suture, Astor, Kashmir.

C/36. Casnedi, R., 1979. Stratigraphic outline of the area between Karakorum and Hindu Kush with probable occurrence of Hercynian geosynclinal stage. Memoir Society Geolia Italia. 20, 277–287

Key words: Stratigraphy, structure, Hindukush, Karakoram.

C/37. Casnedi, R., 1981. Geological reconnaissance in the Ishkuman and Karambar valleys, northern Pakistan. Geological Bulletin, Punjab University 16, 66-70.

The formations crossed on a route travelled in the Ishkuman and Karambar valleys, along the profile of the Karakorum Geophysical project, are described. The section includes a plutonic core of granodioritic compositions surrounded by metamorphic rocks. In this body two batholiths can be identified, the northern one of which seems to constitute the axial batholith of the Karakorum. To the S of this structure there is development of metasedimentary and igneous rocks divided into two complexes; the greenstone complex with slates, phyllites, marbles, intrusives and middle-basic volcanics, and the clastic metasedimentary succession of turbiditic origin. To the N a thick sedimentary

sequence was observed, consisting of sandstones, limestones, dolomites, argillites, marls and conglomerates comprising terms from the Permian to the Cretaceous, never reported before.
Key words: Reconnaissance geology, granites, volcanics, low-grade metasediments, Ishkuman, Karambar.

C/38. Casnedi, R., 1983. Tentative interpretation of the geological structure of the Western Karakorum on the basic of surface and subsurface data at plate scale. Bollettino di Geofisica Teorica ed Applicata (Pamir-Himalaya Volume) 25, 365-373.

Key words: Structure, tectonics, Karakoram.

C/39. Casnedi, R., 1984. Geological Reconnaissance in the Ishkuman and Karambar valleys (Northern Pakistan). Atti Soc. Ital. Sci. Nat., 125, 132-138.

For further details consult Casnedi 1981.
Key words: Reconnaissance, granites, volcanics, low-grade metasediments, Ishkuman, Karambar.

C/40. Casnedi, R., Desio, A., Forcella, F., Nicoletti, M. & Petrucciani, C., 1978. Absolute age of some granitoid rocks between Hindu Raj and Gilgit River (Western Karakorum). Accadmia Nazionale dei Lincei, Series 8, 64, 204-210.

Key words: Granitoid, radiometric ages, Karakoram.

C/41. Casnedi, R. & Ebblin, C., 1977. Geological notes on the area between Astor and Skardu, Kashmir. Rendiconti Accademy Nazionale Lincei, Series 8, 61, 662-668.

Key words: Geology, Astor, Skardu.

C/42. Casnedi, R. & Mosna, S., 1979a. Upper Paleozoic and Mesozoic rocks in the Upper Karambar Valley (Pakistan-Afghanistan border). Revista Italian Paleontologia e Stratigrafia 85, 1-12.

Key words: Paleontology, Karambar valley, western Karakoram.

C/43. Casnedi, R. & Mosna, S., 1979b. Upper Palaeozoic and Mesozoic sedimentary rocks in the Karambar valley (Pakistan Afghan border). Revista Italiana di Palaeontologia Stratigraphia 85, 285-295.

Key words: Sedimentary, Paleozoic, Mesozoic, Karambar.

C/44. Casnedi, R. & Nicora, A., 1985. Short notes on the Shimshal valley geology (Western Karakorum–Pakistan). Rivista Italiana di Palaeontologia i Stratigrafia 90, 463–480.

Key words: Geology, Shimshal, Karakoram.

C/45. Cerveny, P.F., Johnson, N.M., Tahirkheli, R.A.K. & Bons, N.R., 1989. Tectonic and geomorphic implications of Siwalik Group heavy minerals, Potwar Plateau, Pakistan. In: Malinconico, L.L. & Lillie, R.J. (Eds.), Tectonics of the Western Himalayas. Geological Society of America Special Papers 232, 129-136.

Heavy mineral and paleocurreut direction data suggest that the ancestral Indus is an analog of the modern Indus River (Pakistan). During the past 18 m.y., the Indus has maintained a relatively stationary outlet position along the Himalayan Front. Sandstones from three sections of Siwalik strata have been sampled and their heavy mineral suites analyzed. These stratigraphic sections cover some 200 km in an east-west direction in the Potwar Plateau area. In the western and central Potwar Plateau sections, blue-green hornblende makes a conspicuous first appearance at 11 Ma, the boundary between the Chinji and Nagri Formations. Above this boundary, blue-green hornblende dominates the heavy mineral assemblage of Siwalik sand. In the Upper Siwalik beds the heavy mineral suite contains as much as 75 percent blue-green hornblende. Unroofing of the Kohistan Arc terrane is the most likely explanation for this detrital hornblende. In marked contrast, the eastern Potwar region does not show the same abundance of blue-green hornblende. Significantly, the modern river~ of the eastern Potwar do not carry abundant blue-green hornblende either; only the Indus River does. Paleocurrent measurements taken In the Chinji Village section near the center of the Potwar Plateau indicate a northwest-to-southeast flow direction, whereas those in the Trans-Indus 120 km west of Chinji Village indicate a northeast-to-southwest flow direction. These data indicate that the Siwalik sequence of northern Pakistan is configured as a large-scale alluvial fan with the ancestral Indus shifting course hack and forth across the Potwar Plateau region with a frequency of 10^4 to 10^5 yr/cycle. River sinuosity varied systematically from side to side of this fan, with minimum sinnosity attained along a north-south axis, As indicated by the absence of blue-green hornblende, the ancestral Indus did not reach the eastern Potwar Plateau (Kotal Kund area, 100 km east of Chinji) during the past 11 m.y.
Key words: Tectonics, geomorphology, heavy minerals, Potwar Plateau, Siwlaiks.

C/46. Cerveny, P.F., Naeser, C.W., Keleman, P.B., Lieberman, J.E. & Zeitler, P.K., 1989. Zircon fission-track ages from the Gasherbrum diorite, Karakoram Range, Northern Pakistan. Geology 17(11), 1044-1048.

The Gasherbrum Peaks, in the Himalaya of Pakistan, reach elevations of >8000 m. The relief between the peaks and the adjacent valley (Baltoro Glacier) is in excess of 3000 m. Eight samples of the Early Cretaceous Gasherbrum Diorite at elevations between 4880 and 7165 m on Gasherbrum IV were collected for fission-track dating. Zircon fission-track ages from the Gasherbrum Diorite vary from Early Cretaceous to middle Tertiary in age. There is no consistent pattern between age and elevation. The Cretaceous ages indicate that these rocks were never deeply buried, i.e., heated to temperatures in excess of 175°C, to reset the zircons during Cenozoic time. These results also indicate that the uplift of this part of the Himalaya has been either very rapid and recent, or very slow since Early Cretaceous time. This latter possibility is not consistent with the high relief at Gasherbrum and what is known about regional tectonics. Gasherbrum IV zircons, currently at ~4880 m, have never been at depths greater than 6 km, and less than 3 km of material has been removed from the top of the range by erosion since the Early Cretaceous. Rapid uplift has occurred very recently, and erosion rates have not been able to keep pace with this uplift.
Key words: Fission-track ages, diorite, Gasherbrum, Karakoram.

C/47. Cerveny, P.F., Naeser, N.D., Zeitler, P.K., Naeser, C.W. & Johnson, N.M., 1988. History and relief of the Himalaya during the past 18 million years: Evidence from fission-track ages of detrital zircons from sandstones of Siwalik Group. In: Kleinspehn, K.L. & Paola, C. (Eds.), New Perspectives in Basin Analysis. Springer-Verlag, Berlin, 43-61.

Fission-track dating of individual detrital zircon grains can be used to characterize both ancient and modern sedimentary provenance. Ages of zircons in the modern Indus River drainage system of northern Pakistan are controlled dominantly by uplift rates of the source rocks in the Himalaya. Young detrital zircons come from rapidly rising terrain, whereas old zircon ages imply slow or negligible uplift. Modern Indus River sands contain a distinctive population of young, 1 to 5 Ma, zircons that are derived from the Nanga Parbat-Haramosh Massif, an area of rapid uplift (5 m/10^3 yr). Sandstones of the Siwalik Group deposited by the ancestral Indus River over the past 18 million years contain zircons that are only 1 to 5 million years older than the depositional age of the sandstones. Therefore, young zircons have been a consistent component of Himalayan surface rocks for the past 18 million years. These ages imply that a series of uplifted blocks or "massifs," analogous to the contemporary Nanga Parbat area, have been continually present in the Himalaya since 18 Ma, and that over that time the elevation and relief of the Himalaya, on a broad scale, have been essentially constant.
Key words: Fission track ages, sandstone, siwaliks, Himalaya.

C/48. Cerveny, P.F., Tahirkheli, R.A.K., Johnson, N.M. & Bonis, N.R., 1986. Position and source area of the ancestral Indus River during the past 18 million years. Abstracts with Programs, Geological Society of America 18.

Key words: Indus River.

C/49. Chakravarti, D.K., 1935. On the generic reference of a doubtful Rynchorostrine bunomastodontid from Chinji in the Salt Range. Abstracts, Proceedings 22nd Indian Science Congress, 209-210.

Key words: Paleontology, siwaliks, Salt Range.

C/50. Chamberlain, C.P., Jan, M.Q. & Zeitler, P.K., 1989. A petrologic record of the collision between the Kohistan Island Arc and Indian Plate, northwest Himalaya. In: Malinconico, L.L. & Lillie, R.J. (Eds.), Tectonics of the Western Himalaya. Geological Society of America Special Paper 232, 23-32.

Pressure-temperature (P-T) paths observed in pelitic schists on either side of the Main Mantle Thrust in northern Pakistan record the dynamics of the collision between the Kohistan Island-Arc and Indian plate. Geothermometry studies, mineral reaction textures, and thermodynamic modeling of zoned garnets suggest that the rocks in the Kohistan Arc and the Nanga Parbat-Haramosh Massif experienced different pressure-temperature histories as a result of imbrication of these two terranes during thrusting. Rocks in the Kohistan Arc followed decreasing pressure-temperature paths, with early garnet growth occurring at high pressures (9.5 kbar) and later garnet growth at lower pressures (8.5 kbar). Conversely, rocks in the Nanga Parbat-Haramosh Massif record an increasing P-T path history. The early P-T history within the massif was at low pressures (4.0 kbar) and low temperatures (450"C). Later, both pressure and temperature increased to a maximum of 7.5 kbar and 580oC. The contrasting P-T paths observed within these two terranes provide evidence for overthrusting of the Kohistan Arc over the Nanga Parbat-Haramosh Massif along the Main Mantle Thrust.
Key words: Petrology, collision, Kohistan Island Arc, Indian Plate, Himalaya.

C/51. Chamberlain, C.P., Kraw, D., Koons, P.O., Winslow, D. & Zeitler, P.K., 1993. Coupled compression and extension in the NW Himalaya. Proceedings, Conference on Late Orogenic Extension in Mountain Belts (Montpellier, France), BGRM Document no. 219, p.42.

Further information is not available to the authors.
Key words: Tectonics, structure, Himalaya.

C/52. Chamberlain, C.P. & Zeitler, P.K., 1996. Assembly of the crystalline terranes of the northwestern Himalaya and Karakoram, northwestern Pakistan. In: Yin, A. & Harrison M. (Eds.), The Tectonic Evolution of Asia. Cambridge University Press, 138-148.

In northern Pakistan, the collision of three terranes proceeded sequentially, with an initial collision of the Asian plate with Kohistan at 70-100 Ma (Coward et al., 1986; Treloar et al., 1989a), followed by a later collision of Kohistan with the Indian plate at about 50 Ma (Klootwijk et al., 1991). The P-T-t data show that the assembly of these crystalline terranes was a complicated process. The collision of the Asian plate and Kohistan began with initial tectonic thickening and high-pressure, high-temperature metamorphism, followed by post-metamorphic southward-directed thrusting as rocks of the Asian plate were thrust over Kohistan. The timing of these events is poorly constrained, but they must have occurred before 37 Ma (Searle, 1991) and, most likely, during the early stages of collision in the middle to late Cretaceous.

The timing of events related to the collision between the Asian Plate/Kohistan terranes and the Indian plate is much bettered constrained. We know from U-Pb ages of syn-metamorphic granites (Zeitler and Chamberlain, 1991; Smith, 1993;) and Nd-Sm ages of eclogites (Tonarini et al., 1993) that at about 50 Ma the northern margin of the Indian plate underwent initial tectonic thickening and relatively high pressure metamorphism. Following metamorphism, in the interval from 45 Ma to 25 Ma the northern margin of the Indian plate underwent a period of rapid exhumation and uplift. We (Chamberlain et al., 1991) and others (Treloar, Rex, and Williams, 1991) have tentatively suggested that the rapid cooling was a result of extension of Kohistan slid northward along normal faults.
By 20 Ma, movement along the Main Mantle Thrust had ceased, and the Indian plate and Kohistan were locked into place, with much northern Pakistan subsequently undergoing simple post-orogenic uplift and erosion. However, we have discovered that some areas of northern Pakistan are presently undergoing extraordinarily rapid exhumation: the Nanga Parbat-Haramosh massif has experienced long-term denudation rates on the order of 1-km/m.y. over the past 10 m.y., and rates as high as 5-km/m.y. over the past 3m.y. During the recent exhumation, Indian-plate gneisses have undergone granulite-grade metamorphism, intrusion by abundant leucogranites, and intense hydrothermal activity. The cause of this most recent phase of active Himalayan tectonism is unknown.
Key words: Tectonics, continental collision, Himalaya, Karakoram.

C/53. Chamberlain, C.P., Zeitler, P.K., Barnett, D.E., Winslow, D., Poulson, S.R., Leahy, T. & Hammer, J.E., 1995. Active hydrothermal systems during the Recent uplift of Nanga Parbat, Pakistan Himalaya. Journal of Geophysical Research 100, 439-453.

During the last 10 m.y., the Nanga Parbat Haramosh Massif in the northwestern Himalaya has been intruded by granitic magmas, has undergone high-grade metamorphism and anatexis, and has been rapidly uplifted and denuded. As part of an ongoing project to understand the relationship between tectonism and petrologic processes, we have undertaken an isotopic study of the massif to determine the importance of hydrothermal activity during this recent metamorphism. Our studies show that both meteoric and magmatic hydrothermal systems have been active over the last 10 m.y. We suggest that the rapid uplift of the massif created a dual hydrothermal system, consisting of a near-surface flow system dominated by meteoric water and a flow regime at deeper levels dominated by magmatic/metamorphic volatiles. Meteoric fluids derived from glaciers near the summit of Nanga Parbat were driven deep into the massif along the transpressional faults causing δ18O and δD depletions in the gneisses and marked oxygen isotopic disequilibrium between mineral pairs from the fault zones. The discharge of these meteoric fluids occurs in active hot springs that are found along the steep faults that border the massif. At deeper levels within the massif, infiltration of low δ18O magmatic fluids caused δ18O depletions in the gneisses within the migmatite zone. These low δ18O fluids were derived from the young (<4 Ma), relatively low δ18O granites (~8‰c) that are found within the core of the massif. Geochronological evidence in the form of fission track and 40Ar/39Ar cooling ages and U/Pb ages on accessory minerals from the granites and gneisses provide a constraint on the timing of fluid flow in the surface outcrops we examined. Fluid infiltration in the migmatite zone rocks located along the Tato traverse was coeval with metamorphism, granite emplacement, and rapid denudation, in the interval 0.8–3.3 Ma. Finally, we infer from the presence of active hot springs that significant flow systems continue to be active at depth within the central portion of the Nanga Parbat-Haramosh Massif.
Key words: NPHM, metamorphism, hydrothermal system, Himalaya.

C/54. Chamberlain, C.P., Zeitler, P.K. & Erickson, E., 1991. Constraints on the tectonic evolution of the northwestern Himalaya from geochronologic and petrologic studies of Babusar Pass, Pakistan. Journal of Geology 99, 829-849.

Key words: Tectonic evolution, geochronology, petrology, Babusar, Himalaya.

C/55. Chamberlain, C.P., Zeitler, P.K. & Jan, M.Q., 1986. Pressure-temperature-time paths in the Nanga Parbat massif: Constraints on the tectonic development of northwest Himalayas. Abstracts with Programs, Geological Society of America 18, p.561.

Consult the following account for further details.
Key words: Kohistan island arc, Nanga Parbat-Haramosh Massif, P-T-t paths.

C/56. Chamberlain, C.P., Zeitler, P.K. & Jan, M.Q., 1989. The dynamics of a crustal suture in the Pakistan Himalaya. Journal of Metamorphic Geology 7, 135-149.

The pressure-temperature and temperature-time paths derived for rocks in the Kohistan arc and adjacent Nanga Parbat-Haramosh massif record the dynamics of the collision between the island arc and the Indian plate. Studies of P-T-t paths show that the Kohistan arc was thrust over the Nanga Parbat-Haramosh massif at least 25 Ma ago, but not more than 30–35 Ma ago. Rocks in the Kohistan arc followed decreasing pressure paths, with the early metamorphism beginning at high pressures (9.5 kbar) and later metamorphism occurring at 8.0 kbar. In contrast, rocks in the Nanga Parbat-Haramosh massif (Indian plate) experienced increasing pressure and temperature paths. Prior to thrusting, the massif was at low pressures (4.0 kbar) and low temperatures (450°c). Later, the pressure and temperature increased to 8 kbar and 580°c. The authors interpret the convergence (to approximately the same pressure and temperature) of the P-T paths in the two terranes as being the result of thrusting and thermal equilibration between the thrust sheets. $^{40}Ar/^{39}Ar$ cooling ages of hornblendes and other geochronological data suggest that the time of peak metamorphism and hence the completion of thickening was approximately 30–35 Ma ago. Temperature-time paths show that after thrusting, during the period 25–10 Ma, the Kohistan arc and Nanga Parbat-Haramosh massif were uplifted at similar rates (0.5 km Ma). However, in the past 10 Ma the Nanga Parbat-Haramosh massif has been uplifted more rapidly than the adjacent Kohistan arc. Rapid uplift has been accommodated by late faults along the edge of the massif.
Keywords: P-T-t paths, Kohistan island arc, Nanga Parbat-Haramosh massif.

C/57. Chamberlain, C.P., Zeitler, P.K. & Winslow, D., 1992. Metamorphic hydrothermal systems associated with the rapid denudation of the Pakistan Himalaya. Abstracts with Programs, Geological Society of America 24, A112.

Keywords: Metamorphic, hydrothermal, denudation, Himalaya.

C/58. Chambers, A., 1991. The effect of stratigraphic variation on structural style: examples from the western limb of the Hazara-Kashmir Syntaxis, N. Pakistan. Abstract Volume, 6th Himalaya-Karakoram-Tibet workshop, Auris, France, 27-28.

An attempt is made to integrate stratigraphic and structural data in order to generate an evolutionary model of the Lesser Himalaya and Sub Himalaya of N. Pakistan. Field outcrops in the Potwar Plateau and Murree Hills and well data and seismic profiles from the Potwar Plateau constrain the stratigraphy. The regional stratigraphic variations are telescope by Himalayan shorting, which exceeds 200-km in the external zones of Pakistani Himalaya. The true regional stratigraphic is evident only after the restoration of Himalayan structures.

Three stratigraphic cover series separated by major unconformities of base Permian and base Paleocene age is represented in the Potwar region. The crystalline basement is overlain by a series of Eocambrian-Cambrian age that comprises the basal Salt Range Formation and the Jhelum Group clastics and carbonates. The Permian-Cretaceous series represent an essentially shallow marine shelf environment, although the cycles of sandstone, carbonate and occasional laterite indicate transgressive pulses throughout this period. Flexure and erosion is associate with the widespread basal Paleocene unconformity. Erosion increases towards the southeast such that the Paleocene overlies the Cambrian in the eastern Salt Range whilst in the north the unconformity is negligible. Shelf conditions were reestablished in the lower Tertiary before molasse deposition commenced in Miocene times. The thick, but poorly-consolidated, alternating sands and shales of the Rawalpindi and Siwalik Groups form the youngest stratigraphic series.

These stratigraphic series have distinct rheological properties. The weak evaporitic Salt Range Formation forms a major basement-cover decollement throughout the Potwar Plateau. The Permian-lower Tertiary carbonate carapace acts as a rheologically competent unit that deforms brittly. Where it is thick the carapace forms large thrust sheets. However, the action of the Paleocene unconformity reduces the carbonate carapace to approximately 100m thickness, effectively juxtaposing the Eocambrian salt and the Tertiary molasse. The molasse behaves incompetently and collapses to form a series of pop-ups, boxfolds and breaching thrusts above the salt decollement. The western

and eastern Potwar therefore show different structural styles, the former being controlled by the carbonate carapace and the latter by the molasse.
During the south-southeastward propagation of the Pakistani thrust wedge two to major detachments have been exploited, the Hazara Detachment (or MBT) and the Salt Range Detachment (or MFT). The strongly deformed strata of the Murree Hills lie in the hangingwall of the Hazara Detachment. This thrust has been carried more than 80-km across the molasse basin, a process assisted by the presence of talcs and evaporites in the Hazara Slate Formation. Further displacement occurred by duplexing in the footwall of the Hazara Detachement, the floorthrust following the basement-cover contact until the Salt Range Formation was encountered. This decollement is still active today.
The timing of deformation can be dated using palaeomagnetic reversal methods in the molasse sediments of the Potwar Plateau. Dating of events in the Murree Hills is more loosely constrained by metamorphic cooling ages in the internal zones and thrust interference with the southwest-directed Kashmir thrust wedge.
Keywords: Stratigraphy, structure, Hazara Kashmir syntaxis, Himalaya.

C/59. Chambers, A. & Izatt, C., 1992. The evolution of the external Himalayas, N Pakistan: The Galiat and Eastern Potwar, Punjab. Abstract Volume, 7th Himalaya-Karakoram Workshop, Department of Earth Sciences, Oxford University, England, 13.

During the last 10 Ma, the Miocene-Recent molasse series of the external Pakistan Himalayas and its sedimentary substratum has been shortened by over 200-km. This progressive shortening, which was concurrent with the rapid subsidence in the Potwar Basin, can be divided into four phases:
The imbrication of the hangingwall to the Hazara Detachment (or MBT).
Ramping of the MBT from the basement-cover contact (Hazara Formation) to an intramolasse (Murree Formation) and translation of the MBT thrust wedge across the molasse basin by over 80-km.
Collapse of the MBT footwall ramp to produce a duplex at depth. Initially displacement was transferred from the floorthrust within the Hazara Formation to the foreland-wedge MBT. As the duplex propagated southward the roofthrust became hinterland-vergent due to the loss of the competent MBT overburden. This is expressed by backfolding in the Hill Ranges and Northern Potwar, the duplex tip being marked by a frontal monocline.
Deformation of the Southern Potwar in the hangingwall of a salt detachment, the Potwar-Salt Range Detachment (SRT). An abrupt change in structural style is observed as the Himalayan sole thrust encounters the Hazara Formation-Salt Range Formation facies change from intertidal clastics to evaporites.
In this presentation the role of inherited pre-Himalayan stratigraphic variations upon the structural style of Himalayan deformation is emphasised-with particular reference to the evolution of the Potwar Plateau during the Pliocene. A combination of field and seismic data is used to demonstrate the relative control exerted by the three major lithostratigraphic series (Eocambrian evaporites series, the Cambrian-Eocene pre-orogenic "shell" series and the syn-orogenic molasse series) upon structural style in the Potwar Plateau.
It is concluded that, in addition to halotectonics and basement topography, the presence or absence of the Cambrian-Eocene carbonate carapace is paramount in controlling structural style in the Potwar Plateau.
Keywords: Sedimentary, Hazara, Potwar, Himalaya.

C/60. Chandra, U., 1976. Fault plane solution and tectonic implications of the Pattan Pakistan earth quake of December 28, 1974. Tectonophysics 28, T1-T24.

A large destructive earthquake occurred on December 28, 1974 on the western bank of the Indus River near the village of Pattan. The earthquake reportedly killed 5,300 persons, injured 17,000 and left 60,000 people homeless. A seismicity map of the region is presented for the period January, 1963, to March, 1974 on a Mercator projection. Two main linear trends are recognized on the epicenter map. The northwest trend, beginning at 32.3°N, 76.6°E terminates at the southwest alignment of epicenters beginning at 36.0°N, 73.5°E and ending at 33.0°N, 71.0°E. The Pattan earthquake occurred near the junction of the two linear trends. A fault-plane solution for this earthquake has been determined from an analysis of teleseismic P-wave first-motion and S-wave polarization data. The strike and dip of the two nodal planes are N65°E, 68°SE and N50°E, 23°NW, respectively. The solution is compatible with and indicates underthrusting of the Indian plate in this region in the NNW direction along a thrust zone striking northeast.
Keywords: Earthquakes, hazards, tectonics, Pattan, Himalaya.

C/61. Chandra, U., 1978. Seismicity, earthquake mechanisms and tectonics along the Himalayan mountain range and vicinity. Physics of the Earth and Planetary Interiors 16, 109-131.

The historical as well as recent seismicity data and the focal mechanism solutions for 48 earthquakes determined from the observations of world-wide standardized stations network (WWSSN) records, were used to investigate the tectonics of the Himalayan mountain system and vicinity. Seismicity maps of the region showing large earthquakes (magnitude 7.0 and above, and damaging earthquakes that caused fatalities) from the earliest time through 1976, and instrumentally located earthquakes for the period January 1963–March 1974 are presented. Eleven of these earthquakes are estimated to be of magnitude 8.0 and above. The earthquake epicenters generally follow the trend of the mountains with greatest concentrations of seismic activity occurring along the Hindu Kush and Pamir mountain ranges, and near the Quetta, Kashmir and Assam syntaxes. Throughout Tibet, however, the distribution of epicenters is rather irregular and no clear trends are apparent. Two aseismic lineaments, one west of the Sulaiman Range and the other in the Assam Valley, are identified. Also, seismic activity in the vicinity of the Counter Thrust (Indus-Tsangpo suture zone) is rather small. Based on the identification of these aseismic lineaments and from a consideration of the geometry and kinematics of the continental collision model, a hypothesis for the origin of the Himalayan syntaxes is presented.
Focal mechanism solutions confirm northward underthrusting of the Indian Plate along the Main Boundary Thrust and Main Central Thrust system, and eastward underthrusting along the Burmese Arc. Fault-plane solutions indicate left-lateral motion along the Kirthar-Sulaiman Range, right-lateral motion along the Karakoram Fault, left-lateral motion along the eastern extremity of the Himalayan flank of the Assam syntaxis, and right-lateral motion along the northern part of the Naga Hill flank of the syntaxis. These observations are in agreement with the expected sense of lateral (parallel to the collision boundary) mass movement for the continental collision model. Focal mechanism solutions for three earthquakes in east Afghanistan show NW-SE compression. A near-vertical orientation of the axes of tension in the solutions for two earthquakes in the Hindu Kush region is consistent with the sinking of a remnant slab of oceanic lithospere. Normal fault-plane solutions showing NW-SE extension for two events near Gatok, Tibet, and for the recent Kinnaur earthquake are interpreted to indicate a possible subsurface northern continuation of the Aravalli Range of Peninsular India, and its involvement in the tectonic framework of the region. Focal mechanism solutions of three earthquakes near the southern edge of the Shillong Plateau suggest block uplift of the plateau as a horst along the Dauki Fault. The solution for one earthquake near the Yunnan Graben shows NE-SW extension.
Keywords: Seismology, earthquakes, tectonics, Himalaya.

C/62. Charles, C., 1981. Hommes et glaciers de la vallee de la Hunza (Karakorum-Pakistan). Revue de Geographie Alpine 69, 607-615.

Hunza valley sensu lato is the abode of a large number of glaciers, including some of the longest ones outside the polar region. Baltoro, Hispar, Minapin, Passu, are only some. This paper describes many of the glaciers of Hunza Karakoram.
Keywords: Glaciers, Hunza, Karakoram.

C/63. Charles, C., 1985. La vallee de Hunza, Karakorum-Pakistan: Milieu naturale, a menagement traditionnel et mutations recentes de une vallee aride du Nord-Ouest de l’ensemble Himalayen. Ph.D. Thesis, Universite de Grenoble.

Keywords: Geography, glaciers, Hunza, Karakoram.

C/64. Chatelian, J.L., Roecker, S.W., Hatzfeld, D. & Molnar, P., 1980. Microearthquake seismicity and fault plain solutions in the Hindu Kush region and their tectonic implications. Journal of Geophysical Research 85, 1365-1387.

The nature of the Hindu Kush intermediate seismic zone was studied in two microearthquake investigations in 1976 and 1977. By testing several sources of uncertainty the precision of about 600 earthquake locations was estimated to be about 5 km in epicenter and 10 km in depth. Projections of the earthquake locations from several perspectives reveal several regions of aseismicity as well as a highly contorted nature of the active regions. Very little seismicity was recorded in the crust from 0- to 70-km depth. The part of the zone southwest of about 37°N, 71.5°E and shallower than about l60 km is broad and seems to dip north at progressively steeper angles from west to east. Fault plane solutions for this region do not reveal a simple consistent pattern. This region is separated from another active region to the northeast by a curved gap that is nearly 50 km wide. Northeast of this gap the zone dips to the southeast. In the western portion there is an aseismic region around 160-km depth that separates the contorted shallower zone from a narrow (15–20 km wide), consistently steep, deeper zone. As in island arcs, the fault plane solutions for the deeper events show T axes generally lying within the plane of seismicity and P axes perpendicular to the plane. In contrast to island arcs the T axes in general are not parallel to the dip direction, and there seems to be greater variation in the orientation of these axes. The entire western zone plunges to the west at about 20°, and most of the T axes plunge steeply to the west. In detail, the earthquakes tend to occur in clusters that leave aseismic gaps between the clusters. There is a distinct gap of about 15-km width near 70.7°E. This gap seems to separate events with fault planes solutions that in the west have westward plunging T axes and in the east have eastward or vertically plunging T axes. Although many of these features were not detected in previous studies of this region, the data from those studies are consistent with the dips, changes in dip, gaps, and breadth of the seismic zone. Both the variations in dip and breadth of the active zones and, for one gap, the difference in fault plane solutions of earthquakes on either side of it, make the role of the gaps as boundaries clear and suggest their long-term existence. We infer that the configuration of the Hindu Kush seismic zone could possibly be the result of the subduction of oceanic lithosphere from two separate, small basins in opposite directions. The age of the subducted lithosphere is probably greater than 70 m.y., and subduction probably has occurred over a relatively short duration. The rate of subduction probably has been between 20 mm/yr and 48 mm/yr. Correlations of seismic trends with surficial features suggest that in the south the Hindu Kush suture zone lies along or somewhere between the Panjer and Kunar faults and that in the north the Pamir suture zone lies near the Darvaz-Karakul fault. Finally, it seems that the protrusion of India into Eurasia has been a major factor in developing the present configuration of the zone.
Keywords: Seismology, earthquakes, tectonics, Hindukush.

C/65. Chaudhry, A.G., 1970. Geology of Khagram area, Dir district. M.Sc. Thesis, Punjab University, Lahore, 84p.

Keywords: Geology, petrology, Dir.

C/66. Chaudhry, J.A. & Latif, S., 1981. Geology and petrology of Malam Jaba -Yakh Tangai area, District Swat, NWFP. M.Sc. Thesis, Punjab University, Lahore.

Keywords: Petrology, Malam Jaba, Swat.

C/67. Chaudhry, J.I., 1985-87. Stratigraphic Studies of Area around Dhamtaur-Baghseri District, Abbottabad. M.Sc. Thesis, Punjab University, Lahore, 96p.

The present report is a geological study of nearly 30-miles^2 (Dhamtaur and Baghseri area) in southeastern direction of Abbottabad. The study includes a geological map on the scale 1:12500 (1cm=125m) and the stratigraphy of the area, from Precambrian to Upper Paleocene (Thanetian). The geological history of the Hazara Trough and the environmental deposition of the formation are reviewed. Structurally, the area is very complicated within which a generally complex folding and faulting predominates.
Keywords: Stratigraphy, structure, sedimentology, Abbottabad.

C/68. Chaudhry, M.A., 1981-83. Geological mapping with special studies on discontinuities in rocks and their effect on the rockmass strength at Kalabagh Damsite. M.Sc. Thesis, Punjab University, Lahore, 30p.

Keywords: Structure, geotechnical, mapping, Kalabagh damsite.

C/69. Chaudhry, M.A., Farooq, I. & Arshad, M., 1977. Mineralogy and petrology of Shangla Par area, District Swat, NWFP, Pakistan. M.Sc. Thesis, Punjab University, Lahore.

Keywords: Mineralogy, petrology, ultramafics, Shangla, Swat.

C/70. Chaudhry, M.I.R., 1999. Electrical resistivity survey for ground water exploration in Zulmkot Area, District Malakand, N.W.F.P., Pakistan. M.Sc. Thesis, Punjab University, Lahore, 160p.

Keywords: Geophysics, electric resistivity, groundwater, Malakand.

C/71. Chaudhary, M.M., 1986. Nanga Parbat: A study of geographic influence. Geological Bulletin, Punjab University 21, 95-103.

Nanga Parbat is under active investigations in the field of geology. On the other hand there does not exits any notable geographical investigation to elaborate the geographical factors of the area. Here an attempt has been made to elaborate geographical factors at work and their associations. Here a probe has been made to ascertain the commanding position of Nanga Parbat and its influence in shaping the regional geomorphology and the resultant topography.
Key words: Geography, Nanga Parbat, Himalaya.

C/72. Chaudhry, M.N., 1982. Lead and zinc mineralization associated with Lahor granite, Kohistan. The Pakistan Metallurgist 3.

Keywords: Granite, Lead-zinc mineralization, Besham, Kohistan.

C/73. Chaudhry, M.N., Ahmed, R., Mahmood, T. & Ghazanfar, M., 1992. A reconnaissance microfacies study of Kawagarh Formation near Giah, Abbottabad-Nathiagali road, Hazara, Pakistan. Abstracts, First South Asia Geological Congress, Islamabad, 57-58.

Keywords: Reconnaissance, microfacies, Kawagarh Formation, Nathiagali, Abbottabad .

C/74. Chaudhry, M.N. & Ahsan, N., 1999a. Reservoir potential of Datta Formation Hazara Basin, Pakistan. Pakistan Journal of Hydrocarbon Research 11, 1-13.

Keywords: Reservoir potential, hydrocarbons, Datta Formation, Hazara.

C/75. Chaudhry, M.N. & Ahsan, N., 1999b. Sedimentological constraints on India-Asia collision. Abstract Volume, 14th Himalayan-Karakoram-Tibet International Workshop, Terra Nostra 99.

Keywords: Sedimentology, Asia, India, Collision.

C/76. Chaudhry, M.N., Ahsan, N. & Ahmed, F., 2001. Petrography and environment of deposition of Lumshiwal Formation, Karlan Bazar, Nathiagali-Abbottabad Road, Hazara basin, Pakistan. Abstracts, 4th Pakistan Geological Congress, Islamabad, 25-26.

The studied section of the Lumshiwal Formation (Shah, 1977) is located near Karlan Bazar. It is composed of quartz arenites that are cemented by quartz, glauconite, clay, iron oxides and calcite. The amount of cements and their proportions to one or other vary considerably. These arenites are generally off-white, medium grey, yellowish grey to greenish grey in colour.
The quartz is the main detrital constituent of the Lumshiwal Formation (Chaudhry et al., 1998). The arenites are compositionally mature and texturally sub mature to super mature. The maximum development of glauconite is in the middle and upper part of the formation. **i** ne glauconite appears to have developed from clay therefore glauconite rich arenites might have initially been deposited as wackes (Ahsan and Chaudhry, 1999).
The grains of tourmaline, zircon and rutile within the arenites indicate a granitic/gneissic composition of the source rock. Microcrystalline quartz indicates derivation from the textured siliceous rocks. The heavy minerals such as tourmaline, sphene, epidote and zircon also occur as inclusions and their occurrence is restricted. The suite of heavy minerals indicates the S-type granitic or gneissic provenance. The other common accessory minerals are magnetite, haematite and limonite.
The formation contains belemnites, brachiopods, pelecypodes and rare ammonites. This formation overlies the Chichali Formation, which was deposited in reducing conditions (Chaudhry et al., 1998). The lower contact of the Lumshiwal Formation is transitional. The Lumshiwal Formation was deposited in marine subtidal conditions. The presence of relict haematite and films of pyrolusite strongly suggest halmyrolysis in the presence of 02 and CO_2. The evidence of progressive deepening in the upper part of the Lumshiwal Formation resulted in the deposition of the pelagic shelf sea, Kawagarh Formation (Ahsan and Chaudhry, 1998). The upper contact of the formation with the Kawagarh Formation is transitional.
Key words: Sedimentology, Lumshiwal Formation, Abbottabad, Hazara basin.

C/77. Chaudhry, M.N., Ahsan, N., Ahmad, N. & Ahmed, F., 2000. Petrography of Lumshiwal Formation, Karlan Bazar, Nathiagali-Abbottabad Road, Hazara Basin, Pakistan. Pakistan Journal of Geology 12 & 13, 1-12.

Consult the following account for further details.
Keywords: Petrography, Lumshiwal Formation, Abbottabad, Hazara basin.

C/78. Chaudhry, M.N., Ahsan, N., Chaudhary, M.M. & Gondal, M.M.I., 2001a. Chilas sand--fine aggregate for Bhasha Dam. Abstracts, 4th Pakistan Geological Congress, Islamabad, 42-43.

Bhasha Dam with a rated hydroelectric potential of 4500 MW and a storage capacity of millions of acre feet of water is proposed to be build near Bhasha about 40 km downstream of Chilas. This dam is very important for national economy since it will cater the needs of water and power requirements of the country.
Huge amount of coarse aggregate is available in the area. However, there is no mineable fine aggregate deposit around the site proposed for the dam. Our studies show that the nearest source of fine aggregate for the proposed Bhasha Dam is Chilas sand deposit. It was deposited on the Chilas norites. There is no interbedded component of glacial deposits. These sands are overlain by a thick sequence of well-rounded Indus gravel (Chaudhry et al., 1998) which in turn are overlain, at places, by glacial till. The beds of this deposit are nearly horizontal or gently dipping towards the Indus River and contain associated oversized material.
The coarse aggregate is composed of amphibolites (0.4% to 5.8%), diorite (8.5% to 41.2%), dunite (0-2. 1%), leucocratic fine-grained S-type granite (1.9% to 8. 1%), S-type granite mylonite (3.3% to 18.9%), pyroxenite (0-1.17%), greenstone (0-3.6%), norites (12.1% to 19.2%), S-type microgranite (14.7% to 35.6%) and vein quartz (0-1.2%).
The granite mylonite fraction of coarse aggregate is potentially deleterious and may cause Alkali Silica Reaction.
The sand component of this deposit is composed of diorite/tonalite/amphibolite (0.5% to 2.5%), dolerite (0.3% to 0.9%), granite/granitoids (5.8% to 36.5%), jasper* (0.2% to 0.3%), limestone (0-0.6%) schist/gneiss (8.6% to 42.7%), quartzite/polygrain quartz (2.7% to 5.2%), biotite/vermiculite (1.0% to 8.0%), epidote (0 to 2.1%), feldspar (3.8% to 8.7%), garnet (0 to 1.1%). These sands possess minor reactive rock fragments. However, a peculiar problem of Chilas sand is the presence of vermiculite that may expand in the cement concrete. The role of vermiculite as a deleterious constituent in the concrete is still debated. However, our observations of civil structures and rock exposures indicate that concrete structures subjected to hydraulic conditions and containing vermiculite may show expansion.

The engineering properties (BS.8 12, 1965) of Chilas sand are fairly good. It can be quarried and sieved to meet the desired gradation. However, some horizons are very fine grained but their gradation can be improved by adding manufactured fine aggregate. The mechanical and physical properties of the Chilas sand are comparable with Lawrencepur sand (Chaudhry et al., 1999), Ravi and Chenab sands (Ahsan et al., 1999) and Maira sand (Ahsan et al., 2000). The compressive strength of mortars is within the limits specified by CP-110.
Key words: Building material, aggregate, Bhasha dam, Chilas.

C/79. Chaudhry, M.N., Ahsan, N., Chaudhary, M.M. & Gondal, M.M.I., 2001b. Petrographic evaluation of Jalipur mollase as contruction raw material. Abstracts, 4th Pakistan Geological Congress, Islamabad, 60-61.

The Jalipur valley fill is composed of glacial tillites mollassic sediments. The deposit is exposed along Karakoram Highway upstream of Chilas. It is a huge deposit with millions of cubic metres of reserves. The Jalipur mollase is older than 0.78 Ma but younger than 2 Ma (Oslon, 1982; Shroder, 1993). The lower tillite unit which is overlain by Jalipur mollase is indurated. The Jalipur mollase itself is indurated, folded and faulted. The mollase unit is overlain by younger tills. The Jalipur unit occurs only in valley sides and floor. Detailed petrographic studies of coarse as well as fine fraction of Jalipur unit clearly shows that no contribution was made to the Jalipur mollase by the Nanga Parbat gneisses. This indicates the fact that the Nanga Parbat —Haramosh massif was not uplifted at the time the Jalipur mollase was being deposited. This mollase had derived its components from Kohistan Island Arc. It represents a warm period during Shanoz Glaciation period (Shroder, 1993). Its thickness is more than 150m.
The Jalipur mollase was sampled near Jalipur and coarse and fine aggregates were evaluated petrographically. The mollase is cemented mainly by calcite.
The coarse aggregate was sieved through ASTM sieves 2 to No. 4. The retain of each sieve was analysed for rock types. The mollase is composed of amphibolite, diorite, granite, granite mylonite, mylonite, schist, vein quartz, tonalite, slate, quartzite, greenstone, rhyolite and siltstone (wacke). The percentage of rock types is given in Table 1.
The fine aggregate of Jalipur mollase was sieved through sieves of ASTM. The retain of sieve No. 8, 16, 30, 50 and 100 were analyzed under binocular microscope. It is composed of granite/granodiorite (1.1% to 24.6%), diorite/tonalite/amphibolite (0-32.8%), quartzite (8.1% to 21.8%), phyllite/slate (7.2% to 20.4%), greywacke group (0-0.4%), chert (0-0.8%), quartz mica schist (4.60/o to 8.50/o) and schist (0-7.1%). The mineral grains include quartz/polygrain quartz (22.1% to 53.6%), feldspar (4.4% to 8.3%) and amphibole (0.9% to 3.7%). The mineral grains include quartz/polygrain quartz (22.1% to 53.6%), feldspar (4.4% to 8.3%) and amphibole (0.9% to 3.7%). Biotite, muscovite, epidote, magnetite, garnet, tourmaline and zircon are the minor constituents.
The Jalipur coarse as well as fine aggregate contains unacceptable quantities of potentially deleterious reactive phases with Alkali Silica Reaction Potential if used in concrete with OPC. These phases are slate/phyllite, chert and greywacke. These aggregates may be used with low alkali cement or slag cement after testing. The aggregates may also be used with cement-pozzolana, cement-fly ash or cement-silica fume blendes after testing.
Key words: Petrography, Jalipur Mollase, Kohistan.

C/80. Chaudhry, M.N. Ahsan, N. & Ghazanfar, M., 1998. A preliminary account of sedimentology of Hazara basin from Jurassic to Eocene. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 41-43.

The Mesozoic to Eocene Hazara Basin dominated by shelf carbonates is characterised by a distinct package of sediments punctuated by a number of diastems, hiatus and unconformities. The environment of deposition vary from supratidal to shelf edge (250m) and from open shelf to restricted circulation anoxic conditions as a consequence of plate movement. The average)Rhified rates of sedimentation vary from 0. 96mm to 83.30mm per 1000 years.
During upper Hettangian the Hazara landmass changed into a marine basin with the development of a transgressive shore line with the deposition of Datta Formation which overlies either Upper Proterozoic Hazara Formation or Cambrian Hazira Formation.
It was deposited during open marine, lower to upper shoreface, lagoonal to subareal regimes (Chaudhry et al., 1997; Chaudhry et al., 1996; Chaudhry et al., 1995). It is composed of lenses, sheets and layers of poorly sorted medium to coarse grained quartz arenites with rare grit and interlayers of carbonaceous shales, silty shales, marls and oolitic to

pelletoidal limestones. The average lithified rates of sedimentation were approximately 2mm/1000 years. Provenance studies show derivation from an igneous metamorphic sialic Indian plate. Source tong to the south.

The Samanasuk Formation represents an epicontinental intertidal environment with upper shelf ooidic-pelletoidat shoals deposited from Toarcian to Callovian. Cross bedding and burrows are frequent. The sediment are composed of ooidic-pelletoidal wackestones to grainstones, bioclastic limestones and dolomitic horizons. Rare caicirudites also occur. The oyster topped beds and hard grounds represent slow rates of deposition and subareal exposures. The average lithified rate of deposition was about 6mm/1000 years.

At the close of Callovian restricted anoxic environment prevailed and condensed pyrite rich and belemnite-bearing black shale-siltstone sequence represented by Chichali Formation of Oxfordian to Kimmeridgian age was deposited. The lithified sedimentation rates were about, 2.3mm/1000 years.

Strongly reducing conditions changed to mildly reducing conditions with better circulation in Tithonian during which the Lumshiwal Formation was deposited. It is mainly composed of glauconitic quartz arenites (Chaudhry et al., 1997, Chaudhry et al., 1994) with submarine hard grounds. These sediments are generally cemented with quartz, clay, Iron oxides or glauconite. The ubiquitous glauconite indicates slow rates of deposition in mildly reducing environments. The suite of heavy minerals once again indicates sialic igneous metamorphic provenance. The average lithified rates of sedimentation were about 0.96mm/1000 years.

In Cenomanian, the Hazara basin deepened (upto a maximum of 250m as shown by the presence of oligostigena (Ahsan et al., 1993, Ahsan et al. 1994, Chaudhry et al. 1992) during a major global transgression with deposition of Kawagarh Formation composed of. pelagic mudstones, wackestones and packstones. The upper beds (Maastrichtian in age) of Kawagarh Formation were exposed during a widespread regression due to initiate contact of the Indian with the Kohistan Arc at 67±2 Ma prior to main India-Eurasia collision (Bard et al., 1979) at 50-55 ma. The average lithified rates of sedimentation of Kawagarh Formation have been estimated as 9mm/l000 years (Chaudhry et al., 1994).

The subareal exposure under subtropical conditions reworked the Maastrichtian sediments of the Kawagarh Formation into fire clay, pisolitic bauxite and laterite. The rate of accumulation of these residual sediments of Hangu Formation are about 1.77mm/1000 years.

The crustal bulge which developed due to initial Kohistan Arc-Indian Plate contact at 67±2ma (Bard et al. 179, Chaudhry et al., 1994) subsided by Thanetian and Hazara Basin once again changed into an open shelf to deposit nodular Lockhart Limestone in shallow shelf (subtidal) environments. The sediments of the Lockhart Limestone rich in benthic forams are composed of mudstones, wackestones and packstones. The average lithified sedimentation rates are worked out at about 30mm/1000 years.

The carbonate shelf developed into a siliciclastic basin with increased turbidity which suppressed deposition of carbonates and olive grey splintary shales of Patala Formation with occasional limestone bands were deposited. The average lithified rates of deposition of Patala Formation are about 30mm/l000years.

During Ypresian the siliciclastic basin developed into a carbonate platform and deposited the Margala Hill Limestone in upper subtidal to lower subtidal environments. It is composed of mudstones, wackestones and packstones with many intercalations. The average rates of sedimentation of the Margala Hill limestone are about 62.5mm/1000 years.

The Chorgali Formation is composed of shales, mudstones, wackestones and packstones. The same environment that deposited the Margala Hill limestone deposited the Chorgali Formation. The average lithified rates of sedimentation were about 83-3mm/1000 years.

At about 55-50 Ma main collision between India and Asia took place due to which during Lutetian the sea started retreating. In Hazara with brief episodes of transgression-The Kuldana Formation represents these changing conditions and is represented by red continental shale-siltstone beds with interactions of fossiliferous marine limestones. The average lithified rates of sedimentation of this unit are about 71.1mm/1000 years. Thereafter the Himalayas started rising with the deposition of continental Molasse represented by Murree Formation with a Himalayan rather than Indian Plate provenance.

The cement stratigraphy for carbonate sediments of Hazara Basin (except Samanasuk Formation) shows that non ferroan microcrystalline calcite was penecontemporaneous with deposition. The second stage involves that dolomitization of calcite and bioclasts. Replacement of dolomite and bioclasts by ferroan calcite is the third stage. The final stage is the silicification of groundmass, bioclasts and at places the dolomite rhombs. In Samanasuk Formation dolomite occurs as first stage supratidal cement and sparite as early burial cement.

In addition to submarine and very early calcite cement the following order in cement stratigraphy for the pre-Danian clastic units of the Hazara Basin has been worked out: i) thin rim early quartz cement, ii) kalonite cement, iii) early calcic cement, iv) dolomitic cement, v) ferroan calcite cement, vi) deep burial quartz cement and vii) lite diagenetic kaolinite cement.

Key words: Stratigraphy, sedimentology, Jurassic, Eocene, Hazara basin.

C/81. Chaudhry, M.N. Ahsan, N. & Majid, C.M., 1997. Engineering properties, mineralogy, alkali aggregate reaction potential and provenance of Lawrencepur sand Pakistan. Abstracts, National Symposium on Economic Geology of Pakistan, Islamabad, 2p.

Lawrencepur sand is one of the most popular fine aggregate deposits of Pakistan. Detailed analysis of engineering characteristics, mineralogical composition and Alkali Aggregate Reaction (AAR) potential as well as the provenence of this deposit has been studied in detail.

The bulk densities of this sand vary from 82 lhs/cft to 86 lbs/cft. Its grading generally corresponds to the zone 3 or 4 of BS 882/1965 and is therefore considered an excellent tine aggregate for mixing with cement individually or as an additive with other tine aggregates of Pakistan. However, some sand layers contain oversize particles or other sizes larger than permissible limits for fine aggregates and therefore require sonic processing to meet the desired gradings. The Lawrencepur sand was tested in accordance with USBR Designation 14 to determine the organic impurities. The colour of the sand in 3% solution of NaOH was found to be lighter than the standard colour solution. This sand therefore, is free from organic impurities. Soundness test was carried out in accordance with ASTM Designation C88-76. The weight percentage losses range from 0.5% to 1.50% after five cycles of immersion. These results are lower than the maximum allowable limit of 12% (by Na2 SO4).

The Lawrencepur sand was tested petrographically for AAR potential with ordinary portland cement (OPC). It did not show Alkali Carbonate Reaction (ACR) potential. However. petrographic tests show that Lawrencepur sand ranges from innocuous to deleteriously reactive with respect to its ASR potential. These tests were carried out in accordance with ASTM Designation C33-81 and ASTM Designation C289-81. The chemical reactivity tests were carried out in accordance with ASTM Designation C289-8 1. These results range from innocuous to mildly deleteriously reactive.

Mineralogically the coarse sand is composed of lithoclasts as well as mineral grains. the average results and model analysis of coarse Lawrenepur sand are as follows:

quartz/quartzite 33.9%. granite/granodiorite 20.20%. amphibolite/foliated diorite 10.70%, feldspar 10%. mica 5.80%. graywacke group* 5.30%. amphibolite 4.60%, schist 4.0%, phyllite/slate* 3.300 a. iron ore 1.30%. sphene 0.30%. chet.t* 0.20%, tourmaline 0.20%, apatite 0.10% and zircon 0.1 0%. The deleterious constituents are marked with an asterisk(*). The coarse sands are therefore generally potentially reactive with ASR potential. Some parts of this sand deposit specially the medium grained varieties are low in hithoclasts and deleteriously reactive constituents and are therefore innocuous.

The sand has been derived mostly from the Kohistan island arc and the Indian plate constituting the Higher arid Lesser Himalayas. Contribution from the Gawachi back arc basin and the Asian plate is negligible as far as lithoclasts are concerned.

Key words: Engineering geology, alkali aggregates, sand, Lawrencpur.

C/82. Chaudhry, M.N. Ahsan, N. & Majid, C.M., 2000. Alkali aggregate reaction potential and engineering properties of Indus aggregate from Skardu to Thakot, Pakistan. Abstracts, Third South Asia Geological Congress, Lahore, 146-148.

The River Indus plays an important role in the industrial and agricultural economy of Pakistan. A number of dams are proposed to be constructed for water storage and power generation. The construction of these dams at Shyok, up and down stream of Kachura near Skardu, Raikot, Bhasha, Dasu and Patan will require millions of cubic metre of concrete. The (Chaudhry et al., 1999; Ahsan et al., 1999) aggregates of the River Indus for the Civil Engineering Projects. These aggregates were physically and petrographically evaluated for Alkali Aggregate Reaction (AAR) potential.

In the past, deleterious aggregates have been used in Tarbela Dam (Chaudhry and Zaka, 1994) and Warsak Dam (Chaudhry and Zaka, 1998). The aggregates used in Terbela and Warsak dams were considered safe but later on their inservice behaviour proved them deleterious with Alkali Silica Reaction (ASR).

The coarse and fine aggregates of Indus River meet the engineering characteristics as specified by ASTM or BS. The Los Angeles Abrasion Values are between 5.6 to 20.0 %. Specific gravity is 2.5 to 2.9 and water absorption is very low i.e. from 0.5% to 0.8%. The loss after 5 cycles of immersion in sodium sulphate solution ranges from 0.5% to 0.98%. The gradation of coarse and fine aggregates generally corresponds to BS 812: 1967, but at places they are

gap graded. The coarse aggregate of nine terraces of the Indus River from the Shigar Bridge, north of Skardu to Thakot Bridge were evaluated for Alkali Silica Reaction potential. The coarse aggregates were sieved through BS 2" to *3/16"* sieves and retained fractions were separated for identification of rock types.
The rock types include greenstone, quartzite, dunite, leucacmtic fine grained S-type granite porphyritic S-type granitic gneiss amphibolite. S-type granite mylonite, norite, pyroxenite, peridotite, granodiorite, diorite, S-type microgranite, vein quartz, I-type granite, dacite, mica gneisses, microdiorite, schist/gneiss, andesite, rhyolite, black basalt, hornblendite, chert, greywacke, slate, phyllites, dolerite, greenschist, marble, quartzofeldspathic psammite, serpentinite, weathered schist, dacite, porphyry andesite porphyry and rhyolite porphyry. All these rock types mayor may not be present in one sample. Moreover they vary from 0010 to as much as 63% on different sieves. The fine aggregates associated with the coarse aggregates were sieved though ASTM # 4 to # 200 sieves and rock types and minerals of each fraction were identified under the microscope. They include granite, granodiorite, diorite, tonalite, amphibolite, quartzite, slate, phyllite, greywacke, greenstone, basalt, norite, dolerite, quartz mica schist, gneiss, hornfelse, friable sandstone microfractured quartz, mica, greenstone, greenschist, polygrain quartz, feldspar, biotite, epidote, magnetite, garnet, tourmaline, sphene, zircon, calcite, rutile, barite, albite, plagioclase, clay lumps·, acid to intermediate volcanics" and diorite. All of these constituents mayor may not be present in each fraction or deposit. The rock types indicated by asterish (.) are potentially deleterious. The coarse and fine material of these terraces was considered safe in the past. Petrographic studies, mon.ar bar tests and deterioration of concrete containing the Indus aggregates clearly show the deleteriously reactive nature of the Indus aggregates if used with Ordinary Portland Cement. Studies carried out on aggregates using low alkali cements, slag cements and using methods. Ahsan et at., (1999) and Chaudhry et al., (1999) have used Ravi and Chenab sands dilutants to minimize the ASR in the Lawrencepur sands of the Indus River. Experimentation and further studies to control the reaction by using silica fumes and dilution with innocuous aggregates are being carried out.
Key words: Engineering geology, alkali aggregates, sand, Skardu, Thakot.

C/83. Chaudhry, M.N., Ahsan, N., Mahmood, T. & Masood, K.R., 2001. Sedimentology of Margala Hill limestone, Neelum valley, Azad Kashmir, NW Lesser Himalayas. Abstracts, 4th Pakistan Geological Congress, Islamabad, 59-60.

The Margala Hill Limestone (Latif, 1970) at Chahla Bandi, Azad Kashmir (Ghazanfar et al., 1987) is composed of light grey to dark grey limestone. The formation at the base is thinly bedded. It is overlain by calcirudite that contains abundant pelecypode shells. Some shells are reworked. Highly fissile dark grey shale that overlies the shelly beds and contains marcasite nodules. The shale is followed by highly nodular limestone. The nodules are upto 30 cm x 50 cm x 13 cm and contain very thin shale partings. This zone is 29m thick. It is very dark grey in colour and gives very strong fetid smell. An argillaceous marly limestone that is 28 metres thick overlies the dark grey limestone. It is overlain by medium bedded to highly nodular limestone towards the top of the formation. This zone is grey and weathers to light grey.
On the basis of petrographic and field observations, the formation is divided into six facies. These facies from bottom to top include: a) Poorly developed nodular limestone facies, b) Calcirudite facies, c) Biostromic limestone facies, d) Highly nodular limestone facies, e) Argillaceous limestone facies, and t) Massive to nodular limestone facies.
After the collision of India-Asia (Bard et al. 1979; Chaudhry et al. 1994) a ramp (Ahsan et al. 2000) developed that received the Eocene sediments in Azad Kashmir. The formation started deposition in the middle subtidal zone on siliciclastic sediments of Patala Formation. It was followed by reworking of the facies (a) sediments and a brief period of subtidal exposure. Then a rapid transgression deposited kiohermal limestone facies. The many limestone facies was deposited in a relatively calm conditions followed by the deposition of massive nodular limestone. The groundmass of the microfacies is non-ferroan calcite that at places has been neomorphosed. Rare dolomite is associated with some horizon. Evidences of physical and chemical compaction are well preserved.
Palynological contents of the samples included moderate population of Dinoflagellates, Mycorrhizal spores and Acritarchs. Pollen, spores and cuticular fragments were rare to very rare. Most conspicuous were Ptenidophytic spores (PunctatLsporites, Lacinitriletes and Acanthotriietes) and Ccilpate pollen (Tricolpites).
Key words: Limestone, sedimentology, Margala Hills Limestone, Azad Kashmir.

C/84. Chaudhry, M.N., Ahsan, N., Masood, K.R., Baloch, I.H. & Spencer, D.A., 1997. Facies, microfacies, paleontology, depositional environment and economic potential of Datta Formation of Early Jurassic age from Attock Hazara Fold and Thrust Belt, Lesser Himalayas (Salt Range, Pakistan). Abstract volume, 12th Himalaya-Karakorum-Tibet International Workshop, Rome, Italy, 133-134.

The Datta Formation (Danilchick, 1961; Shah, 1977) of Early Jurassic age is an important and persistent lithostratigraphic unit exposed in the Upper Indus Basin and Attock Hazara Fold and Thrust Belt of Pakistan. Its lithologies, thickness and environment of deposition vary widely. In the Hazara area, it unconformably overlies the Hazara Formation of Precambrian age. Here its basal part is a gritty sublithic arenite (Chuhan et al., 1990). The clasts were derived from the underlying slates during an Early Jurassic transgression (Chaudhry et al., 1994). The overlying package is composed of lenses and sheets of calcite and/or quartz-cemented quartz arenites. These are fine to coarse grained, generally sub-angular to sub-rounded, poorly to very well sorted, texturally sub-mature to mature and compositionally mature. This dominantly quartoze package also contains a few lenses of oolitic and pelletoidal limestones, marls, carbonaceous and silty shales. Diastesm, at few places in this unit, are marked by hard-grounds.
The following order of cementation of stratigraphy for the Hazara area has been worked out: early submarine and calcite cementation followed by thin rim early quartz cementation followed by thin rim early quartz cementation => Kaolinite cementation => early calcite cementation => dolomitic cementation => ferroan calcite cementation => deep burial quartz cementation => late diagenetic Kaolinite cementation. The diagenetic events of the rock package in the Hazara area will be discussed in relation to the burial and uplift history of the basin. Submarine, early calcite cementation was followed by Kaolinite and thin rim quartz cements at shallow depths in the domain of meteoric or mixed meteoric-marine water circulation. This was followed at greater depths (under alkaline and mildly reducing conditions), by the precipitation of ferroan calcite. Transformation of Kaolinite to illite probably started at around 1000-meter depth. Extensive quartz cementation, suturing and reduction in porosity started at greater depth and was completed at depths of 4,000-4,200 meters at which the main phase of oil and gas maturation was completed. The late stage Kaolinite cement was formed during final stages of uplift by the alteration of surviving K-feldspar in the domain of meteoric circulation.
Zircon, tourmaline, epidote, sphene and biotite represent the heavy mineral suite for the Datta Formation and indicate an ultimate igneous metamorphic sialic source with minor basic/met basic component. The overall composition of sandstone, textural and compositional maturity, the restricted suite of heavy minerals, and their amounts and shapes, indicate a recycled origin for the sandstones of the Datta Formation. The granitoid component was S-type. Lack of kyanite, sillimanite and garnet suggests that high-grade gneisses were not exposed in the source area. This fact is further supported by the presence of indicolite, which indicates allochthones granitoid intrusions in the epizone with thermal aureoles.
The environment of deposition of the Datta Formation varies from open marine, lower to upper shore face, lagoonal to sub-areal. It was deposited along the northern edge of the Indian Plate along a mixed siliciclastic-carbonate shoreline during an overall transgression in Early Jurassic.
However, minor phases of off-laps and on-laps have been identified. The Datta Formation in the Western Salt Range is composed of fining-upward clastic fluvial sequences. Each cycle is composed of coarse-grained (often pebbly) sandstone or conglomerate lying on a scoured surface. This unit is interpreted as a channel lag deposit, which is overlain by cross-stratified sandstone interpreted as a point bar. This, in turn, is topped by overbank silt and clay deposits. The sequence also contains palaeosol horizons. The Datta Formation in the Western Salt Range represents fluvial deposits laid down by small shallow meandering streams subject to intense periodic flooding.
In the Attock region, to the west of Hazara, the Datta Formation is composed of three main horizons: the basal part is a thin and often discontinuous laterite bed; the middle part contains bauxitic clays composed of variable quantities of Kaolinite, boehmite and diaspore (Baloch, 1986); while the top unit is composed of variegated sandstones and shale of continental to transitional marine origin. This unit also contains recoverable amounts of rutile and anatase. In this area, the Datta Formation is composed of a continental residual deposit while in Hazara the unit is predominantly marine in origin. In the Hazara area small quantities of silica sand have been mined for the glass and chemical industries. Large quantities of refractory clays, high alumina clays, silica sand and small quantities of ochre are being mined from Attock, as well as parts of Kala Chitta and Salt Range. Our recent studies on the fire clays and high alumina clays have yielded encouraging results for recovering rutile and anatase from fire clays and high alumina clays of Attock. It is an important reservoir rock for hydrocarbons in the Upper Indus Basin.
Since the Datta Formation lacks diagnostic fauna, detailed palynnological study of samples from the Salt Range and Hazara were carried out in order to constrain the age of this formation. The Datta Formation contains well preserved rich and diverse palynoflora, dominated by torate and auriculate miospores of Gleicheniidites (Ross) Delcourt and Sprumont and Triquitrites (Wilson and Coe) Potonie and Kremp types, respectively. Bisaccates were totally absent.

Cuticular fragments with sunken stomata and papillate outgrowths indicating a xerophytic habitat were observed in most samples. Some other important genera include Leiotriletes Naumova ex Potonie and Kremp 1954. Todisporites Couper 1958, Calamospora (Loose) Schopf Wilson and Bentall 1944, Cyathedites Couper 1953, Granulatisporites Ibrahim 1933, Concavisporites (Leschik) Nilson 1958 and Verrucosisporites potonie and Kremp 1954. Triquitrites and Gelicheniidites represent approximately 45% of the total microflora. Although the auriculate group was the most numerous, simple trilete miospores (Leiotrites, Punctatisporites, Todisportes) contributed an average of 5%. The most outstanding feature of the palynoflora was the persistent occurrence in the lower half of the Formation of any Early Jurassic marker pollen Classopollis classoides (Pflug) Pocock and Jansonius 1961.
Key words: Microfacies, palaeontology, depositional environment, Datta Formation, Jurassic, Himalaya.

C/85. Chaudhry, M.N., Ahsan, N., Zaka, K.J. & Majid, C.M., 1997. Alkali aggregate reaction potential of Indus gravel and sand between Raikot Bridge and Kalabagh. Pakistan. Abstracts, National Symposium on Economic Geology of Pakistan, Islamabad, 2p.

Following River-Water Treaty with India. Pakistan lost rights over the waters of Sutluj and Ravi rivers. Therefore, the river Indus with its water and power potential is rightly regarded as the life line of Pakistan. A very large number of dams. barrages. bridges and other civil structures are likely to be built using sand and gravel of this river and its terraces. The amount of aggregate required is collosal. This warrants systematic studies of gravel and sand of the river Indus. A part of the work carried out on the Indus aggregates is presented in this paper.
The effects of deleterious alkali-aggregate reactions are often very profound and severely detrimental to concrete structures affecting their strength, stiffness, serviceability. safety and stability.
This paper for the first time, presents an overall preliminary evaluation of alkali-silica and alkali-carbonate reaction potential of coarse as well as fine aggregates of the Indus river between Raikot bridge and Kalabagh. Bulk aggregate samples were drawn from near Raikot bridge. Besham. Tarbela Darn. Attock. Lawrancepur. Harrow-Indus confluence and Kalabagh to study heir deleterious alkali-aggregate reaction (AAR) potential as well as their physical and engineering characteristics.
In addition to petrographic evaluation of alkali-silica and alkali-carbonate reaction potential of these aggregates, their physical properties like water absorption (0.5 to 0.8%). hulk densities (80-90 Lbs/cft). specific gravities (2.60 to 2.85) and organic impurities for coarse and fine aggregates and mechanical properties such as aggregate crushing value (9% to 30%). aggregate impact value (6% to 25%). Los Angeles abrasion test (5 to 20%) and soundness test (1 .50% to 10%) were also determined.
In addition to these, tests a detailed quantitative petrographic analyses of all the samples were carried out in order to determine their deleterious alkali-aggregate reaction potential. At many places these fine aggregates are gap graded.
Metagraywackes. metasubgravwackes and rnetavolcanics were previously regarded as safe since they had undergone metamorphic reconstitution in low grade. We present theoretical bases for drawing a boundary line between reactive and non-reactive metagravwackes and acid to intermediate metavolcanics.
These studies show that while these aggregates possess excellent physical and engineering properties they show alkali-silica reaction potential. The reactive rock types identified are metagraywackes, rnetasubgreywackes. phyllites slates, acid to intermediate volcanics, granite mylonites and cherts. However, the reactive rock types and their amounts vary widely (Chaudhry et al. 1992; Zaka et al. 1995) between Raikot Bridge and Kalabagh. Not all the reactive rock types may be present at all these sites but nevertheless all these samples show deleterious alkali-aggregate reaction potential.
Chemical reactivity tests on these aggregates are inconclusive and molter bar tests over a period of six months to one year do not give unacceptable expansion. However extended morter bar tests show unacceptable expansion. lnservice behaviour of Indus gravel and sand at Tarbela Dam and behaviour of similar aggregates in Warsak Dam has been found unsatisfactory. Evidence of alkali-silica reaction has been proved in these structures. Five possible preventive measures can he taken to avert alkali-silica reaction i.e. I) use of low alkali cement instead of ordinary portland cement. ii) use of silica fumes. iii) addition of fly ash, iv) use of slag cement and v) addition of pozzolana.
Since a large number of dams and other civil structures are planned to he built on the river Indus requiring huge quantities of cement, therefore on account of cost considerations, we do not recommend the use of low alkali cement. Silica fumes has a short history of application, therefore, its affectiveness in controlling alkali-carbonate reaction has not yet been proved under inservice conditions over extended period of time. At present we do not have large quantities of indigenous fly ash available. The use of this material therefore must wait till under-construction and planned coal fired power plants become operational. Slag cement can be usefully employed where settling time and quick attainment of peak strength is not required. The only other practical solution at the moment appears to be

manufacturing of pozzolana and producing suitably blended cements. We very strongly recommend this economical and effective solution where slag cement cannot be used.
Key words: Alkali aggregates, Indus gravel, Raikot, Kalabagh.

C/86. Chaudhry, M.N. & Ashraf, M., 1977. Petrology of the Karak bentonite-Kohat District, NWFP, Pakistan. Geological Bulletin, Punjab University 14, 1-26.

A detailed petrographic, chemical, mineralogical and statistical study of the Karak bentonite is being presented for the first time. A total of 46 petrographic analyses, 47 chemical analyses, 6 X-ray analyses, 11 D. T. A. analyses and 11 spectrographic analyses have been discussed. The study shows it to be a mixed layered montmorillonite-illite with MgO in excess of CaO. It is originally thought to have been deposited as a montmorillonite which on a depth of burial of about 10000 feet and in the presence of K+ ions has been converted to a mixed layer montmorillonite-illite. The clay is transported and well stratified. It was deposited in a shallow undulating evaporitic basin with water reduced to nearly 1/3 of its original volume and varying slightly on either side.
Key words: Petrology, mineralogy, bentonite, Karak.

C/87. Chaudhry, M.N. & Ashraf, M., 1980. The volcanic rocks of Poonch District, Azad Kashmir. Geological Bulletin, University of Peshawar 13, 121-128.

The volcanic rocks of the Poonch District are confined to the Pir Panjal Range of Upper Haveli, Poonch District. The volcanic rocks belong to two distinct ages. The Dogra Trap is basaltic and is confined within the Precambrian Dogra Slates. The Panjal Trap along with basal agglomeratic slates and Tuffs are Upper Carboniferous. The flows are mainly basaltic to andesitic. The pyroclasts occurring towards the top are intermediate to acidic in composition. The Panjal Trap is overlain by the 'Gondwana Group' of upper part of Upper Carboniferous to Permian.
This paper deals with the geology, petrography, chemistry and geochemistry of the Poonch volcanics. Map of the area on 1:50000 has been prepared. This is the first detailed petrological study of the Poonch Volcanics. A total of thirty nine petrographic analyses, thirty two chemical analyses and fifteen spectro-chemical analyses of the volcanics are presented.
Key words: Volcanics, slates, Pir Panjal Range, Poonch, Azad Kashmir.

C/88. Chaudhry, M.N. & Ashraf, M., 1981. Petrology of Middle Siwalik rocks of Kotri area, Azad Kashmir. Geological Bulletin University of Peshawar 14, 183-191.

Sandstones and shales of the Middle Siwalik of the Kotli area have been studied petrographically, chemically and spectrochemically. By comparing the overall compositions of these rocks and those of the rock fragments present in the constituent sandstones, it has been concluded that the Middle Siwalik rocks have been derived from igneous, metamorphic and sedimentary formations lying to the north and northeast of the area, towards the Pir Panjal Range.
Key words: Petrography, geochemistry, sandstone, siwaliks, Azad Kashmir.

C/89. Chaudhry, M.N. & Ashraf, M., 1984. Geology, petrography and spectrochemistry of Gondwana rocks of Poonch District, Azad Kashmir. Kashmir Journal of Geology 2, 11-18.

Geology, petrography and spectrochemistry of Gondwana metaconglomerates, quartzites and schists have been described and discussed. Ten modal analysis of Gondwana metaconglomerate bed, four modal analyses of Gondwana schists, five spectrochemical analysis of Gondwana metaconglomerate and tow spectrochemical analysis of Gondwana schists are presented for the first time from Poonch. The geological and petrographic evidence supports the view (Wadia 1928) that the Gondwana Group of rocks were deposited under continental conditions. It has been further suggested that the environment of deposition varied from oxidizing to reducing. The upper Haveli Tehsil of Poonch with Agglomeritic slates and tuff, Panjal Trap and Gondwana Group rocks belongs to the Kashmir geologic province while the remaining part (with the Palaeozoic rocks missing) should be grouped with the Hazara province. The two contrasting provinces are separated by the great boundary fault.
Key words: Petrography, detrital sediments, Gondwana rocks, Azad Kashmir.

C/90. Chaudhry, M.N. & Ashraf, M., 1985. Petrology of Murree Formation of Poonch District, Azad Kashmir. Kashmir Journal of Geology 3, 13-36.

A detailed petrographic, chemical and spectrochemical study of Murree Formation from Poonch Distt. of Azad Jammu and Kashmir is being presented for the first time. This study includes petrographic analysis of 22 sandstones, 31 shales and 13 limestones; chemical analysis of 23 sandstone, 6 shales and 13 limestones, chemical analysis of 23 sandstones, 6 shales, and 3 limestones and spectrochemical analysis of 10 sandstones, 8 shales and 4 limestones.
A comparison of the Murree Formation and Siwaliks of Poonch is presented to show similarities between the two. It is shown that the two have been derived from the same source.
The view held so far (following Wadia, 1928) that the Murree Formation has been derived from Dharwar and Cuddapah rocks of Peninsular India is despelled. Instead, it is clearly shown that the Murree Formation like the Siwalik (Chaudhry and Ashraf, 1981) have been derived from the rising Himalayas.
In Poonch area it is shown that the Murree Formation are marine, while the middle and upper Murrees are of continental origin with local lacustrine conditions.
Key words: Petrology, geochemistry, Murree Formation, Azad Kashmir.

C/91. Chaudhry, M.N. & Ashraf, M., 1986. Petrology of ultramafics from Shangla-Alpuri-Malam Jabba area, Swat. Kashmir Journal of Geology 4, 15-33.

Chromite and chrome spinel bearing metamorphosed ultramafics occur south of the MMT within a eugeosynclinal assemblage composed of green schist, slices of blue schist and mafic lavas. The rocks originally peridotites are now composed of serpentinites, serpentinised peridotites and a varied assemblages of talc-carbonates. The mineral assemblages show that the main metamorphic phase took place between 325 ºC and 500 ºC. That would correspond to low to very low grades of metamorphism. This paper presents petrography, chemistry and metamorphism of these rocks.
Key words: Petrology, geochemistry, ultramafics, serpentinization, Shangla, Alpurai, Swat.

C/92. Chaudhry, M.N., Ashraf, M. & Hussain, S.S., 1979. Molybdenum mineralization associated with Igneous–metamorphic rocks in Kohistan and Swat districts along Karakoram Highway. The Pakistan Metallurgist, 1 & 2, and 1980, 2 (1&2), 11–12.

Key words: Igneous rocks, metamorphism, molybdenum mineralization, Kohistan, Swat.

C/93. Chaudhry, M.N., Ashraf, M. & Hussain, S.S., 1980b. Preliminary study of Nickel mineralization in the Swat district, NWFP. Contributions to Geology of Pakistan, 1, 9–26.

Important areas of interest where significant reserves of Nickel ore may be expected are Shangla, Malam Jaba and Tutan Banda (Swat). Some minor occurrences are also found in Aspanr, Bar-Malakand and Ursak (Dir). Petrographically the nickel bearing rocks are ultramafics e.g. altered serpentinites (talc-carbonate rocks), sulphide bearing serpentinites and limonitic altered serpentinites, norites and allied rocks, studied so far by authors from the Swat-Dir areas, do not show nickel mineralization although these rocks deserve further study.
Chemical and spectrographic studies indicate higher values of nickel in the ultramafics than the background values (NiO in various rocks varies generally from 0.4 to 0.8% and the usual background value is less than 0.2%.
Key words: Nickel, minerlization, Swat.

C/94. Chaudhary, M.N., Ashraf, M. & Hussain, S.S., 1981. Petrology of Koga nepheline syenites and pegmatites of Swat District. Geological Bulletin, Punjab University 16, 83-97.

Detailed petrography, chemistry and petrogenesis of the Koga nepheline syenite intrusion is being described. A total of 70 petrographic modal analyses and 56 chemical analyses of various types of nepheline syenite and its associates were carried out. The data was processed on ISM 1130 computer using FORTRAN IV language, thus averages,

standard deviations and correlation co-efficients were worked out. The nepheline syenites show characteristics of miaskitic type. A generalised evolutionary sequence of the nepheline syenitic rocks is as follows;
Pulaskite-nepheline syenite-foyaite-sodalite syenite-fenite-carbonatite.
The intrusion is a part of the alkaline province lying between Loe Shalman and Chamla. The province is composed of northern nepheline syenites, syenties and carbonatites and southern soda granites and soda porphyries. The extent of eastward extension of this province is not known. The province is associated with substantial dislocations.
Key words: Petrology, geochemistry, pegmatites, nepheline syenites, Buner.

C/95. Chaudhry, M.N., Ashraf, M. & Hussain, S.S., 1983. Lead-zinc mineralization of lower Kohistan District, Hazara Division, NWFP, Province, Pakistan. Kashmir Journal of Geology 1, 31-42.

Lead and zinc mineralization of galensphalerite type was discovered for the first time from Besham are of Kohistan. The mineralization is mainly of hypothermal to mesothermal vein type. Economically important deposits occur as veins within the igneous metamorphic zones formed by the interaction of Lahor granite and pelitic-calcareous metamorphics. Disseminated lead-zinc mineralization also occurs in skarns, altered granites, silicified granites and quartz veins. Petrography, ore microscopy, and chemistry of the mineralized rocks is presented and related to the field evidence to draw conclusions about the nature and origin of mineralization.
Key words: Mineralization, Lead-Zinc, Besham, Kohistan.

C/96. Chaudhry, M.N., Ashraf, M. & Hussain, S.S., 1984. Lead-zinc mineralization of lower Kohistan District, Hazara Division, North West Frontier Province, Pakistan. Abstract, First Pakistan Geological Congress Lahore, 23-24.

Consult the preceding account for further information.
Key words: Mineralization, Lead-Zinc, Besham, Kohistan.

C/97. Chaudhry, M.N., Ashraf, M., Hussain, S.S. & Iqbal, M., 1976. Geology and petrology of Malakand and a part of Dir (Toposheet 38, N/14). Geological Bulletin, Punjab University 12, 17-39.

A geological map of a part of the Malakand Agency and of southern Dir district covered by the toposheet No. 38 $^{N}/_{14}$ is presented. Succession of rocks of the area has been worked out. Detailed petrography of all the major units of the area is described. Six modal analyses of the pelitic rocks, fifteen modal analyses of the calcareous rocks including marbles, six modal analyses of the amphibolites, thirteen modal analyses of the Malakand granite gneiss and twenty-seven modal analyses of the Malakand granite are presented. Twelve chemical analyses of the granite were done. Petrogenesis of the rocks of the area is presented.
Key words: Petrography, calcareous, marbles, amphibolite, granite, Malakand, Dir.

C/98. Chaudhry, M.N., Baloch, I.H., Ahsan, N. & Majid, C.M., 2000. Engineering properties, mineralogy, alkali aggregate reaction potential and provenance of Lawrencepur sand, Pakistan. In: Hussain, S.S. & Akbar, H.D. (Eds.), Proceedings, National Symposium on Economic Geology of Pakistan, 1997, Islamabad, 241-253.

Key words: Mineralogy, engineering properties, alkali aggregates, Lawrencepur.

C/99. Chaudhry, M.N. & Chaudhry, A.G., 1974. Geology of Khagram area, Dir District. Geological Bulletin, Punjab University 11, 21-43.

A map of ninety square miles of the area is presented. Bojites, diorites, trondhjemite, norite, hypersthene gabbro, hypersthene diorite, pyroxenite, intermediate pegmatite and amphibolites occur in the area. Normal igneous

differentiation of two different magma types is postulated to be responsible for two different types of related rocks i.e., basaltic magma of andesite rhyolite association, which, resulted in the formation of bojite, diorite, tonalite and trondhjemite and the tholeiitic magma which gave rise to norite, hypersthene gabbro, hypersthene diorite and pyroxenite. The study suggests that the formation of complex progressed by independent intrusions of earlier basaltic magma of andesitic, rhyolitic association to latter of tholeiitic nature with subsequent differentiation.
Keywords: Geology, petrography, mafic and intermediate rocks, amphibolites, Dir.

C/100. Chaudhry, M.N., Chuhan, F.A. & Ghazanfar, M., 1994. Microfacies, diagenesis, environment of deposition and burial history of Datta Formation from Baraoter, District, Abbottabad. Kashmir Journal of Geology 11 & 12, 43-58.

Datta Formation of Early Jurassic age from Baraoter, Abbottabad-Nathiagali area, has been studied, for the first time from petrological/sedimentological point of view. The 11.37m thick section shows a marked vertical variation in lithology. The units included from bottom to top are medium grained kaolinite-illite and quartz cemented quartz arenite, fine grained glauconitic sandstone, medium to fine grained quartz and kaolinite-illite cemented quartz arenite, alternating bands of carbonate cemented medium to fine grained quartz arenite and oolitic pelletoidal limestone, medium grained ferruginous quartz arenite, coarse grained carbonate cemented quartz arenite, fine grained quartz and carbonate cemented quartz arenite, very fine grained arenaceous limestone, fine grained carbonate and quartz cemented quartz arenite, mudstone, and coarse grained arenaceous dolomite with steaks and layers of grit. There is a very restricted suite of heavy minerals, which include tourmaline, zircon, epidote and sphene. This suite indicates ultimate derivation from an igneous metamorphic sialic basement with subordinate basic/metabasic component. The granitic component was predominantly S-type. The diagenetic events have been interpreted with respect to the burial and uplift history. The maximum depth of burial is estimated at 4150m at which oil and gas maturation and reduction of primary porosity occurred. Kaolinite is the first cement to form followed by quartz and ferron carbonate cementation. At depth beyond 1000m, kaolinite transforms into illite. Kaolinite is early diagenetic as well as formed at the final stage. The environment of deposition is also highly variable from continental, subtidal, inter-tidal and supra tidal.
Keywords: Sedimentology, Datta Formation, Abbottabad.

C/101. Chaudhry, M.N. & Ghazanfar, M., 1983. A plate tectonic model for N.W. Himalayas, Pakistan. Kashmir Journal of Geology 1, 109-112.

For further information, consult Chaudhry, Ghazanfar and Ashraf, 1984.
Keywords: Plate tectonics, Himalaya.

C/102. Chaudhry, M.N. & Ghazanfar, M., 1986. Petrology of Panjal ophiolites. Abstracts, Symposium/Workshop on Plate Tectonics and Crust of Pakistan. Institute of Geology, Punjab University, Lahore, 22-23.

Geological set-up, geochemistry, petrography, petrogenesis and petrotectonics of Panjal greenstones from middle Kaghan Valley is presented for the first time. These greenstone ophiolites are tholeiites, alkali basalts and spilites of oceanic character. The Panjal volcanics which show pillow structures at many places were once considered subareal. Petrological and field evidence will be presented to show that they are in fact oceanic in character.
The sequence Panjal volcanics-Agglomeritic slate-Tanols taken together may mark the opening and then closure of an ocean (proto-Tethys), which developed on the rifted continental margin, what is now the Indo-Pak plate.
It is shown that the Panjal lavas are primary in nature and have been derived through a high degree of partial melting of pyrolite.
Keywords: Geochemistry, petrology, Panjal ophiolites.

C/103. Chaudhry, M.N. & Ghazanfar, M., 1986. A third suture in northwest Himalayas. Abstracts, Symposium/Workshop on Plate Tectonics and Crust of Pakistan. Institute of Geology, Punjab University, Lahore, 23-24.

The MKT and MMT are two sutures so far identified in NW Himalayas and Northern Areas. In the region of Kaghan and Neelum Valleys the Main Boundary Thrust (MBT) constitutes an older Upper Palaeozoic-Lower Mesozoic suture-The Panjal suture.
The Panjal Volcanics - Agglomeratic slate-Tanol sequence tectonically is very significant and interesting and needs to be studied in greater detail. The Tanols which in Kashmir have Middle Palaeozoic age appear to indicate that the landmass of Kashmir-Hazara was developing series of disconnected basins marking the beginning of a phase of continental rifting which later led to the development of an incipient sea the Panjal sea.
The agglomeratic slate is a complex lithologic unit indicating a variety of environments including glacial and also containing an acid to intermediate volcanic suite representing a cratonic rift assemblage and an island arc affinity.
The presence of marine intertrappean limestones, relio pillow structures in Kaghan Valley and their tholeiitic to alkaline affinity indicates a suboceanic character for Panjal Volcanics.
The Tanol-Agglomeratic slate-Panjal sequence in the Kaghan Valley is enclosed between two major faults, which, together with others in between, constitute the Main Boundary Thrust (MBT) in this area. The MBT in Kaghan and Neelum Valley, Azad Kashmir, has therefore, acted as a suture along which representatives of a Palaeozoic incipuent ocean floor developed in a rifted continental margin and were thrust onto the rocks of continental marginal affinity.
Keywords: Structure, tectonics, suture, Azad Kashmir.

C/104. Chaudhry, M.N. & Ghazanfar, M., 1987. Geology, structure and geomorphology of upper Kaghan valley, Northwestern Himalaya, Pakistan. Geological Bulletin, Punjab University 22, 13-57.

The part of Kaghan valley between Batakundi and Babusar pass (nearly 900 sq. km has been geologically surveyed and mapped at 1 : 50,000 scale for the first time. Besides a detailed field description of rock units, brief petrographic description, comments on metamorphism, origin of migmatites, granite gneisses and granites of the area, description of structure and geomorphology are included. The Pre-cambrian metasediments of Sharda Group are mainly calc-pelites and marbles, with subordinate psammites and minor orthoquartzites. These rocks belong to the upper amphibolite facies of regional metamorphism. The associated syntectonically folded para-autochthonous garnet-tourmaline granite gneisses and migmatites are S-type and are formed due to high grade metamorphism and anatexis of pelites and psammites, feldspathic psammites and metatuffs (?) of Sharda Group. The minor undeformed Tertiary granites are from late-to post-tectonic S-type anatexites. The amphibolites are mainly mefaigneous and pretectonic. Thin metasedimentary layers of amphibolite also occur associated with calc-pelites. Burawai Synform and Besal Antiform and Bela Synform are the major fold structures of the area. These have themselves been deformed further. These structures are large more like structural basins and elongated domes. Geomorphically the higher parts of the area close to Kaghan and Kohistan watersheds show Alpine sculpture with glacial troughs and associated cirques, lakes and moraines. Relatively infrequent and patchy signs of glaciation also persist along the trunk valley of River Kunhar down to Kaghan township.
Keywords: Structure, geomorphology, Kaghan valley, Himalaya.

C/105. Chaudhry, M.N. & Ghazanfar, M., 1990. Position of the Main Central Thrust in the tectonic framework of the western Himalaya. Tectonophysics 174, 321-329.

Investigation in the western part of Northwest Himalaya have indicated a marked contrast in the stratigraphy, metamorphism and tectonics of the rocks north and south of Batal in the Kaghan valley and Luat in the Neelum valley. It is proposed that the Batal-Luat line represents the trace of the Main Central Thrust (MCT).
Contains 3 tables and 2 figures.
Keywords: Tectonics, MCT, Himalaya.

C/106. Chaudhry, M.N. & Ghazanfar, M., 1993. Some tectono-stratigraphic observations on northwest Himalaya, Pakistan. Pakistan Journal of Geology 1 & 2, 1-19.

Keywords: Tectonics, stratigraphy, Himalaya.

C/107. Chaudhry, M.N. & Ghazanfar, M., 1995. Geology and tectonic of the Kaghan valley. Abstracts, 2nd South Asia Geological Congress, Columbo, 36-37.

For further information consult Chaudhry and Ghazanfar, 1987.
Keywords: Tectonics, Kaghan valley, Himalaya.

C/108. Chaudhry, M.N. Ghazanfar, M. & Ahsan, N., 1994. Rates of sedimentation of Kawagarh Formation at Giah, Abbottabad-Nathiagali road and timing of uplift at K-T boundary in Pakistan. Pakistan Journal of Geology 2 & 3, 29-32.

It is postulated that lithified rates of sedimentation of Kawagarh Formation at Giah were on the average about 9 mm/1000 years, although Maastrichtian is not present at Giah section yet a substantial part of Maastrichtian is suppose to have been deposited but was removed through the process of lateritization. It is postulated that the Hangu Formation formed in upper most Maastrichtian, may have extended to lowermost Danian. Therefore, the Lockhart Formation is Danian in Age. The rapid regression resulting in the formation of Hangu Laterite started due to initial contact of Indian Plate with Kohistan Arc 67 ± 2 Ma prior to main collision between Indian and Asian Plate completely sandwiching Kohistan Island Arc at 55 Ma.
Keywords: Sedimentation, Kawagarh Formation, collision, Nathiagali, Abbottabad.

C/109. Chaudhry, M.N., Ghazanfar, M., Ahsan, N. & Masood, K.R., 1997a. Age, stratigraphic position and provenance of Murree Formation from Murree Hills and the syntaxial region. Abstracts, 3rd GEOSAS Workshop on Siwaliks of South Asia, Islamabad. Geological Survey of Pakistan, Records 109, 9-10.

The red sandstone, siliciclastic molasse sequence of Murree Formation with subordinate rudites, rare mans and limestone horizons has for a long time been regarded as Miocene in age and derived from Cuddapah and Dharwar rocks of Indian Peninsula.
On the basis of plant and vertebrate fossils, Pilgrim (1910) assigned an to Middle Miocene age to this Formation in Kohat, Potwar and Salt Range. In the Syntaxial Region, Calkins et al., (1975) assigned a possible Oligocene age to the lower part of the Murree Formation on the basis of an apparent gradational contact with the underlying Eocene rocks of their “Kalachitta group”.
However Bossart and Ottiger (1989) on the basis of larger benthic foraminifera studied from four richly fossiliferous marine calcareous zones from within the Murree Formation assigned a Late Paleocene to Middle Eocene age to the Murree Formation. Two of these four horizons have been shown as fault slices of “Kalachitta group” of Paleocene to Lower Eocene age by Calkins et al., (1975). Calkins et al. (1975) as well as Ghazanfar et al. (1986) have mapped and described Paleocene and Eocene formations lying stratigraphically below the same Murree Formation which has been assigned a Late Paleocene to Middle Eocene age by Bossart and Ottiger (1989).
We examined in detail these four richly fossiliferous marine calcareous horizons. They have distinctly sheared contacts, often with fault breccias and at places with tectonic melanges. Nowhere is there a transitional contact between these marine fossiliferous, calcareous and marly horizons and the enclosing maroon to deep red siliciclastic continental deposits. Around Chahla Bandi in Neelum Valley near Muzaffarabad part of the Syntaxial region, underlying the Murree Formation with a slight unconformity represented by calcirudites occurs a complete and well defined sequence of formations of Lower Paleocene to Middle Eocene age namely Lockhart Formation, Patala Formation, Margala Hill Formation, Chor Gali Formation and Kuldana Formation.
Near Kuldana village in Murree Hills as well as on Kummi Spur near Balakot in Kuldana Formation of Middle Eocene age grades upwards conformably into the Murree Formation. Therefore in this region we regard the Murree Formation as Upper Middle Eocene since the underlying beds of Kuldana Formation are Middle Eocene in age.
A preliminary palynological study of the Murree Formation carried out for this paper from the Syntaxial Region rules out a Paleocene to Lower Eocene age for the Murree Formation.
Prior to 1975, Murree Formation was supposed to have been derived from the Cuddapah and Dharwar rocks of Indian Peninsula (Wadia, 1926). However Calkins et al, (1975) were the first to suggest the possibility that the

Murree Formation of the Syntaxial Region was derived from the rising mountains to the North. Chaudhry and Ashraf (1985) on the basis of petrographic studies of Murree rocks with special emphasis on lithoclasts and heavy minerals from Poonch area of Azad Kashmir conclusively demonstrated a specifically Pin Panjal source region for these rocks. Bossart and Ottiger (1989) on the basis of microprobe analysis of spinals suggested "Kohistan Island Arc" as one of the source regions. Author on the basis of detailed petrographic studies on the lithe arenites of Murree Formation from Poonch, Kotli, Neelum and Murree areas furnished concrete evidence that Murrees were derived from the lower grade meta-sediments and allochthonous plutons to the north from rising Himalayas and Pin Panjal, but contribution of resistant heavy minerals including spinals from the Peninsular region is not ruled out.
Keywords: Stratigraphy, provenance, Murree Formation, Murree Hills.

C/110. Chaudhry, M.N., Ghazanfar, M., Ahsan, N. & Masood, K.R., 1997b. Age, stratigraphic position and provenance of Murree Formation of North West sub-Himalayas of Pakistan and Azad Kashmir. Proceedings of the third GEOSAS Workshop, GSP, 81-91.

The red shale, sandstone clastic sequence of Murree Formation with rare marls and limestone bands has for a long tome been regarded as Miocene age and derived from Cuddapah and Dharwar rocks of Indian Penensula. More recently age from Late Palaeocene to Middle Eocene have been proposed for the Murree Formation of Western Syntaxial region between Balakot and Kawat. It has also been proposed that the source area for the Murree Formation lay to the north in the rising Himalaya rather than to the south in the Indian Pensisula. On the basis of field studies and paleontological data, it is suggested that this time transgressive unit is neither Paleocene nor Lower Eocene in age anywhere in NW Himalayas in Pakistan and Azad Kashmir. Palynological studies of the Murree Formation from the Syntaxial region and Murree Hills clearly indicate an age from Eocene to Oligocene. We suggest that a complete sequence from Hangu Formation of Danian age to Kuldana Formation of Middle Eocene age are also present in the southern part of the western limb of the Hazara Kashmir Syntaxis. A Miocene age has been generally accepted for this formation in Kohat-Potwar region on the basis of fauna and flora. We therefore suggest that the overall age range for the Murree Formation is from Middle Eocene to Early Miocene. We provide further evidence to reinforce the proposition that the dominant source area lay to the north in the rising Himalayas but insist that subordinate contribution from the Indian Peninsula is not ruled out. The source area to the north was composed of a sedimentary to low-grade metamorphic cover with volcanic horizons (pierced by granitoids) and ophiolites.
Keywords: Stratigraphy, provenance, Murree Formation, Murree Hills.

C/111. Chaudhry, M.N., Ghazanfar, M. & Ashraf, M., 1984. A plate tectonic model for northwest Himalayas, Karakorum and Hindu Kush lying between and adjacent to MMT and MKT. Abstracts, First Pakistan Geological Congress, Lahore, 16-18.

A new plate tectonic model based on a petrotectonic approach is being presented for the first time.
Tahirkheli et al. (1979) and Bard et al. (1979) have expressed their thoughts~ on the sequence of tectonic events in the NW Himalayas in Pakistan. They have indicated an initial ocean - ocean collision leading to the formation of an island arc in the north of the Indo-Pak plate. Later, according to these authors, this area was sutured to the south with the Indo-Pak and to the north with the Asian continents, and that the sequence of rocks constituting this island arc system is now located between two thrusts, the Main Mantle Thrust (MMT) in the south, and the Main Karakorum Thrust (MKT) in the north. They have called it the Kohistan Island Arc sequence.
Field studies in the Section between Shewa and Chitral, however, revealed a different picture. The petrotectonic zones in the section between Shewa and Chitral and adjoining areas are more or less symmetrically disposed on either side of the central layered intrusions which represent oceanic lithosphere (and not granulites, as proposed by Jan et al. 1980) There are southern and northern melanges, southern and northern volcanic-sedimentary zones (arcs) and the trench zone (so far well established only on the southern side).
In other sections, due to extensive thrusting and transport of crustal chunks, the situation has become much more complicated. However, the identification of various petrotectonic elements and their interpretation shows that they represent elements of the above mentioned petrotectonic units plus chunks and protrusions of IndoPak and Asian masses. The present model is therefore considered applicable to NW Himalayas, Karakorum and Hindu Kush lying-between and adjacent to the MMT and MKT.
Petrotectonic relations also indicate an initial subduction of Tethyan plate under the lndo-Pak continent. This is contrary to the currently postulated northwards subduction, only.

The central layered intrusions represent oceanic lithosphere as against the idea that they form lower part of the so-called Kohistan Island Arc sequence (or that they are granulites). This latter term i.e. Kohistan Island Arc' may be used only for a narrower zone south of the MMT. The huge succession that has been previously called the Kohistan Island arc actually comprises a number of distinct petrotectonic provinces viz, from south, southern island arc, southern mélange zone, central layered intrusions, northern mélange zone and the northern island arc of Asian plate affinity.
The presently mapped or postulated position of MKT also needs correction. It should be placed south of the northern island arc and not to its north. In this paper chunks of sheeted complex, pillow lava and the latest elements of Tethys's sediment sin the area are related. Extrusive and intrusive elements on the Indo-Pak plate are identified. The existence of a tension related alkaline province on the Asian mass and a northern trench zone are predicted.
Keywords: Plate tectonics, MMT, MKT, Himalaya.

C/112. Chaudhry, M.N., Ghazanfar, M., Ashraf, M. & Baloch, I.H., 1989. Observation on Precambrian orogeny and the age of the metamorphism in Northwest Himalaya, Pakistan. Kashmir Journal of Geology 6 & 7, 19-22.

Presence of Tertiary granites in Himalayas has clouded the earlier metamorphic history of Northwest Himalaya. Evidence from the relationship of various rocks units throws fresh light on the chronology and intensity of older metamorphic events which go back to 1840 ma. In particular, a Late Precambrian event rose to amphibolite facies. A Prermo-Trias event of much lower intensity is also indicated.
Keywords: Orogeny, Tertiary, metamorphism, Himalaya.

C/113. Chaudhry, M.N., Ghazanfar, M., Ashraf, M. & Hussain, S.S., 1984. Geology of the Shewa-Dir-Yasin area and its plate tectonic interpretation. Kashmir Journal of Geology 2, 53-63.

Regional Geology of a large area between Shewa, Malakand, Warsak in the south and Hunza, Yasin, Chitral in the north through the valleys of Dir and Swat has been broadly described Petrography and Model compositions of the principal petrologic units are presented. Chemistry of some of these rocks has also been discussed. Petrotectonic significance of the principal rocks units in the area is assessed. A number of linear petrotectonic belts have been established running approximately east west between Shewa in the south and Yasin in the north. It is suggest that the mass of rocks enclosed in the Kohistan area between the Indian and Asian plates is not a single island arc sequence but comprises on the other hand at least two and possibly three island arcs and associated trenches. The extensive amphibolite, and complex is separate and does not represent the lower part of a single Kohistan island arc sequence as suggest in the past but comprise at least three distinctive belts two belts of obducted melanges with a central belt consisting of a possibly trapped portion of the Tethy's oceanic crust. Finally a southward subduction of the Tethyan lithosphere is postulated under the Indo-Pak plate in contrast to north directed subduction of the Indian plate as suggested in the past. A sequence of different subduction zones is suggested.
Keywords: Petrology, tectonics, Malakand, Hunza, Chitral.

C/114. Chaudhry, M.N., Ghazanfar, M., Baloch, I.H., Adil, M., Ahsan, N. & Chuhan, F.A., 1995. Sedimentology, depositional environment and economic potential of Datta Formation of Early Jurassic age of Attock-Hazara fold and thrust belts. In Abstracts first Nepal Geological Congress, 15-16.

For further information, consult Chaudhry, Chauhan and Ghazanfar, 1994.
Keywords: Sedimentology, deposition environment, Jurassic, Datta Formation, Attock.

C/115. Chaudhry, M.N., Ghazanfar, M. & Hussain, M.S., 1989. Petrology, metamorphism and origin of aglomeratic slates in Kaghan, Mansehra District, Pakistan. Punjab Bulletin, Punjab University 24, 61-70.

The Agglomeratic Slate in Kaghan Valley is a lithologically heterogeneous unit. It is composed of graphitic schist, micaceous quartzite, feldspathic quartzite, pelitic schist, feldspathic chlorite calcite schist, marble and metaconglomerate. The graphitic schist and feldspathic quartzites contain volcanogenic material. In Kashmir it contains well defined volcanic horizons. The unit was deposited under varying environmental conditions, continental, lagoonal and marine in a deepening cratonic rift, and represents continuation and, at places a replacement of Tanawals of Kashmir.
Keywords: Petrology, metamorphism, slates, Kaghan, Mansehra.

C/116. Chaudhry, M.N., Ghazanfar, M., Hussain, S.S. & Dawood, H., 1995. Problems of petrotectonic modelling of suture zones in northern Pakistan. Abstracts, International Symposium on Himalayan Suture Zone of Pakistan. Pakistan Museum of Natural History, Islamabad, 12-15.

The southern suture in northern Pakistan, popularly known as the Main Mantle Thrust (Tahirkheli, 1979) is as a whole composed predominantly of partially to completely dismembered ophiolitic suite. This suture zone is the true equivalent of the Indus- Tsangpo suture zone. Suturing of the Kohistan Island Arc to Indo- Pak Plate along this zone occurred at around 65 ma (Spencer, 1993; Smith et al., 1994; Chaudhry et al., 1994) to 35 ma (Treloar et a1.,1995).
The lithologies exposed are harzburgite tectonites derived from depleted mantle, dunites, peridotites and wherlites derived from upper mantle cumulates, layered and isotropic gabbros, sheeted dykes, pillow lavas, ribbon cherts, pelagic clays as well as flyschoid sediments. Because of extensive dismemberment it is rare to find all these lithologies in a single section. This has lead to divergent petrotectonic interpretations based heavily on geochemical consideration without regard to structural or geological constraints. The sections composed of plutonic ultramafic and mafic rocks have generally been interpreted as arc related and emplaced at the base of amphibolites. One or another part of a particular section on the basis of major or trace elements alone has been assumed are related without considering the entire section and structural relations of the internal units.
Keywords: Tectonics, petrology, suture zones, Pakistan.

C/117. Chaudhry, M.N., Ghazanfar, M., Hussain, S.S., Dawood, H. & Spencer, D.A., 1998. Location of the Main Central Thrust and the subdivision of the Indian plate Himalaya in the Lower Swat region and Malakand region, Northern Pakistan. Geological Bulletin, Punjab University 33.

Keywords: Indian plate, MCT, Swat, Himalaya.

C/118. Chaudhry, M.N. Ghazanfar, M., Meier, A., Ramsay, J.G., Spencer, D. & Wahrenberger, C., 1991. New stratigraphic and fossil finds in the Higher Himalayas of the upper Kaghan valley, NE Pakistan. Abstract Volume, 6th Himalaya-Karakoram-Tibet workshop, Auris, France, 29.

A collaborative project between the EHT and Punjab University during the summer of 1990 has led to important new discoveries bearing on the stratigraphic and structural relationships of the various rock groups marking up the Higher Himalaya Unit of NE Pakistan.
A coherent three unit stratigraphic subdivision appears to hold over most of the region. A basement consists of granitic gneiss which is overlain by a group of meta-pelitic to semipelitic sediments of original greywacke aspect which, although strongly recrystallized and locally granitized, still show traces of graded bedding with consistent younging directions away from the granitic basement. Although the relationships between these units is clear, suggesting that the granitic gneisses were metamorphic basement to a regionally overlapping group of sediments, no clear angular discordance has yet been discovered on outcrop scale.
The two basement groups are overlain by a thick series of calcareous pelites lithologically similar to the "schists lustres" of the European Alps, and interpreted as a sedimentary cover. These rocks locally contain good sedimentational "way up" structures, synsedimentary extension faults and fossils (stromatolites, trace fossils). Considering the amphibolites metamorphic grade of these rocks, the preservation of fossil is remarkable. The base of the cover succession is marked by extensive thick sheets of amphibolite locally showing deformed amygdates

suggesting that they were initially basaltic lavas, and thinner sheets of amphibolite of similar petrographic aspect are found throughout the succession.
As yet no firm ages have been placed on these stratigraphic units. However, lithological correlations with rocks of Swat, the Srinagar Basin and Ladakh suggest that the granitic gneisses are probably of Pre-Cambrian age. The metapelites are of Lower Paleozoic age and the calc-schists and associated basaltic lavas may be correlated with various basic volcanic rocks of Paleozoic and younger age (perhaps some being equivalent to the Panjal Trap). The overall distribution of these three units is suggestive of the presence of large scale recumbent fold nappes, but this pattern is complicated by the intensive development of later superposed fold phases and the formation of regional tectonic dome and basin structures.
Keywords: Stratigraphy, metamorphic rocks, tectonics, palaeontology, Kaghan valley, Mansehra.

C/119. Chaudhry, M.N., Ghazanfar, M. & Mian, M.A., 1983a. A plate tectonic model for Northwest Himalayas. International Seminar on Stratigraphy of Pakistan, Lahore, 1-7.

See Chaudhry, Ghazanfar and Ashraf, 1984.
Keywords: Plate tectonics, Himalaya.

C/120. Chaudhry, M.N., Ghazanfar, M. & Mian, M.A., 1983b. A plate tectonic model for Northwest Himalayas. Kashmir Journal of Geology 1, 109-112.

See Chaudhry, Ghazanfar and Ashraf, 1984.
Keywords: Plate tectonics, Himalaya.

C/121. Chaudhry, M.N., Ghazanfar, M. & Qayyum, M., 1986. Metamorphism at the Indo-Pak plate margin, Kaghan valley, District Mansehra, Pakistan. Geological Bulletin, Punjab University 21, 62-86.

This paper presents for the first time mineral assemblages, textures, structures, index mineral zones, metamorphic facies and metamorphic grades of the rocks lying between Paras and Babusar Pass, Kaghan valley. The metamorphic rocks are regionally metamorphosed and belong to a medium pressure type metamorphic series. The rocks range from unmetamorphosed units to high-grade metamorphic units e.g. from greenschist facies to high amphibolite facies. In terms of index minerals, they range from biotite to sillimanite zones and in terms of metamorphic grades the rocks range from very low grade to high grade metamorphism.
Keywords: Plate tectonics, barrovian metamorphism, structure, Kaghan valley.

C/122. Chaudhry, M.N, Ghazanfar, M., Ramsay, J.G., Spencer, D.A. & Qayyum, M., 1992. Northwest Himalaya-A tectonic subdivision. Abstracts, First South Asia Geological Congress, Islamabad, p.9.

Keywords: Plate tectonics, Himalaya.

C/123. Chaudhry, M.N, Ghazanfar, M., Ramsay, J.G., Spencer, D.A. & Qayyum, M., 1994. Northwest Himalaya-A tectonic subdivision. 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, 175-184.

Detailed geological mapping of the valleys of Neelum, Kaghan, Indus, Swat and Dir has afforded numerous excellent sections across the Northwest Himalaya. It has now become possible to characterize the tectonostratigraphy in these areas and define the major thrusts bounding the main tectonic units. The location of the Main Central Thrust (MCT) near Naran in the Kaghan Valley and its extension into the Neelum (to the east) and Swat valley (to the west) as finally formalized the correlation and extension of the transverse subdivision of the

Himalayas from India and Kashmir into Pakistan. This paper presents a systematic account of the stratigraphy, metamorphism and tectonics of the Himalayan subdivisions in Pakistan. The four major zones of the Himalayas, the Tethyan or Tibetan Himalaya, the Higher Himalaya, the Lesser Himalayas and the Sub-Himalaya have now been followed from the Neelum Valley, Azad Kashmir, through the valleys of Kaghan and Swat into Dir. The presence and nature of the northernmost belt of the Tethyan Himalaya is also established. The separation of the various tectonic zones of the Himalaya paves the way for synthesis and correlation of local stratigraphic, metamorphic and structural studies along various sections and their correlation with researches in Kashmir, Kumaun, Nepal and further east.

Keywords: Plate tectonics, tectonostratigraphy, structure, Kaghan, Indus, Swat, Dir, Himalaya.

C/124. Chaudhry, M.N., Ghazanfar, M. & Spencer, D.A., 1996a. Main Central Thrust in northwest Himalaya, Pakistan. Abstract volume, 11th Himalaya-Karakoram-Tibet Workshop, Flagstaff, Arizona (USA), 31-32.

The transverse subdivision of the Himalayas, established in Eastern and Central Himalaya in India and Nepal, could not be fully extended to Kashmir and adjoining Pakistan since these areas have remained unmapped until very recently. In addition, these areas constitute the Western Himalayan Syntaxial Region characterized by sharp bends in strike with extensive imbrication and strike slip faulting that results in the attenuation or even elimination of some units. This, coupled with lack of mapping until very recently, made it difficult to extend geologic or tectonic trends from India and Eastern Kashmir into Western Kashmir and Pakistan, which resulted in various workers trying to connect the MCT trend from India into Kashmir with Panjal Thrust (PT) or MBT (Gansser 1964; Sinha 1989). This view was generally accepted for over two decades. Acceptance of such a view would lead to combining together in one block of terranes, which have entirely different tectonostratigraphic, tectonometamorphic, tectonomagmatic and structural characteristics.

Yeats and Lawrence (1984) regarded the Raikot Fault on the western margin of the Nanga Parbat Haramosh Massif as a terminal tear fault of the Main Central Thrust. Tahirkheli (1992) demarcated a NE-SW Trending Shon argali Thrust as the “MCT” between Astor and Ratta. In our opinion Raikot and Shon argali faults run entirely within the HHC block (see Spencer, 1995 for full review problems of locating the MCT in Pakistan).

Heim and Gansser (1939), while working in Garhwal and Kumaun, defined a major thrust between the sedimentary formations and moderately metamorphosed rocks. This thrust was subsequently formalized as the Main Central Thrust (MCT). They also described the inverse metamorphism from these areas. However, they did not recognize tectonic break between Mesozonal and Katazonal rocks. Sinha (1989) has followed Gansser (1964) in defining the Main Central Thrust (MCT) in the Central Himalayas. Valdiya (1984) based on an abrupt break in the grade of metamorphism and on the change in petrological composition of the rocks of the central crystalline, defined a thrust plane (MCT) at an even higher stratigraphic level (at the base of kyanite-sillimanite bearing rocks) than the one defined by earlier workers. He named this thrust as the Vaikrita Thrust.

A large number of Himalayan workers now believe that the MCT is an intracontinental thrust which demarcates the boundary between the Lesser and Higher Himalayas that resulted in the considerably thickening of the continental crust. It is a north dipping generally 5 to 20 km thick low to high angle shear zone associated with mylonitisation, a strong stretching lineation and strong foliation. It is also marked by the inverse metamorphism and a sudden jump in metamorphic grade from greenschist to upper amphibolite facies with a differing tectonic style on either side of the shear zone (Brunel, 1986; Valdiya 1984; Ghazanfar and Chaudhry et al. 1994).

The Main Central Thrust firs located in the Kaghan and Neelum Valleys (Ghazanfar and Chaudhry, 1986) now extended across the entire NW Himalayas of Pakistan is a 500k to 5km thick zone of ductile deformation with the development of a strong schistosity is oblique but is being rotated into the shear zone. The ductile shear zone develops in the turbidites of Kaghan, as well as in the Malakand area. In zones of strong deformation within the turbiditic sequence, bedding is replaced by a strong mylonitic fabric. Therefore S0 and S1 have both been rotated into parallelism with the shear zone deformation. The thicker arenaceous beds are by contrast more folded and boundinaged. The mineral stretching lineation is strong and parallels the shear zone. Sheath folds are also present with eye-like structures developed due to fold hinges, which are curved and rotated towards parallelism with the shear zones. All kinematic indicators suggest a top to the south sense of shear.

There is a significant PT break on either side of ductile deformation. Rocks to the south of MCT in the Malakand and Swat fall in lower greenschist facies while rocks in Kaghan and Western Kashmir fall in middle greenschist facies. The rocks lying to the north of the proposed MCT in Western Kashmir and Pakistan fall in upper amphibolite facies (kyanite-sillimanite grades) and local eclogite facies. The structure style on either side of MCT is also very

different. The rocks to the north (HHC) occur as elongated structural basins and domes with fold interference pattern (Types 1 and 3) with major axis trending from NNE to the east of Besham Syntaxis and NNW to the West of Besham Syntaxis. The deformation is ductile with hardly any apparent fault. The rocks to the south of MCT generally trend EW. The deformation is brittle and is comprised of tight folds and abundant thrust comprising a schuppen structure.
Based on this work, both the Lesser and Higher Himalaya are now therefore recognizable in the NW Himalaya and are continuations of the better known LH, MCT and HH last seen in India.
Keywords: Plate tectonics, MCT, MMT, MKT, Himalaya.

C/125. Chaudhry, M.N., Ghazanfar, M. & Spencer, D.A., 1996b. Evidence for Pre-Mesozoic affinity of the Karakoram Himalaya to the Indian Plate, Northern Pakistan. Abstract volume, 11th Himalaya-Karakoram-Tibet Workshop, Flagstaff, Arizona (USA), 33-34.

The Karakoram Himalaya form a distinctive topographic and mountainous range in Central Asia. Geologically, they are classified as part of the Eurasian Plate, a collage of terranes into which the Indian Plate collided to form the Himalayan mountain range at times estimated from 65 to 45 Ma.
Recent mapping and traverses of the Karakoram Himalaya lead us to suggest that there is distinctive stratigraphical correlation between the units of the Karakoram Himalaya (Eurasian Plate) and the Himalaya (Indian Plate). In fact, we suggest that these similarities are so strong that he likelihood should be considered that the Karakoram Himalaya and the Indian Plate were until the early Mesozoic, attached as part of the same block or plate. With the closure of Paleo-Tethys and the opening of Neo-Tethys, a rifted piece of the Indian Plate (Karakoram Himalaya) subsequently broke away from Gondwanaland (and the juvenile Indian Plate) and was subjected to a passive collision, with eventual suturing, to Eurasia. The fact that he pre-collisional history of the Karakoram Himalaya is known to be co relatable to the Lhasa block of Southern Tibet in the east (Searle, 1991) and the Helmand Block of eastern Afghanistan un the west (Blaise et al., 1977; Stocklin, 1977; Wolfart and Wittekindt, 1980), suggests that a distinctive belt with a similar pre-Mesozoic stratigraphy can be traced, north of the Indus Suture, from west and east of the Karakoram Himalaya. Here we provide evidence of a north to south correlation with the Indian Plate. For discussion purposes, we also suggest a new terminology for the Karakoram Himalaya with the implications that this has for its tectonic history. The classification that we have used is based on that of the Himalayan subdivisions (i.e., Higher Himalaya and Lesser Himalaya). We suggest that in the Karakoram the distinctive units of the Higher Karakoram and Lesser Karakoram can be found and, more importantly, be correlated to their Indian Plate equivalent (Table 1 and 2).

Table 1: Stratigraphic Correlation between the Higher Himalaya (Swat-Besham, Kaghan- Azad Kashmir) and the Higher Karakoram (Hunza).

Lower Swat & Besham		Kaghan & Azad Kashmir		Hunza Valley	
Alpurai Group	Tilgram Fm Calc-pelite & marble with minor pelite Salampur Fm Pelite-psammite Turbite with amphibolite sheets	Burawai Group	Bans Formation (Pelites) Seri Fm Thick sequence of calc-pelite & marble with amphibolites Old Battakundi Fm Pelites psammite Turbite with amphibolite sheets	Baltit Group	Ganesh Fm marble, calc-pelite and amphibolite
Pacha Group	Swat granite Manglaur Formation Pelite-psammite turbidites Migmatites, minor, marble, calc schist & graphitic schist Kolangi Formation	Purbinar Group	Saiful-Muluk Granite Lulu Sar Formation pelite-psammite minor marble & graphitic schist Gittidas Granite		Minapin Formation Pelitic-psammite with minor marble & graphitic schist. Hasanabad Granite-

	(migmatites) Targhao Granite Gneiss (granite gneiss & migmatite)		Jalkhad Nar Formation migmatites & enclaves Ratti Gali Granite Gneiss (granite gneiss & migmatite)		migmatite with meta sedimentary enclaves & horizons

Table 2: Stratigraphic Correlation between the Lesser Karakoram of western Pakistan and the Lesser Himalaya (Peshawar Basin)

Zait & Parpish Formations Dolomite limestone; limestone Carboniferous/Triassic	Bampokha Formation Limestone/dolomite Carboniferous/Triassic?
Lun shales Shale, sandstone and limestone (Late Devonian)	Jafar Kandao Formation Limestone, dolomite & quartzite (Devonian) Girarai Formation Pelite, calc-pelite & marble (Age unknown)
Broghil Formation Slate, limestone, dolomite, quartzite (Ordovician/ Silurian?)	Panjpir Formation Slate, limestone & dolomite (Silurian) Misri Banda Quartzites Ordovician/Cambrian (?) S
Chitral Slates Slate, wackes, quartzites and some marble beds. Pre-Cambrian	Attock Slates Slates, wackes, quartzites and some marble beds Pre-Cambrian

Keywords: Plate tectonics, Eurasian plate, stratigraphic correlation, Karakoram, Himalaya.

C/126. Chaudhry, M.N., Ghazanfar, M., Spencer, D.A, Hussain, S.S. & Dawood, H., 1995a. Higher Himalaya of Pakistan- A tectonic stratigraphic review. Abstract Volume, 10th Himalaya-Karakoram-Tibet Workshop, Switzerland.

Mapping of extensive areas in Neelum, Kaghan, Besham, Lower Swat, Malakand and Dir has made it possible to delineate the Main Central Thrust, MCT, and define the area of the Higher Himalaya Crystalline, HHC, slab in Pakistan and Azad Kashmir. This paper presents a first time integrated account of the stratigraphy, metamorphism and deformation of this major division and hinterland area of the Northwest Himalaya. Between Indus Suture, or the MMT, to the north and MCT in the south the HHC slab, extends from Bajaur on the Pak-Afghan border in the west to across the Neelum Valley of Kashmir in the east. The slab has a variable width. It is widest in the area of Nanga Parbat Syntaxis and is attenuated in the area of Hazara Kashmir Syntaxis.
Stratigraphically the Higher Himalaya in Kaghan, Besham and Swat comprises the oldest exposed rocks of Pakistan. The basement is composed of a lower autochthonous to parautochthonous granitoid-migmatite complex with metasedimentary enclaves and abundant pegmatites, a middle pelite-psammite sequence with paragneiss horizons of garnetiferous quartzofeldspathic rocks, abundant pegmatites, intrusive bodies of granite and contact migmatites and an upper pelite-psammite package in kyanite-sillimanite grades with subordinate pegmatites and granites. Marble, amphibolite and graphitic pelite are minor lithologies. It is overlain by two unfossiliferous cover sequences. The First cover comprises a thick calcpelite, marble sequence with an overlying pelites unit in Upper Kaghan and an underlying turbidite unit with interbedded amphibolites in Lower Swat. The basic volcanics show a stratigraphic upward jump into the lowermost part of the overlying calcpelites in the area of Upper Kaghan. We suggest that the basement and the First Cover are Proterozoic in age although the age of the cover in Kaghan is debated and has also been suggested as late as Triassic. The Second Cover comprises low-grade graphitic pelites, cab pelites and marbles, which mainly crop out below the Indus Suture. On the basis of dates on cross cutting granite veins the Second Cover may also be Late Proterozoic or it may be Palaeozoic and are here interpreted as the Tibetan Tethyan sediments elsewhere lying unmetamorphosed to the north of the HHC. However, both the age and affinity of these Second Cover rocks is debated. The basement granitoids and the overlying First Cover rocks together form the crystalline HHC slab, and are both characterised by metamorphism in the upper amphibolite facies. The metamorphism shows

sudden downward jumps to greenschist facies both in the north across an extensional detachment (Trans-Himadari Fault, THF, or the Zanskar Shear Zone) into the Tethyan cover and in the south across MCT into the Lesser Himalaya. Eclogites have been reported from the Besal area of Upper Kaghan which indicate T=650^{0}C ± 50 and P=15 to 16 Kbars corresponding to a depth of 55 to 60 km. Elsewhere although the temperature was about the same the indicated depth ranged between 35 to 45 km. Whereas the whole of the HHC slab is metamorphosed in the upper amphibolite fades the conditions tend to become more intense structurally downward and the cores of major domes such as Besal, Besham and Kolangi may exhibit ultrametamorphism with profuse migmatisation and generation of anatectic granites. The common model based on cooling ages considers the dominant metamorphism Himalayan in age and explains the PT conditions by burial of the Indian Plate under Kohistan consequent upon collision between India and Kohistan (Ca 50 Ma) and its subsequent imbrication Extensive mapping in the field has however not revealed evidence of thrust imbrication in the terrain of Higher Himalaya. The model as it stands also fails to explain such features as greenschist facies metamorphism of Indus Suture mélange and of the underlying low grade Tethyan cover as well as preservation and age of blue schist and the short time interval between collision and exhumation. Numerous evidences have been cited to suggest that the Higher Himalaya slab suffered at least one pre-Himalayan metamorphism, here suggested to be upto the amphibolite facies upon which a variable Himalayan metamorphism has been imprinted. Deformation in the HHC slab is characterised by the north-south trending kilometric scale domes and basins and a ductile regime. These structures are unique to the Higher Himalaya being truncated by the MMT and MCT in north and south. The Kohistan area and the Lesser Himalaya (except for the HKS) in the south both show east-west trends and a schuppen structure under conditions of increasing brittle deformation.
Keywords: Tectonics, stratigraphy, MCT, Higher Himalayan crystallines, Himalaya.

C/127. Chaudhry, M.N., Ghazanfar, M., Spencer, D.A., Hussain, S.S. & Dawood, H., 1995b. The division between Lesser and Higher Himalaya in Pakistan. Abstracts, International Symposium on Himalayan Suture Zone of Pakistan. Pakistan Museum of Natural History, Islamabad, 24-26.

Lack of mapping on the ground, presence of an island arc in this section, the presence of Nanga Parbat and Hazara Kashmir Syntexis and the continuing Kashmir dispute had complicated the task of tectonic correlation between the Pakistani northwest Himalaya with the Himalaya to the east. With the mapping of Neelam, Kaghan and Swat areas the stage was set for the delineation of the MCT for the subdivision of the Lesser and Higher Himalaya in Pakistan and correlate it across Kashmir to Kumaun and Nepal Himalaya. The MCT has now been defined from Luat in Neelam Valley and Kashmir across Batal in Kaghan through Malakand and Swat to Dir and Bajaur in the extreme west of Pakistan the HHC and the Lesser Himalaya stand differentiated.
The MCT is Characterized by a kilometric zone of milonites in the greenschist facies with a general top to the south sense of thrusting, The Major Boundary Thrust (MBT) is distinguished by major difference in lithostratigraphic packages on both sides, a sudden jump in metamorphic grade and a marked difference in tectonic style.
The HHC slab extend from Neelam Valley to Bajaur is characterized by a turbiditic basement sequence extensively migmatised in the lower part and a calc-pelitic cover sequence. A second low grade sequence appears in synclinal inliers on the high rocks of HHC. It appears the same low grade rocks appear between the suture zones and the Indian Plate in upper Kaghan as well as Banna area of Allai.
Keywords: Lesser Himalaya, Higher Himalaya.

C/128. Chaudhry, M.N., Ghazanfar, M., Spencer, D.A., Hussain, S.S. & Dawood, H., 1999. Evidence for Pre-Mesozoic affinity of the Karakoram Himalaya to the Indian plate, Northern Pakistan. Geological Bulletin, Punjab University 33 & 34, 1-7.

Consult the Chaudhry et al., 1996b above for further information.
Keywords: Plate tectonics, Eurasian plate, stratigraphy, Karakoram, Himalaya.

C/129. Chaudhry, M.N., Ghazanfar, M., Spencer, D.A., Hussain, S.S. & Dawood, H., 1997. The higher Himalaya in Pakistan-A tectonicstratigraphic synopsis. Geological Bulletin, Punjab University 31 & 32, 21-41.

Following the demarcation of the Main Central Thrust (MCT), the mapping and tectonostratigraphic characterisation of the Higher Himalaya across northern Pakistan and Azad Kashmir has been made for the first time. This slab has a variable width. It is widest in the area of the Nanga Parbat Syntaxis and is attenuated in the region of the Hazara-Kashmir Syntaxis. This paper presents an integrated account of the stratigraphy; deformation and metamorphism of this major tectonic division and hinterland area of the Northwest Himalaya. The Higher Himalaya is comprised of a lower basement and an upper cover unit. The basement is constituted predominantly of granitoids, migmatites, pelite schists and micaceous quartzites with minor calc-pelite gneisses, marbles and discordant amphibolites. The cover consists predominantly of calc-pelite gneisses, with subordinate marbles and pelite schists and extensive amphibolites at its base. The Higher Himalaya is characterised by the development of kilometric scale elongated structural basins and domes with a fold interference pattern (types I & 3) that trend either northeast-southwest (Kaghan), north-south (Besham) and north northwest-south southeast (Swat). These fold trends are truncated at a high angle to the south across the Main Central Thrust in the Lesser Himalaya and to the north by the Tethys and Indus Suture Zone rocks. The, nature of deformation in the Higher Himalaya is ductile. The rocks of the 'Higher Himalaya have been metamorphosed to upper amphibolite facies or kyanite-silliminite grade. However around Besal in Upper Kaghan and at places in Upper Neelum valley the rocks have suffered eclogite facies metamorphism. The Pressure-temperature estimates by various workers give generally upper amphibolite facies metamorphism which range from 600' to 700' C at 7-11 Kbars. However, the basement and cover lithologies of the Besal area in Upper Kaghan valley have undergone eclogite facies metamorphism at T=65&5U0 C and P=15-17 Kbars, corresponding to depths of 55 to 65 kilometers. To the south of the Higher Himalaya across the Main Central Thrust, the Lesser Himalayan rods take a marked downward jump in metamorphic grade to greenschist facies. Similar observations also were found to the north in the Tethyan lithologies which overlie the HHC slab or occur as fault slivers close to the suture.
Keywords: Mapping, tectonics, stratigraphy, MCT, Higher Himalaya.

C/130. Chaudhry, M.N., Ghazanfar, M. & Walsh, J.N., 1993. The Panjal sea, Kashmir Hazara microcontinent and Hercynide geology of Northwest Himalaya. Abstract Volume, 8th Himalaya-Karakoram- Tibet Workshop, Vienna, 13.

This paper discusses the tectonic significance of the Permian Panjal Volcanics Kaghan Valley on the basis of an overview of geology, field relations and associated rocks. It is proposed that more than 400-km long rift related, generally terrestrial Panjal suite developed into an incipient ocean, the Panjal Sea with continental to oceanic transitional to oceanic crust in Kaghan area. Major element, trace element and R.E.E. characteristics appear to corroborate this conclusion.
North o this incipient ocean lay the Kashmir Hazara micro-continent. The Permian Panjal Sea which developed during rifting of Gondwanaland closed during Triassic when the overlying Malakand limestone was deposited and Neo Tethys started opening to the north of the Kashmir-Hazara microcontinent.
Keywords: Tectonics, Panjal volcanic, Kaghan, Himalaya.

C/131. Chaudhry, M.N., Ghazanfar, M., Walsh, J.N. & Hussain, M.S., 1992. The Panjal Sea, Kashmir-Hazara microcontinent and Hercynid geology of Northwest Himalaya in Pakistan. Pakistan Journal of Geology 1, 81-99.

Consult the previous paper for further information.
Keywords: Tectonics, Panjal volcanic, Kaghan, Himalaya.

C/132. Chaudhry, M.N., Ghazanfar, & Zaka, K.J., 1992. Petrology, economic geology and origin of Siwalik sandstone from Northern and Western Pakistan. Abstracts, First South Asia Geological Congress, Islamabad, p. 54.

Keywords: Petrology, sandstone, siwaliks.

C/133. Chaudhry, M.N., Hassan, G. & Zaka, K.J., 1992a. Researches into geotechnical, petrographic and chemical aspects of Indus gravel and sand as concrete aggregate. Abstracts, First South Asia Geological Congress, Islamabad, p.9.

River Indus, the life line of Pakistan, is the single most important and major potential source of water and power in the country. Most of the future high dams, barrages, thermal and nuclear plants and bridges will be located on Indus river. This will require billions of cubic meters of concrete. The value of aggregate alone will run in billions of rupees. Aggregate may limit the strength of concrete, its durability and structural performance. Aggregate has generally been considered as inert material. In actual place, aggregate is far from inert in its characteristics and exerts a profound influence on the performance and durability of concrete. Indus gravel have shown excellent physical characteristics and are designated as most suitable for concrete. However, in service behaviour and mortar bar tests over extended periods have shown the development of significant distress. The causes of distress have been identified as alkali silica and alkali silicate reaction (A.S.R, A.St.R) between meta wackes, metagreywackes, micro-fractured quartzite and meta volcanics and the high alkali cement. Notwithstanding such evidence the controversy still rages as to the actual and relative causes of deterioration between physical and environmental factors and reactivity of aggregate.
This paper is an outcome of researches to resolve this controversy and to present a proper evaluation of various geotechnical, petrographic, mineralogical and chemical characteristics of the Indus aggregate. In the opinion of the authors, the ILS.R. and A3t.R. potential of these aggregate is a significant factor to be considered for future projects and it is proposed that this aggregate may be used either with low alkali cement (total alkalis less than 0.5%) or with the addition of appropriate quantity of pozzolanous additive or slag cement.
Keywords: Aggregate, petrography, geotechnical, Indus gravel, sand.

C/134. Chaudhry, M.N., Hassan, G. & Zaka, K.J., 1992b. Researches into geotechnical petrographic and chemical aspects of Indus gravel and sand as concrete aggregate. Pakistan Journal of Geology 1, 1-14.

Consult the preceding account for details.
Keywords: Aggregate, petrography, geotechnical, Indus gravel, sand.

C/135. Chaudhry, M.N., Hussain, S.S. & Dawood, H., 1992a. The Lithostratigraphic framework of North-West Himalaya, south of the Main Mantel Thrust along Mingora-Daggar section, Swat, Pakistan. Abstracts, First South Asia Geological Congress, Islamabad, p.54.

Consult the following account.
Keywords: Stratigraphy, MMT, Mingora, Himalaya.

C/136. Chaudhry, M.N., Hussain, S.S. & Dawood, H., 1992b. The Lithostratigraphic framework of North West Himalaya, south of the Main Mantel Thrust along Mingora-Daggar section, Swat, Pakistan. Pakistan Journal of Geology 1, 29-41.

The Mingora-Daggar section constitutes the northern edge of the Indo-Pak plate west of Besham syntaxis. The rocks exposed in the area range in age from Precambrian to Eocene. Manglaur group is the oldest rock unit of the area and is divided into lower Pacha formation and an upper Ilam granite gneiss formation. Pacha formation is Precambrian in age, falls in upper amphibolite facies and is composed predominantly of psammite and pelite with smaller proportion of marble, calc-silicate marble, graphitic schist, amphibolite, migmatites and old basement non porphyritic garnet tourmaline granite gneisses outside the area. Ilam porphyroblastic granite gneiss intrudes Pacha Formation and is probably Precambrian in age. Other granitic rocks are syn to post tectonic and Tertiary in age. One of these syntectonic bodies mapped is Tertiary Amlukdarra tourmaline garnet microgranite gneiss. Alpurai group of Precambrian age overlies the porphyroblastic Ilam granite gneiss and is divided into lower Salampur formation composed of pelite psammite interbedded with abundant amphibolites and an upper Tilgram formation comprised basically of banded garnetiferous calc-pelite and marble with subordinate graphitic garnetiferous schist and

garnetiferous amphibolites. Dagar formation is comprise predominantly of low grade graphitic schist and phyllite with subordinate phyllitic pelite, marble, calc schist and green schist. Kazmi et a (1984) named this unit as Saidu schist and regarded its age as lying between Palaeozoic and Mesozoic. This formation is regarded here as Precambrian in age. Bampokha group is Lower to Middle Palaeozoic in age falls in greenschist facies of regional metamorphism and is divided into Girarai formation and Tursak formation. The Girarai formation is composed mainly of calc-pelites, light gray to gray marble and subordinate graphitic schist. The Tursak formation is compose dominantly of white and bicoloured white and gray marble with subordinate calc-pelites, pelites and graphitic schist/phyllite. The Creto-Tertiary Mingora ophiolitic mélange comprise tectonic blocks of greenschist, greenstone, talc-carbonate, amphibolite, gabbro, serpentinite, peridotite, harzburgite, siliceous and graphitic metasediments and a few Assilina and Nummulite bearing (Eocene) carbonate slices.
Keywords: Stratigraphy, MMT, Mingora, Himalaya.

C/137. Chaudhry, M.N., Hussain, S.S. & Dawood, H., 1992c. Position of the Main Central Thrust and sub-division of Himalaya in Swat. Pakistan Journal of Geology 1, 59-65.

Geological investigations and large scale mapping in Swat area of Western Himalaya has now made it possible to precisely locate the position of the Main Central Thrust (MCT). There is a clear and well-marked contrast in the tectonic style and degree of metamorphism and gross stratigraphy to the north and south of this line. The delineation of the Main Central Thrust in the area under study now makes it possible to extend the tectonic zones of Himalaya in Neelum and Kaghan to the West of Indus River. See also the following one.
Keywords: Tectonics, MCT, Himalaya.

C/138. Chaudhry, M.N., Hussain, S.S. & Dawood, H., 1994. Position of the Main Central Thrust and subdivision of Himalayas in Swat, 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, 208-211.

Detailed fieldwork recently carried out in southern Swat and Malakand has made it possible to locate the position the Main Central Thrust (MCT). Across this very important line there is a marked contrast in tectonic style, stratigraphy as well as metamorphism.
Between the Main Mental Thrust (MMT) to the north and MCT to the south lies the Higher Himalayan crystalline block. This deep-seated blocks was rapidly uplifted between these two major thrusts due to collision between Indo-Pak plate and Asian plate thus exposing some of the deepest rocks of the Northwest Himalaya in Pakistan. On the basis of delineation of these major structural lines, the Himalaya in Swat has been subdivided into Kohistan Himalaya, Tethyan Himalaya, Higher Himalaya and Lesser Himalaya.
Keywords: Tectonics, MCT, Himalaya.

C/139. Chaudhry, M.N., Hussain, S.S. & Dawood, H., 1997. Massive sulphide and porphyry mineralization associated with Gawachi back arc basin, Chitral, Ishkuman, Chatorkhand, Gakuch, Yasin, Gilgit and lower Hunza valleys. Abstracts, National Symposium on Economic Geology of Pakistan, Islamabad, 3p.

Geology, petrology and mineralization of the MKTZ ophiolites. Rakaposhi volcanics and associated rocks of the Yasin Group have been studied in Shishi Gol. Drosh and Mirkhani areas of Chitral and Ishkuman. Chatorkhand-Gakuch. Yasin, Gilgit river valley and lower Hunza river valley. On the basis of tectonostratigraphic elements and tectonomagmatic characterisation of the mafic and ultramafic rocks and associated sediments, a back arc basin named here as the ~Gawachi back arc basin", has been defined by us. This basin has previously been considered by many workers as simply top of the Kohistan island arc. The Gawachi back arc basin, is composed of Rakaposhi volcanic complex and Yasin Group of middle Jurassic to Cretaceous age. These rocks have been intruded by plutons of the Kohistan arc. These plutons are sodic deformed plutons. potassic deformed plutons and potassic undeformed plutons (Treloar et at. 1989. Bard 1983).
The Rakaposhi volcanics have been classified on the basis of field characteristics. petrography and geochemistry. Most of the rocks are either basalts or basaltic andesites. Hardly any proper rhyolite could be found. Subordinate

lithologies defined on the above basis are andesites and dacites. These finds are contrary to the general implicit belief expressed in many reports and publications that these greenstones are predominantly composed of andesites, dacites and rhyolites. Tectonomagmatic discrimination diagrams were used to characterise the tectonic setting. Bonanitic characteristics are shown by certain volcanic sections. Other sections show an arc type, ocean floor and even MORB characters. Tectonomagmatic signatures as well as the contents of immobile elements coupled with tectonostratigraphic set up strongly indicate a back arc basin environment. But of course. arc input in this zone is also recognised. The Yasin Group is composed of siliciclastic as well as calciturbidites flyschoid sediments and pelagic limestones topped by platform carbonate and siliciclastic sediments. The final fill of this hack arc basin is comprised of molassic fill of Reshun Formation. However this paper deals mainly with the massive sulphide mineralization and also touches upon porphyry type mineral shows. Petrology and tectonostratigraphy of the region will be dealt with in a separate publication. Mineral models were worked out for extensive Cu-Pb-Zn-Ag mineralization in Kaldam Gol-Purgar Got area. This volcano-sediment hosted deposit occurs in the Chitral part of the Gawachi back arc basin and holds promise for Ag and Au anomalous zones as well.
Values of 1.0% Cu and Zn and upto 905 ppm Ag and 8.5 ppm Au have been found in samples of mineralized zone from Purgar Gol in Shishi area of Chitral. This zone is an extension of Kaldam Gol massive sulphide mineralization.
Cu-Pb-Zn-Ag mineralization from Kaldam Gol and adjoining areas of Drosh in Chitral has been studied in detail for metal values, extent of mineralization and host rock alteration. Substantial anomalies of Au values are also being reported. This mineralization occurs in a sedimentary-volcanic zone associated with the back arc basin. It has all the characteristics of massive sulphide .deposits. The genesis of this mineralization has been discussed. Our studies and modelling show that this area holds potential for Au and Ag mineralization as well. This mineralization is likely to be much more extensive than realised so far. These mineral shows have anomalous values of Cu and merit further exploration. Porphyry type Cu mineralization from Kaldam Gol and adjoining areas has also been reported by some workers. A volcano-sedimentary zone iii the Reshun formation of Darn area. Shishi valley. Chitral, hosts Cu mineralization. Only a few exposures of this mineralization have been observed so far.
The mineralization in lower Hunza valley and Singal is associated with the Rakaposhi volcanics and the associated metasediments. The peak metamorphism occurred at about 80 ma. This metamorphism is associated with the closure of the back arc basin between Asian plate and the Kohistan island arc. The metallic sulphide mineralized zones have been deformed and metamorphosed during this event. Due to this metamorphism and subsequent alteration, the primary zones of alteration associated with mineralization are difficult to delineate properly. The Normal mineralized zone (Leghari et al. 1986) is again associated with Rakaposhi volcanics and shows anomalous values of Cu. Zn, Pb. Mo and Mn. This is a composite mineralized zone. Here massive sulphide mineralization has been superposed by porphyry type overprint.
The Garesh mineralized zone is pyrite rich and occurs intimately associated with Rakaposhi volcanics. Although this mineralization is of pyrite type yet it shows somewhat anomalous values of Cu. Pb. Zn and Au. The Jutial mineralized zone is in the nature of “massive pyrite deposit” and is associated with neotaturbidites of flyschoid origin. The mineralization in the Singal area (Khan et at. 1987) is also intimately associated with the Rakaposhi volcanic complex. The metallic contents are somewhat anomalous with respect to Cu. Zn. Co. Mo, and Fe.
A substantial volcano-sedimentary sulphide mineralized zone of Gawachi back arc basin (1 50m x 300m) is being reported from Mayoon Nala, Ishkuman valley. The extension of this zone is covered by scree and talus. The actual zone of this massive sulphide deposit may be much bigger than the exposed area. The metal values of this zone are being studied. In Drosh area amphibolites of the mélange zone contain disseminated Cu mineralization. These are strongly metamorphosed massive sulphide deposits.
Sulphide mineralization associated with Rakaposhi volcanics as well as associated metasediments has been studied in detail. The modified and reconstituted sulphide alteration zones have been studied and reinterpreted in some detail. On the basis of these studies working mineral models for sulphide mineralization have been established. These mineral models can now be applied for the search and study of other comparable areas. Disseminated copper mineralization “shows” associated with Kohistan arc diorites and associated porphyries have been studied and interpreted in Ashret and Mirkhani areas of Chitral. Mineral models for these deposits have been worked out. The Ashret and Mirkhani mineralization is related to porphyry type mineralization.
Keywords: Mineralization, porphyry, sulphide, Gawachi back arc basin, Chitral, Ishkuman, Yasin, Gilgit, Hunza.

C/140. Chaudhry, M.N., Hussain, S.S., Qamar, N.A., Islam, Z., Akhtar, J. & Rehman, S., 1987. Geology and petrology of Barawal-Dir-Bibior area (toposheet No. 38 M/16), Dir District, N.W.F.P., Pakistan. Geological Bulletin, Punjab University 22, 143-153.

A consolidated map of about 250 sq. miles of Dir-Barawal-Bibior area is presented on a scale of 1”=1 mile. Out of this 100 sq. miles has been mapped by the authors for the first time, Geology, petrology and genesis of the igneous, metamorphic and sedimentary rocks of the area has been described. The amphibolites of the area represent an obducted subduction mélange which is a metamorphosed sequence originally composed of a variable admixture of submarine Lavas and an assortment of sediments of calcareous and siliceous marly nature and arc-derived detritus. Quartzites and calcareous schists have been derived mainly from the arc zone.
The quartzites are overlain by slightly metamorphosed marls, calcareous shales and limestone beds and bonds. The calcareous rocks contain Eocene foraminifera. Volcanic horizons containing flows as wen as pyroclasts occur interbedded with metasediments. The arc-related acid to intermediate intensives occur intruding the metamorphic sequence.
Keywords: Mapping, petrography, igneous-sedimentary-metamorphic rocks, Barawal, Dir.

C/141. Chaudhry, M.N., Iqbal, M.A. & Ahsan, N., 1994. Petrology of Lumshiwal Formation from Gulgaah Nala near Chinali Bridge, Abbottabad-Nathiagali Road, Hazara with special reference to Nandpur Gasfield, Punjab Platform. Pakistan Journal of Hydrocarbon Research 6, 41-52.

A detailed study of petrology of Lumshiwal Formation of Early Cretaceous age from Gulagah has been carried out for the first time. The objective was to study the petrography, provenance, environment of deposition and diagenesis of the Formation and to compare it broadly with Nandpur gasfield section of Punjab Platform where it is a gas reservoir.
The section of Lumshiwal Formation from Gulagah Nala near Chinall Bridge is medium to thick bedded glauconite sandstone with intercalations of shale. This is petrographically divisible into 8 internal units. The unit overlying Chichali Formation is clay and quartz cemented arenite. The other units are mainly quartz, glauconite and carbonate cemented, moderately well to well sorted, sub-mature to mature quartz arenites and shale. The maximum development of glauconite is in the central part. Since glauconite appears to have originated from clay, the glauconite rich arenites might have originally been wackes. Some horizons are selectively cemented with flint. However, intraclasts of quartz grains cemented with fling are also observed towards the top of the Formation.
Accessory tourmaline, zircon, epidote and sphene which may occur either as discrete grains or as inclusions within quartz grains suggest an ultimate derivation from sialic igneous metamorphic basement with minor contribution from basic source. Granitoids were mainly S-type. However, overall mineralogy and texture suggest recycling.
The Lumshiwal Formation indicates low energy conditions in the sub-tidal zone. The formation of glauconite itself reveals slow rates of sedimentation and mildly reducing conditions. diagenetic history indicates the formation of glauconite, secondary quartz, feldspar and flint earlier and ferroan calcite and dolomite at a later stage. Development of stylolites in the carbonate parts and suturing of quartz grains occurred during deep burial. The last stage involves the formation of ferroan dolomite during final uplift with part converting into dedolomite.
Keywords: Sedimentology, Cretaceous, Lumshiwal Formation, Abbottabad.

C/142. Chaudhry, M.N., Jafferi, S.A. & Saleemi B.A., 1974. Geology and petrology of the Malakand granite and its environs. Geological Bulletin, Punjab University 10, 43-58.

A detailed geological map on the scale of 3.8″ to a mile of about 50 square miles of the area around the Malakand Pass is presented on a reduced scale. Detailed petrology and geology of the Malakand granite and the associated argillaceous, calcareous and arenaceous metamorphic rocks are being presented here for the first time. Five chemical analysis of the Malakand granite, one analysis of the pegmatite vein and one analysis of the Malakand granite gneiss along with their mode and norm are given. The metamorphics range in grade from biotite to garnet grade of the regional metamorphism. Malakand granite has been derived from the Malakand Granite gneiss but has undergone reconstitution and silicification.
Keywords: Petrography, petrology, granite, Malakand.

C/143. Chaudhry, M.N., Kasuri, R.A. & Ahsan, N., 1997. Facies, microfacies, diagenesis and environment of deposition of Lumshiwal Formation at Thub near Ayubia, District Abbottabad. Pakistan Journal of Hydrocarbon Research 9, 57-56.

A detailed study facies, microfacies, diagenesis and environment of deposition of Lumshiwal Formation of Early Cretaceous age from Thub Top near Ayubia has been carried out for the first time. The objective was to study the facies, microfacies, provenance, environment of deposition and diagenesis of the formation in the northwestern part of the oil and gas producing Indus Basin. The formation is producing gas at Nandpur and Panjpir located near Sargodha high in the northern part of Punjab platform. This section of Lumshiwal Formation is divisible into 5 facies and 20 microfacies. Compositionally all the sandstone horizons are mature. Texturally only one microfacies is immature and one microfacies is super mature, rest of the microfacies are mature to sub-mature. The sandstone is predominantly fine to very fine grained, only one microfacies is medium grained, and two microfacies are coarse grained.

Quartz and glauconite are the common cements while iron oxides, clay and flint occurs as subordinate cements.

Accessory to trace amounts of tourmaline, zircon, epidote and sphene which may occurs either as discrete grains or as inclusions within quartz grains suggest an ultimate derivation from sialic metamorphic-igneous basement with minor contribution from basic sources. The source granitoids were mainly S-type. However, overall mineralogy and texture strongly suggest recycling.

The Lumshiwal Formation was deposited in low energy conditions in the subtidal zone. The formation of glauconite itself suggests slow rates of sedimentation and mildly reducing conditions. Diagenetic history indicates the formation of glauconite followed by flint and kaolinite. This was followed by ferron calcite and dolomite at a later stage. Suturing of quartz grains occurred during deep burial. Fracturing of quartz grains occurred during tectonic deformation in brittle regime. Microcrystalline quartz developed along fracture cleavage. The last stage involved the formation of ferroan dolomite during final uplift with parts converting into dedolomite.

Key words: Facies, microfacies, diagenesis, Lumshiwal Formation, Abbottabad.

C/144. Chaudhry, M.N., Kausar, A.B. & Lodhi, S.A.K., 1974. Geology of Timurgara-Lal Qila area, Dir District, NWFP, Pakistan. Geological Bulletin, Punjab University 11, 53-73.

One hundred and twenty square miles of the Timurgara-Lal Qila area, a part of Hindu Kush Range, and situated in the middle of Dir Distt. N. W. F. P. was mapped on 4″ = 1 mile scale. A map on the reduced scale is presented. The oldest rock of the area is an amphibolite. This has been intruded by a diorite intrusion followed by a noritic intrusion. The amphibolites have formed as a result of the regional metamorphism of basic igneous rocks. The diorite body is composed of diorite, quartz diorite and tonalite. It has formed by the crystallization of a diorite magma of pyroxene andesitic composition. The latter basaltic magma of strong tholeiitic affinities formed the norite intrusion. Differential crystallization of this magma gave rise to peridotites, pyroxenites, norite and gabbro. Petrogenesis of the area is discussed at length and sixty modal analyses of the various types have been presented.

Key words: Maps, amphibolites, petrography, Dir.

C/145. Chaudhry, M.N., Mahmood, A. & Chaudhry, A.G., 1974. The ortho- amphibolites and the para-amphibolites of the Dir District, NWFP, Pakistan. Geological Bulletin, Punjab University 11, 89-96.

Extensive field and laboratory studies have been carried out on the amphibolites of the Dir District. As a result, the Dir amphibolites have been divided into southern Dir amphibolite belt and northern Dir amphibolite belt. As a result of field and laboratory studies and on the basis of textural, mineralogical and field characteristics, the northern Dir amphibolites have been called para-amphibolites, while southern Dir amphibolites have been called ortho-amphibolites.

Key words: Amphibolites, metamorphism, Dir.

C/146. Chaudhry, M.N., Mahmood, A. & Shafiq, M., 1974. Geology of Sahibabad–Bibior area, Dir District, NWFP Geological Bulletin, Punjab University 10, 73-89.

Fifty square miles of Bibior–Sahibabad area, a part of Hindukush Range and situated ten miles south of the town of Dir, was mapped on 3″ = 1 miles scale. A map on the reduced scale is presented.

The area is composed of igneous and metamorphic rocks. Igneous rocks include granodiorite and some minor granite intrusions. The metamorphic sequence is represented by calcareous schists and amphibolites. Calcareous schists are the oldest rocks of the area. Study of fossils recovered from a marl band show Eocene age. Amphibolites are formed as a result of regional metamorphism of calcareous pelitic rocks.
Granodiorite is intrusive into amphibolite. It is a massive granitoid of igneous origin. A mixed zone ranging from 100 to 250 yards in width is formed due to interaction of the granitic magma and the amphibolite.
Seventy-two thin sections of various units were studied. Sixteen modal analysis of leuco-amphibolite, twenty-three of the mela-amphibolites, nine of the mixed zone, six of the granodiorite, four of the calcareous schists and two of the minor veins and bodies are presented.
Key words: Maps, granitoids, amphibolites, calcareous schists, Dir.

C/147. Chaudhry, M.N., Mahmood, T., Ahmed, R. & Ghazanfar, M., 1992. A reconnaissance microfacies study of Kawagarh Formation near Giah, Abbottabad-Nathiagali Road, Hazara, Pakistan. Pakistan Journal of Hydrocarbon Research 4, 19-32.

The Kawagarh Formation of Upper Cretaceous age from near Giah, Abbottabad-Nathiagali Road, Hazara, has been studied in detail for internal units, microfacies and diagenetic fabrics. A total of eighteen microfacies and five internal units have been defined. The eighteen microfacies is based on depositional textures cum composition from bottom to top are Wackestone (Biomicrite)-Dolomitic limestone, Dolomitic limestone, Wackestone (Biomicrite), Dolospar, Wackestone (Biomicrite)-Dolomitic limestone, Dolospar, Wackestone (Biomicrite)-Dolomitic limestone, Calcitic Dolomite, Wackestone (Biomicrite), Sandy Wackestone (Biomicrite), Sandy Dolomitic limestone and Sandy Dolospar. A total of five facies units have been established which (internal units) from bottom to top are mixed dolomitic limestone and dolospar Unit, Biomicrite Unit, Sandy Biomicrite Unit, Sandy Dolomitic limestone Unite and Sandy Dolospar Unit. The lower three units contain predominantly Late Cretaceous planktonic foraminifer species of Globotruncana and deeper water Algae (Oligosteginids) and are considered to have been deposited in deep water low energy environments (outer shelf close to the edge) while the upper two units which contain rare planktonic foraminifera and are sandy in nature are interpreted to have been deposited in shallower waters (Littoral to inner shelf) with ingress of detrital material. There is evidence to suggest that the dolomitization in the lower two units took place mainly during the deep burial diagenesis which dolomitization in the upper two units owes its origin to ground water mixing during early diagenesis. A study of diagenetic fabrics show that mechanical compaction is unimportant while chemical compaction is wide spread.
Key words: Reconnaissance, microfacies, Cretaceous, Kawagarh Formation, Abbottabad.

C/148. Chaudhry, M.N., Manzoor, A., Ghazanfar, M. & Ahsan, N., 1994. Sedimentology of Datta Formation at Kalapani, Abbottabad, NW Himalayas, Pakistan. Geological Bulletin, Punjab University 29, 11-27.

Key words: Sedimentology, Datta Formation, Abbottabad.

C/149. Chaudhry, M.N., Nadeem, M. & Ahsan, N., 2000. Sedimentological studies of Chorgali Formation at Chahla Bandi of the Western limb of Hazara Kashmir Syntaxial region in Azad Jammu and Kashmir. Abstracts, Third South Asia Geological Congress, Lahore, 62-63.

Key words: Sedimentology, Hazara Kashmir syntaxis, Chorgali Formation, Azad Kashmir.

C/150. Chaudhry, M.N., Sattar, A. & Mateen, A., 2001. Muscovite bearing peraluminous granites from upper Kaghan valley, NW Himalaya, Pakistan. Abstracts, 4th Pakistan Geological Congress, Islamabad, 61-62.

Upper Kaghan Valley in NWFP provides a cross-section through the Higher Himalayas of Pakistan. The Higher Himalayas are composed of a lower basement and an upper cover unit. The basement is comprised of granitoids,

turbidites, migmatites with minor marble and pelite-psammites horizon and discordant amphibolites. The cover consists predominantly of garnetiferous calc-pelites, marbles and pelites with extensive amphibolites at the base.
A spectacular feature of the lithologies of Higher Himalayan slab in the Upper Kaghan Valley is the occurrence of granitoids. These granitoids are peraluminous and mainly syenogranites and monzogranites, containing muscovite + biotite + garnet± apatite + tourmaline and rare opaques.
The peraluminous granitoids are generally subdivided into two main groups; the muscovite bearing peraluminous granitoids (MPGs) and the cordierite bearing peraluminous granitoids (CPGs), which are both anatectic but can be distinguished on the basis of mineral content, texture, rock associations and mode of emplacement. A generalized petrogenetic model for peraluminous granitoids assigns that cordierite bearing peraluminous granites are generated where mantle derived magmas are injected into or have underplated crustal rocks. While muscovite bearing peraluminous granites are produced mainly in orogenic zones affected by major crustal shears or overthrust structures through wet anatexis of crustal rocks and crystal fractionation of the magma.
The granitoids from Higher Himalayas of Upper Kaghan Valley have composition close to the granitic minimum melt. They are mainly leucogranites i.e. felsic granites rich in K-feldspar and sodic plagioclase and little mafic minerals and primary muscovite, so they are categorized as muscovite bearing peraluminous granites.
Key words: Peraluminous granites, petrography, Kaghan valley, Himalaya.

C/151. Chaudhry, M.N., Shahbaz, S.T., Chaudhry, M.A., Malik, M.N., Shakir, M.K., Murtaza, G. & Shamsuddin, 1981. Lithostructural Mapping of Kalapani, Kathwal and Kakul area, District Abbottabad. M.Sc. Thesis. Geology Department, Punjab University, Lahore.

Keywords: Lithostruture, mapping, Abbottabad.

C/152. Chaudhry, M.N. & Shams, F.A., 1983. Petrology of the Shewa porphyries of the Peshawar Plain Alkaline Igneous Province, NW Himalayas, Pakistan. In: Shams, F.A. (Ed.), Granites of Himalaya, Karakoram and Hindu Kush. Institute of Geology, Punjab University, Lahore, 171-181.

Chemical analyses and petrography are presented of acid black porphyries and acid grey porphyries, riebeckite porphyrics and riebeckite gneisses belonging to Peshawar Plain alkaline igneous province, north-west Pakistan.
Study shows that the intrusive rocks have developed from an anatectic melt generated at deep crustal level and emplaced along roughly en-echolon weak planes of a zone which suffered intermittent and alternate periods of variable tension and compression. The alkaline rocks had developed during the period of tension whereas acidic rocks had developed during the period of non-tension to compression. This zone was a complimentary centre to the regional belt of strong but variable compression along margin of the Indo-Pak plate in the North. Implications of this study are commented upon for regional application.
Key words: Petrology, Shewa alkaline porphyries, Peshawar Plain Alkaline Igneous Province, Himalaya.

C/153. Chaudhry, M.N. & Shams, F.A., 1984a. The triple amphibolite belt of northwest Himalayas, Karakorum and Hindu Kush, northern Pakistan. Abstracts, First Pakistan Geological Congress, Lahore, p.22.

Three amphibolite belts have been distinguished for the first time from NW Himalayas, Karakoram and Hindu Kush west of the Nanga Parbat-Haramosh loop. They have been named as ‘Southern Amphibolite Belt, “Middle Amphibolite Belt” and “Northern Amphibolite Belt” Their structures, textures and mineral compositions are summed up, compared and contrasted. Their geotectonic disposition is also discussed.
It is proposed that the three belts represent obducted blocks of a subduction mélange. The “Southern Amphibolite Belt represents the obducted mass of the subducted and transformed Tethyan tholeiites formed at the mid-oceanic rises with small amounts of marine sediments. The “Middle Amphibolite Belt” also represents subduction mélange of submarine tholeiites formed at oceanic rise with substantial amounts of marine and arc-derived sediments. This belt is dispositioned south of the outer arc. The “Northern Amphibolite Belt”, again is a part of the subduction mélange formed south of the main inner arc This belt represents fairly pure transformed marine tholeiites. All the three amphibolite belts contain mantle derived d exotic blocks of peridotite, harzburgite and eclogite.

Key words: Amphibolite belts, oceanic tholeiites, Himalaya, Karakoram, Hindukush.

C/154. Chaudhry, M.N. & Shams, F.A., 1984b. Geology of northern Indus Kohistan and parts of Chilas District, northern Pakistan. Abstracts, First Pakistan Geological Congress, Lahore, 69-70.

For the first time, a geological map of 600km2 of the Northern Indus Kohistan and parts of Chilas District, Northern Areas, is being presented on a scale of 1" = 4 miles.
The rock units mapped and studied from South to North are:-
North Yasin Granite
Amphibolitic Diorite, Diorites and amphibolites
Norite, Noritic Gabbro
Amphibolitic Diorites
The Southern Amphibolite Belt
Volcano-sedimentary zone
South Salkhala
The above units have been studied petrographically as well as chemically. The petrography and chemistry are described and discussed in the light of field relations and petrotectonic dispositions.
The Salkhalas represent elements of the lndo-Pak shield edge. The sedimentary - volcanic zone may represent a remnant arc, the amphibolites and norite represent oceanic lithosphere, the diorites and amphibolitic diorites represent subduction related partial melting products of oceanic crust at intermediate depth and under hydrous conditions. The Yasin granite is a typical anatectic rock containing xenolithic elements of greenstone. This is very young and postdates subduction and obduction episodes as of independent origin.
Key words: Geology, petrography, geochemistry, Kohistan, Chilas.

C/155. Chaudhry, M.N., Spencer, D.A, Ghazanfar, M., Hussain, S.S. & Dawood, H., 1997. The location of the Main Central Thrust in the Northwest Himalaya of Pakistan: Tectonic Implications. Geological Bulletin, Punjab University 31 & 32, 1-20.

A number of workers have proposed different positions for the Main Central Thrust in the northwest Himalaya of Pakistan. These positions have varied from considering the Punjal Thrust, the Oghi Shear Zone and even the Raikot Fault, as well as many other intervening locations in the area between the Main Mantle Thrust in the north and the Main Boundary Thrust in the south, as the Main Central Thrust. All these positions are enumerated and critically appraised in their context of the geology of the area. They are subsequently evaluated to see whether, they follow the tectonic requirements of the Main Central Thrust as a Boundary Thrust that marks the contact between the Higher and Lesser Himalaya. It is subsequently argued that, except for the Batal Fault near Naran (in Upper Kaghan Valley) Luat Fault (in Neelum Valley) and the tectonic lineament near Malakand (in Lower Swat), no other position fulfils the required criteria specified for the definition of Main Central Thrust. These most likely positions of the Main Central Thrust, according to this review, were only located after extensive geological mapping of the terranes in Neelum and Kaghan Valleys and in the area of Besham and lower Swat.
Keywords: MCT, Panjal, Raikot, Kaghan, Himalaya.

C/156. Chaudhry, M.N., Taufique, A.R. & Chaudhry, M.M., 2000. Preliminary sedimentological studies of Murree Formation of outer Himalaya of Azad Kashmir & Pakistan. Abstracts, Third South Asia Geological Congress, Lahore, 55-58.

Key words: Sedimentology, Murree Formation, Himalaya.

C/157. Chaudhry, M.N., Walsh, J.N., Ghazanfar, M. & Hussain, M., 1992. The Panjal sea, Kashmir-Hazara microcontinent and Hercynide Geology of Northwest Himalaya in Pakistan. Pakistan Journal of Geology 1, 81-99.

This paper discussed the tectonic significance of the Permian Panjal Volcanics of Kaghan Valley on the basis of an over view of geology, field characteristics, associated rocks and plots of major and trace elements. On the basis of these studies it is proposed that the 400 km long Panjal rift developed into an ensialic marine basin with a thinned continental crust which in Kaghan further developed into an incipient ocean in Permian. This ocean closed in Late Permian followed by the deposition of unmetamorphosed oolitic Malkandi limestone of Triassic age.
Key words: Tectonics, continental rifting, geochemistry, Panjal volcanics.

C/158. Chaudhry, M.N., Walsh, J.N., Khan, M.S. & Ghazanfar, M., 1995. Petrology and geochemistry of the Panjal volcanics of the Northwest Himalaya in Pakistan. Abstract Volume, 10th Himalaya-Karakoram-Tibet Workshop, (ETH Zurich) Switzerland.

Geological and geochemical (major, minor and trace elements including rare earth elements) data for the Panjal volcanics of the NW Himalaya are presented. These data show that the Panjal volcanics are mainly tholeiitic basalts. The rocks are moderately enriched in trace elements and the light REE elements relative to N-type MORB. These basalts are characterized by Zr/Y 1.7 to 3.92, Zr/Nb 2.6 to 33, Ti/Y 266 to 400 ratios and LREE enrichment [(La/Yb)N = 3.29 to 11.16, (La/Sm)N = 1.96 to 4.09, (Sm/Yb)N= 1.68 to 3]. These characteristics suggest derivation of magma from an enriched mantle source, probably a mantle plume. The lavas exhibit from within plate to P-type mid ocean ridge trace element characteristics with minor crustal contamination.
Trace elements and REE element data indicate that the lavas were derived by partial melting of garnet lherzolite followed by fractionation of olivine and pyroxene. The geological and geochemical data suggest that the Panjal volcanics in the Kaghan area developed in a progressively evolving rift initially within an ensiatic environment and finally reaching the stage of a PMORB type crust.
Key words: Petrology, continental rifting, geochemistry, Panjal volcanics, Himalaya.

C/159. Chaudhry, M.N. & Zaka, K.J., 1994. Terbela Dam: A discussion on the discrepancy between the laboratory testing and inservice behaviour of Indus aggregate in cement concrete. Dam Engineering 5, 63-80.

This paper discusses the problem of alkali aggregate reaction (AAR) developed in the Tarbela Dam, which was built in 1976 on River Indus in North-West Frontier Province of Pakistan. In Tarbela Dam natural sand and gravels from the riverbed were used after proper testing by petrographic, chemical and mortar bar methods (TAMS report, WAPDA 1965). After testing, aggregates were considered non-deleterious and were used with ordinary Portland cement having alkali level ranging from 0.9% to 1.03% (Table IX). These aggregates contain large amounts of slightly metamorphosed acid to intermediate volcanics, argillites and greywacks.
Although these aggregates contain large quantities of potentially deleterious rock types yet they were presumably regarded safe either because their parent rocks had undergone metamorphism or on the grounds that they had large quantities of mildy reactive rock type and therefore, would not develop deleterious reaction. The inference drawn from petrographic studies was further strengthened by the quick chemical tests carried out in accordance with ASTM C289 and mortar bar tests carried out in accordance with ASTM C227 which did not predict AAR potential of Indus aggregates at Tarbela.
Three years after the completion of Tarbela Dam only one incidence of AAR was reported. However, it was only after twelve years of completion that AAR was confirmed at a number of places. Therefore the need for alternative or modified chemical mortar bar test is stressed. Petrographic examination can however, prove most useful for quickly predicting AAR in Indus River aggregates like the ones used in Tarbela and similar aggregates which contain deleterious metamorphosed rocks like greywacks , acid to intermediate mesocrystalline volcanics and argillites.
Key words: Tarbela dam, Indus aggregates.

C/160. Chaudhry, M.N. & Zaka, K.J., 1998. Petrographic evaluation of alkali aggregate reaction concrete structures of Warsak Dam, NWFP Pakistan-A case study. 8th International IAEG Congress Vancouver/ Canada, 2841-2846.

This paper presents a case study of Alkali Aggregate Reaction (AAR) in concrete structures of Warsak Dam. The dam has suffered deterioration due to AAR and had undergone extensive repairs during 1985-86. The fractures in the concrete structures are of two types. The first type of fractures is random and may not be directly related to deleterious reaction. The second type of fractures shows distinct pattern resembling map cracks. AAR and gel formation were positively identified and confirmed, This paper is based on Petrographic, chemical and X Ray Diffraction (XRD) studies of cores and sample of AAR affected parts of the dam carried out since the confirmation of AAR. Microfractrued and strained quartzite, phyllite/slate, metagreywacke partially reconstituted merocrystalline acid to intermediate meta-volcanics and jasper/cherts are directly affected by deleterious reaction.
Key words: Petrography, alkali aggregates, Warsak dam.

C/161. Chaudhry, M.N., Zaka, K.J. & Hassan, G., 1994. Geotechnical, petrographic, chemical characteristics and inservice behaviour of Indus aggregate for concrete. 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, 378-381.

Key words: Geotechnical, petrography, Indus aggregates.

C/162. Chaudhry, M.S., 1980-82. The engineering geology and geotechnical aspects of some structures at Kalabagh Dam Project. Institute of Geology, M.Sc. Thesis, Punjab University, Lahore, 1-150.

Key words: Engineering geology, geotechnical, Kalabagh dam.

C/163. Chaudhry, R.S., 1987. Petrogenesis of Cenozoic sediments of Northwestern Himalayas. Geological Magazine, 108, 43-48.

Cenozoic rocks of north-western Himalayas (excluding the sub-Recent, Recent and Karewa deposits) are represented by the Subathu, Dagshai, Kasauli and Siwalik rocks, which together have a thickness of over 10,000 m and range in age from Upper Palaeocene to Middle Pleistocene. From field and laboratory investigations it is propounded that these sediments, except the Middle and Upper Siwalik, have been derived from low and medium grade metamorphic rocks, acid plutonics and sedimentary rocks of the nearby Himalayan terrains. For the Middle and Upper Siwalik rocks, detritus was supplied by sedimentary and trap rocks as well as by the underlying medium and high grade metamorphic and plutonic rocks. A major part of these sediments has been derived from the rising Himalayas rather than from the Peninsular Shield as believed hitherto. The Subathu rocks were deposited in shallow to moderately deep marine environments; the Dagshai rocks under shallow freshwater conditions; and the Kasauli and Siwalik rocks in a shallow fast-sinking basin. All these sediments accumulated under conditions of rapid erosion, short transportation and rapid deposition.
Key words: Petrogenesis, sediments, Cenozoic, Himalaya.

C/164. Chaudhry, Z.H., 1963. Petrographic study of the chromite deposits of Harichand; the enclosing dunite and surrounding rocks. M.Sc. Thesis, Munich University.

Key words: Petrography, chromite, dunite, Harichand, Malakand Agency.

C/165. Cheema, A.Q., 1999-2000. Structure, stratigraphy, petrography, micropaleontology and petroleum geology of Kotli-Tattapani area, District Kotli, Azad Jammu and Kashmir (Pakistan). M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 217p.

The Himalayan mountain belt is the result of Tertiary collision between the Indian and Eurasian plates. The kotli-Tattapani area of the Kashmir foreland fold-and-thrust belt is the part of the Sub-Himalaya of Pakistan. A sequence of Cambrian to Cenozoic rocks is folded and imbricated along the northeastern margin of the Indian plate.

In Cambrian time, the calcareous to arenaceous facies of Muzaffarabad formation are deposited under shelf to outer shelf environment. The Muzaffarabad formation is unconformably overlain by the Paleocene Hangu Formation. The Hangu Formation is deposited under tropical to subtropical environments. The absence of Ordovician to Cretaceous rocks in the area is the result of non-deposition due to pre-Eocene Himalayan uplift. Subsequently, after the deposition of the Hangu Formation, the Early Eocene Tattapani Formation is deposited under shallow marine environment. This marks the Early Eocene transgression of the Neotethys ocean.
In Middle to Late Eocene the variegated shales of the Kuldana Formation are deposited in open marine, lagoonal and fluvial environments. The Kuldana Formation marks the transition from marine to continental environment. This shows the closing of the Neotethys ocean and the initiation of deposition of the Himalayan molasses in the Kashmir foreland basin.
In Oligocene to Miocene, the hinterland in the northeast was uplifted and the low to medium grade basement and cover rocks were exposed to the weathering and erosion. The detritus derived from the orogen was deposited as molasse of the Murree and Nagri Formations in the Kashmir foreland basin.
The Cambrian to Cenozoic rocks show at least three phases of deformation. These deformational phases are D1, D2 and D3. D1 deformational phase is the major event in the area and can be divided into D1a and D1b. The D1a is marked by the F1 southwest-vergent folds and northwest-directed thrusts. The F1 folds and D1a thrusts are northwest-southeast trending. The D1b is marked by northeast-directed backthrust and backsteepening of axial planes of F1 folds. The D2 deformation is related to the F2 cross-folding of northwest-southeast trending outcrops and fold axes of F1folds. The F2 cross-folds are the result of counter clockwise rotation of Indian plate. F2 folds are associated with the development of the Hazara-Kashmir syntaxis. The D3 deformation is related to the northeast-southwest late Himalayan extension. This deformational phase caused the north-northwest trending normal faults, horst and graben structures.
Key words: Structure, stratigraphy, petrography, micropaleontology, petroleum geology, Azad Jammu and Kashmir.

C/166. Cheema, I.U., 1990. Late Astaracian small mammals of the Chinji Formation of Ghok Thalian, Pakistan. Abstracts, 2nd Pakistan Geological Congress, University of Peshawar, p. 41.

A small mammal assemblage of a middle Chinji Formation locality PMNH 8608 contains at least fourteen species of ten rodent and insectivore families including a single specimen of chirpotera. Cricetids are represented by three species, which resemble those from the Banda Daud Shah assemblage. Antemus chinjiensis is the only murid recognised but included in them are the three molars of relatively larger dimensions having extra cusps (styles) which have not been noted earlier as yet. Prokanisamys benjavuni and Kanismys indicus constitute the typical middle Miocene rhycomyid site in the Siwalik sequence. Comparison with other Chinji Formation fauna indicate that this high species diversity is normal and presents a stable species composition during most of the Middle Miocene. Murid species appear to have the shortest life-span and hence their chronological successive species are used for precise faunal dating. The PMNH 8608 locality is assigned a late Astaracian age and closely resembles the Daud Khel local fauna assemblage.
Key words: Palaeontology, mammals, Chinji Formation, siwaliks.

C/167. Cheema, I.U., Rajpar, A.R. & Raza, S.M., 1997. Preliminary analysis of the vertebrate fauna from the Siwaliks of Chakwal District; Kallar-Kahar-Dhok Tahlian area, Potwar Plateau, Pakistan. Geological Bulletin, Punjab University 31 & 32, 161-168.

About 440 mammalian fossils were collected from 20 different sites in Kallar Kahar-Dhok Tahlian area. Small collection of interesting carnivores consisting of Herpestes SP. and gen. et. sp. Indet. of Mustelidae family are simultaneously of 130 Mya and 16.0 Mya. Gen et. sp. Indet. Of Mustelidae is the first fossil record in the Siwaliks of Pakistan, which seems to have closer affinities with African fauna. Similarly canine of a *Sivapithecus indicus* also reveals the first appearance of a Hominoid in this area
Key words: Palaeontology, mammals, vertebrates, siwaliks.

C/168. Cheema, I.U., Sen, S. & Flynn, L.J., 1983. Early Vallesian small mammals from the Siwaliks of Northern Pakistan. Bulletin du Museum National d'Histoire Naturelle Section C Sciences de la Terre Paleontologie Geologie Mineralogie, 53, 267-280

Key words: Palaeontology, mammals, siwaliks.

C/169. Cheema, M.R., 1968a. Biostratigraphic study of Khanaspur-Mandri Area, District Hazara. M.Sc. Thesis, Punjab University, Lahore, 109p.

Key words: Biostratigraphy, Haripur, Hazara.

C/170. Cheema, M.R., 1968b. Biostratigraphy of Changla Gali area, District Hazara, West Pakistan. M.Sc. Thesis, Punjab University, Lahore.

Biostratigraphical study of the Khanaspur Mandri area has been done. A geological map on the scale 8” -1 mile is prepared. A new time -rock unit, the Nummulitic Shales representing the youngest lithostratigraphic unit is identified and mapped. The lithologies and environments of deposition of each formation are discussed. Their ages are reviewed in the light of new faunal evidences, if any, and regional correlations are suggested.
A systematic and detailed sampling of U. Cretaceous to Middle Eocene strata was done to investigate foraminiferal assemblages of different stratigraphic units, fauna species and many genera are identified. All the species are described but only very few genera are dealt with. Three species, Assilina mukshpuriensis nov., Assilina depressa nov., and Lokhartia smouti nov., and a variety Lokhartia altispira var conica nov. are erected new.
Cretaceous -Tertiary boundary and Pa1aeocene -Eocene, boundary is placed on faunal evidence. Palaeoecologic conditions are inferred for Cretaceous and Lower Tertiary times as depicted by the faunal assemblages.
Key words: Biostratigraphy, Abbottabad, Hazara.

C/171. Cheema, M.R., 1970. Sedimentology of Miranjani algal limestone member, Nathiagali. Geological Bulletin, University of Peshawar 5, 57-61.

Microscopic sedimentological study of the Miranjani Algal Limestone Member of the Hazara Formation (Hazara Slates) of Nathiagali area, District Hazara, is made, following the petrographic classification of limestones of Folk (1959).
Varied association of all three basic constituents of limestones allochems, microcrystalline calcite and sparry calcite is met with indication a diversity of physiochemical conditions. Mega and microscopic sedimentary structures and composition are used to inter environment of deposition for every thin section and for the unit, as a whole. Systematic of algal material is not dealt with except for identifying it as “Green Stomatolytic Algae”. Ostracodes were met within a thin section which, however, could not be identified.
Key words: Sedimentology, Miranjani limestone, Abbottabad, Hazara.

C/172. Cheema, M.R. & Alam, G.S., 1990. Pyrite deposits of Naz Bar area, Yasin valley, Gilgit District, Northern Area, Pakistan. Geological Survey of Pakistan, Information Release 333.

Pyrite deposits are located in the Yalter Bar Multan Bulang Bar area of Naz Bar at a distance of about 23 miles from Yasin village, Gilgit Agency. The deposits are in the form of 3 lenses and 12 pockets, exposed at 5 locations at high elevation ranging from 13,500 feet to 16,000 feet A.S.L.
The pyrite is hydrothermal in origin and is developed within the quartzites and phyllites of the Permo-Carboniferous Darkot group. Geological reserves are estimated at 1.7 lakh tons. Out of these, 1.54 lakh tons are present in one lense (Location A) with average sulphur and iron content of 30 and 45 percent, respectively. Pyrite also contains copper from 0.476 to 0.834% and cobalt from 0.061 to 0.976 per cent .
Key words: Pyrite, Yasin valley, Gilgit.

C/173. Cheema, M.R., Raza, S.M. & Ahmad, H., 1967. Cainozoic. In: Shah, S.M.I. (Ed.), Stratigraphy of Pakistan. Geological Survey of Pakistan, Memoir 12, 56-98.

Key words: Cenozoic, Pakistan.

C/174. Cheema, T.K., 1990-91. The structure, stratigraphy & petrography of the western limb of Hazara-Kashmir Syntaxis, Mansehra-Dalola areas, Hazara, Pakistan. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 174p.

Key words: Structure, stratigraphy, petrography, Hazara-Kashmir Syntaxis, Mansehra, Hazara.

C/175. Chen, W.P. & Roecker, S.W., 1980. Regional variation of the focal mechanism of intermediate depth earthquakes and seismicity in the Karkorum-East Hindu Kush area. EOS (Transactions of the American Geophysical Union) 61, 1031.

Key words: Seismology, earthquakes, Karakoram, Hindukush.

C/176. Chilasi, E.U., 1999-2000. Geological mapping of Muzaffarabad-Chattar Kalas area with special emphasis on slope instability analysis and hazards evolution of Abhal area, Muzaffarabad (A.K.). M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 117p.

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, landslide hazard, Azad Kashmir.

C/177. Chishti, H.M. & Ahmad, N., 2000. Charaterization of pyrolysis derived hydrotreated shale oil from a Pakistani oil shale. Abstracts, Third South Asia Geological Congress, Lahore, p.124

Hydrotreatment has received increasing attention in upgrading shale oil. The aim of this work was to elucidate the compositional changes after hydrotreatment of Salt Range shale oil. Pyrolysis derived raw shale oil from Salt Range oil shale was hydrotreated in stirred reactor with a cobaltmolybdenuma (CD-Mo) catalyst at 395 ºC and 15 Mpa of hydrogen pressure for 12 hours. The pyrolysis and hydrotreated oils were analysed for elemental analysis, liquid chromatography fractionation, size exclusion chromatography and gas liquid chromatography/mass spectrometry. Distribution of nitrogen and sulphur compounds in raw pyrolysis and hydrotreated upgraded oils was determined. Hydrodenitrogenation of nitrogen containing compounds occurred concurrently with the hydrogenation of non-nitrogen containing aromatic hydrocarbons. In particular the pyrolysis and catalysis oils were analysed for polycyclic aromatic hydrocarbon (pAH) compounds and for nitrogen containing PAH (PANH) and Sulphur containing PAH (PASH). Analysis of the product oils showed that three and four ring higher molecular weight compounds decreased in concentration. Removal of nitrogen and sulphur proceeded successively with time which resulted in corresponding reduction in the concentration of nitrogen and sulphur containing PAR.
Key words: Pyrolysis, oil shale, hydrocarbon.

C/178. Chishti, H.M., Ahmad, N. & Rashid, S., 2000. Influence of final pyrolysis temperature on pyrolysis of Kark oil shale from Pakistan. Abstracts, Third South Asia Geological Congress, Lahore, 124-125.

The final pyrolysis temperature has received special interest in the fixed bed pyrolysis of oil shale. Kark oil shale from Pakistan was retorted in a bench scale static bed reactor at various pyrolysis temperatures. 'The pyrolysis oUs were collected in a series of cold traps. Gases evolved were analysed off-line by packed colour gas chromatography. The composition of oils and gases were determined in relation to the various final pyrolysis temperatures. Oils were analysed by a number of techniques for determining composition including liquid chromatography, gas chromatography/mass spectrometry size exclusion chromatography, chemical class fractionation and elemental analysis. Products of pyrolysis were liquid condensate, non-condensable gases and solid residue (spent shale). The yield of oil was maximised at 520°C. Both the hydrocarbon and non-hydrocarbon gases increased with increase in final pyrolysis temperature. A consistent decrease in spent shale was observed with increase in pyrolysis temperature. Hydrogen to carbon ratio (H/C) and the aromatic content the product oils was found to respectively decrease and increase with increase in final pyrolysis temperature.
Key words: Pyrolysis, oil shale, Kark.

C/179. Chishti, M.N.A., 1977-79. Lithostructural Mapping and Geology of Baragali-Bagnoter Area, Abbottabad District, Pakistan. M.Sc. Thesis, Punjab University, Lahore, 169p.

Approximately 20 miles^2 of Baragali-Bagnotar area in the form of a strip on both sides of Nathiagali-Abbottabad road has been mapped at the scale 1:10,000. It is a mountainous humid region with fairly high relief. The stratigraphic sequence ranges from Precambrian Hazara slates to the Kuldana Formation of Middle Eocene. The structure of the area is in the form of a major synclinorium, which is interrupted and deformed by high angle thrust faults dipping southeast near the surface. Over 50 thin sections were studied under the microscope and a detailed petrography and petrogenesis are included.
Key words: Stratigraphy, structure, lithology, petrography, Abbottabad.

C/180. Chohan, N.A., Qureshi, M.H. & Faruqi, F.A., 1984. Evaluation and exploitation of some industrial minerals for the development of refractories. Abstracts, First Pakistan Geological Congress, Lahore, p. 32.

Key words: Industrial minerals, refractories.

C/181. Chroston, P.N. & Simmons, G., 1989. Seismic velocities from Kohistan volcanic arc, Northern Pakistan. Journal of the Geological Society, London 146, 971-979.

The rocks bounded by the Main Mantle Thrust and the Northern Suture in northern Pakistan constitute an exhumed section through a Cretaceous volcanic arc. Samples have been collected from all the principal lithological groups of the arc, and P and S-wave seismic velocities have been measured in the laboratory with the prime objective of comparing the velocities with those determined by seismic refraction experiments on modern volcanic arcs. Velocities were measured at up to 0.7 GPa and consideration has been given to the effect of confining pressure, pore pressure and temperature and to the deformation and metamorphism involved in the Himalayan collision.
The reconstructed velocity section through the arc shows a distinct ‘upper crust’ comprising granitic-dioritic intrusions, metasediments and volcanics with a P-wave velocity of 6.2–6.4 km S^{-1} depending on the parameters used. Beneath, the ‘lower crust’ of amphibolites and pyroxene granulite has a velocity mainly about 6.4–6.7 kms $^{-1}$, though the garnet granulites extend to 7.8 km S^{-1}. The more mature arc with a higher proportion of granitic rocks would show a slightly lower upper crustal velocity than the younger arc. Velocity inversions might be expected with a thermal gradient of as little as 10–15 ˚C km^{-1}, depending on the pore pressure. In general, the proposed velocity structure is comparable with that of volcanic arcs and with many other sections of the continental crust.
Key words: Seismology, seismic velocity, MMT, MKT, Kohistan arc.

C/182. Chuhan, F.A., Chaudhry, M.N. & Ghazanfar, M., 1992. Microfacies, diagenesis and environment of deposition of Datta Formation from Jaster Gali, District Abbottabad, Hazara, Pakistan. Geological Bulletin, Punjab University 27, 47-62.

Datta Formation shows marked vertical variation in the environment of deposition from continental, subtidal, intertidal to supratidal. However, in the Galiat area this formation is predominantly marine as opposed to dominantly continental facies of Salt Range. The petrographical/sedimentological study of this formation shows the following lithologic units. Fine grained quartz and clay cemented ferruginous sublithic arenite with streaks and layers of grit; alternating bands of medium grained intraclast bearing oolitic-pelletoidal limestone intercalated with nodular marl; fine grained quartz cemented quartz arenite intercalated with shale; fine to medium grained quartz cemented quartz arenite ; nodular marl ; limestone (sparse biomicrite, - wackestone); coarse to medium grained oolitic, carbonate cemented quartz arenite with streaks and layers of grit. Recycled clastic component is dominant. Tourmaline, zircon, epidote and sphene indicate an ultimate derivation from an igneous, metamorphic sialic basement with _subordinate basic/metabasic component, the granitic component was predominantly S-type. The diagenetic events show that kaolinite cement is early as well as formed at final stage. The early "diagenetic kaolinite cement was partially transformed to illite at a depth of at least 3500-4000m whereas quartz and non-ferroan carbonate cements were formed after the early diagenetic kaolinite. The non-ferman carbonate cement was transformed to ferroan carbonate cement· A part of ferroan dolomite, so formed, was probably dedolomitized at the final stage.
Key words: Microfacies, diagenesis, deposition environment, Datta Formation, Hazara.

C/183. Ciry, R. & Amiot, M., 1965. Sur quelques foraminferes Permiens d'Asie Centrale. In: Italian Expeditions to the Karakorum (K2) and Hindu Kush, (A. Desio leader), Scientific Reports IV (1), 127-133. Paleontology-Zoology-Botany. Brill, Leiden.

Key words: Italian expedition, Permian foraminifera, Central Asia.

C/184. Cita, M.B. & Ruscelli, M.A., 1959. Cretaceous microfacies from western Pakistan and Afghanistan. Revista Italiana di Palaeontologia 65, 3p.

Key words: Microfacies, Cretaceous, Afghanistan, Pakistan.

C/185. Clavarino, J.G., Dawney, R.L. & Sweatman, T.R., 1995. Gold exploration in northern Pakistan: Status and prospects. Proceedings, International Round Table Conference on Foreign Investment in Exploration and Mining in Pakistan, Islamabad, October 16-18, 1994, 93-119.

Key words: Gold exploration, North Pakistan.

C/186. Colbert, E.H., 1933. Siwalik mammals in the America Museum of Natural History. Transactions, American Philosophical Society, New Series 26, 401p.

Key words: Palaeontology, mammals, siwaliks.

C/187. Collins, D., 1988. Meltwater characteristics as indicator of glacial and hydrological processes beneath valley glaciers in Karakoram. Abstracts, Neogene Karakoram and Himalayas. University of Leicester.

Key words: Glaciers, hydrologic process, meltwater, Karakoram.

C/188. Collins, D.N. & Hasnain, S.I., 1994. Runoff and sediment transport from glaciated basins at the Himalayan scale. University of Manchester, Alpine Glacier Project, Working Paper 15, 14p.

Key words: Glacial basins, sediment transport, Himalaya.

C/189. Collinson, J.D., Lewin, J. & Wells, N.A., 1983. Transient streams in sand-poor redbeds: early-middle Eocene Kuldana Formation of northern Pakistan. Special Publications of the International Association of Sedimentologists, 6, 393-403.

The Kuldana Formation is a sand-poor redbed complex that prograded into the Persian Gulf-like Kohat depositional basin of northern Pakistan at the end of an early Eocene marine regression. It was formed by a poorly developed system of small, episodic, briefly active, shallowly incised and readily abandoned streams that wandered into a very flat, aggrading, semi-arid basin. Their deposits are about 95% red mud and 5% predominantly trough-bedded and fining-upward channel sand. The streams did not meander, however, because avulsion was too frequent. During low flow they became braided but their bedforms underwent little alteration. Partly because of the basin's flatness, the only available coarse clastics in eastern areas were calcareous soil nodules and, locally, fish and mammal bone fragments. The primary determinants of this stream system seem to have been a below-grade basin floor and a semi-arid climate.
Key words: Red-beds, drainage, basin configuration, Eocene, Kuldana Formation.

C/190. Comucci, P., 1933. Rocce del bacino del ghiacciaio Siacen. In: Relazioni Scienfiche della Spedizione Italiana de Filippi nell’Himalaia Caracorum e Turchestan Cinese (1914), Series 2(11). Zanichelli, Bologna, 3-48.

This is a description of the lithology of rocks from the Siachen Glacier basin, eastern Karakoram.
Keywords: Glacier, rocks, Siachin.

C/191. Comucci, P., 1935. Scisti a Dasso nel Baltistan. Rendiconti Accademia Nazionale dei Lincei, Series 6(21), 284-287.

The pelitic schistose rocks of the Dasu area in Baltistan are described.
Keywords: Metamorphism, schists, Baltistan.

C/192. Comucci, P., 1936. Relazioni sommaria sulle rocce raccolte della spedizione. Appendix La Spedizione Geografica Italiana al Karakorum, 1929. Arti Grafiche Bertarelli, Milano, 23-28.

A summary of the Italian expedition to Karakoram mountains is given in this account. It contains some details of the rocks collected by the expedition in 1929.
Keywords: Petrography, Karakoram.

C/193. Comucci, P., 1937. Dei una singolare roccia del ghiacciaio Baltoro (Karakorum). Rendiconti rel Accadmia Nazionale dei Lincei, Series 6, 25, 648-734.

Keywords: Baltoro glacier, Karakoram.

C/194. Comucci, P., 1938. Le rocce raccolte dalla Spedizione Geografica Italiana al Karakoram (1929). Memorie R. Accadmia Nazionale dei Lincei, Series 6A, 7(3), 93-235.

This is a detailed description of a large number of rocks collected during the 1929 Italian Expedition to the Karakoram Mountain Range.
Keywords: Petrography, Karakoram.

C/195. Contin, G., Lombardo, B., Petrini, R., Rolfo, F., Antonini, P., Vison, D. & Le Fort, P., 1998. Geochemistry of metabasaltic and metadoleritic garnet granulites from the NE Nanga Parbat-Haramosh Massif, Northern Pakistan. Preliminary results. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop. Abstract Volume, 45-47.

In the NE Nanga Parbat-Haramosh Massif (NPHM) of the NW Himalayan syntaxis (Stak and upper Turmik valleys, Susrut Nala) metabasaltic and metadoleritic dykes of garnet granulite intrude garnet-kyanite-biotite-muscovite para- and orthogneisses of the Higher Himalayan basement complex. Compositionally the garnet granulites are tholeiitic to mildly alkaline basalts and (rarely) picritic basalt and picrite. In a Ti-Zr-Y diagram most of the samples plot in the field of within-plate basalts as defined by whereas the metapicrites and a few metabasalts lie in the compositional field of ocean floor basalts because of their higher contents of Y.
Significant variations of major and trace element contents occur between the metapicrites (mg# 0.75-0.67) and the most evolved metabasalt, an alkali metabasalt from the Subsar area of the Indus valley (mg# 0.27), which still has the pristine igneous plagioclase and titaniferous ferroaugite. Harker diagrams show a good agreement in trends of major and trace elements plotted against an index of magma evolution such as MgO and the less mobile element Zr. A positive correlation exists between Zr and P_2O_5, K_2O, TiO_2, Ba and Rb whereas Ni and Cr are negatively correlated with Zr. SiO_2, Na_2O, Al_2O_3, Y and Sr show more scattered trends relative to Zr. Such trends, particularly the enrichment in incompatible elements, and major elements variations are explained by polybaric fractional crystallization of olivine, clinopyroxene and plagioclase at low pressures and low amounts of water.
MORB-normalized spidergrams show subparallel trends of enrichment up to 100x MORB values and variable depletion of Ni and Cr from the metapicrite to the alkali metabasalt. The observed enrichment is consistent with the effects of the fractional crystallization mentioned above. A negative Sr anomaly is observed for all samples with the exception of the metapicrites. The Sr anomaly is larger for the alkaline metabasalt and it might be explained as the effect of plagioclase fractionation. REE data for one metapicrite and three metabasalts indicate a positive Eu anomaly (Eu/Eu*=3D1.15) and LREE enrichment for the metapicrite, whereas the metabasalts appear more REE-enriched with higher LREE/HREE ratios. The positive Eu anomaly decreases with the increase of the REE content. These features may result from fractional crystallization after removal of mafic phases in an earlier magmatic stage or by presence of inherited cumulus plagioclase previously equilibrated with a magma in conditions of very low oxygen fugacity. However, the range observed in contents of REE and other trace elements (for example Rb and Nb) cannot be completely accounted for by a simple mechanism of fractional crystallization starting from a parental magma of composition similar to the less evolved metabasalts. Open-system magmatic fractionation or element mobility during metamorphism is therefore invoked for these cases. Further isotopic studies could better identify the dominant mechanism of differentiation and the possible role of crustal contamination. The NPHM metabasic dykes are geochemically similar to the Lower Carboniferous Baralacha La Dyke Swarm of SE Zanskar, Upper Lahul and NW Spiti [5] and to the amphibolite-facies metabasaltic dykes of the Higher Himalayan basement of the Western Syntaxis area [6]. On the other hand, different trends of Ba, Rb and Y during fractionation and the different contents of TiO2 and P2O5 suggest a different magmatic evolution of the NPHM metabasic dykes relative to the Middle Permian Panjal Traps basalts of SE Zanskar, Upper Lahul and NW Spiti studied by.
Keywords: Geochemistry, mafic granulites, NPHM, Himalaya.

C/196. Conway, W.M., 1894. Climbing and Exploration in the Karakoram-Himalayas. Fisher-Unwin, London.

Keywords: Mountaineering, Karakoram, Himalaya.

C/197. Cornwell, K., 1998. Quaternary break-out flood sediments in the Peshawar basin of northern Pakistan. Geomorphology 25, 225-248.

The presence of horizontally bedded, fining upward sequences of sands, silts, and clays throughout the Peshawar basin of northern Pakistan has previously been ascribed to Pleistocene lakes within the basin. Close inspection of these sediments, however, show sedimentological properties that suggest these stacked sequences are more characteristic of deposits of periodic break-out flood deposits and not lacustrine deposits. Exposures near the villages of Piran, Nowshera, Jehingira, Jalala and along the Kabul River show evidence of subaerial exposure (mudcracks and bioturbation zones), lateral continuity and fracture sets. At least three distinct cycles of deposition are apparent in the basin, each exhibiting slightly different structural and sedimentological properties. The groupings and dimensions of the rhythmite sequences indicate that within each cycle multiple episodes of flooding occurred. The absence of significant erosional and depositional features, as well as the preservation of mud rip-up clasts and bioturbation zones further suggests that the periods between episodes of flooding were probably on the order of 101 to 102 years. Evidence of ice-dams and lakes in the Indus drainage system is abundant. Cross-valley moraines and lacustrine deposits that stretch many kilometers upstream are visible in the middle Indus valley between the villages of Sazin and Shatial and Skardu. Calculated ratios of sediment to water suggest that an upstream reservoir at least 32 km3 and perhaps as large as 128 km3 would have been required to produce the extent of rhythmites observed in the Peshawar basin. Generating a reservoir of this size in the Indus drainage system was accomplished near the villages of Sazin–Shatial where large cross-valley moraines and upstream lacustrine sediments indicate large ice-dams as do the moraines and lacustrine sediments near Gilgit and Skardu. The origin of the graded sediments in the Peshawar basin, however, has not been correlated to the failure of a specific ice-dam. The temporal relationship of the graded sediments is unclear. Limited thermoluminescence (TL) analysis of the youngest set of graded sediments (referred to as `lake beds' by previous investigators) in the Peshawar basin suggest an age of at least 130,000 years BP. This time correlates to the Yunz stage of glaciation along the middle Indus valley which spans from the mid to late Pleistocene to about 130,000 years BP.
Keywords: Break-out flood sediments, Peshawar Basin, Pleistocene lakes, lacustrine deposits

C/198. Cornwell, K. & Hamidullah, S., 1992. Geomorphic evidence of catastrophic flooding along the middle Indus valley. Geological Bulletin University of Peshawar 25, 113-121.

Catastrophic floods have inundated the middle Indus River valley throughout the late Quaternary. These floods have produced very distinct geomorphic signatures within the valley such as boulder beds, plunge pools, and chutes. These features have been mapped and measured to develop estimates of flood hydraulic parameters. The bedrock nature of the Indus valley along this stretch constrains floodwater from lateral migration or significant down cutting within the channel. This constraint results in increased flow velocity and greater flood power.
Keywords: Floods, geomorphology, Quaternary, Indus valley.

C/199. Costello, C.P., 1864. Observation on the geological features etc. of the country in the neighbourhood of Bannoo and the sanatorium of Shaikh Bodeen. Journal of Asiatic Society of Bengal 33, 378-380.

Keywords: Geology, Bannu, Shaikh Badin, DI Khan.

C/200. Cotter, G. de. P., 1928. Mentions of Devonian limestone series in the Kurram Agency (Approx 33º 54’ N: 70º 06’E). Geological Survey of India, Record 60, 102-103.

Keywords: Limestone, Devonian, Kurram Agency.

C/201. Cotter, G, de P., 1929. The erratics of the Punjab. Records, Geological Survey of India, 61 (4), 327-336.

Cotter gave a list of the blocks near Campbellpur, Jand and Pindi Gheb, resting on alluvium deposits (sand, silt, clay with beds of coarse gravel), or directly on Siwaliks or Mesozoic limestone. He described near Jassian a deposit of “morainic kind” formed by blocks of various lithology that emerge from a “mixture of sand and gravel”. The author thought that the erratics were deposited due to some catastrophic event (glacial outburst of water or of mud-

avalanche). In proof he mentions the events of December 1840 and January 1841, when a natural dam formed by landslide near Gor, south of Bunji, collapsed, causing exceptional flooding of the Indus and the river was described as “an absolute wall of mud”.
Key words: Punjab erratics, Indus flood.

C/202. Cotter, G. de. P., 1931. Some recent advances in the geology of northwest India. Proceedings, 18th Indian Science Congress, 293-306.

Keywords: Geology, India.

C/203. Cotter, G. de. P., 1933. The geology of the part of the Attock district west of longitude 72°45’ E. Geological Survey of India, Memoirs 55(2), 63-161.

This paper details the sedimentary geology, stratigraphy and structure of the area, including the Siwaliks.
Keywords: Structure, mapping, stratigraphy, siwaliks, Attock.

C/204. Cotter, G. de. P., 1934. Notes on the geological structures and distribution of the oil bearing rocks of Shaikh Boodeen. Journal of Asiatic Society of Bengal 33, 378-380.

Keywords: Structure, hydrocarbons, Shaikh Budin, DI Khan.

C/205. Coulson, A.L., 1936a. A soda-granite suite in the North West Frontier Province. Proceedings India National Institute of Sciences 2(3), 103-111.

Coulson gave an account of the sodic alkaline granites of Warsak area in Mohmand and Mullagori. He also described and correlated granitic rocks and porphyries of Shewa Shahbaz garhi with the Warsak granite. This account provided the foundation of the proposal (Kemp and Jan, 1971) for the existence of an alkaline igneous province in Northern Pakistan
Keywords: Sodic granite, Warsak, Shewa-Shahbazgarhi, NWFP.

C/206. Coulson, A.L., 1936b. Marble of the North West Frontier Province. Geological Survey of India, Record 71, part 3, 328-344.

This is one of the earlier accounts of the geology and economic potential of marbles in North West Frontier province, now part of Pakistan.
Keywords: Marble deposits, economic geology, NWFP.

C/207. Coulson, A.L., 1936c. Octahedral pyrite crystals from Kohat District, North West Frontier Province. Geological Survey of India, Record 71(4), 436-437.

Keywords: Pyrite, Kohat, NWFP.

C/208. Coulson, A.L., 1937a. Marble and dolomite of Ghundai Tarako, North West Frontier Province. Geological Survey of India, Record 72(2), 227-239.

This is one of the earlier accounts of the geology and economic potential of marbles in North West Frontier province, now part of Pakistan. The marble and dolomite deposits of Ghundai Tarkao are discussed.
Keywords: Marble, dolomite, NWFP.

C/209. Coulson, A.L., 1937b. Pleistocene glaciation in North Western India, with special reference to the erratics of the Punjab. North West Frontier Province. Geological Survey of India, Record 72, part 4, 422-439.

This is an account of the extent of Pleistocene glaciation in NW India, and in particular of the erratic rock blocks in the sandy plain of Punjab. He does not agree with the explanation given by Cotter (1929) for the origin of the erratics. He argues that owing to the aerial distribution of the erratics the alleged catastrophic flood should have advanced not along the present course of the Indus through the gorge of Attock, but along the Indobrahm, the paleoriver considered responsible for the sedimentation of the local succession of Siwaliks. He says that this ancient river followed the course of the present Soan, south of the Kala Chitta Range. However Coulson twends to consider the possibility of the erratics being moved by icebergs breaking off the snout of glaciers and then carried by water flowing into a large lake before the last tectonic events created the present fluvial system.
Key words: Pleistocene glaciation, Punjab erratics

Keywords: Glaciation, Pleistocene, Punjab, India.

C/210. Coulson, A.L. 1937c. Gold in the North West Frontier Province (with discussion). Mining Geology Institute, India, Transactions 33, part 2, 191-206. Abstract, Proceedings 24th Indian Science Congress, Hyderabad, 238-239.

Keywords: Heavy minerals, gold, NWFP.

C/211. Coulson, A.L., 1939. The underground water supply of the Peshawar and Mardan Districts of the North West Frontier Province; with an appendix on the Kohat Valley. Geological Survey of India, Record 74(2), 229-259.

Keywords: Groundwater supply, Peshawar, Mardan.

C/212. Coulson, A.L., 1940. The mineral resources of North West Frontier Province. Geological Survey of India, Record 74(2), 1-55.

Keywords: Mineral resources, NWFP.

C/213. Coward, M.P., 1985. A section through the Nanga Parbat sytaxis, Indus valley, Kohistan. Geological Bulletin, University of Peshawar 18, 147-152.

The Nanga Parbat gneisses show polyphase Himalayan age deformation, the last major phase being the development of large upright folds which form the syntaxial structure. These folds are related to a different kinematic system to the main thrust systems of Pakistan and probably formed due to localized high strain near the pinning point of the Himalayan thrusts at the western end of the Himalayan arc.
Key Words: Deformation, structure, Nanga Parbat, Himalaya.

C/214. Coward, M.P., 1985. Aspects of Kohistan tectonics. Abstract Volume, 1st Himalayan Workshop, Department of Geology, University of Leicester.

The Himalayas are generally considered in terms of India/Asia (or Tibet) collision, the thrusts developing in a piggy bank sequence on to the foreland. The structure of Kohistan shows that this is only a small part of the story. Much of the deformation in the Kohistan arc relates to early (80-100 my) compression and southward directed overthrusting, post-dating Cretaceous collision of the arc with "Asia" and occurring while India lay some several thousand kilometers to the south. Following the collision with India there was considerable further deformation, rethrusting

the Asia Plate back over Kohistan, imbricating late to post-Cretaceous sediments and accounting for some of the necessary shortening of the Asia-Tibet plate, north of the suture. This shortening must have occurred in a break-back position relative to the main Himalayan thrusting.
Key Words: Tectonics, collision, India-Asia, Kohistan, Himalaya.

C/215. Coward, M.P., 1987. The evolution of mountain belts: structure of the Himalayas and Tibet. Science Progress, Oxford. 71. 249-273.

Mountain belts form by isostatic uplift, related to a decrease in density of the local lithospheric column. This may develop from (a) localized heating of the mantle, (b) by the addition of new low density material within or below the crust, but (c) more generally it develops from crustal thickening related to continental collision. Early views on mountain belts assumed homogeneous thickening processes, but we now know that horizontal or low-angle displacements play a larger part. Collision involves the subduction of oceanic crust and the eventual underthrusting of one crustal segment beneath that of another plate. The structures developed depend on the strength of the underplating crust, that is, on the original geothermal gradient, rock type and time since underthrusting commenced. For a thrust to have a large displacement, it needs to overcome the resistance to shearing. It builds up a thrust wedge, whose critical taper depends on the basal shear strength. As erosion removes material, the wedge shape is modified by thickening, or by the accretion of new material from beneath and many of the small to medium scale structures in mountain belts are related to this process. The most dramatic mountain belt is that of the Alps-Himalayas, formed as India collided with Asia at about 55 my ago, this time being fairly accurately constrained by the syn-tectonic sediments as well as the history of the Indian ocean. Structural sections through the faulted sedimentary cover to the Indian plate indicate a minimum of 470 km displacement. Thrust rates can be measured by dating syn- to post-tectonic sediments from the front of the thrust wedge, giving about 1 cm/year. From a study of the Indian ocean floor, however, we know that India has moved into Asia some 2500 km, at a rate of about 5 cm/year for the past 50 my. Some of this extra displacement may be taken up by major crustal thickening in Tibet, where the crust doubled in thickness between about 50 and 20 my ago. The remainder must be taken up further north, in central Asia, or by the lateral expulsion of parts of Tibet and adjacent China, along major faults, such as that marking the Kun Lun mountains in northern Tibet. To solve the deep structure of mountains such as the Himalayas, or high plateau such as Tibet, we need new techniques, such as the deep seismic reflection profiling. Such work will be expensive, but it is only when we understand the deep structure and its relationship to what we see at the surface, that we will be able to fully model the kinematics and mechanics of crustal movements.
Keywords: Orogeny, tectonics, Himalaya.

C/216. Coward, M.P. & Butler, R.W.H., 1985. Thrust tectonics and the deep structure of the Pakistan Himalaya. Geology 13(6), 417-420.

The systematic restoration of thrust systems provides a powerful constraint on the deep structure of orogenic belts. A balanced cross section, through the imbricated upper crust of the Indian plate in the footwall to the Main Mantle thrust of the western Himalaya, restores to a minimum width of 730 km, the implicit shortening being in excess of 470 km. This requires the Himalaya and southern Tibetan region to be underlain by a wedge of Indian crust. However, a full appraisal of gross crustal structure awaits deep seismic control.
Keywords: Tectonics, structure, Himalaya.

C/217. Coward, M.P., Butler, R.W.H., Chambers, A.F., Graham, R.H., Izatt, C.N., Khan, M.A., Knipe, R.J., Prior, D.J., Treloar, P.J., Williams, M.P. & Barnicoat, A., 1988. Folding and imbrication of the Indian crust during Himalayan collision. Philosophical Transaction of the Royal Society of London A326, 89-116.

India collided with a northern Kohistan--Asian Plate at about 50 Ma ago, the time of ocean closure being fairly accurately defined from syntectonic sediments as well as the effect on magnetic stripes on the Indian Ocean floor. Since collision, Asia has over-ridden India, developing a wide range of thrust scrapings at the top of the Indian Plate. Sections through the imbricated sedimentary cover suggest a minimum displacement of over 500 km during Eocene to recent plate convergence. This requires the Kohistan region to the north to be underlain by underthrusted

middle to lower Indian crust, deformed by ductile shears and recumbent folds. These structures are well seen in the gneisses immediately south of the suture, where they are uplifted in the Indus and Nanga Parbat syntaxes. Here there are several phases of thrust-related small-scale folding and the development of a large folded thrust stack involving basement rocks, the imbrication of metamorphic zones and the local development of large backfolds. Some of the important local structures: the large late backfolds, the Salt Ranges and the Peshawar Basin, can all be related to the necessary changes in thrust wedge shape as it climbs through the crust and the three dimensional nature of the thrust movements associated with interference between the Kohistan and western Himalayan trends.
Keywords: Collision, structure, Indian crust, Himalaya.

C/218. Coward, M.P., Butler, R.W.H., Khan, M.A. & Knipe, R.J., 1987. The tectonic history of Kohistan and its implications for Himalayan structure. Journal of the Geological Society, London 144, 377-391.

The tectonic history of Kohistan, northern Pakistan, involves two collisional events. Cleavage and folding developed at 90-100 Ma along the northern suture between the Kohistan island arc and the Asian plate. At the same time there was major folding and shearing of the lower part of the Kohistan arc, approximately 100 km south of the suture. This deformation was followed by ocean subduction south of the Kohistan arc, generating the Kohistan calc-alkaline batholith, with subsequent ocean closure during the Eocene and obduction of the Kohistan arc, together with the adjacent part of the Asian plate, over the Indian continental crust. The construction of balanced cross-sections through the imbricated upper part of the Indian continental crust, in the footwall to this southern suture indicates a minimum displacement of 470 km, requiring the western Himalayan hinterland to be underlain by a large wedge of Indian middle to lower crust. There is some shortening of the overriding Kohistan and Asian plates by thrusts and shear zones, but it is insufficient to satisfy the palaeomagnetic data; there must be major crustal shortening, involving thrusts, in the Hindu Kush and Pamirs north of Kohistan.
The post-Eocene thrust direction, which for most of Pakistan is towards 160°, is almost perpendicular to that immediately to the east in the Himalayan belt, generating complex refolded thrust patterns in the Hazara syntaxis and large scale folding and rapid uplift with associated brittle faulting and seismic activity adjacent to the Nanga Parbat syntaxis. These different thrust trends indicate that major thrust movement as well as the folds and deformation fabrics, cannot always be related to plate movement vectors, but are modified by, or develop from, complex rotations during place collision or from the gravitational spreading of a thickened crust. A regional approach is required to recognize and correctly attribute the various components in thrust displacements.
Keywords: Tectonics, Kohistan, Himalaya.

C/219. Coward, M.P., Izatt, C., Ries, A.C. & Williams, M.P., 1992. Passive margin subsidence and inversion along the western margin of the Indian Plate. Abstract Volume, 7th Himalaya-Karakoram Workshop, Department of Earth Sciences, Oxford University, England, 15-16.

Palaeogeographical plate reconstructions, restoration of cross sections and analysis of present day outcrop data have been used to put forward a model for the development of the north-western margin of the Indian Plate (Katawaz basin, Kirthar and Sulaiman Ranges).
The margin was affected by Permo-Triassic Karroo rifting event in an approximately E-W extensional field, continuing in the early Jurassic as India and Madegascar broke away from Africa. The early Cretaceous saw a change in the orientation of the extensional stress field (N-S) as India began to break away and move north along its current path. The Cretaceous is characterized by volcanism, mainly clastic sedimentation, transtension and transpression, and end Cretaceous ophiolite obduction.
The end Cretaceous is also marked by a regional phase of uplift, and volcanic extrusion of the Raj Mahal and Deccan Traps. Rapid subsidence occurs throughout the Tertiary, marine carbonate shelves and shale rich offshore basins in the Palaeocene-Eocene, shallowing to marine-continental basins in the late Tertiary.
During the Palaeozoic NW India lay on the eastern flank of intra-continental basins whilst still part of Gondwanaland. An early basement fabric may have been acquired at this stage. The NW margin of Pakistan/India has been subjected to various phases of uplift and shortening, the most prominent being during the end-Cetaceous/Paleocene and during the Pliocene. Major tectonic inversion of the Katawaz and Sulaiman Ranges occurred during the Pliocene/Pleistocene. Previous thin-skinned models call for geometrically unreasonable amounts of shortening. Our models call for approximately 23-25 km shortening, reactivating Mesozoic faults at depth.

The western margin of the Indian plate was a passive margin, and remains connected by transitional crust to oceanic crust of the Arabian Sea until the Mio/Pleistocene. the Chaman Fault marks the eastern edge of the overriding Afghan plate expelled laterally from N. Pakistan during the Pliocene. The western edge of Pakistan then collided with this expelled block.
The inversion model has implications for the overall structure and shortening in NW Pakistan. Many of the thrust uplifts may not be thin-skinned; for example, earthquake data suggest the reactivation of faults at depth beneath the Kohat region. The thin-skinned overthrusts sheet of the Himalayas is therefore uplifted by faults reactivating basement structures. This revised model has exciting hydrocarbon potential for Pakistan.
The above history has implications for total Himalayan shortening. It suggests that the edge of the Asian plate was much farther north than previously suggested and hence if collision occurred at 55 to 40 mm, Greater India might have been much larger than previously supposed. Much of the shortening in the Himalayas/Tibet probably occurred in the Indian Plate rather than the Asian Plate.
Keywords: Plate tectonics, structure, palaeogeography, Jurassic, Cretaceous, Indian Plate.

C/220. Coward, M.P., Jan, M.Q., Rex, D., Tarney, J., Thirwall, M. & Windley, B.F., 1982. Geo-tectonic framework of the Himalaya of N Pakistan. Journal of the Geological Society of London 139(3), 299-308.

In the Karakorum Range there is a structurally complicated Cretaceous arc comprising the Kohistan sequence. On its northern side the Northern Suture consists of a mega-mélange and is bounded to the S by tightly folded pillow-bearing volcanics and sediments. To the S the Kohistan Plutonic Belt consists of (southwards): (a) early foliated and late post-tectonic tonalites and diorites, (b) aplites and pegmatites (up to 30% of rock volume), (c) basic dykes up to 10 m thick, (d) the Chilas Complex, a stratiform cumulate body over 300 km long and 8 km thick (chromite-layered dunites, gabbros and norites) with a low pressure granulite-facies mineral fabric of tectonic origin, (e) an amphibolite belt with a complex mixture of other rocks, and (f) the Jijal Complex, a 200 km^2 tectonic wedge of high pressure granulites and chromite-layered dunites. Cumulate graded units in the Chilas Complex show that it is folded by an isoclinal anticline (F_1). The mid-upper crust of the arc is folded by a 50 km half-wavelength F_2, syncline. The whole Kohistan sequence with its two phases of isoclinal folds was tilted during Himalayan collision so that the structures are now subvertical. The Southern Suture (Main Mantle Thrust) has a wedge of glaucophane schists. The Indian plate contains a basement of psammites and schists intruded by Cambrian granites and overlain by isoclinally folded and metamorphosed carbonates and shales.
Keywords: Geotectonics, structure, collision, Cretaceous, Kohistan, Himalaya.

C/221. Coward, M.P., Jan, M.Q., Rex, D., Tarney, J., Thirwall, M. & Windley, B.F., 1982. Structural evolution of a crustal section in the western Himalayas. Nature 295, 22-24.

Recent field work on the Kohistan complex in the Karakorum Range of North Pakistan has shown its stratigraphy to be repeated by several phases of tight to isoclinal folding. This reveals a close association between igneous activity and a late deformation and complicates the previously proposed island arc model.
Keywords: Structure, tectonics, collision, Himalaya.

C/222. Coward, M.P., Jan, M.Q., Rex, D., Tarney, J., Thirwall, M. & Windley, B.F., 1984. Geology of the South Central Karakoram and Kohistan. In: Miller, K.J. (Ed.), The International Karakoram Project 2, 71-85. Cambridge University Press.

The Indus suture in northern Pakistan splits into two branches that bring rocks of diverse nature in contact. The northern suture consists of a mega-mélange passing northwards into pelitic and calcareous rocks, which show a rapid increase in grade of metamorphism away from the suture. These rocks are intruded by the calc-alkaline Karakoram batholith. Sedimentary rocks to the north of the batholith are mostly Paleozoic in age and are dominated by slates and shale with some calcareous and arenaceous rocks, and extend up to the Chinese border. The southern suture, with associated ultramafics and a wedge of blueshists, is bordered on the south by the rocks of the Indian plate consisting of a basement of psammites and schists intruded by Cambrian granites and overlain isoclinically folded and low grade metamorphosed cover of carbonates and shales.

Between the two sutures occur rocks of the Kohistan sequence represented by, from north to south, tightly folded pillow-bearing volcanics and sediments; early foliated and late post-tectonic tonalities and diorites with small but abundant intrusions of aplites and pegmatites and basic to intermediate dykes; the Chilas complex, a stratifrom cumulate body over 300-km long and 8-km thick; an amphibolite belt with a complex mixture of other rocks; and the Jijal complex, a 200-km2 tectonic wedge of high-pressure mafic granulites and chromite-layered ultramafics. The Chilas complex is folded by an F1 isoclinal anticline and the upper part of the Kohistan plutonic belt by a major F2 syncline. The whole of the Kohistan sequence with its two phases of isoclinal folds was tilted during the Himalayan collision so that the structures are now sub vertical.
Keywords: Structure, tectonics, collision, Kohistan, Karakoram, Himalaya.

C/223. Coward, M.P., Khan, M.A., Butler, R.W.H., Knipe, R.J., Prior, D., Treloar, P.J. & Williams, M.P., 1986. Folding and imbrication of the Indian crust during Himalayan collision. Royal Society of London, Spec. Meeting.

India probably collided with a northern Kohistan-Asian plate at about 55 Ma ago, the time of ocean closure being fairly accurately defined from syntectonic sediments as well as the effect on magnetic stripes in the Indian Ocean floor. Since collision, Asia has over-ridden India, developing a wide range of thrust scrapings at the top of the Indian plate. Sections through the imbricated sedimentary cover suggest a minimum displacement of over 500 km during Eocene to recent plate convergence. This requires the Kohistan region to the north to be underlain by underthrusted middle to lower Indian crust, deformed by ductile shears and recumbent folds.
These structures are well seen in the gneisses immediately south of the suture, where they are uplifted in the Indus and Nanga Parbat syntaxes. Here there are several phases of thrust-related small- scale folding and the development of a large folded thrust stack involving basement rocks, the imbrication of metamorphic zones and the local development of large backfolds. Some of the important local structures: the large late backfolds, the Salt Ranges and the Peshawar basin, can all be related to the necessary changes in thrust wedge shape as it climbs through the crust.
Keywords: Structure, collision, India, Himalaya.

C/224. Coward, M.P., King, G. & Windley, B.F. 1980. An island arc section in the Himalayas. Nature 284, p. 218.

This gives a brief description of an International Conference of the Geodynamics Working Group held at Peshawar in November 1997. There is a very brief mention of some of the rocks and overall makeup of the arc.
Keywords: Island arc, Himalaya.

C/225. Coward, M.P., Rex, D.C., Khan, M.A., Windley, B.F., Broughton, R.D., Luff, I.W., Petterson, M.G. & Pudsey, C.J., 1986. Collision tectonics in the NW Himalayas. In: Coward, M.P. & Ries, A.C. (Eds.), Collision Tectonics. Geological Society of London, Special Publication 19, 203-219.

West Himalayan tectonics involve the collision of microplates between the Indian and Asian Plates. The Kohistan Complex consists largely of tightly folded basic volcanics and sediments generated as Late Jurassic to Late Cretaceous island arcs. These were intruded by post-folding Mid-Cretaceous — Eocene plutonics produced from continued subduction of the Indian Plate after closure of a suture between Kohistan and the Karakorum. The Himalayan structures show major thrust sheets and the Kohistan Arc is essentially a crustal ‘pop-up’ with southward-upright and northward-verging structures developed above a thick ductile decoupling zone (the Indus Suture), which can be traced for >100 km beneath Kohistan on large reentrants. This pop-up formed by a two stage process, closure of the Northern Suture followed by closure of the southern Indus Suture. Granitic rocks of the Kohistan-Ladakh Batholith (dated at ≅ 100-40 Ma) post-date most of the structures related to the Northern Suture but were deformed and carried southwards on shear structures related to the Indus Suture. Post-collisional deformation carried this Kohistan Complex on deep decoupling zones over the Indian Plate on a series of imbricated gneiss sheets, the thrusts climbing up section in the movement direction so that in the far S some override their own molasse debris. Folds above these deep decoupling zones deformed their overlying thrust sheets into large antiforms - i.e. the Nanga Parbat and Hazara Syntaxes. The Nanga Parbat Syntaxis probably formed due to a shear couple near

a branch line where one of the main Himalayan thrusts joined the Indus Suture beneath Kohistan. Crustal delamination, to produce the imbricated gneiss sheets, could not account for all the displacement of India into Asia, suggested by palaeomagnetic data. There must also have been lateral displacement as demonstrated by the large oblique-slip shear zone in the Hunza Valley, N of Kohistan.
Keywords: Collision, tectonics, Kohistan, Himalaya.

C/226. Cox, L.R., 1930. Fossil fauna of the Samana Range and some neighbouring areas: Part 4. Lower Albina Gastropoda and Lamellibranchia. Geological Survey of India, Memoirs, Palaeontologia Indica, New Series, V. 15, Mem. 4, 39-49, 1pl.

Keywords: Paleontology, Gastropoda, Lamellibranchia, Samana range, Hangu.

C/227. Cox, L.R., 1931. Fossil fauna of the Samana Range and some neighbouring area, Pt. 8 The Mollusca of the Hangu Shales. Geological Survey of India, Memoirs, Palaeontologica India, New Series, 15, Mem. 8, 129-214, 6 pls.

Keywords: Paleontology, mollusca, Samana range, Hangu.

C/228. Cox, L.R., 1935. The Triassic, Jurassic and Cretaceous Gastropoda and Lamellibranchia of the Attock district. Geological Survey of India, Memoirs (New Series) 20(5), 1-27.

Keywords: Paleontology, Triassic, Jurassic, Cretaceous, Gastropods, Lamellibranchia, Attock, India.

C/229. Cox, L.R., 1938. Eocene mollusca from North West India. British Museum (Natural History) Annual Magazine Series 11, 1(2), 161-171.

Keywords: Paleontology, Eocene, mollusca, India.

C/230. Cox, L.R., 1956. Fossil invertebrate collection from India and Pakistan in the British Museum (Natural History). Palaeontological Society of India Journal 1, 94-98.

Keywords: Fossils, invertebrates, India, Pakistan.

C/231. Craw, D., Chamberlain, C.P., Zeitler, P.K. & Koons, P.O., 1997. Geochemistry of a dry steam geothermal zone formed during rapid uplift of Nanga Parbat, northern Pakistan. Chemical Geology 142, 11-22.

Natural dry steam zones (vapour only) are relatively rare; most geothermal systems contain both liquid and vapour and typically follow a boiling point-depth (BPD) relationship. The Nanga Parbat uplift-driven conductive thermal anomaly results in a geothermal system which follows a BPD relationship at shallow levels, but below about 3 km fluid inclusions show that the hydrothermal fluid is dry steam with fluid densities from 0.36 to as low as 0.07 g/cm3. This dry steam zone may persist down to the brittle-ductile transition. The dry steam has salinities up to 5 wt.% dissolved salts, and up to 22 mole% dissolved CO, The dry steam originated as meteoric water high on the slopes of Nanga Parbat, with 6”O as low as - 16%0. Oxygen isotopic exchange with the host rock was facilitated by high temperatures (340” to 450°C) and low fluid densities so that the fluid meteoric isotopic signature was completely obliterated. Hence, quartz veins formed by the migrating dry steam have 6r80 between +9 and + 15%0, a range which is indistinguishable from quartz in the host rocks.
Quartz vein precipitation from dry steam requires 3 to 5 orders of magnitude greater volume of fluid than typical hydrothermal fluids. The dry steam zone at Nanga Parbat has formed due to near-isothermal depressurization of very hot fluid during rapid tectonic uplift at rates > 3-6 mm/year.
Keywords: Geothermal, tectonics, geochemistry, oxygen isotopes, hydrothermal, Himalaya.

C/232. Craw, D., Koons, K.O., Winslow, D., Chamberlain, C.P. & Zeitler, P.K., 1994. Boiling fluids in a region of rapid uplift, Nanga Parbat Massif, Pakistan. Earth and Planetary Science Letters 128, 169-182.

The Nanga Parbat massif of northern Pakistan is currently undergoing rapid uplift ($\sim$ 5–10 mm a^{-1}), resulting in near-surface elevated temperatures. Numerous quartz veins cut geologically young structures (< 2 Ma), attesting to widespread young fluid flow. Fluid inclusions in quartz veins are predominantly low density water vapour (down to 0.05 mg m^{-3}), with some low density carbon dioxide vapour, and the fluid is predominantly meteoric in origin. Fluid inclusions provide evidence for boiling near to the critical points for water and for 5 wt% NaCl solution (up to 410°C). Head-driven meteoric water was convecting in fracture permeability under hydrostatic pressures which followed the boiling point-depth curve and near-boiling springs emanate from the surface. Hydrostatic pressures persisted to depths of about 6 km below the topographic surface, or near to sea level, where the brittle-ductile transition is inferred to lie. Numerical modelling of conductive heat flow in an area of high relief during rapid uplift indicates that the shape of the near-surface conductive geotherm is significantly influenced by topographic relief. Reasonable approximations for topography at Nanga Parbat produce a conductive geotherm which implies high, near-surface geothermal gradients (> 100°C km^{-1}, and the isotherms describe a giant pillar of heat. Above about 4 km, fluid temperature is greater than conductive rock temperature in permeable zones which carry convecting boiling meteoric fluid.
Keywords: Hydrothermal system, fluid inclusions, uplift, NPHM, Himalaya.

C/233. Crawford, A.R., 1974. The Salt Range, the Kashmir syntaxis and the Pamir arc. Earth and Planetary Science Letters 22, 371-379.

The enigmatic Salt Range of Pakistan is suggested to have been rotated about 75° counter-clockwise from an original position in line with the main Himalayan front, about a pole near the eastern end of the Range. Rotation was a consequence of the creation of the Pamir Arc by major block movements in Central Asia which also produced the Kashmir Syntaxis. Although direct palaeomagnetic testing of the hypothesis is not possible, Cambrian pole positions obtained from the Purple Sandstone and Salt Pseudomorph Beds of the Salt Range lie anomalously on the Precambrian part of the apparent polar wander curve for Gondwanaland. These revert to positions in correct chronological sequence on that curve if rotation is allowed for.
Keywords: Salt Range, Kashmir syntaxis, Himalaya.

C/234. Crawford, A.R., 1974. A greater Gondwanaland. Science 184, 1179-1181.

Keywords: Gondwanaland.

C/235. Crawford, A.R., 1974. The Indus suture line, the Himalaya, Tibet and Gondwanaland. Geological Magazine 111, 369-383.

Misunderstanding exists about the origin of the Himalaya, Indo-Tibetan relationships and the extent and history of Gondwanaland. The Indus Suture Line is a relic of fracture to the mantle but for a period only represented by the faunas of the ‘exotic blocks’ of the Tibetan Himalaya, i.e. Permian—Late Jurassic. Tibet appears originally to have been part of a plate including India, but submerged while India remained continental. Associated with the fracture extending to the mantle represented now by the Indus Suture Line, shallower subparallel fractures developed within which the Gondwana sediments of the Himalaya were preserved. These, together with the salt at the base of the Tethyan marine sequence, facilitated intra-continental orogeny when, much later, India was affected by vigorous sea-floor spreading and plate movement in the NW Indian ocean after it had become attached to Asia.
The northern plate boundary was beyond Tibet, on the N side of the Tarim Basin Block, and along the Tien Shan. The Tien Shan present peculiar features, particularly very deep long intramontane depressions such as Issyk Kul in USSR and Turfan-Hami in China, and their stratigraphy shows persistent mobility. The Tarim Basin Block has moved sinistrally relative to Tibet and in Gondwanaland lay near northern Western Australia. The suggested extent of Gondwanaland explains the present lack of continental crust W of Western Australia, now in Tibet, and the

intracontinental origin of the Himalaya is consistent with the absence of recent volcanism in an area of considerable seismicity. The association of Tibet with India in Gondwanaland destroys the effectiveness of arguments against continental drift based upon the extension of Indian stratigraphic sequences across the Himalaya. The hypothesis of an enlarged Gondwanaland is given support by recent Chinese discoveries of terrestrial vertebrate fossils of Gondwanic type near the Tien Shan.
Keywords: Gondwanaland, plate tectonics, Indus suture, Himalaya.

C/236. Crawford, A.R., 1979. Gondwanaland Pakistan region. In: Farah, A. & DeJong, K.A. (eds), Geodynamics of Pakistan. Geological Survey of Pakistan, Quetta, 103-110.

Keywords: Gondwanaland, plate tectonics, Himalaya.

C/237. Crawford, A.R., 1979. The myth of a vast oceanic Tethys, the India-Asia problem and Earth expansion. Journal of Petroleum Geology 2, 3-9.

Keywords: Tethys, plate tectonics, Himalaya.

C/238. Crawford, A.R., 1981. Isotopic age data for the eastern half of the Alpine Himalayan belt. In: Gupta, H.K. & Delany, F.M. (Eds.), Zagros, Hindukush, Himalaya Geodynamic Evolution. American Geophysical Union Transaction, 189-204.

This account gives a summary and discussion of isotopic ages determined for the rocks of Himalayan region in Pakistan. The data are scanty.
Keywords: Geochronology, Himalaya.

C/239. Crawford, A.R. & Davies, R.G., 1975. Ages of Pre-Mesozoic formations of the Lesser Himalaya, Hazara District, Northern Pakistan. Geological Magazine 112, 509-514.

Three samples of low-grade metamorphic rocks from the Hazara Group, northern Pakistan, analysed as total-rock samples by the Rb—Sr method, give model ages of 765±20 and 950±20 Ma. The results are discussed in terms of the stratigraphy of Hazara, northwestern Iran, and certain other areas.
Keywords: Geochronology, metamorphic rocks, Hazara group, Himalaya.

C/240. Crawford, M., 1985. Field relationships of the Karakoram Batholith and metamorphic rocks of the Hunza valley, North Pakistan. Abstract Volume, 1st Himalayan Workshop, Department of Geology, University of Leicester.

The W-E striking Karakoram batholith in the Hunza Valley is very heterogeneous on both small and large scales but is dominantly calc-alkaline in composition. The main mineralogy is quartz, plagioclase and biotite with hornblende also often occurring in the more mafic areas. There are no mafic dykes but making up 40% of the batholith volume in places are two suites of leucogranitic dykes, one suite being concordant with the foliation and the other later and discordant. These dykes contain quartz, alkali feldspar, garnet, biotite and muscovite and probably represent the residual magma. A little tourmaline indicates late boron-rich fluid phase.
To the north the foliation dips south and low-grade metamorphic chiastolite slates of the contact aureole have a south dipping contact with the batholith. A migmatitic belt forms the southern part of the batholith and this is truncated against metamorphic rocks to the south by a north dipping thrust plane.
South of the batholith the foliation dips north and there is a sharp change in the direction of foliation dip near the center of the batholith. Thrust planes and lithological contacts are parallel to the foliation suggesting the folding and thrusting episodes were synchronous and there may be related to the emplacement of the batholith. The metamorphic rocks show a Barrovian-type sequence of facies and include metapelites, calc-silicates and pure carbonate bands. With increasing grade from greenschist to amphibolite facies a series of index minerals

representing isoreaction-grade change through chloritoid to staurolite to kyanite to sillimanite with gneissic melting next to the batholith. The isogrades dip north and the metamorphism increases to the north so the sequence is therefore inverted.
Keywords: Geology, Karakoram batholith, Hunza.

C/241. Crawford, M.B., 1988. Leucogranites of the NW Himalaya: mantle-crust interaction beneath the Karakoram and the magmatic evolution of collisional belts, Ph.D. Thesis, University of Leicester.

The Karakoram Axial Batholith in N. Pakistan records the magmatic development of the Eurasian continental margin since the late Jurassic. Magmatism prior to the collision of India with Eurasia at c.45Ma is represented by subdcution-related, calc-alkaline granodiorite plutonism. The chemical variation within these plutons is caused by high-level fractionation processes. However, heterogeneous isotope data suggest that the source of these magmas was the mantle wedge, enriched by a subducted slab component, with the melts being contaminated by a Sr-rich crustal component.
There are two types of post-collisional leucogranites. The Sumayar pluton is related to restricted partial melting of sillimanite-grade metapelites triggered by fluxing of fluids from the underthrust Indian crust. This water-saturated, minimum melt is considered to be an analogue of the High Himalayan leucogranites.
The other Karakoram leucogranites are related by fractionation to a more basic monzogranitic parent, whose geochemistry indicates a lower crustal source. However, melting of typical crust cannot explain the anomalously high large ion lithophile element (LILE) content of the monzogranites. Associated with the granites are ultra-potassic, LILE-enriched lamprophyres. This LILE-enrichment is attributed to alteration of the mantle wedge by fluids and /or siliceous melts from the slab. Amphibole in the resulting metasomatic assemblage acts as a sink for the otherwise incompatible LILE. As a result of heating and thermal relaxation beneath the thickened continental crust, enriched amphibole, stable in the pre-collisional after collision to give the lamprophyres. Fluid precursors to this melting contaminated the source region of the granites selectively enriching it in LILE and triggering/promoting melting. The identification of the above magma-types, which have different generative processes and magmatic triggers, in other collisional environments, will lead to information about the evolution of similar orogenic belts.
Keywords: Leucogranites, Karakoram batholith, Himalaya.

C/242. Crawford, M.B. & Searle, M.P., 1992a. Crustal structure and collision-related granitoid magmatism of the Hunza Karakoram, north Pakistan. Abstract Volume, 7th Himalaya-Karakoram Workshop, Department of Earth Sciences, Oxford University, England, 17.

The Karakoram batholith in the Hunza segment of the Karakoram Range, north Pakistan, is dominated by a pre-50 Ma collision, calc-alkaline, quartz diorite-granodiorite batholith which separates a dominantly sedimentary terrain to the north from a regional metamorphic terrain to the south. The southern part of the batholith and the metamorphic rocks to the south are affected by strong south-vergent thrusting related to the collision, which has brought deeper level, hotter rocks over higher level, cooler rocks, creating an apparent inverted metamorphic profile. Isograds have been disrupted by large-scale, post-metamorphic thrusts. Stretching lineations are dominantly north-dipping throughout. The northern part of the batholith is relatively undeformed and shows an intrusive contact with the sediments to the north and an andalusite-hearing contact metamorphic aureole.
A massive dyke complex, the Hunza dykes, intrude the early phase of the batholith as well as the high-grade sillimanite gneisses to the south. The Hunza dykes consist of a co-genetic suite of monzogranites, granodiorites and leucogranites, which are related by feldspar-biotite fractionation. They are volatile-depleted non-minimum melts with unevolved Sr isotope ratios and LILE-enriched signatures similar to the Baltoro pluton further east. The Sumayar pluton intrudes the kyanite and staurolite-grade metamorphic rocks south of the batholith and is a homogeneous, water-saturated, minimum-melt leucogranite, with a major element composition similar to that of the Manaslu leucogranite of central Nepal. Abundant tourmaline and high Sr isotope ratios (>0.8) together with REE modeling indicate a metapelitic source for the Sumayar leucogranite.
The massive post-collisional Baltoro monzogranite-leucogranite pluton is not continuous across to the Hunza region. The Hunza dykes are, however, almost certainly related to the Baltoro pluton, and represent lower crustal magmas derived by dehydration melting of metasediment following the India-Kohistan-Asia collision events. Consideration

of the petrogenesis of the Hunza dykes and the Sumayar pluton allow inferences to he made concerning the deep crustal structure of the Hunza Karakoram.
Keywords: Structure, granitoid magmatism, collision, Hunza, Karakoram.

C/243. Crawford, M.B. & Searle, M.P., 1992b. Field relationships and geochemistry of pre-collisional (India-Asia) granitoid magmatism in the central Karakoram, northern Pakistan. Tectonophysics 206(1-2), 171-192.

In the central Karakoram Range, northern Pakistan, seven major granitic units which were emplaced prior to the Eocene (ca. 50 Ma) India-Asia collision have been mapped and analysed geochemically. The mid-Cretaceous Hunza plutonic complex dominates the Karakoram batholith in the west and is composed of quartz diorite-granodiorite plutons which have been deformed in the south by later collision-related thrusting. The Sost and Khunjerab plutons intrude the Palaeozoic-early Mesozoic sediments north of the batholith. In the east pre-collision magmatic units occur both north of (K2 gneiss, Broad Peak quartz diorite, Muztagh Tower unit) and south of (Hushe gneiss) the batholith which is dominated by a Miocene monzogranite-leucogranite pluton (Baltoro unit). The plutonic units to the north of the batholith are mid- to late Cretaceous with an age range of ca. 115-80 Ma whereas the Hushe gneiss to the south is dominantly Jurassic spanning the age range 200-145 Ma.
All the pre-collision magmatic units display similar chemical and isotopic characteristics. Major, trace and REE variations in the Hunza plutonic complex are controlled by high-level fractionation of clinopyroxene, hornblende, plagioclase, biotite, ilmenite and allanite. High LILE/HFSE and LREE/HREE ratios, together with negative Nb, P and Ti anomalies suggest an ultimate source in the mantle wedge above the subducting slab. $^{87}Sr/^{86}Sr$ initial ratios (0.7055-0.7157) in the Hunza plutonic complex can best be explained by contamination of a mantle-derived magma by a crustal component with highly radiogenic Sr.
All the units except the Hushe gneiss are probably related to subduction during closure of a back-arc basin between the Karakoram to the north and the Kohistan-Dras arc to the south during the mid- to late Cretaceous, and correlate with widespread plutonism from the same period in Kohistan, Ladakh and southern Tibet along the southern margin of Asia. The Hushe gneiss is probably related to an earlier northward-directed subduction phase during the Jurassic.
Keywords: Structure, geochemistry, pre-collision granitoid magmatism, Karakoram.

C/244. Crawford, M.B. & Searle, M.P., 1993. Collision-related granitoid magmatism and crustal structure of the Hunza Karakoram, north Pakistan. In: Treloar, P.J. & Searle, M.P. (Eds.), Himalayan Tectonics. Geological Society of London, Special Publication 74, 53-68.

Keywords: Structure, magmatism, collision, Hunza, Karakoram.

C/245. Crawford, M.B. & Windley, B.F., 1990. Leucogranites of the Himalaya/Karakoram: implications for magmatic evolution within collisional belts and the study of collision-related leucogranite petrogenesis. Journal of Volcanology and Geothermal Research, 44, 1-19.

Two types of leucogranite have been identified in a collisional setting in the Himalaya. Type-a (e.g., Manaslu, High Himalaya) are syn-tectonic crustal melts related to “hot over cold” thrusting and subsequent fluid fluxing. Type-b (e.g., Baltoro, Karakoram) is related to lower crustal melting during/following crustal thickening and thermal re-equilibration, followed by crystal fractionation. For type-b, melting is triggered/promoted in the lower crust by input of heat and material from the sub-continental lithospheric mantle which is contemporaneously melting due to removal of the slab input and downward displacement.
Both these granite types can be explained in terms of recent thermal models for continental collision, and so might be expected to be found in other orogenic terranes. These models also show that extension and thinning will occur as a result of the crust becoming gravitationally unstable, due to thickening, sometime after collision. Thinning will lead to upwelling and melting of asthenosphere which could then intrude the base of the crust and promote further melting. This could explain the common occurrence of A-type granitoids as final plutonic events in orogenic terranes following intrusion of the collision-related type-a and type-b granites.
Existing genetic classification schemes only classify granites in terms of source-type or broad environmental affinity (e.g., collisional). To further subdivide such broad environmental fields it is considered that processes and a general

evolutionary model must be used. Source-type is not suitable due to the number of source components that are often involved and the overlap of these components from one environment to another. One or two selected features of a granite are not, however, sufficiently exclusive to identify different petrogenetic histories. We propose that an evaluation of field style, mineralogy, isotope and elemental geochemistry should be used to subdivide the collisional granite field into type-a and type-b (or Manaslu and Baltoro-types) respectively.
Keywords: Collision, leucogranites, magmatic evolution, Himalaya, Karakoram.

C/246. Cressey, G., 1986. Geikielite and perovskite in serpentine-brucite marble from Baltistan, Northern areas (Kashmir), Pakistan. Mineralogical Magazine 50, 345-346.

Keywords: Mineralogy, serpentine-marble, Baltistan, Pakistan.

C/247. Crick, J.C., 1904. Notes on the two cephalopoda obtained by Lt. Col. Skinner, R.A.M.C., from the valley of the Tochi River on the North West Frontier of India. Geological Magazine 1, 490-493.

The valley of the Tochi River is an outlying corner of the British Empire in India forming a portion of Waziristan, the boundary of which was delineated in 1894–5 by an Anglo-Afghan Commission from the Afghan provinces of Khost on the north and Birmul on the west. Mr. F. H. Smith, of the Geological Survey of India, accompanied this Commission as geologist, and his observations “On the Geology of the Tochi Valley” were published in 1895 in the “Records of the Geological Survey of India” (vol. xxxviii, pt. 3, pp. 106–110, pl. iii). On p. 109 he says:—“The range of hills between Idak and Mirán Shah is formed by an anticlinal ridge which approximately strikes north and south, and which is composed of these lower Eocene beds. In the core of the anticlinal a considerable thickness of massive dark grey limestone is exposed, in which I could find no fossil remains; the age of this limestone is therefore doubtful, and there is no evidence of any kind to show whether it belongs to the lowest tertiary or upper Mesozoic age.”
Keywords: Palaeontology, cephalopods, Tochi valley, Waziristan.

C/248. Crick, J.C., 1905. Cephalopoda from the North West Frontier of India. Geological Magazine 2, 47-48.

This is a discussion of the previous account by the same author. Other workers have given their opinions on the subject.
Keywords: Palaeontology, cephalopods, Tochi valley, India.

C/249. Critelli, S. & Garzanti, E., 1991. Petrology of remnant ocean sandstones derived from the Himalayan suture belt. Abstract Volume, 6th Himalaya-Karakoram-Tibet workshop, Auris, France, 31-32.

After the Indian-Eurasia collision, which determined the final closure of the Neotheys Ocean in the early Eocene, “recycled orogenic” arenites began to be deposited in remnant oceanic basins at both sides of the Indian Peninsula. These sediments, of late Oligocene to early Pliocene age, were progressively incorporated in accretionary prisms formed at subduction zones both to the east (Andaman-Mentawi islands: Moore 1979) and west (Makran: Critelli et al. 1990) of the collision zone. Detritus derived from the elevated Himalayan chain is still being accumulated today in the two greatest turbiditic cones of the world, floored by remnant oceanic crust (Bengal and Indus Fans: Ingersoll and Suczek, 1979; Suczek and Ingersoll 1985).
Detrital modes of these “recycled orogen” clastic wedges are all comparable, and testify to a predominant contribution from the Himalayas. They thus represent the distal “flysch” equivalent of ancient and recent “molasses” (Siwaliks: Prakash et al; 1980, Indo-Gangetic Plain, Potter, 1978), deposited in subaerial foreland basins floored by Indian continental crust.
A major difference in detrital modes among these deposits is represented by the significant volcanic contribution from active magmatic arcs to the subduction complex sandstones (Nias and Makran). Both the Indus and Bengal

turbiditic cones and the ancient and recent foredeep deposits were instead entirely derived from the uplifted Himalayan Chain. While volcanic detritus is absent in the Siwaliks and Ganges sands, recycled volcanoclastics derived from the Transhimalayan arc and Indus-Tsangpo suture zone are transported by the Indus and Brahmaputra rivers up to the turbiditic cones of the Indian Ocean.

Indus	61	7	32	--	--	35	11	54
Ganges	74	10	16	--	--	64	0	36
Brahmaputra	51	26	24	--	--	40	27	33
Indus Fan	43	30	27	0.03	0.66	52	11	37
Bengal Fan	57	28	14	0.01	0.68	87	4	9
Siwaliks	57	7	36	0.10	--	63	tr	37
Nias	70	11	19	0.05	0.70	35	29	36
Makran	56	10	34	0.04	0.68	31	37	32

Figure 1 – Detrital modes of modern sands and Tertiary sandstones derived from the Himalayan Chain data for modern river sands are in QFR rather than QFL mode.

Keywords: Petrology, sandstone, Suture belts, Indus fan, Bengal fan, siwaliks, Himalaya.

C/250. Critelli, S. & Garzanti, E., 1994. Provenance of the lower Tertiary Murree redbeds (Hazara-Kashmir Syntaxis, Pakistan) and initial rising of the Himalayas. Sedimentary Geology, 89(3-4), 265-284.

The Murree Supergroup of northern Pakistan is represented by an over 6 km thick succession of deltaic redbeds and intercalated impure foraminiferal limestones of latest Paleocene to Middle Eocene (Ierdian to Lutetian) age, cropping out in the northern part of the Hazara Syntaxis, and by redbeds of younger age (early Middle Eocene to Early Miocene) cropping out in the southern part of the Syntaxis (Rawalpindi area).The quartzolithic composition of the Murree redbeds testifies to a “collision orogen” provenance. Detritus was derived from a suture belt including thrust sheets of metasedimentary and subordinately sedimentary rocks, volcanic or volcaniclastic rocks, and ophiolites. Phyllite rock fragments are most common in the Ilerdian sandstones, whereas volcanic and carbonate rock fragments are more abundant in the Lutetian sandstones. Minor quantities of chert and serpentine schist, indicating contribution from uplifted subduction complex sources, as well as siltstone, shale and limestone grains, are invariably present. Detrital modes of sandstones and southwestward progradation of Tertiary clastic wedges both testify to provenance from the proto-Himalayan chain located to the north, and uplifted since the very first stages of the India/Asia continental collision at the end of the Paleocene. The coeval Chulung La redbeds of the Tethys Himalaya instead, consisting of volcanic and subordinate ophiolitic detritus, testify to exclusive provenance from the obducting Trans-Himalayan are-trench system. This major petrographic difference may be accounted for by the different structural setting of the Chulung La “piggy-back” and Murree foreland basins. These two distinct collisional basins have been separated probably since the onset of collision by a fold-thrust belt, beginning to rise in the position occupied today by the High and Lesser Himalayan structural domains. Throughout the Murree Supergroup, main petrographic parameters do not vary greatly, and volcanic, sedimentary, low-grade metasedimentary and ophiolitic detritus persisted until the Early Miocene, indicating slow progressive growth of the chain. Only during the Middle Miocene, when the highly metamorphosed rocks of the High Himalaya were carried southward along the Main Central Thrust (MCT), the mountain range began to rise to dramatic heights, and huge amounts of detritus started to feed the Siwalik foreland basin sandstones and the remnant ocean turbidites of the Indus and Bengal Fans.

Keywords: Provenance, Murree red beds, Tertiary, Hazara Kashmir syntaxis, Himalayan orogeny.

C/251. Crompton, T.O., 1984a. The Pakistan to Russia triangulation connexion: past and project error analyses. In Miller, K.J., The International Karakoram Project, Volume 1. Cambridge University Press.

Using those data available, an error analysis of the triangulation connexion from Gilgit to the Russian border, which was observed by Kenneth Mason's 1913 expedition, is performed. This analysis is compared with an error analysis of the projected re-observation of this connexion. The latter analysis may be treated, in part, as an optimization process enabling crucial measurements for the control of scale, to be identified, based on a priori estimates of measuring accuracies.
The paper continues with some comments on how the calculation of the observations should proceed with a view to abstracting tectonic movements by comparison of the two epochs of measurement. The difficulties of obtaining such results and heir statistical significance are described. Finally, looking to the future, the relevance of the 1980 observations is discussed in the context of possible repeat measurements within, say, the next ten years.
Keywords: Tectonic movement, triangulation, Russian, Pakistan.

C/252. Crompton, T.O., 1984b. The calculation of crustal displacement and strain from classical survey measurements. In: Miller, K. J. (Ed.). The International Karakoram Project 2. Cambridge University Press.

This paper identifies some of the problems inherent in the determination of planimetric displacement and strain in the earth's crust by repeated survey measurements. An approach which avoids the use of co-ordinates is developed. The technique should be familiar to the surveyor and, at the same time, useful to the geophysicist. After some discussion of the relative accuracies of 1913 and 1980 measurements, the paper concludes with a simple application using data acquired during the International Karakoram Project.
Keywords: Crustal displacement, Karakoram.

C/253. Cronin, V.S., 1982. The physical and magnetic polarity stratigraphy of the Skardu Basin, Baltistan, northern Pakistan. M.A. thesis, Dartmouth College, Hanver, New Hampshire, 226p.

Keywords: Magnetic stratigraphy, Skardu basin, Karakoram, Himalaya.

C/254. Cronin, V.S., 1989. Structural settings of the Skardu intermontane basin, Karakorum Himalaya, Pakistan. Geological Society of America, Special Paper 232, 183-202.

Skardu Basin is a northwest-trending intermontane basin along the Indus River in the Karakoram Himalaya Mountains of Pakistan. Seismotectonic domain boundaries in the Karakoram Himalaya commonly cross lithologic and some older structural boundaries. Four major structural-seismotectonic domains exist in the Skardu area: the Himalayan seismic zone, characterized by thrust tectonics; the complex Hindu Kush-Pamir seismic zone; the Skardu quiet zone, characterized by strike-slip, extensional, and rotational tectonics with relatively little seismicity; and the southern edge of Eurasian lithosphere (Tarim-Kun Lun-Tibet) northeast of the Karakoram fault. The Skardu quiet zone is interpreted to be within the Himalayan thrust prism, above an aseismic detachment along which stable sliding or ductile faulting accommodates displacement. Stresses transmitted into the Skardu quiet zone laterally from the Himalayan seismic zone toward Eurasia and perhaps upward front the inferred basal detachment result in gross clockwise rotation, translation to the north-northwest, and a right-lateral sense of shear in the Skardu region.
Landsat lineaments defined by major drainages suggest an array of fractures and faults in the Skardu quiet zone. Field data suggest that the lineaments generally reflect distributed shear along myriad small faults rather than displacement exclusively localized on major, discrete fault surfaces. Extensive glacial and fluvial erosion have accentuated trends characterized by relatively dense fracturing and faulting. At its confluence with the Indus at Skardu, the Shigar River flows through a breach that may have originated as a pull-apart structure similar to the pull-apart basin along the upper Sutlej River.
The preserved vestiges of the upper Cenozoic Bunthang sedimentary seqnence reflect Skardu's early basin phase. Uplift along the Nanga Parbat-Haramosh syntaxis and along the northeastern margin of the Himalayan seismic zone

may have contributed to the ponding of the Indus River in the Skardu Basin during Bunthang time. These axes of uplift may be related to movement of the Himalayan thrust wedge from a region of easy basal slip (Skardu quiet zone) to a region of increased resistance to basal slip (Himalayan seismic zone, or, in the ease of the NP-H syntaxis, the Hindu Kush-Pamir seismic areas). Regional uplift within the Skardu quiet zone may reflect thickening of the thrust prism in response to variations in shear resistance along the detachment. Quaternary glacial lake beds located on the floor of Skardu Basin are generally on deformed in the western half of the basin. Local deformation within the lake beds in the eastern half of the basin is probably due to interaction with glaciers.
Keywords: Structural setting, Skardu basin, Karakoram, Himalaya.

C/255. Cronin, V.S. & Johnson, G.D., 1992. The revised chrono-stratigraphy of the Late Cenozoic Bunthang sequence of Skardu intermontane basin, Karakoram Himalaya, Pakistan. In: Shroder, J.F. (Ed.), Himalaya to the Sea. Routledge, London, 91-107.

Keywords: Stratigraphy, Late Cenozoic, Skardu basin, Karakoram.

C/256. Cronin, V.S., Johnson, P.W., Johnson, N.M. & Johnson, G.D., 1989. Chronostratigraphy of the upper Cenozoic Bunthang sequence and possible mechanisms controlling base level in Skardu intermontane basin, Karakoram Himalaya, Pakistan. Geological Society of America, Special Paper 232, 295-305.

A 1.3-km-thick section of basin-fill sediments within the Skardu intermontane basin of the Karakoram Himalaya, termed the Bnnthang sequence, is predominantiy reversely magnetized. Glacial deposits and landforms are closely associated with the Bunthang sequence. This implies that basin filling took place between glacial advances and prior to the present Brunbes normai chron, i.e., between 3.2 and 0.73 Ma. Four major facies lnterfinger within the Bunthang sequence: glacial facies; lacustrine facies, indicative of periods during which the Indus River was ponded within the basin; aggradational fluvial facies that represent periods during which the gradient of the Indus River was controlled by rising base leveI downstream; and alluvial fanglomerates that prograde transversely from the basin margin into the basin at different stratigraphic levels. The last facies represents periods of decreased sedimentation by the Indus River relative to alluvial sedimentation from the basin margin.
Downstream from the Skardu Basin, the Indus River crosses the Nanga Parbat-Haramosh syntaxis; this is an area of rapid late Cenozoic uplift (as much as 1 cm/yr). Differential uplift of the Nanga Parbat-Haramosh syntaxis relative to its surrounding terrain led to local variations in Indus River gradient. Temporary poding of tile Indus River is inferred to have occurred when the uplift rate of the Nanga Parbat-Haramosh syntaxis exceeded the rate of downcutting by the Indus River. Temporary blockage of the Indus River Gorge through the Nanga Parbat-Haramosh syntaxis by glaciers or by major landslides may also have led to variations in base level. Temporal variations in the gradient and base level of the Indus River downstream from the Skardu Basin, are reflected in the different facies that lnterfinger within the Bunthang sequence at Skardu.
Keywords: Stratigraphy, Cenozoic, Skardu basin, Karakoram.

C/257. Cronin, V.S., Schurter, G.J. & Sverdrup, K.A., 1992. Landsat image analysis of drainage lineaments to locate possible faults and structural discontinuities along the Nanga Parbat-Haramosh Massif, northwest Himalaya. Abstract Volume, 7th Himalaya-Karakoram Workshop, Department of Earth Sciences, Oxford University, England, 18-19.

The Nanga Parbat-Haramosh Massif (NPHM) of northern Pakistan is a prominent salient of allocthonous Indian continental crust that is exposed within the Kohistan-Ladakh magmatic arc. Nanga Parbat (8126 m) has the greatest local relief and one of the most rapid rates of uplift yet observed in continental crust. The northerly trend of the NPHM is nearly perpendicular to the active thrust faults of the Himalayan foreland. The reasons for the rapid uplift and anomalous trend of the NPMM are not yet fully understood.
A better understanding of the NPHM awaits collection of a more complete suite of primary structural, seismic, and lithologic data throughout this area. Published structural geologic mapping in this area is inconsistent and very incomplete, particularly in areas that are not close to the roads that follow the Indus, Gilgit, Hunza and Astor Rivers. In this study, satellite imagery was analyzed to supply a family of hypotheses regarding the structures exposed at the

surface that may be active in accommodating the. uplift of the NPHM. The development of these hypotheses will enhance both the focus and economy of future structural reconnaissance mapping along the NPHM.
The study area is located between latitudes 35015'N and 36o15'N and longitudes 74ol5'E and 75o15'E. A collection of photographic prints of Landsat 2 MSS band 7 imagery was analyzed to identify lineaments defined by stream drainages that may have developed along structural discontinuities. Discontinuity types relevant at this scale include faults, joints, contacts, spatially persistent foliation, and lithologic variations that result in differential weathering. Virtually all of the ~2500 drainages that are clearly observable on the imagery were manually digitized using a 1200 lpi digitizer. Each drainage was recorded as a polyline. of short, linear drainage segments. The azimuth of each drainage segment was determined, and the ~12,000 segments were sorted by azimuth into 36 overlapping sets. A given set contains the endpoint coordinates of each segment whose trend lies within a specified 10o wide azimuthal class. Each set of drainage segments was then automatically re-plotted on a separate map to indicate more clearly the location of linear arrays of drainage segments.
Drainage lineaments are defined as essentially collinear arrays of drainage segments that are traceable across at least one drainage divide. Assisted by the maps of drainage segments, a set of ~200 lineaments was identified by direct inspection of the Landsat imagery. Multiple images of the same Landsat frame were used to Identify lineaments, taking advantage of differing sun angles and snow conditions. Most of the lineaments extend for many kilometers, and cross several drainage divides.
The drainage lineaments identified in this study include the traces of the few known active faults in the NPHM area; the Stak, Baroluma, and Raikot Faults. It is reasonable to hypothesize that structural activity is being accommodated on more than the few active faults that have been mapped in this area, given that the NPHM is in one of the most structurally active areas on Earth. Many of the lineaments that do not correlate with known faults or lithologic contacts are located in areas that have not yet been mapped adequately, or at all. We suggest that at least some of the drainage lineaments correspond to previously unmapped active faults. Evaluation of the various hypotheses concerning the origin and significance of these lineaments requires fieldwork.
Keywords: Landsat imaging, drainage, seismicity, structure, NPHM, Himalaya.

C/258. Cronin, V.S., Schurter, G.J. & Sverdrup, K.A., 1993. Preliminary Landsat lineament analysis of the northern Nanga Parbat-Haramosh massif, northwest Pakistan. In: Searle, M.P. & Treloar, P.J. (Eds.), Himalayan Tectonics. Geological Society of London, Special Publication 74, 193-206.

Analyses of mosaic of Landsat2 MSS band 7 images covering the northern Nanga Parbat-Haramosh Massif (NPHM) has yielded approximately 540 lineaments defined by sets of collinear drainage segments and aligned linear greytone boundaries. Segments of the few well-mapped faults along the NPHM as lineaments are identified. The paucity of field data concerning faults, joints, lithological fabric and contacts prevent from interpreting most of the lineaments. However, some of the poignant lineament trends probably mark the trace of previously unmapped active faults that accommodate the recent uplift of the NPHM. The origins of these lineaments must be established through structural geological field work.
Keywords: Structure, active faults, Landsat, NPHM, Himalaya.

C/259. Cronin, V.S., Sverdrup, K.A. & Schurter, G., 1990. Landsat drainage lineaments, seismicity and uplift of the Nanga Parbat–Haramosh Massif, northwest Himalaya. Geological Society of America, Abstract with Programs. No. 22, A232.

Consult the following account for further information
Keywords: Landsat imaging, drainage, seismicity, NPHM, Himalaya.

C/260. Crookshank, H.C., 1947. Report on mineral discovery of the GSP, since August 1947. Geological Survey of Pakistan, Record 3, part 1, 9p.

Keywords: Mineral discovery, GSP.

C/261. Crookshank, H.C., 1951. Mineral resources of Pakistan. Pakistan Journal of Science 3, 93-96.

Keywords: Mineral discovery, economic geology.

C/262. Crookshank, H.C. & Heron, A.M., 1955. Discovery of economic minerals of Pakistan. Geological Survey of Pakistan, Records 7(2), 146p.

This and the two preceding contributions of HC Crookshank, valuable at the time of publication, are now only of historic value. Subsequent publications, mostly by the Geological Survey of Pakistan, provide more up-to-date information on the mineral resources of Pakistan. These are referred to in this compilation
Keywords: Mineral discovery, economic geology

C/263. Cugia, M., 1936. Determinazioni di magnetismo terrestre. Appendix 2: La Spedizione Geografica Italiana al Karakorum, 1929. Arte Grafiche Bertarlli, Milano, 8-13.

The Italian expedition of 1929 to the Karakoram Range also conducted geophysical studies. This report is an account of the studies related to terrestrial magnetism.
Keywords: Geophysics, terrestrial magnetism, Italian expedition, Karakoram.

C/264. Currie, E.D., 1930. The fossil fauna of the Samana Range and some neighbouring areas. Pat 2, the Albian Echinodea. Geological Survey of India, Palaeontologica Indica, Memoirs (New Series) 15(2) 17-23.

Keywords: Paleontology, Albian Echinodea, Samana Range, Hangu.