P/1. Paar, W. & Ruschka, S., 1977. Ein vorkommen von alumohydrocalcit von Chitral, West Pakistan, und neue beobachtungen an chrome haltigem alumohydrocalcit von Nowej Rudy, Polen (= Neurode, Schleisen). Der Aufschluss 28, 269-272.

Mineralogical information about alumohydrocalcite mineral from Chitral is provided. The mineral is compared with newly discovered chrome-containing alumohydrocalcite of Poland.
Key word: Hydrocalcites, mineralogy, Chitral, Poland.

P/2. Paffen, K.H., Pillewizer, W. & Schneider, H.J., 1956. Forschungen im Hunza-Karakorum. Erdkunde 10(1), 1-33.

Key word: Hunza, Karakoram.

P/3. Paganini, P., 1912. Relievi fotogrmetrici nella regione del Karakoram, eseguiti dalla spedizione di S.A.R. il Duca degli Abruzzi. Boll. Soc. Geogr. Ital., Ser. V, I, (8), 819-840, (9) 947-965.

Key words: Photogrammetry, Karakoram.

P/4. Page, N.J., Haffty, J. & Ahmad, Z., 1979. Platinum, palladium and rhodium concentrations in mafic and ultramafic rocks from the Zhob Valley and Dargai Complexes, Pakistan. U.S. Geological Survey Professional Paper 1124F, 1-6.

This is an earlier study of mafic-ultramafic rocks from Zhob and Dargai, two of the largest ophiolite occurrences of Pakistan. Analytical data are presented for Pt, Pd and Rh in the rocks.
Key word: Ultramafics, platinum, palladium, Zhob, Malakand.

P/5. Pakistan Council of Scientific and Industrial Research 1963. Properties of some Pakistani bentonites. Proceedings, CENTO Symposium on Industrial Rocks and Minerals, Lahore, 161-165.

Key word: Industrial rocks, Bentonite.

P/6. Pakistan-Japanese Working Group 1981. Stratigraphy and correlation of the Marine Lower Triassic in the Surghar Range and Salt Range, Pakistan. Memoir Faculty of Science, Kyoto University, Series Geology and Mineralogy, 25p.

Key word: Stratigraphy, Surghar Range, Salt Range, Triassic.

P/7. Pakistani-Japanese Research Group 1985. Permian and Triassic systems in the Salt Range and Surghar Range, Pakistan. In: Nakazawa, K. & Dickins, J.M. (Eds.), The Tethys - Her paleogeography and paleobiogeography from Paleozoic to Mesozoic. Tokai University Press, Japan, 221-312.

Key word: Stratigraphy, Surghar Range, Salt Range, Permian, Triassic.

P/8. Palmer-Rosenberg, P.S., 1985. Himalayan deformation and metamorphism of rocks south of Main Mantle Thrust zone, Karakar Pass area, southern Swat, Pakistan. M.S. Thesis, Oregon State University, Corvallis, 67p.

The Swat and northern Buner area to the south of the Main mantle thrust is occupied by Precambrian metasedimentary rocks with intrusions of granitoids. These rocks have passed through episodes of deformation and metamorphism. This thesis describes Himalayan orogeny related metamorphism and deformation in the rocks.
Key word: Deformation, metamorphism, MMT, Karakar pass, Swat, Buner.

P/9. Pan, Y., Zheng, D. & Zhang, Q., 1992. Introduction to integrated scientific investigations on Karakorum and Kunlun mountains. China Meteorological Press, Beijing.

This is a summarized account of the geology and geography of the Kunlun Mountain, and the n northern flank of the Karakorum Range in China. The Khunjerab area is shown to be occupied by Late Mesozoic rocks. The Yanshanian granitoid at Khunjerab is reported to have a U-Pb age of 104 Ma. Bodies of similar granitoids are shown to occur up to Gez, some 250 km to the north.
Key words: Geology, geography, Kunlun, Karakoram

P/10. Pande, K., Sarin, M.M., Trivedi, J.R., Krishnaswami, S. & Sharma, K.K., 1994. The Indus Rivers system (India-Pakistan): Major-ion chemistry, uranium and strontium isotopes. Chemical Geology 116, 245-259.

The Indus River is one of the large river systems draining the Himalaya. We report in this paper the major-ion chemistry, Sr and U isotope systematics of the Indus system, particularly its headwaters. The results show that: (1) on an average about a third of the cations in the waters can be from silicate weathering; however, most of the (Ca + Mg) is likely to be from the weathering of carbonates and evaporites; (2) the $^{87}Sr/^{86}Sr$ of the waters ranges between 0.7085 and 0.7595, the higher values (> 0.72) are typical of the tributaries draining the Precambrian granite/gneissic terrains. The $^{87}Sr/^{86}Sr$ of the Indus main channel, throughout its entire stretch, shows only minor variations, 0.7104–0.7116. The Indus transports ~8.8 $\cdot$ 10^6 mol Sr to the Arabian Sea annually with a $^{87}Sr/^{86}Sr$ of 0.7111 if our results of Sr concentration and $^{87}Sr/^{86}Sr$ measured at Thatta can be considered typical of the Indus throughout the year; and (3) the U concentration in the Indus and its tributaries is generally high, 0.37–10.3 μg 1^{-1}. The source for the high uranium can be the weathering of granites, zones of uranium mineralisation and black shales.
The Indus results when compared with our earlier data on the Ganga-Brahmaputra show that in all these three river systems carbonate weathering is the dominant source of (Ca + Mg) and HCO3 and that U concentrations are high. In the case of $^{87}Sr/^{86}Sr$, the Indus waters are less radiogenic; however, its tributaries draining the Precambrian granites/gneisses have $^{87}Sr/^{86}Sr$ in excess of 0.72, similar to that in the rivers of the Ganga system. The low 87Sr86Sr of the Indus, 0.7111, suggests that its contribution to the Sr isotope evolution of oceans since the Cenozoic is less significant than that of the Ganga-Brahmaputra.
Key word: Hydrochemistry, U and Sr isotopes, Indus River.

P/11. Papritz, K., 1989. The Geology of the Kaghan Valley (NE-Pakistan): Aspects of Tectonics, Metamorphism and Geochemistry. Master's Thesis, ETH, Zurich, 143p.

Key word: Tectonics, metamorphism, geochemistry, Kaghan valley, Himalaya.

P/12. Papritz, K. & Rey, R., 1989. Evidence for the occurrence of Permian Panjal trap basalts in the lesser- and higher-Himalayas of the Western Syntaxis area, NE Pakistan. Eclogae Geologicae Helvetiae 82, 603-627.

The Panjal volcanics of Permian age constitute a prominent belt in western Kashmir. This work provides evidence for their occurrence in the Hazara-Kashmir syntaxial area and surroundings.
Key word: Panjal volcanics, Permian, Hazara-Kashmir syntaxis, Himalaya.

P/13. Paracha, M.H., Unwar, K. & Fazle, R., 1976. Groundwater conditions in Yar Hussain unit of Mardan District. M.Sc. Thesis, Peshawar University.

Key word: Hydrology, groundwater, Mardan.

P/14. Paracha, W., Kemal, A. & Abbasi, F., 2000. Kohat duplex in northern Potwar Deformed Zone, Pakistan. Geologica 5, 99-107.

Key word: Deformation, structure, Potwar, Kohat.

P/15. Park, S.K. & Mackie, R.L., 1997. Crustal structure at Nanga Parbat, northern Pakistan, from magnetotelluric soundings. Geophysical Research Letters 24(19), 2415-2418.

A magnetotelluric survey in northern Pakistan contains effects from both 2D and 3D structure. Identification of the effects of the sediments along the Indus River valley using 3D modeling permitted the selection of modes that could be accurately inverted with 2D inversions. The resulting 2D model reveals generally resistive (> 500 km) upper crust (0–8 km), a more conductive (30–50 km) middle to lower crust (8–40 km), and a resistive (> 300 km) upper mantle. Shallow crustal (< 10 km) conductors correlate with a hydrothermally altered fault zone and/or carbonaceous metamorphic rocks near the Raikot fault. A prominent midcrustal conductor located beneath Nanga Parbat is required to fit the data, but its depth, dimensions, and conductivity are poorly constrained by existing data.
Key word: Sediments, magnetotelluric study, structure, Nanga Parbat, Himalaya.

P/16. Park, S.K. & Mackie, R.L., 1998. Lack of crustal fluids beneath Nanga Parbat, northern Pakistan: Results from magnetotelluric soundings. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 146.

The Nanga Parbat-Haramosh Massif (NPHM) in the Himalaya of northern Pakistan is a finger of Indian crust extending northward into the Kohistan-Ladakh island arc. Collision between Kohistan and the Indian plate about 55 Ma along the Main Mantle Thrust (MMT) placed plutonic and high-grade metamorphic rocks of Kohistan above the Indian plate. In the past 10 M.y., differential erosion of NPHM has exposed the underlying Indian crust. Recent and rapid denudation has provided a unique glimpse into modern reworking of old continental lithosphere by metamorphic processes and partial melting. As part of a multidisciplinary study of NPHM, a magnetotelluric (MT) study was conducted to determine the distribution of fluids and partial melt in the crust. Mafic partial melts, water-saturated silicic melts, brines and metamorphic or igneous waters, metallic solid phases, and graphite are all capable of increasing the conductivity of the crust and upper mantle.
This MT study was interpreted with both 2-D and 3-D models to account for the complex geology and physiography. North of Nanga Parbat in Kohistan, the upper crust (0-8 km) is generally resistive (> 500 ohm-m), the middle to lower crust (8-40 km) is generally conductive (30-50 ohm-m), and the upper mantle is again resistive (> 300 ohm-m). This structure is reminiscent of the typical continental crust in which the generally conductive middle layer reflects fluids trapped in the ductile region of the crust and is similar to the structure seen on the INDEPTH profile of Tibet. Immediately north of Nanga Parbat, the Raikot fault is imaged to depths of 8-10 km as a vertical, tabular conductive body. The high conductivity of the fault is attributed to fluids migrating along the fault zone and to hydrothermal alteration. South of Nanga Parbat, the MT data show a moderately conductive region at midcrustal levels which appears to match a shear zone mapped by geologists. The shear zone is likely conductive because it offers a more porous conduit for fluid migration; hydrothermal alteration is seen in the zone in the eastern end of Rupal Valley.
There is no evidence of conductive bodies beneath the Nanga Parbat peak between Fairy Meadows and Rupal Valley to depths of at least 50 km. The data are matched instead by very high resistivities (>5000 ohm-m) indicative of igneous and/or high-grade metamorphic rocks. If magma is present beneath Nanga Parbat, then it must be the result of water-unsaturated partial melting of continental crust (which would result in high resistivities). The simpler interpretation is that magma is not present, however.
Key word: Magnetotelluric studies, structure, MMT, Nanga Parbat, Himalaya.

P/17. Park, S.K. & Mackie, R.L., 2000. Resistive (dry?) lower crust in an active orogen, Nanga Parbat, northern Pakistan. Tectonophysics 316, 359-380.

Conductivity models beneath the Nanga Parbat Haramosh Massif (NPHM) derived from magnetotelluric soundings reveal that there is no widespread, interconnected, conductive aqueous fluid to minimum depths of 40 km below sea level. Given the continuing tectonic denudation, young granitic and migmatic bodies indicating partial melt at shallow crustal depths, and active seismicity, this result is surprising in light of similar studies in active tectonic regimes elsewhere. Away from the NPHM, models reveal the usual conductive lower crust. We propose that deep magmatic and metamorphic fluids are produced beneath NPHM in isolated zones but that the active deformation permits their escape through the brittle-ductile transition. A magnetotelluric survey in an area as complicated as Nanga Parbat required the development of methodologies for utilizing standard two-dimensional inversions in a three-dimensional environment. We show here how to identify which parts of the magnetotelluric responses are adequately represented with two-dimensional approximations. Unlike previous efforts, we do not attempt to crate a set of generic rules that may be applicable to all geologic environments. Instead, a procedure is outlined that can be tailored to each interpretation. One important result of this work is that magnetotelluric data along a profile can be used to constrain structure off the ends of the profile.
Key word: Geophysics, tectonics, granites, Nanga Parbat, Himalaya.

P/18. Parker, N.A., 1968. Lightweight aggregate as a potential industry for Pakistan. US Geological Survey/Geological Survey of Pakistan, (IR) PK-48, 11p.

A common characteristic of growing economics throughout the world is the ever increasing demand for all kinds of construction materials, at which sand, gravel, and crushed stone play a most important part. Increasing sophistication in building, and structural designs, in turn demands more exacting specifications in aggregate (sand, gravel, and crushed stone mixtures) requirements for concrete; furthermore in the construction of large buildings, reduction in weight, through the use of light-weight but strong aggregate, becomes important.
In East Pakistan the topography and geology is such that rock suitable for concrete aggregates is in limited supply. In such areas where the natural material or aggregate are lacking but where clay, shale, and slate are present the development of a light weight (synthetic) aggregate industry offers a mean of supplying much of the demand.
In 1971, a chemist by the name of Hayde found that by heating certain clays, shales and slates to incipient fusion he was able to produce an extremely light weight material of high strength and excellent insulation properties. By reason of patent held by Mr. hayed, only seven plants were licensed under the “Haydite” patent, and the industry did not develop extensively until the expiration of basic license.
Key word: Light weight aggregate, clay, sand.

P/19. Parona, C.F., 1917. Faune Cretaciche del Caracorum e degli altipiani Tibetane. Rendiconti della Reale Accademia Nazionale dei Lincei, Series 2(26), 53-57.

Key word: Fauna, Cretaceous, Karakoram.

P/20. Parona, C.F., 1928. Faune Cretaciche del Caracorum e degli altipiani Tibetane. In: Realizioni Scientifiche della Spediozione Italiana de Filippi nell’Hmalaia, Caracorum e Turchestan Cinese (1913-1914), Series 2(6), 3-39. Zanichelli, Bologna.

Key word: Fauna, Cretaceous, Karakoram, Tibet.

P/21. Parona, C.F., 1932. Appunti su fossili raccolti sul Caracorum durante le esplorazioni F.de Filippi (1913-14) e Giotto Dainelli (1930). Atti della Reale Accademia delle Scienze dei Torino 3, 179-193.

Key word: Fossils, Cretaceous, Karakoram.

P/22. Parona, C.F., 1933. Alcuni fossili raccolti al Caracorum da G. Dainelli. In: Realizioni Scientifiche della Spediozione Italiana de Filippi nell'Hmalaia, Caracorum e Turchestan Cinese (1913-1914), Series 2(11), 127-140. Zainchelli, Bologna.

Key word: Fossils, Cretaceous, Karakoram.

P/23. Parrish, R.R. & Tirrul, R., 1989. U-Pb age of the Baltoro granite, northwest Himalaya, and implications for monazite U-Pb systematics. Geology 17(12), 1076-1079.

The Baltoro granite is a major late- to post-tectonic plutonic phase of the Karakoram batholith of the northwest Himalaya in northern Pakistan. U-Pb zircon analyses indicate both emplacement at 21.0 ±0.5 Ma and significant Precambrian zircon inheritance. Dates on monazite are 17-19 Ma and are interpreted to have remained near their closure temperature of about 700 °C for several million years after emplacement, resulting in Pb loss by diffusion. We suggest that the granite was emplaced into rocks which were at high temperature and that they remained so until late Miocene northeast-tilting, rapid uplift and/or tectonic denudation, and cooling.
Key word: Geochronology, U-Pb dating, granite, Baltoro, Himalaya.

P/24. Parrish, R.R., Tirrul, R., Rex, D.C., Rex, A.J. & Searle, M.P., 1988. U-Pb and ^{40}Ar-^{39}Ar geochronology and evolution of the Karakoram batholith, Northern Pakistan. Abstracts, 4th Himalaya-Karakoram-Tibet Workshop, Lausanne, Switzerland, p.13.

Key word: Geochronology, U-Pb dating, Ar-Ar dating, Karakoram batholith.

P/25. Parsons, E., 1926. The structure and stratigraphy of the north-west Indian oilfields. Journal of the Institute of Petroleum Technology 12, 439-505.

This account includes the structure and stratigraphy of the old oil fields of NW India. These include those to the north of the Salt Range in the present day Pakistan.
Key word: Structure, stratigraphy, oilfields, Punjab, India.

P/26. Pascoe, E.H., 1919. The early history of the Indus. Brahmaputra and Ganga. Quarterly Journal of the Geological Society of London 75, 138-157.

The ideas expressed in this paper are the outcome of a study of the Punjab oil-belt. The principal hypothesis proposed has been advanced simultaneously by Dr. H. G. E. Pilgrim. F.G.S., in a paper still in manuscript, to explain the formation of the Siwalik boulder-conglomerates. That paper will, I hope, soon be published, but I have taken the liberty of following up an interesting point to which Dr. Pilgrim has drawn attention: namely, the frequent V-shaped course of the north-bank tributaries of the Ganges where they leave the belt of Siwalik deposits.
Briefly, the hypotheses that I desire to bring forward may be summarized as follows:—
(i) That in Eocene times a gulf extended from Sind northwards as far as Afghanistan, and thence curved eastwards and south-eastwards through Kohat and the Punjab to the neighbourhood of Naini Tal.
(ii) That this gulf gave place to a great river, the head-waters of which consisted of the portion of the Brahmaputra flowing through Assam. This river flowed westwards and north-westwards along the foot of the Himalaya us far as the North-West Punjab, where it turned southwards along a line not very different from that of the modern Indus, and emptied itself into the Arabian Sea. In other words, the Assam Brahmaputra was once the head- waters of the Indus.
(iii) That two separate rivers or two branches of the same river, debouching into the Bay of Bengal, cut back and beheaded this old Indus, the
Key word: Indus, Brahmaputra, Ganga, India.

P/27. Pascoe, E.H., 1920. Petroleum in the Punjab and North-West Frontier Province. Geological Survey of India, Memoirs 40(3), 331-393.

Key word: Hydrocarbons, Punjab, NWFP.

P/28. Pascoe, E.H., 1923. General report for the year 1922. Geological Survey of India, Records 55.

Key words: Geology, India.

P/29. Pascoe, E.H., 1924. General report of the Geological Survey of India for the year 1923. India Geological Survey Records 55(1).

Key words: Geology, India.

P/30. Pascoe, E.H., 1950. A manual of the Geology of India and Burma. Volume 1, 1-483. Government of India Press, Calcutta.

For details, consult information under volume 3 of the Manual.
Key words: Geology, India, Burma

P/31. Pascoe, E. H., 1959. A manual of the geology of India and Burma. 2, 485-1338. Government of India Press, Calcutta.

For details, consult information under volume 3 of the Manual.
Key words: Geology, India, Burma

P/32. Pascoe, E.H., 1964. A manual of the Geology of India and Burma. Volume 3, 1345-2130. Government of India Press, Calcutta.

Pascoe presented in three comprehensive volumes all the information available on the geology, stratigraphy, structure, mineral deposits and other geological aspects of sub-continental India and Burma. This is the most comprehensive compilation of the geological account of the region and a very important contribution to our knowledge. The book is a must for all libraries interested in the geology of the sub-continent. vol. 1 deals with the Pre-Cambrian rocks, vol. ii with the Palaeozoic and Mesozoic, vol. iii with the Deccan Traps, the Tertiary, the Pleistocene, and Recent deposits, and vol. iv will contain geographical and general indexes. The preface to the first volume is given in the following, and sets up the format and contents of the three volumes published. The fourth was not published.
This is the first volume of an important work which, when completed, will take first place as a standard book of reference on the geology of India and Burma. The complete *Manual* will consist of four volumes : vol. 1 deals with the Pre-Cambrian rocks, vol. ii with the Palaeozoic and Mesozoic, vol. iii with the Deccan Traps, the Tertiary, the Pleistocene, and Recent deposits, and vol. iv will contain geographical and general indexes. The second edition, revised by R. D. Oldham, was published in 1893, and when the late Sir Edwin Pascoe began the work of preparing a new edition in 1933, he was faced with a formidable task. The first three volumes were ready for the printers in 1939, and more than half the book had been set up in type when Japan entered the war. Owing to the extreme shortage of paper in India at that time, it was impossible to print off even the first volume, and the type, weighing 2 tons, was broken up and melted for munitions. Thus faced with a long delay in publication, the author once more revised the text of volumes i and ii, and was still engaged on volume iii when he was taken seriously ill in 1949. The first two chapters give an admirable summary of the physical geography and geological history of India and Burma, which every student of regional geology could read with profit. Throughout this account the reader cannot fail to be impressed by the contrast between the rapidity of recent geological changes in the mountains and the almost ageless

permanence of the main features in the peninsula. Thus we read of violent movements in the front ranges of the Himalaya during Pleistocene times, and of the probability that important river captures have taken place during historical times. In contrast with this we are told that the Aravalli range (folded and uplifted before the end of the Pre-Cambrian) is in fact a remnant of one of the most important watersheds of Peninsular India; it may well have been from this watershed, for instance, that some of the rivers flowed in which the rich coal deposits accumulated. The remaining eleven chapters are devoted to the Pre-Cambrian rocks, which are divided into two major groups, separated by a profound unconformity. The author wisely makes no attempt to extend smaller divisions to the whole of India, but describes in full detail the sequences found locally in the various parts of his territory, and then gives his opinions on their correlation. It would be futile to attempt to review the wealth of information contained in these chapters, whose value can only be appreciated when they are appealed to for reference. Nevertheless, a few subjects of outstanding interest deserve special mention. There is an excellent description of the remarkable manganiferous schists of the Dharwar System, with their valuable ore-bodies in the Central Provinces, and the discussion of the banded iron ores also contains much of general interest, particularly in the comparison with similar rocks in the Pre-Cambrian of other continents. The author has taken great pains to present a logical and well-argued account of the post- Dharwar intrusions, and to give a strictly impartial and balanced discussion of the charnockites and their associated problems. The attempt to sort out the complicated relationships of the various masses of gneiss, both to each other and to the adjacent schists, clears away a good deal of confusion and misconception about the chronology of the pre-Purana rocks of Peninsular India.

In the absence of Cambrian fossils, it is not easy to determine the age of some of the unaltered but unfossiliferous sediments in relation to the beginning of the Palaeozoic era. There is reason for regarding the bulk of the Purana group, which includes the Cuddapah and Delhi systems, as being Pre- Palaeozoic in age, and this conclusion is supported by such evidence as is available from radioactive minerals. The Vindhyan System, on the other hand, contains rocks unlike any known before the Cambrian either in India or elsewhere, and the author removes the Vindhyan from the Purana and refers it, with some doubt, to the earliest Palaeozoic. In his preface the author points out that the *Manual* is to be regarded as a work of reference rather than as a students' textbook, and the treatment of the Pre-Cambrian rocks in this volume is fully in keeping with this purpose. The information is so detailed, indeed, that the book may well prove to be of considerable service to local geologists in India, as the author intended. It is pleasantly written, and notwithstanding the wealth of local detail, is far from being heavy reading; but without its index it is by no means easy to use, and we must hope that the appearance of volume iv will not be unduly delayed. The price is extremely reasonable when compared with that of books of a similar calibre which have been published recently. It is perhaps a pity that a work of such scholarship and distinction, destined to face many years of constant use, could not have been given a more attractive format and a more robust binding; most of the copies seen by the reviewer had already suffered damage before reaching their destination in this country. But these are trifling matters: it is a cause of great satisfaction that Sir Edwin Pascoe's edition of the *Manual* is at last being published. For many years to come it will remain as a fitting memorial not only to the author himself, but also to the whole staff of the Geological Survey of India, with their long record of devoted service and distinguished achievement during the period which has now come to an end.

The second edition of this well-known and useful book has been considerably revised and improved. While the author keeps, for the most part, to the well-tried methods given in the previous edition, he is careful to point out improvements or alternative methods which have been devised during the past twelve years. In the chapter on Normal Methods for Silicate Rocks more attention is given to methods of determining ferrous iron, lithium, chromium, and vanadium, while new sections on phosphate rocks and on the determination of free and combined silica appear in the Notes on Technological Applications. The chapter on Special Methods has much enlarged sections on determination of ferrous iron in refractory silicates, and of manganese, with new sections on the direct determination of sodium or potassium, the determination of minute quantities of nickel, and on micro- and semi-micro- methods of analysis. It is a pity that no mention is made of the polarograph or of the flame photometer as these are likely to be increasingly used in silicate analysis in the future. The chapter on Errors is enlarged and made more valuable, and the final chapters on Occurrence of the Various Elements and on Computations as a Check on the Accuracy of Chemical Analyses have been virtually rewritten. Incidentally, the statement on page 258 that Al occurs surrounded by four oxygens in the structures of minerals is very misleading. In calculating the structural formulae of minerals, the author advocates the use of molecular weights to two places of decimals and five-figure logarithms, so that the results are accurate to three places of decimals. It is doubtful if the average chemical analysis of a mineral is of a high enough degree of accuracy to give a structural formula accurate to more than two places of decimals. Errors occur in the valency checks given in Tables X (p. 314) and XI (p. 316). In Table X, Si^{+4} should be 7-868, Al^{+3} should be 0-240, Li is shown with two positive charges. In Table XI, Al + 3 should be 8-292, Ti + " should be 0-356, Mg^{+2} should be 6-216, and Mn + = should be 0 030. The author points out that the kind of valency check used by him is no check on the accuracy of the chemical analysis of a mineral. But valency checks balancing excess negative charges caused by substitution of metal ions of lower valency than that proper to a group, with excess positive

Key words: Geology, India, Burma

P/33. Pathan, M.T., 1973. An outline of the Geology of Pakistan. Geological Survey of Pakistan, Geonews 3(1), 9-11.

A generalized account on the geology of Pakistan, and briefly covers the area of this document.

Key words: Geology, Stratigraphy, Pakistan

P/34. Patriat, P. & Attache, J., 1984. India-Eurasia collision chronology and its implications for crustal shortening and driving mechanism of plates. Nature 311, 615-621.

The motion of the Indian plate is determined in an absolute frame of reference and compared with the position of the southern margin of Eurasia deduced from palaeomagnetic data in Tibet. The 2,600±900 km of continental crust shortening observed is shown to have occurred in three different episodes: subduction of continental crust, intracontinental thrusting and internal deformation, and lateral extrusion. The detailed chronology of the collision and plate reorganizations in the Indian and Pacific oceans supports the hypothesis that slab-pull is a dominant driving mechanism of plate tectonics.

Key words: Chronology, collision, Plate movement, India-Eurasia.

P/35. Pêcher, A., Giuliani, G., Kausar, A.B., Malik, R.M. & Muntaz, H.R., 2001. Geology of Nanga-Parbat Himalaya in Nangimali ruby deposit area (Azad Kashmir, Pakistan). Journal of Asian Earth Sciences 19, p.50.

The Nangimali ruby deposit in the southern part of the Nanga Parbat Himalaya has been investigated through field work, geochemistry, stable and radiogenic isotopes. It outcrops in the Shontar valley in a large north-vergent syncline consisting of high-grad e metamorphic gneisses capped by a metasedimentary series dominated by marbles and amphibolites. The ore-body is stratiform. Ruby is found within 0.1 - 2 cm thick shear-veinlets and gash veins cutting dolomitic marbles and carbonate-bearing bands.

The marbles of the Nangimali Formation display restricted ranges in $\delta^{18}O$ (from 23.6 to 27 .6 ‰ relative to SMOW) and in $\delta^{13}C$ (from - 1.9 to *2.6 ‰* relative to PDB). Fluid infiltration along the shear-zone in the marble has no effect on the isotopic signatures of the carbonates. Fluids are metamorphic and CO_2 is derived from the decarbonation of marbles.

Mass-balance and geochemical analyses suggest that the mobilisation by the fluids of aluminium and chromium in the marbles is sufficient to enable the formation of ruby in the shear-zone. Rubies have been indirectly dated using a stepwise ^{40}Ar - ^{39}Ar laser heating technique on syngenetic phlogopites, The Miocene age records a Neogene cooling in the South of the Nanga Parbat massif and a minimum formation age for ruby of 16 Ma.

Key words: Geology, Ruby, corundum, Nanga Parbat, Azad Kashmir, Himalaya.

P/36. Pêcher, A. & Le Fort, P., 1996. Is Nanga Parbat an active indenter or a passive dome? Abstract volume, 11th Himalaya-Karakoram-Tibet Workshop, Flagstaff, Arizona (USA), 113-114.

1 – Tectonic interpretation around the Himalaya-Karakoram boundary has consider the present structure, clearly revealed by the geological map (Figure):

Nanga Parbat has the shape of an indenter in the heart of the Himalayan western syntaxis, bending out the “Indus-Tsangpo suture”, i.e. the accepted limit between the Himalaya an the Ladakh-Kohistan island arc; the rectilinear pattern of the southern Karakoram and “Shyok suture”, the traditional limit between the Karakoram and the Ladakh to Kohistan island arc, forms a strong contrast with the Indus-Tsangpo suture; between the two, the green belt of the island arc, made up of the Greenstone complex to the north and the Askore amphibolite to the south, continues without interruption from Ladakh to Kohistan; the two, “sutures” are clearly recent tectonic boundaries that crosscut all previous deformation.

2 – In both the Karakoram and the Himalaya the ductile syn-metamorphic deformation displays recumbent isoclinal folding in amphibolite grade metamorphism as the major structural event.

In the Karakoram, this deformation involves granitoid bodies and marble levels in plurikilometric folds; In the Himalaya, similar structures can be observed although they may be less conspicuous due to the abundance of basement gneissic material. In places, marble horizons draw large scale (kilometric) isoclinal folds; In the Karakoram-Ladakh contact zone, this same style of deformation persists, but the lithological contrast is less obvious. Polygenic conglomerates, with pebbles originating in both units, are highly affected by the syn-metamorphic deformation in greenschist metamorphic grade. The major difference between the Karakoram, north, and Ladakh-Kohistan, south, lies in the rapid, though continuous, decrease in metamorphic grade.

The Himalaya-Kohistan contact is known to be a brittle reverse fault, the Raikot fault (Lawrence et al., 1983; Madin et al., 1989). To the north, this fault dies out in the upper Darchan valley, and does not join the E-W strip of the Greenstone complex. The Himalaya-Ladakh contact is well exposed in the upper Turmik valley and is marked by a ductile shear zone with right-lateral strike-slip, clearly indicated by rotation at map scale of the syn-metamorphic folds (Pognante et al., 1993). This shear-zone in the same Greenstone complex strip. On the right bank of the Chogo Lungma glacier, the northern contact shows no evidence of normal faulting, but, in some places, thrusting of the greenstone complex over the Himalayan gneisses can be observed. Locally, in the Remendok valley, the northern contact is overprinted by a slightly deformed leucotrondhjemitic body.

3 – Taking into account all the previous observations, it appears that: during the main metamorphic stage, all three units have behaved as a single and continuous crustal piece. The ductile structures are post collisional. These structures do not result from indenting by a Himalayan indenter. In addition, the linearity of the main structures of southern Karakoram cannot be explained without a significantly more extensive Himalayan basement, that is not restricted to Nanga-Parbat indenter, but which probably also underlies Ladakh and Kohistan.

If the present geometry of Nanga-Parbat does not represent that of an indenter, it must result from other mechanisms. One such mechanism is doming in a NW-SE compressive regime with a strong transcurrent component, instead of a frontal collision. Nanga-Parbat from this perspective would correspond to a gneissic dome at crustal scale. Further analysis of its western side may tell whether the dominant regime has more recently rotated to that of transcurrent shortening.

Key words: Tectonics, structure, Nanga Parbat, Himalaya.

P/37. Pêcher, A. & Le Fort, P., 1998. Is the Dobani-Dasu ultramafic lineament an internal suture for Ladakh and Kohistan? Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 147-149.

In Ladakh, the contact between the Greenstone complex and the Askor amphibolite is underlined by a series of isolated pods and masses of serpentinised ultramafics, one of the major ones cutting the Turmik valley at Dasu. The Dasu lineament has been followed eastward into the Komara valley where a kilometer-thick body of metaperidotite is wrapped in a shell of foliated serpentinite, interlayered with chlorite-talc-magnesite schist and albite epidote-tremolite-chlorite rodingite. Westward we have encountered blocks of serpentine in the valley north of Skoyo. Further to the north-west, besides ultrabasic rocks and calc-silicate fels that occur in lower Remendok valley, in a similar structural position, boulders of serpentinized material occur now and then.

In Kohistan, almost exactly symmetrical to the Dasu lenticular stripe across the Himalayan spur, squeezed against the northern end of the Raikot fault, we have discovered a similar stripe of serpentinised ultramafics: the Dobani lineament. Twenty-five kilometers long, it rises from the village of Khaltaro, follows the right (west) bank of the Darchan river, crosses to the north of the Dobani peak (or Bilchar Dobani, 6134 m) in the upper part of the Gutumi glacier, forms a large kilometric band on the northern side of the Bilchar valley, and finally thins out on the right bank of the Bagrot river between the villages of Datucho and Sinakkar. Further to the west, it does not cross as such the Dyor and Hunza valleys, but leads into the tectonic lineament, that follows the edge of the Bilchar meta-volcano-sedimentary formation. There the two intricated formations could form a tectonic melange.

In Ladakh the metaperidotites are usually antigoritic serpentinites with cumulitic textures, and two generations of olivine (magmatic and metamorphic). In Kohistan the serpentinised peridotites are accompanied by pyroxenites. The Dobani-Dasu ultrabasic lineament separates the island-arc into two units. It is possible to consider these serpentinites as a part of the ophiolitic sole of the island arc as described near Dras (Ladakh, NW India). Thus, the Chalt-Turmik volcanics, with the MKT lineament to the north and the Dasu-Dobani ultramafics to the south, compare well with the Dras volcanics that have tectonic melanges on their northern and southern sides. In our view,

it could mark the limit between the volcano-sedimentary back-arc basin and the island-arc itself that includes peraluminous crustal material of Katchura Gilgit type.
The ultramafics that divide Kohistan and Ladakh in two sub-units are a good marker of the global deformation of the arc. Parallel to the general structural trend, away from the NPHM, they are bent when getting closer to the contact with the Himalayan gneisses. To the east, the bending of the lineament marks and supports the right-lateral movement also evidenced in the Greenstone complex. To the west, the curvature of the Bilchar-Dobani ultramafics would also indicate a right-lateral movement, whereas the movement observed in the mylonitic Himalayan gneiss of the upper Darchan valley, is left-lateral and obviously not of the same age. The two dextral shear zones could represent a meridian vertical slicing of the Himalayan crust that has driven the NPHM doming and the Raikot fault.
Key word: Ultramafics, structure, Dasu, Ladakh, Kohistan, Himalaya.

P/38. Pêcher, A. & Le Fort, P., 1999. Late Miocene tectonic evolution of the Karakoram-Nanga Parbat contact zone (northern Pakistan). In: Macfarliane, A., Sorkhabi, R.B. & Quade, J., (Eds.), Himalaya and Tibet: Mountain root to mountain tops. Geological Society of America, Special Papers 328, 145-158.

In northern Pakistan, the northwestern syntaxis of the Himalaya is marked by the spur of the Nanga Parbat-Haramosh massif, bounded by the Arc formation of Ladakh and Kohistan, and located south of the Karakoram rang. The three units are separated by two major tectonic features, corresponding to late reactivation of the southern Indus-Tsangpo suture and northern Shyok suture. Field mapping in the as-yet poorly known Nanga Parbat-Haramosh massif-Karakoram contact zone, together with structural, metamorphic, and geochronological data, has led to new constraints on the interpretation of this key zone, viz.: (1) the backarc belt continues without interruption from Ladakh to Kohistan; (2) thee southern Karakoram, the Arc, and the northernmost part of the Nanga Parbat-Haramosh massif display the same recumbent isoclinal folds and related metamorphic schistosity as the major structural event; (3) ductile deformation ended after 6 or 7 Ma; (4) in front of the Nanga Parbat spur, there is no evidence of normal-type faulting, or of karakoram indentation, either considering the lithological boundaries or the metamorphic fabric; (5) on both sides of the spur, the right-lateral and left-lateral cartographic displacements mainly reflect the late doming of the initial arc-massif contact, a south-directed shear zone. Thus, the three units, east of the Raikot fault, define an east-west-trending broad zone that has thermally and tectonically behaved as a single crustal piece. The northern part of the Nanga Parbat-Haramosh massif can be considered to be a large dome in the westward extension of the Karakoram domes, a line of domes that developed east of the Raikot fault and possibly initiated as a crustal-scale fold system, induced by broad and diffuse northwest-southeast dextral shearing in transpressive regime.
Key word: Tectonics, structure, NPHM, Ladakh, Kohistan, Himalaya.

P/39. Peltzer, G. & Tapponnier, P., 1988. Formation and evolution of strike-slip faults, rifts and basins during the India-Asia collision: An experimental approach. Journal of Geophysical Research 93, 15085-15117.

The processes which have governed the formation and evolution of large tertiary strike-slip faults during the penetration of India into eastern Asia are investigated by plane strain indentation experiments on layered plasticine models. The results show the influence of boundary conditions as well as that of the internal structure of the plasticine model on the faulting sequence. The ubiquity of strain softening in experimental deformation of a variety of rocks, as well as the widespread occurrence of shear zones in nature, suggest that long-term deformation of the continental lithosphere may also be primarily influenced by the geometry of large faults which rapidly develop with increasing strain. The deformation and faulting sequence observed in the plasticine indentation experiments may thus be compared to collision-induced strike-slip faulting in Asia, particularly to total offsets and rates of movements on the faults. The experiments also illustrate mechanisms for the formation of extension basins near active continental margins.
Key Words: Structure, deformation, collision, India-Asia.

P/40. Pelve, A.V., Burtman, V.S., Ruzhentzev, S.V. & Suvorov, A.I., 1964. Tectonics of the Pamir-Himalayan sector of Asia. Proceedings 22nd International Geological Congress 11, 441-464.

Key word: Tectonics, structure, Pamirs, Himalaya.

P/41. Pennington, W.D., 1979. A summary of the field and seismic observations of the Pattan Earthquake, 28th December, 1974. In: Farah, A. & DeJong, K.A. (Eds.), Geodynamics of Pakistan. Geological Survey of Pakistan, Quetta, 143-144.

The Pattan earthquake, magnitude 6.0, caused considerable loss of life and damage to property, resulting both from severe ground shaking and from rockfalls. This earthquake is the largest yet observed in the Indus-Kohistan Seismic Zone, west of the western Himalayan syntaxis, where the Himalayan arc terminates. The focal mechanism and aftershock distribution indicate thrusting in a NNE-SSW direction, similar to that which is expected for Himalayan thrusting, but not what would be expected from surface geologic mapping.
Key word: Earthquakes, seismology, Pattan, Himalaya.

P/42. Pennock, E.S., 1988. Structural interpretation of seismic reflection data from the eastern Salt Range and Potwar Plateau, Pakistan. M.S. Thesis, Oregon State University, Corvallis, 55p.

Approximately 1600 km of seismic reflection profiles from the eastern Salt Range and Potwar Plateau (SR/PP) of Pakistan are integrated with available magnetostratigraphic, surface geologic and well data, to categorize structural styles, determine the timing of deformation and estimate the amount of telescoping of the sedimentary cover. The eastern SR/PP is similar to other fold-and-thrust belts underlain by evaporites in that: 1) it is part of a zone of overthrusting that extends considerably farther over the Himalayan foreland than adjacent areas not underlain by evaporites; 2) the overall thrust wedge has a narrow cross-sectional taper; 3) structures verge toward the hinterland as well as toward the foreland; and, 4) fold trends are long and continuous, consisting of tight, salt-cored anticlines separated by broad synclines. Disharmonic folding of the sedimentary section relative to the underlying basement is due to effective decoupling along the intervening salt layer. Subsurface mapping on top of a strongly reflective package of Cambrian to Eocene strata reveals that many surface folds are cored by both foreland- and hinterland-dipping, blind thrusts, and some are fault propagation folds. In some cases, intersecting thrusts result in local triangle zones; other surface folds have a pop-up geometry. The dip of the basement towards the inner part of the fold-and-thrust belt is relatively gentle in the eastern SR/PP (1°-l.5°) compared to the central SR/PP (2°-3°) . Mechanical considerations demonstrate that, unlike the relatively undeformed central SR/PP, a broad deformational zone has developed in the eastern SR/PP to provide a surface topographic slope necessary to maintain a critical taper of the thrust wedge. Furthermore, previous paleomagnetic studies indicate that deformation across much of the eastern PP preceded tectonic rotation. This implies that individual structural trends developed perpendicular to the transport direction and were then rotated into their current NE-SW alignment in response to ramping over a basement buttress in the central SR/PP. Cross-section balancing indicates that approximately 23.1 km of shortening has occurred across the foreland in the eastern SR/PP since 5.5 Ma, 17.8 km in the last 2.5 Ma. The shortening rate of 7 mm/yr for that time interval is roughly 15% of the 40-50 mm/yr convergence rate between the Indian and Eurasian plates.
Key word: Seismology, structure, Salt Range, Potwar.

P/43. Pennock, E.S., Lillie, R., Zaman, A. & Yousaf, M., 1989. Structural interpretation of seismic reflection data from the eastern Salt Range and Potwar Plateau, Pakistan. American Association of Petroleum Geologists, Bulletin 73, 841-857.

Consult the preceding account for further information.
Key word: Structure, seismology, Potwar, Salt Range.

P/44. Perri, M.C., Talent, J.A.T., Ahmad, I., Ali, A., Molloy, P.D. & Conaghan, P.J., 2000. Prevalence of Triassic limestone sequences in northern Pakistan. Abstracts, Geological Society of Australia 61 (Palaeontology Down Under 2000), 79-82.

Key word: Limestone, Triassic, Pakistan.

P/45. Pervez, M.K., 1987. Geology of a part of Attock-Cherat and Kalachitta Ranges in the vicinity of Nizampur, Pakistan. M.Phil. Thesis, University of Peshawar, 120p.

Rocks of the Attock-Cherat and Kalachitta Range are thoroughly mapped and studied to work-out their structural patterns. The two Ranges are separated by a well-defined Hissartang Thrust. The rocks of the Attock-Cherat Range, of Precambrian to Paleozoic age, consist of sedimentary and meta-sedimentary sequences. Lying unconformably on these are Mesozoic and Tertiary strata. Rocks of the Kalachitta Range in the study area range in age from Jurassic to recent. These are mostly limestone, shales and sandstones. Three main thrust faults (oriented E-W) divide the area into four blocks. The Khairabad thrust mars-off the northern block, the cherat thrust limits the central block and the Hisartang thrust separates the southern block from the Kalachitta range. These thrusts are the splay faults of the MBT, which runs south of the Kalachitta range. The push from north on these thrusts have been the major cause of the deformation of these Ranges. The big synclinorium in the Kalachitta rocks north of the Indus River is resulted because of the movement on Hissartang thrust. A model is proposed to explain the structural relationship of the rocks of the Attock-Cherat Range, east of Indus River. During the movement along the Hissartang fault a splay fault was cutoff in this area producing a low angle Hissartang back thrust. The rootless patches of Jurassic limestone on Palaeozoic sequence, east of the Indus River, indicate that the Mesozoic strata are thrusted over the Paleozoic rocks. Previously, the Hisartang thrust was considered to exist beneath the alluvium of Nizampur and Campbellpur Basins (Yeats and Hussain, 1986). As a result of present work it is relocated just at the southern foot of the Attock-Cherat Range. Similarly, the structural style of the central and southern blocks does not display a homocline system as was suggested by Yeats and Hussain (1986), but is dominantly a south verging overturned folded system.
Key word: Geology, sediments, stratigraphy, Kalachitta, Attock-Cherat.

P/46. Pervez, S., 1985-87. Geology and petrography of Luat-Thod Area, Neelum valley (A.K.) with special emphasis on granites. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 77p.

The project area is a part of Middle Himalayas and covers about 350 sq. km. located between Doarian and Thod in Neelum Valley (Azad Kashmir) at the scale 1: 25,000 of topographic sheet No. 43 F/13, 43 F/14 and 43 J/2 of survey of Pakistan. The studied area comprises of broader lithology of Salkhala formation containing predominantly metapelites, psammites and calcareous material. Various granitic and basic bodies are also outcroping the area. Basic bodies are present as dykes and sills. All the quartzofeldspathic rocks (Granites) of the area are the products of metasomatism (Granitization) and these are possibly the part of Nanga Parbat Haramosh massif. The area is rich in economic rocks and mineral deposits are discussed briefly.
Key word: Mapping, petrography, granites, Azad Kashmir.

P/47. Peters, J.J. & Lindsley, R.L., 1988. Pakistan garnet compositions. Mineralogical Record 12(2), 128-129.

Microprobe analyses for 1 spessartine and 4 almandines from the gem pegmatites of Pakistan yield Mn/Fe ratios of 2.5:1, 0.8:1, 0.8:1, 0.7:1 and 0.5:1, which corresponds with compositions of Alm28Sp70Pyr0, mAlm55Sp44Pyr1, Alm55Sp44Pyr1, ALm67,Sp40Pyr1(sic) and Alm66Sp32Pyr1, respectively.
Key word: Mineralogy, garnets.

P/48. Petrini, C.F., 1936. Chenni illustrativisulla compilazione della carta Topografica al 75.000 della spedizione. Appendix to: La Spedizione Geogrfica Italian al Karakorum, 1929, 25-32. Arti Grafiche Bertarelli, Milano.

Key words: Topographic survey, Italian Expedition, Karakoram.

P/49. Petrov, I., Schmetzer, K. & Bank, H., 1977. Violette topase aus Pakistan. Neues Jahrb. Min. Mh. 483-484.

The optical and X-Ray data of the violet prismatic topaz from Katlang area Mardan are given here. From both the data it is concluded that the investigated topaz crystals are OH-rich with ~15% F. the violet color is due to Cr 3+ ions as in violet topaz from the river Sanarka (or, as recently called, Kamenka), Urals, USSR.
Key word: Gems, topaz, Katlang, Mardan, USSR.

P/50. Petrushevsky, B.A., 1977. The Indus-Pamirs zone: One of the most important transversal lineaments in Asia. Bulleten Moskovskogo Obshestva Ispytatelei Priordy 5 (In Russian).

Key word: Structure, tectonics, Indus-Pamir.

P/51. Petterson, M.G., 1984. The structure, petrology and geochemistry of the Kohistan batholith, Gilgit, Kashmir, N. Pakistan. Ph.D. thesis, Leicester University.

This is perhaps the most detailed study of the Kohistan batholith. In addition to geochemistry and petrology, several phases of magmatism were identified. Careful mapping around Gilgit shows that the batholith there is made up of repeated pulses of granitic plutons. Details of the work are represented in a series of papers in the following.
Key word: Structure, petrology, geochemistry, Kohistan batholith, Gilgit, Kashmir.

P/52. Petterson, M.G., Crawford, M.B. & Humayun, M., 1992. Sr, Nd and O Isotope Data from the Kohistan Batholith, N Pakistan: Constraints on the evolution of the Kohistan mantle and crust from 102 Ma to 30 Ma. Abstract Volume, 7th Himalaya-Karakoram Workshop, Department of Earth Sciences, Oxford University, England, p.70.

The 102 Ma-30 Ma Kohistan batholith forms a major part of the Kohistan arc terrane, N Pakistan. It intruded in three distinct stages which correlate with the existence of Kohistan; (i) as an island arc (102 Ma-85 Ma), (ii) as an Andean-type margin (85 Ma-40 Ma) and (iii) as a collisional zone trapped between the colliding Indian and Eurasian plates. Sr and Nd isotope data are now available for five granitoid plutons from the batholith: the Matum Das (102 Ma), Gilgit (54 Ma), Shirot (40 Ma) plutons and two acid sheet units (Parri and Indus Confluence) dated at 30 Ma. The range of isotope values for these units are: $^{87}Sr/^{86}Sr$ 0.7039-0.7052, E^{Sr}-6.8 to 10.36, 143Nd/144Nd 0.512861-0.512723, E^{Nd} 6.91 to 2.04.
The E^{Sr} and E^{Nd} data for the Matum Das, Gilgit and Shirot plutons plot within the mantle (upper left) quadrant on an ESr-E^{Nd} diagram. The Indus Confluence, and most notably, the Parri acid sheets plot in the upper right quadrant on an ESr-E^{Nd} diagram as they have both positive E^{Nd} and E^{Sr} values. The full data set follows a temporal evolutionary trend: E^{Sr} increases and ENd decreases with time. These data imply a mantle or primitive arc crust origin for the Matum Das, Gilgit and Shirot granitoids, with contamination of mantle derived magmas by immature Kohistan crust becoming more important with time. The Parri acid sheets are probably the result of upper crustal anatexis; possibly being melt derivatives of a thick meta-sedimentary sequence which crops out between Gilgit and Jaglot.
O18 data have recently been produced for a wide range of plutonic units including three of the above (Gilgit, Shirot and Parri). O18 values vary between 6%o and 9.2%O; the leucogranites having O18values >8%o; the bulk of the gabbro-diorites have O18 values between 6.5%o and 7.7%o, whilst three gabbro-diorites have O^{18} values of 6-6.5%o. The high O18 for the leucogranites is consistent with a crustal melt origin. Munir Humayun interprets the O^{18} values of 6.8%o-7.7%o for granitoids as indicating a primitive arc crustal melt origin, with the Nd and Sr isotope compositions being inherited from their precursor mantle source. MGP and MBC feel that the granitoid data could also be explained by subduction zone fluids ± subducted sediment elevating the O^{18} of a mantle source, followed by limited assimilation of high O^{18} crust.
Key word: Geochemistry, Sr and Nd isotopes, Kohistan batholith.

P/53. Petterson, M.G., Crawford, M.B. & Windley, B.F., 1993. Petrogenetic implications of neodymium isotope data from the Kohistan batholith, North Pakistan. Journal of the Geological Society of London 150, 125-129.

Neodymium data are presented for five granitoid (trondhjemite, granite and leucogranite) plutonic units from the Kohistan batholith aged 102 Ma to 29 Ma. These have present day l43Nd/144Nd ratios of between 0.512980 and 0.512734, calculated initial 143Nd/144Nd ratios of between 0.512861 and 0.512705 and Nd values of between 6.91 and 2.04. There is a decrease in εNd with time which is inversely correlative with a similar increase in εSr.
Three plutonic units (Matum Das, Gilgit and Shirot) formed from a source enriched in Sm and depleted in Rb or radiogenic Sr relative to bulk earth, whilst a fourth unit (the Indus Confluence acid sheets), is only slightly enriched in radiogenic Sr. These four units define a temporal trend from the least evolved Matum Das pluton to the most evolved Indus Confluence acid sheets. This trend was produced as a result of subducting oceanic sediment or seawater-altered oceanic crust which melted or dehydrated and increasingly modified the isotopic composition of an original mantle protolith situated above the subducting plate. The data preclude any significant input to the magmatism from ancient crust. New data presented here, together with other published data, indicate an immature metavolcanic crustal source for the Matum Das pluton, and a plutonic basement crustal source for the Indus Confluence acid sheets. These crustally derived units retain a mantle isotopic signature indicating that the geochemical signature of Kohistan evolved by remobilization of recently formed arc crust in addition to new inputs of mantle-derived magma.
A fifth plutonic unit (the Parri acid sheets) shows a clear compositional break from the other units, being significantly enriched in radiogenic Sr and Nd with respect to bulk earth. The source to the Parri acid sheets is interpreted as metasedimentary rocks with a high Rb/Sr ratio and a crustal residence time of c. 70 Ma.
Key word: Petrogenesis, Nd isotopes, geochemistry, Kohistan batholith.

P/54. Petterson, M.G. & Windley, B.F., 1985. Rb-Sr dating of the Kohistan arc-batholith in the Trans-Himalaya of N. Pakistan, and tectonic implications. Earth and Planetary Science Letters 74, 45-57.

The Kohistan arc-batholith in northern Pakistan is situated between the Indus Suture and the Northern Suture. It belongs to the Trans-Himalayan belt which continues eastwards as the Ladakh arc-batholith in northwest India and the Gangdese batholith in southern Tibet. In Kohistan the island arc consists (upward sequence) of the Chilas stratiform complex of norites, noritic gabbros and chromite-layered dunites which formed in the sub-arc magma chamber, plutons of tonalite and diorite, one of which has a Rb-Sr isochron age of 102 ± 12 Ma, the Chalt volcanics of basaltic tholeiites succeeded by andesites to rhyolites, and the Yasin Group sediments which formed in overlying intra-arc basins and which contain Albian-Aptian faunas. All these rocks were deformed by major fold structures which are correlated with the formation of the Northern Suture. NE-SW trending basic Jutal-Nomal dykes (north of Gilgit) cross-cut all the above structures and have a39Ar/40Ar hornblende age of 75 Ma. Thus the Northern Suture must have formed in the period 102 ± 12 to 75 Ma. With the island arc attached to the Eurasian plate, further northward subduction of the Tethyan plate gave rise to an Andean-type batholith, two plutons of which have Rb-Sr isochron ages of 54 ± 4 Ma and 40 ± 6 Ma. The Dir-Utror Group of calc-alkaline lavas (and sediments with Eocene fossils) are remnants of the volcanic cover of the Andean-type batholith. We suggest that late Cretaceous blueschists formed during subduction under the active continental margin, and that continental collision and formation of the Indus Suture was in the Eocene. The batholith was intruded by layered aplite-pegmatite sheets at 34 ± 14 Ma and 29 ± 8 Ma (Rb-Sr ages) in post-collisional times. The87Sr/86Sr initial ratios of all the dated rocks range between 0.7039 and 0.7052.
Key word: Chronology, Rb-Sr isotopes, geochemistry, Kohistan batholith.

P/55. Petterson, M.G. & Windley, B.F., 1986. Petrology and geochemical evolution of the Kohistan-arc batholith, Gilgit, North Pakistan. Geological Bulletin Peshawar University, 19, 121–149.

The Kohistan batholith is the most north-westerly part of the Trans-Himalayan batholith which extend some 2700 kms from near Lhasa in the east to Pakistan in the west. Detailed framework of an area of 2500 km2, centered on the town of Gilgit, had shown that the batholith had evolved in the three distinct stages:
An early bi-model sequence of high-K gabbroic diorites and high SiO2, low K tonalites, which have been deformed and folded, together with associated meta-volcanic and -sedimentary country rocks around a major syncline (the Jaglot Syncline). These early plutonics, which comprise 1/3 of the batholith, have a penetrative, gneissose fabric

which is orientated parallel to the major structural trends of the area. These rocks formed in an island arc environment. An undeformed sequence of basic dykes, gabbros, diorites, granodiorites and granites which cut the structure associated with the Jaglot Syncline. These rocks formed in an Andean-type continental margin.
Extensive swarms of layered aplite-pegmatite sheets, which formed after the terminal collision between India and Eurasia. Some of these rocks formed by crustal melting. Five rock units have yielded Rb-Sr whole rock isochron ages. These are 102 ±12 Ma for an early, deformed tonalite, 54 ± 4 Ma and 40 ± 6 Ma for two second stage granitoids, and 34 ± 14 Ma and 29 ±8 Ma for two late leucogranitic sheets.
Even the least evolved gabbros of stages 1 and 2 are enriched in Rb, K Ba, Sr, P and LREE relative to Nb, Zr, Ti, Y and HREE. With fractionation LFS/HFS, K/Na and LREE/HREE element ratios increase and the batholith displays a calc-alkaline trend with respect to Mg, Fe, Na and K. The main magmatic trend of the batholith can be explained by the fractionation of amphibole-plagioclase-magnetite ± clinopyroxene in the basic-intermediate rocks and plagioclase-K-feldspar-biotite and magnetite in he acid rocks. Zircon, apatite, and sphene were important accessory minerals. Low 87SR/86Sr initial ratios (0.7039-0.7052) suggest that the ultimate source for the majority of the plutonics was the upper mantle. However the stage 1 tonalite and some of the stage 3 leucogranites were formed by partial melting.
Key word: Petrology, geochemistry, Kohistan batholith, Gilgit.

P/56. Petterson, M.G. & Windley, B.F., 1991. Changing source region of magmas and crustal growth in the Trans-Himalayas: evidence from the Chalt volcanics and Kohistan Batholith, Kohistan, northern Pakistan. Earth and Planetary Science Letters 102, 326-341.

The Kohistan batholith and Chalt volcanics form a major part of the Kohistan island arc terrane in northern Pakistan. They record some 70–80 Ma of magmatism within the northwestern Himalayan orogen; the Chalt volcanics are Albian-Aptian (mid-Cretaceous), and currently available Rb-Sr age data for the batholith indicate an intrusive age span of 102 to 30 Ma. The volcanics are composed of medium-K, calc-alkaline andesites and low-K, high-Mg, tholeiites, some of which have boninitic and basaltic komatiitic chemistry. Three intrusive stages are recognised in the batholith: (1) (110–90 Ma) comprises low-K trondhjemites and medium-high-K calc-alkaline gabbro-diorites with associated hornblendite cumulates; (2) (85–40 Ma) comprises low-high-K, calc-alkaline gabbro-diorites (with hornblendite cumulates, granodiorites and granites; and (3) (circa 30 Ma) comprises biotite ± muscovite ± garnet leucogranites. 87Sr/86Sr0 for the batholith range between 0.7039 and 0.7052.
Four magmatic source regions (Sce 1–Sce 4) have been identified. Sce 1 is a variably metasomatised mantle wedge situated above an active subduction zone during stages 1 and 2. Sce 2 is a harzburgite depleted with respect to major elements and incompatibles, whilst retaining “subduction-related” trace element ratios. Sce 2 melted during stage 1 within a fore-arc position during the subduction of young, hot oceanic crust to provide the necessary extra thermal input for harzburgite anataxis. Melts from Sce 2 produced the high-Mg tholeiitic volcanics. Sce 3 melted during stage 1 to produce the low-K trondhjemites, and it is envisaged as incompatible element-depleted primitive arc crust with a similar composition to the depleted Chalt volcanics. Sce 4 melted at 30 Ma during stage 3 as India underthrust Eurasia: frictional heating and dehydration of the Indian plate caused crustal anatexis within the deep Kohistan arc and these melts formed the stage 3 leucogranites. The low $^{87}Sr/^{86}Sr$ initial ratios for the great bulk (> 95%) of the batholith indicate that it represents a major juvenile addition to the continental crust. This conclusion has important implications for crustal growth theories of island arc accretion and batholith underplating.
Key word: Magmatism, orogeny, crustal growth, Chalt volcanics, Kohistan batholith.

P/57. Petterson, M.G. & Windley, B.F., 1992. Field relations, geochemistry and petrogenesis of the Cretaceous basaltic Jutal dykes, Kohistan, northern Pakistan. Journal of the Geological Society of London 149, 107-114.

A 75 Ma Cretaceous suite of low-medium-K basalt to basaltic andesite dykes intrudes the Kohistan terrane between Jutal and Chalt, Gilgit area, northern Pakistan. Orientational data suggest they intruded in response to NW–SE to N–S tension. The dykes cut the Albian–Aptian Chalt Volcanic Group and the 102 Ma Matum Das trondhjemite pluton. They cut the fold structures and penetrative fabrics associated with the collision between Kohistan and Eurasia and thus constrain the age of formation of the Northern Suture. The dykes define two groups on the basis of trace element geochemistry and geochemical trends. A depleted D-type group has low concentrations of incompatible elements (2–8 x primordial mantle) and (Ce/Yb)N ratios <1. An enriched E-type group is relatively enriched in both

low field strength and light Rare Earth elements and exhibits increasing incompatible element concentrations with increasing Zr. Trace element and field data suggest that the dykes are genetically linked and formed by partial melting of a mantle source which has been metasomatized by subduction-related processes. Models involving (i) different degrees of partial melting (ii) two-stage partial melting and (iii) partial melting of a heterogeneous source are considered.
Key word: Geochemistry, petrogenesis, basalt dykes, Cretaceous, Kohistan.

P/58. Petterson, M.G., Windley, B.F. & Luff, I.W., 1991. The Chalt volcanics, Kohistan, Pakistan, high-Mg tholeiitic and low-Mg calc-alkaline volcanism in a Cretaceous Island Arc. Physics and Chemistry of the Earth 17, 19-30.

The Chalt Volcanic Group, together with the Drosh volcanics form a thin, arcuate, 300 km long, linear belt cropping out to the south of the Northern Suture, Kohistan, N Pakistan The upper volcanics are interbedded with sediments which have yielded fossils of Albian-Aptian age. Contemporaneous volcanics occur to the south of the Shyok Suture in Ladakh (the Dras volcanics). The Chalt volcanics comprise a sequence of lavas and volcanoclastics which vary in composition from high-Mg basalt and andesite to low-Mg basalt, andesite and rhyolite. They have undergone greenschist to lower amphibolite grade metamorphism. Geochemically the volcanics are divisible into two groups: (1) High-Mg basalts and andesites, some of which approximate basaltic komatiite and boninite in composition. This group has high MgO, Ni and Cr contents, low concentrations of incompatible trace elements such as Ce, Y, Zr, Ti, Rb and K, and it displays tholeiitic trends with fractionation; the closest modern analogues are boninites and low-K tholeiites. (2) Basalts, andesites and rhyolites which exhibit typical calc-alkaline trends with fractionation. These are enriched in low field strength elements (e.g. Rb, Ba, Sr, K) and LREE (e.g. Ce) relative to high field strength elements and HREE (e.g. Zr, Ti, Y). Concentrations of incompatible elements increase with fractionation; their closest modern analogues are medium-K calc-alkaline andesites. These two magma groups have separate mantle sources, an MgO-rich incompatible element depleted residual harzburgite type source for the high-Mg volcanics, and a mantle source enriched in LFS elements relative to HFS elements for the calc-alkaline volcanics. Evidence from the volcanics indicates lateral variations in magmatism and source composition along the Cretaceous Kohistan island arc. The arc was situated between the Indian and Eurasian plates, and it was produced as a consequence of north- directed subduction of Tethys.
Key word: Volcanism, Chalt volcanics, Kohistan, Himalaya.

P/59. Petterson, M.G., Windley, B.F. & Sullivan, M., 1990. A petrological, chronological, structural and geochemical review of Kohistan batholith and its relationship to regional tectonics. Physics and Chemistry of the Earth 17, 47-70.

The Kohistan batholith located west of Nanga Parbat, is situated entirely within the Kohistan terrane between the Northern and Indus sutures and is the most northwesterly component of the Trans-Himalayan batholith. It is an ENE-SSW elongate 300 km x 60 km body consisting of many plutons which intrude Chalt volcanics to the north and a meta-sedimentary sequence to the south. The batholith can be subdivided into three stages on the basis of field relations, petrology and geochronology: stage-I; an early bi-modal sequence of deformed gabbro-diorites and trondhjemites, stage-II; gabbro-diorites, granodiorites and granites, with the magmatism becoming more acidic with time, and stage-III; dense swarms of leucogranitic sheets. Two magmatic types are recognised in stage-I and the early part of stage-II which are a low-K tholeiitic and a medium high-K calc-alkaline, respectively. Only the latter continued throughout the later part of stage-Hand stage-111. Radiometric ages constrain the three magmatic stages to the following periods; stage-I, pre-Northern Suture which formed between 102 and 85 Ma; stage-II, post-Northern Suture and 40 Ma with most basic magmatism at 85-60 Ma and acid magmatism at 60-40 Ma; stage-Ill, ca. 30 Ma.
The three magmatic stages of the batholith correlate with the tectonic development of Kohistan arc, i.e. stage-I plutons formed in an island arc, stage-11 plutons formed at an Andean-type margin, and late stage II plutons and stage-III plutons during syn- to post-Himalayan collision times (Kohistan collided with India at ca. 45 Ma). Sr isotope data suggest that stage-I and I1 plutons are mantle-derived, and that stage-III plutons are possible melts of the Kohistan crust. K-Ar and Ar-Ar mineral ages show that uplift rates in Kohistan are greatest within the Nanga Parbat syntaxis and that the Kohistan crust to the north and west of Gilgit cooled through the blocking temperature for biotite (330 ^{O}C) at about 60-40 Ma.
Key word: Petrology, chronology, structure, geochemistry, tectonics, Kohistan batholith, Himalaya.

P/60. Phillips, W.M., Quade, J., Shroder, J.F. Jr. & Poths, J., 1996. Cosmogenic ^{3}He in garnet, Raikot valley, Nanga Parbat, Northwestern Himalaya, Pakistan. Abstract volume, 11th Himalaya-Karakoram-Tibet Workshop, Flagstaff, Arizona (USA), 116.

Garnet is common in gneisses and leucogranites exposed in the Raikot Valley where previous workers have documented high-grade metamorphism, partial melting, high strain, and rapid denudation during the Quaternary. With the ultimate goal of quantifying Nanga Parbat denudation rates and glacial histories, we are evaluating garnet for 3He surface exposure dating. For successful 3He work, garnet must a) retain cosmogenic 3He; b) posses low concentrations of 3He inherited from pre-metamorphic surface exposure or mantle sources; and c) contain low Li, U, and Th in order for nucleogenic 3He and radigenic 3He to be minimized.
Preliminary results from a road cut with ~ 3m shielding from cosmic rays and from a weathered erratic are promising. Helium inherited during garnet growth (crush data) has radiogenic 3He/4He ratios, and variable but low 3He and 4He concentrations. Nucleogenic and/or muonic 3He (shielded sample fusion data) is <2% of cosmogenic 3He gained during long exposure (erratic fusion data). Using estimates of the 3He production rate4 in Al76Py15Sp5Gr4, the glacial erratic sample has an exposure age of 55.1±4.1 ka5. This is a minimum age due to shielding by heavy winter snow and possible (probably minor) erosion of the boulder.
Key word: Metamorphism, denudation, garnet, Nanga Parbat, Himalaya.

P/61. Piat, D., 1974. Le rubis himalayen de'Hunza. Bulletin Association Frances Gemmologie 41, p.5.

The province of Hunza is situated in the far north of Pakistan and ruby crystals are found in calcite which is often penetrated by large pegmatite and biotite bands. The color is fine transparent rose.
Key word: Gemstones, ruby, marble, Hunza.

P/62. Picard, C., Kausar, A.B., Amossê, J., & Rahim, S., 1998. The Kohistan arc, northern Pakistan: an example of PGE and PGM distribution in convergence zones. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 149-151.

Latest studies on the distribution of PGE indicate that the highest absolute abundances of PGE concentrations are generally associated with chromitite and nickel sulphide occurrences in large ultramafic-mafic layered intrusions (Stillwater and Bushveld) or in greenstone belts of komatiitic affinity. Most of them are related to distensive tectonic regime or mantle plume activity. The Kohistan arc, northern Pakistan has several discontinuous and elongated ultramafic and mafic bodies that formed at the base of an immature intra-oceanic island arc in response to northward-directed subduction of neo-Tethys ocean lithosphere during Late Jurassic and Cretaceous. Each-either contain or have the potential for PGE mineralization.
Massive chromitite occurs in lenses and pods in dunite of Jijal complex and reach 2 to 3 meters thickness and 50 meters strike length. No chromite assemblages of large concentrations (1-2 vol.%) are known in ultramafic-mafic rocks from Thak Gah and Sapat areas. In the last two complexes, chromitite and Cr-rich spinel is the most common accessory phase which occur as low-grade disseminations (dunite and pyroxenite) as well as in layers (mm scale) in dunite. Jijal complex has also primary pyrrhotite, chalcopyrite, pentlandite, bornite and pyrite and they are sparsely distributed in the different cyclic units of this complex. Surprisingly, no megascopically visible sulphide phase has been found in Thak Gah and Sapat complexes.
The whole-rock abundance PGE + Au data from Cr-rich, Cr-poor, sulphide-rich and silicate rocks of Thak Gah ultramafic-mafic complex, Chilas; Sapat ultramafic-mafic complex, Kaghan valley; and Jijal ultramafic-mafic complex were determined to know the primary distribution of PGE in these arc-related rocks and their behaviour during normal igneous processes. Thak Gah complex mostly composed of layered dunite, pyroxenite, anorthosite, troctolite and gabbro covers an area as large as 5 sq. km, east of Chilas. The complex, interpreted as intruded in the Chilas gabbro-dioritic complex (Khan et al., 1989), displays restricted range of total PGE contents (7.71 to 33.54 ppb) and exhibits positive slope (Pd/lr=3.95 to 50.33). The abundances of total PGE range from 13.13 to 33.54 ppb

in dunites; 7.71 to 13.10 ppb in pyroxenites; 6.44 to 15.74 ppb in layered gabbro and 9.04 to 20.45 ppb in gabbro norite. No PGE enrichment zone has been found in this complex.
The Sapat complex along with Jijal complex form a closely spaced group to the south of Kohistan arc and extends NE-SW immediately to the north of MMT. The complex occupies over 13 km^2 and has ultramafic sequence at the base and gabbro sequence at the top. Dunite (total PGE= 13.72 to 31.02 ppb) shows a strong Ir (1.93 to 4.06 ppb), Ru (4.12 to 8.29 ppb) enrichment and slight impoverishment in Rh, Pd and Pd resulting flat to slightly negative Pd/lr ratio (1.31 to 0.36). Clinopyroxenite shows abundant concentration of PGE, ranging from 48.95 to 57.87 ppb, and exhibits extremely steep positive patterns (Pd/lr=1 12.46 to 146.76). Layered gabbro has low total PGE concentration of 12.66 ppb and less steep positive pattern (Pd/lr=10.13) as compared to clinopyroxenite. These data suggest that silicate melt feeding Thak Gah and Sapat complexes were carrying appreciable levels of PGE and Au.
The Jijal complex, northern Pakistan, is a 150 km2 body of dunites, olivine clinopyroxenites, websterites, garnet websterites and garnet gabbro, resting tectonically over the gneissic basement of the Indian plate. Both the ultramafic and mafic phases contain minor amounts of base metal sulphides and chromites with which the platinum group elements (PGE) are associated. The abundances of PGE range from 9 to 86 ppb in olivine clinopyroxenites; 13 to 54 ppb in websterites; 17 to 54 ppb in dunites; 9 to 41 ppb in garnet clinopyroxenites and 9 to 27 ppb in garnet gabbro. Several PGE enriched horizons occurred through the series: 1) chromite- rich levels (la to ld) moderately enriched in Ir+Ru+Rh in lower dunites; 2) two disseminated sulphide bearing pyroxenites levels (2a and 2b) with strong concentrations of Ir-Rh-Ru-Pd-Pt, Cu and Ni (ΣY.PGE = 345 and 1417 ppb); and 3) one disseminated sulphide bearing garnet gabbro horizon (3) with moderate Pt-Pd concentrations (ΣPGE 196 ppb) in upper part of the complex. The mineralogy of Pd- and Pt-bearing platinum group minerals (PGM) appears to be commonly associated with sulphide-bearing as intercumulus sulphides. The PGM's include merenskyite, temagamite and melonite. In addition Miller et al. (1991) have reported atheneite, tetraauricupride, electrum and hessite from the same complex. No PGE bearing phase was recognized in the chromite bearing levels.
Mantle normalyzed PGE profiles from the chromite-rich dunite present a sawtooth appearance with low Pt - Pd and high Ir, Ru, Rh which may be related to early ferrochromite crystallization correlative with high oxygen fugacity (Amossê & Allibert, 1993). However, most of the ultramafic and mafic samples show fractionated mantle normalized PGE patterns with relatively high (Pd/lr)n. These ratios mainly result from melt and fractionation processes. Pt and Pd were extracted during partial melting, and concentrated in the silicate melt whereas Ir and Ru were remained in the residual mantle. Crystallization of chromite and, to a lesser extent, olivine will further deplete the Ir and Ru in melt and any rock that subsequently forms from this fractionated magma will have more steeper positive slopes than the original liquids (i. e. higher Pd/lr ratio).
Key word: PGE, ultramafics, Jijal, Chilas, Sapat, Kohistan arc, Convergence zones, Himalaya.

P/63. Picard, C., Rolland, Y. & Pêcher, A., 1998. The Masherbrum greenstone unit: transported arc or ophiolitic suture? Geological Bulletin, University of Peshawar 31. Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 151-153.

During summer 1997, field work has been conducted in Hushe, Thalle, and Skoro valleys (NE Pakistan). Main aim of this campaign was the study of volcanic rocks throughout the suture zone. In the northern part of this zone, a narrow strip of basic rocks, the Panmah ultramafic unit, has been interpreted as an ophiolite in an intra - Karakorum Mesozoic suture (Searle et al., 1989). Thus, it seems important to compare these basic rocks with the Shyok suture zone volcanic rocks. Our observations of this unit, on both sides of the Masherbrum glacier (see Figure 1B) have shown numerous imbricated scales, viz: ultrabasites of harzburgitic composition (cartoon 3, Figure 1B), gabbros locally flaserised and doleritic dykes (1). Lavas and greywackes (2). These lithological associations suggest some ophiolitic afinities compatible with the interpretation of an oceanic crust relict.
Structurally, the basic rocks are separated from crinoid bearing limestones (5, Fig. 1A-B) by a folded tectonic contact (4, Fig. 1B). Both the basic and the sedimentary units are metamorphosed in the greenschist facies and lie on the Hushe gneiss unit, metamorphosed in the amphibolite facies. This metamorphic contrast and the structural relations show that the basic + metasedimentary units form a klippe on the Hushe gneiss. Preliminary geochemical data (major elements, REE) suggest an arc signature. The basic rocks of the Masherbrum area could possibly be related to the Kohistan-Ladakh volcanics, located 30 km southwestwards, on the south side of the MKT.
Key word: Structure, metamorphism, greenstone, ophiolites, MKT.

P/64. Pickford, M., 1976a. A new species Taucanamo (Mammalia: Artiodactyla:Tayassuidae) from the Siwaliks of the Potwar Plateau, Pakistan. Pakistan Journal of Zoology, 8 (1), 13-20.

Key word: Mammals, Taucanamo, palaeontology, Potwar, Siwaliks.

P/65. Pickford, M., 1976b. An Upper Miocene Pholidote from Pakistan. Pakistan Journal of Zoology 8, 21-24.

Key word: Palaeontology, Pholidote, Upper Miocene, Siwaliks.

P/66. Pickford, M., 1977. Pre-Human from Pakistan. New Scientist 75, 578-580.

Key word: Pre-Human, Pakistan.

P/67. Pickford, M., 1978a. New evidence concerning the fossil Aardvarks (Mammalia, Tubalidentatata) of Pakistan. Tertiary Research 2, 39-44.

Key word: Mammals, Fossils.

P/68. Pickford, M., 1978b. The taxonomic status and distribution of Schizochoerus (Mammalia, Tayassuidae). Tertiary Research, 2(1), 29-38.

Key word: Palaeontology, Mammals, Fossils.

P/69. Pickford, M., 1982. Miocene Chalicotheriidae of the Potwar Plateau, Pakistan. Tertiary Research 4, 13-29.

Key word: Palaeontology, Miocene, Siwaliks, Potwar.

P/70. Pilbeam, D., 1978a. Rearranging our family tree. Human Nature, 1(6), 38-45.

Key words: Vertebrates, palaeontology

P/71. Pilbeam, D., 1978b. Rethinking human origins. Discovery, 13(1), 2-9, Peabody Museum of Natural History, Yale University, New Haven.

Key words: Vertebrates, palaeontology**,** Human origin, Siwaliks

P/72. Pilbeam, D., 1979a. Recent finds and interpretations of Miocene hominoids. Annual Review of Anthropology 8, 333-352.

Key words: Vertebrates, palaeontology, Miocene hominoids, Siwaliks.

P/73. Pilbeam, D., 1979b. Miocene hominoids from the Siwalik Group of Pakistan. American Journal of Physical Anthropology, 50, 471.

Key words: Vertebrate, paleontology, Miocene hominoids, Siwaliks

P/74. Pilbeam, D., 1980. Major trends in human evolution. In: Konigsson, L. K. (Ed), Current Argument on Early Man, 261-285. Pergamon Press, New York.

Key words: Vertebrate, palaeontology, hominoids, evolution, Siwaliks

P/75. Pilbeam, D., 1982. New hominoid skull material from the Miocene of Pakistan. Nature 295, 232-234.

Key words: Vertebrate, paleontology, hominoid skull, Siwaliks.

P/76. Pilbeam, D., Behrensmeyer, A.K., Barry, J. & Shah, S.M.I., 1979. Miocene sediments and faunas of Pakistan. Postilla 179, 1-45.

Five field seasons of work on the Siwalik sediments of Northern Pakistan have greatly expanded the knowledge of these Miocene sediments and their vertebrate faunas. Six long stratigraphic sections on the north limb of the Soan synclinorium near the town of Khaur were measured. These columns, the longest of which is over 3000 m provide the stratigraphic framework for the paleontological studies and give a detailed description of the lithological sequences in the Khaur region. The formational units of previous workers are poorly defined and of little practical value for biostratigraphy or chronostratigraphy. Three major lithological facies are recognized: a blue-gray sand facies; a buff sand facies; and a silt/clay facies. Intensive paleomagnetic sampling allows a provisional correlation to the La Brecque magnetic time scale. The paleomagnetic sampling also defined a series of isochrons, 1 of which was followed laterally along a 30 km-long belt of outcrop. Certain lithological horizons also may be reliable chronostratigraphic markers. Fossils are usually found only in the buff sands or their laterally equivalent fine-grained floodplain and levee deposits. Three types of fossil localities are recognized based on the characters of the fossil assemblages and the sediments. Localities in channel-related deposits were formed as composite events averaged over time and space, and therefore provide information suitable for paleoecological reconstructions. On the basis of appearances of key species a series of 11 biostratigraphic zones are provisionally defined. These span the sequence from the Lower Siwaliks to the base of the Upper Siwaliks. The faunas of the 3 lowest zones show similarities to the Asteracian faunas of Europe and to the East African middle Miocene faunas. Zones 4-8 appear to be a period of faunal endemism although there are some resemblances to European and Asian faunas.
Key word: Sediments, stratigraphy, vertebrates, Miocene, Potwar, Siwaliks.

P/77. Pilbeam, D., Barry, J., Meyer, G.E., Shah, S.M.I., Pickford, M.H.L., Bishop, W.N., Thomas, H. & Jacobs, L.L., 1977. Geology and palaeontology of Neogene strata of Pakistan. Nature 270, 684-689.

A joint study of the Potwar Plateau of Pakistan is yielding abundant material for stratigraphic and palaeontological reassessment.
Key word: Stratigraphy, Palaeontology, Potwar.

P/78. Pilbeam, D., Meyer, G.E., Badgley, C., Rose, M.D., Pickford, M.H.L., Behrensmeyer, A.K. & Shah, S.M.I., 1977. New hominoid primates from the Siwaliks of Pakistan and their bearing on hominoid evolution. Nature, 270, 689-695.

Siwalik deposits in the Punjab have yielded a rich collection of hominoid primate remains. They have important bearing on the evolution of the hominids. Together with other recent finds they indicate the need for some changes in hominoid classification.
Key word: Vertebrate palaeontology, hominoids.

P/79. Pilbeam, D.R., 1976. Neogene hominoids of South Asia and the origins of Hominidae. In: Tobias, P.V. & Coppens. Y. (Eds.), Les plus anciens hominids, 39-59. UISPP, IX Congres, Colloque VI. CNRS.

Key words: Palaeontology, Neogene hominoids, hominoid, Siwaliks.

P/80. Pilbeam, D.R., & Grant, E.M., 1974. Yale in Kenya and Pakistan: Paleontology in two continents. Discover 9(2), 73-81. Peabody Museum of Natural History, Yale University, New Heven.

Key word: Palaeontology, Kenya, Pakistan.

P/81. Pilbeam, D.R. & Jacobs, L. L., 1978. Changing views of human origins. Plateau, 51 18-31. Museum of Northern Arizona, Flagstaf.

Key word: Vertebrate palaeontology, human origin.

P/82. Pilbeam, D.R., Rose, M.D., Badgeley, C. & Lipschutz, B., 1980. Miocene hominoids from Pakistan. Postilla, 181.

Key word: Hominoids, Miocene.

P/83. Pilbeam, D.R. & Smith, R., 1984. New skull remains of sivapithicus from Pakistan. In: Shah, S.M.I., & Pilbeam, D.R. (eds.), Geological Survey of Pakistan, Memoir 11, 1-8.

Key word: Palaeontology, Pakistan.

P/84. Pilgrim, E.S., 1913. The correlation of the Siwaliks with mammal horizons of Europe. Geological Survey of India, Records 43(4), 264-326.

Key word: Palaeontology, Mammals, Siwaliks, Europe.

P/85. Pilgrim, G.E., 1910. Preliminary notes on a revised classification of the Tertiary fresh-water deposits of India. Geological Survey of India, Record 40(3), 185-205.

Key word: Classification, Freshwater deposits, Tertiary.

P/86. Pilgrim, G.E.., 1917. Preliminary note on some mammal collections from basal beds of Siwaliks. Geological Survey of India, Records, 48 (2) 98-101.

Key word: Palaeontology, Mammals, Siwaliks, Europe.

P/87. Pilgrim, G.E., 1926. The Tertiary Formations of India and interrelation of the marine and terrestrial deposits. Proceedings, Pan- Pacific Science Congress 1923, 896-931.

Key word: Marine deposits, Tertiary Formations, India.

P/88. Pilgrim, G.E., 1940. Middle Eocene mammals from northwest India. Proceedings, Zoological Society of London, Series B, 110(1-2), 127-152.

As this account does not have an abstract, the first few paras are taken for ready reference.
Mr. W. K. Edwards, Keeper of the Geological department of the British Museum, and Dr. A. T. Hopwood have very kindly invited me to study a small collection of vertebrate fossils which was presented to the Museum by Mr. E.S. Pinfold, of the Attock Oil Company. They were originally discovered by him in the Lower Khirthar series, south of Fort Munro in Dera Ghazi Khan district, on the right bank of the Indus. Better preserved specimens were collected by Mr. T. G. B. Davies and other geologists in three sites on the southern edge of the kala Chitta Range, in the Attock district of the Punjab, which runs almost from Rawal Pindi to the Indus River. These last lie near the top of the Lower Charat series, at a horizon which is believed to be identical with that of the first-named locally. The Lower Chharat series is now correlated, on the basis both of the stratigraphy and of the foraminiferal fauna, on the one hand with the Lower Khirthar series of Sind, Baluchistan, and the North-West Frontier Province, and on the other hand with the Lower Lutetian stage of the Eocene of Europe. Although remains are extremely fragmented, and, indeed for the most part generally indeterminable, yet an interest attaches to them beyond what such fragment would ordinarily possess, because, they include the first land mammals of Eocene age which have been found in India proper, and are of an even earlier age than those which for several years have been known to occur in the Pongaung series (probably Ludian) of Pakokku, Burma.
The fossils were collected from the following localities. A brief list of the specimens which each has yielded is added, while full descriptions of such of them as merit it will be found in the body of the paper.

1. Lammidhan, north west of Basal and 1-1/2 miles due west of Ganda kas village (lat. 33 38’ 15”; long. 72 11’ 20”) on India topographical survey sheet no. 43 c/2, from the Planorbis Freshwater Beds of the Lower chharat stage, which is considered by Nuttall 91926, p.121), Lt. Col. L.M. Davies, and E.S. Pinfold to be the equivalent of the Lower Khirthar stage of other parts of India, and probably of Lower Lutetian age, contrary to the opinion formerly expressed by L.M. Davies (1926, 1927) and by Cotter (1933, pp 74, 95).

Key word: Mammals, Eocene, India.

P/89. Pillewizer, W., 1956a. Der Raikot-Gletscher am Nanga Parbat im Jahre 1954. Zeitschrift für Gletscherkunde, 3(2): 181-194.

Key word: Glaciers, Raikot, Nanga Parbat.

P/90. Pillewizer, W., 1956b. Die glaziologischen arbeiten im Hunza-Karakorum und am Nanga Parbat. Erdkunde 10, 15-22.

Key word: Glaciology, Hunza, Nanga Parbat, Karakoram.

P/91. Pillewizer, W., 1957. Bewegungsstudien an Karakoram-gletschern. Petermanns Geogrrafishe Mitteilungen Erganzunsheft, 262, 53-60.

Key word: Glacial movement, Karakoram.

P/92. Pillewizer, W., 1958. Neue Erkentnisse uber die Blockbewegung der Gletscher. Zeitschrift für Gletscherkunde, 4(1-2), 23-33.

Key word: Glaciers, Block movement.

P/93. Pillewizer, W., 1960. Zwischen wuste und gletchereis. Deutsche Forscher im Karakorum. Published H. Haack, Gotha.

Key word: Desert, Ice, Glacier, Karakoram.

P/94. Pinet, C. & Jaupart, C., 1987. A thermal model for the distribution in space and time of the Himalayan granites. Earth and Planetary Science Letters 84, 87-99.

In southern Tibet, crustal thickening due to the India-Asia collision has led to the formation of two granite belts. One is located at the southern edge of the accretionary wedge of Tethyan sedimentary rocks, close to the contact with basement gneisses of the Tibetan slab. The other is found within the wedge itself, close to the Kangmar thrust trace. Available ages suggest that the granites appeared first in the southern belt and then in the Kangmar belt. This sequence seems to violate the chronology of thrusting. Another feature of the Himalayas is that melting started only about 20 Ma after the onset of thickening, which is much less than the thermal time constant of thick crust. We give a thermal model, based on the assumption of conductive heat transfer, which explains these features. The model relies on the geometry of a sedimentary accretionary wedge bounded by low-angle thrust faults and on the existence of a thermal conductivity contrast between old basement and young sedimentary rocks. The wedge of sedimentary rocks acts as an insulating cap and its southern edge heats up along the contact with basement rocks. On a horizontal cross-section, there is a temperature maximum along this southern edge, which explains why melting starts there. The early thermal evolution is sensitive to local conditions and granites first appear in the vicinity of the most radiogenic parts of the basement. The distribution of granites in space and time is seemingly random, reflecting different melting events in different radiogenic environments in the heterogeneous basement. This model predicts a relationship between radioactivity and age which is compatible with available data. The results emphasize that there are large horizontal temperature variations across a thickened region and that granite ages are not related simply to the timing of tectonic phases.
Key word: Thermal model, granites, collision, Himalaya.

P/95. Pinfold, E.S., 1918a. Notes on structure and stratigraphy in the northwest Punjab. Geological Survey of India, Records 49, 137-160.

The stratigraphy and structure of the northwest Punjab (present day Pakistan) is given in this account.
Key word: Structure, stratigraphy, Punjab.

P/96. Pinfold, E.S., 1918b. Conditions governing the occurrence of oil in the Punjab. Journal of the Asiatic Society of Bengal, New Series 14, 173-184.

The oil-springs of the Punjab are so numerous and prolific that they must have been known and used from very early times. A bibliography of the references to them up to 1891 is given as an appendix to a paper by Holland in the Records of the Geological Survey of India, volume xxiv, page 96. As far back as 1869 the Punjab Government made its first attempt to drill for oil, and a boring was put down by Fenner, of the P.W.D., at Jafar about five miles west of Fatehjang. There are no oil springs at Jafar and the geological evidence is unfavorable. The boring proved a failure, but this did not discourage the oil authorities and in the early seventies an expert, F. W. Lyman, was commissioned to examine and report on all the then known oil localities. His results and recommendations were published in a long report dated 1879. I have been unable to find any record of what borings were put down on Lyman's recommendations; some wells were drilled at Chharat, five miles northwest of Fatehjang, and others, possibly at Jaba in the Salt Range. The Chharat bores yielded some oil, but the venture was a failure commercially.
In 1890 a more ambitious attempt to develop the oil localities was made by a syndicate in which the Townsend brothers had the main interest. Wells were drilled by Canadians at Sudkal, near Fatehjang, at Jaba, and at Alugud in the Trans-Indus Salt Range. Some of these wells were carried down to over 700 feet; small quantities of oil were obtained at each locality, but the project was eventually abandoned. Still another failure has to be recorded. In 1912 Indolex Syndicate imported a Swiss geologist, Professor Preisswerk, under the direction of the Austrian oil authority, professor Zuber of Lemberg. A well was drilled on a closely compressed limestone anticline near Golra junction during cold season of 1913-14. The well was carried to about 1000 feet but obtained only a few gallons of oil.
Key word: Hydrocarbons, Punjab, Attock.

P/97. Pinfold, E.S., 1938. North West India. The Science of Petroleum 1, p.138.

Key word: Hydrocarbons, Punjab, Attock.

P/98. Pinfold, E.S., 1939. The Dunghan Limestone and the Cretaceous-Eocene unconformity in the Northwest India, Geological Survey of India, Record 74(2), 189-198.

Key word: Dungan Limestone, K-T unconformity, India.

P/99. Pinfold, E.S., 1940. Correlation of Laki beds. Geological Magazine 77, 481-483.

The Laki beds (Eocene) of northwestern India are thickest in the Suleiman foothills. These are correlated with the Laki of the Salt range, the Kohat district, and the Punjab.
Key word: Stratigraphy, Laki beds, Eocene, Suleiman foothills, Salt Range, Kohat.

P/100. Pinfold, E.S., 1947. The oil fields of North West India. Reviews, Institute of Petroleum Rev. 1, 281-184.

Key word: Hydrocarbons, Oilfields, Attock, Punjab.

P/101. Pinfold, E.S., 1953. Western Pakistan: The world's oil fields, The Eastern Hemisphere. Science of Petroleum 6.

Key word: Hydrocarbons, World oilfields, Punjab.

P/102. Pinfold, E.S., 1954. Oil production from Upper Tertiary fresh-water deposits of West Pakistan. American Association of Petroleum Geologists, Bulletin 38, 1653-1660.

Key word: Hydrocarbons, Tertiary, oil production.

P/103. Pinfold, E.S., Davies, T.G.B. & Gill, W.B., 1947. Scientific problems in the development of the oil field in the Northwest India. Transactions National Institute of Sciences, India 2(8), 231-240.

Key word: Oilfields, Punjab, India.

P/104. Pirzada, A.A., 1978. Geology of the Paras area, Kaghan valley. M.Sc. Thesis, Punjab University, Lahore, 153p.

Key word: Petrology, mapping, Kaghan valley, Mansehra.

P/105. Pirzada, A.A., Azhar, A.M. & Nasimuddin, 1997. Lithofacies variations in Nagri Formation across southwest Potwar Plateau. Abstracts, 3rd GEOSAS Workshop on Siwaliks of South Asia, Islamabad. Geological Survey of Pakistan, Records 109, 31-33.

Numerous surface radioactive anomalies at different stratigraphic levels in sandstones of Nagri Formation of Southwestern Potwar Plateau, along with other favorable factors for its uranium potential i.e. source, mobilization and trapping, was the prime motive behind the present study. To achieve this objective, four geological sections covering the whole thickness of Nagri Formation were studied. From NW to SE, these sections are Daud Khel,

Dhok Zamah, Dhok Miani and Thatla, 57 number of sandstone, clay/siltstone samples were got analyzed to ascertain petrographic composition.
Nagri Formation, an important and extensively outcropping formation of middle Siwaliks of Potwar Plateau has been traditionally presented as a thick sequence of multistoried sandstones of bluish grey color intervened by dull red mudstones and siltstones. However, during the course of present study, significant departures from the stratotype descriptions have been noted in South West Potwar Plateau (SWIPP). These variations are in thickness, geometry, grain size, sand-clay ratio, provenance etc. Nagri formation of south west Potwar represent comparatively finer facies which is evidenced from sand-clay ratio, relatively finer grain size of sandstones, and dominance of clay clast over other types.
Highly variable thickness of total Nagri was observed within a strike distance of about 80 km. From NW to SE, its thickness is 1050 m at Daud Khel, 44lm at Dhok Zamah, 593 m at Dhok Miam and 750 m at Jhatla. If no tectonic thinning or thickening is involved (which has not been evidenced), then thickness variations are due to basin configuration of the Potwar foredeep during Nagri time.
Sandstones of Nagri Formation, from bottom to top and from NW to SE, are dominantly lithic arenites with the exception of Dhok Zamah where one sample from Middle Nagri and one sample from Lower Nagri show arkosic composition. The composition of rock fragments indicate that the source rocks of Nagri Formation are predominantly low-grade metamorphics and sedimentary, whereas contribution from igneous and volcanic rocks is very subordinate.
Key word: Sedimentology, stratigraphy, sandstone, Nagri Formation, Potwar Plateau, Siwaliks.

P/106. Pirzada, A.A., Din, N., Rashid, C.M. & Majid, A.A., 1995. Tectonic setting of the Potwar Plateau. Abstracts, International Symposium on Himalayan Suture Zone of Pakistan. Pakistan Museum of Natural History, Islamabad, 23-24.

Potwar Plateau (PP) is a part of the Sub-Himalayan tectonic zone. It shows partial, differential salt induced decoupling which causes its lesser northward movement than its immediate surroundings. As a result of this underlying salt. PP is not only over spilling southwards but also westwards, onto the Kalabagh thrust, due to uplift and room available.
It is a composite tectonic unit which North Potwar Deformed Zone (NPDZ) and Southeast (SEPP) corner representing independent blocks. There is an interplay of basement and cover tectonics in which, generally, the basement reaction is in the form of faulting and cover reaction is in the form of folding. PP is bounded on three sides by thrusts and on eastern side by strike slip fault. All the boundaries are tectonically controlled.
NPDZ structures are not true thrusts but are shear boundaries between isoclinal folds along which thrusting took place due to continued stress. Soan Syncline is a result of thrusting on Northern and Southern sides of the PP. In East PP the anticlines have resulted from Salt build-up, mainly along basement normal faults, while synclines are undeformed areas between two anticlines, SEPP Corner is a triangular block formed due to transfer of stress, from· Salt Range Thrust (SRT), onto Donmli-Diljabba Thrust. Southwest PP is much less deformed than rest of the PP where faulting predominates over folding in extant distribution and intensity.
Key word: Tectonic setting, stratigraphy, Potwar Plateau, Siwaliks.

P/107. Pivnik, D.A., 1988. Magnetostratigraphy and sedimentology of the Hazara intermontane basin, Pakistan. Geological Bulletin, University of Peshawar 21, 85-104.

The Hazara Intermotane Basin (named herein) is nestled within the Hazara Hill Ranges located on the hanging wall of the Main Boundary Thrust. The Havelian Group represents the fill of this basin and consists of unconsolidated silts, sands and gravels. Paleomagnetic investigations of the silts consisted of both thermal and alternating-field demagnetization experiments for nearly all of the sites of the two measured and sampled stratigraphic sections sampled. All sites are normally polarized and correlated with the Brunhes Chron (0.73Ma to present). Sedimentological analysis shows that the Havelian Group was deposited as a sandure, a large, silt-laden plain of glacio-fluvial sediments consisting of fluvial gravels, sands and windblown loess. It is interpreted that this sandur emerged from valleys of the Hills Ranges which contained Alpine-type glaciers in their upstream reaches. Minimum sedimentation rates determined for the Havelain Group range from 0.07 to 0.27 mm/yr, and are remarkably similar to those determined for the Potwar loess (Rendell, 1988). No evidence was found to suggest that the Havelian Group was deposited as a result of tectonic activity in the foredeep.

Key word: Magnetostratigraphy, sedimentology, Hazara intermontane basin.

P/108. Pivnik, D.A. & Johnson, G.D., 1995. Depositional response to Pliocene-Pleistocene foreland partitioning in northwest Pakistan. Geological Society of America Bulletin 107, 895-922.

Pliocene–Pleistocene synorogenic deposits of the Upper Siwalik Group in the northwest Pakistan foreland record changes in dispersal patterns, provenance, and sedimentary facies in response to Himalayan contraction. Three depocenters in the northern Pakistan foreland have been studied: the Peshawar and Campbellpore Basins, situated north of the ranges associated with the Main Boundary fault; and the Soan syncline depocenter, situated in the northern Potwar Plateau, south of the Main Boundary fault. In the Peshawar Basin, an early generation of northward-prograding alluvial fans and gravelly braided streams deposited at ca. 3.0 Ma was folded by en echelon pressure ridges bounded by high-angle reverse faults between 1.7 and 1.4 Ma. The alluvial fan and fluvial deposits were entrenched and infilled by a second generation of northward-flowing braid plain deposits. In the Campbellpore Basin, southwestward-directed fluvial and alluvial-fan deposition in response to uplift of the Kawa Ghar hills began at ca. 1.8 Ma. In the Soan syncline depocenter, deposition occurred at ca. 2.0 Ma as southeastward-flowing braided streams emanating from the Khair-i-Murat uplift, and a southwestward-flowing, gravelly, meandering river derived from highlands to the northeast.
Previous stratigraphic and structural interpretations of this part of the Himalayan foreland have included north-dipping, imbricated thrust faults and duplex structures to characterize the deformation patterns in the region. Recently acquired seismic and other geophysical and surficial structural data from the western part of the foreland indicate that the foreland has experienced strike-slip as well as contractile deformation. The structures that controlled depositional patterns of the Upper Siwalik Group are localized uplifts bounded by high-angle reverse faults and not regional thrust faults. The pattern of Pliocene–Pleistocene uplift and resultant deposition across the foreland does not indicate a progression of deformation in either the foreland or hinterland directions, typical of fold-and-thrust belts.
Key word: Depositional environments, Pliocene, Pleistocene, Siwaliks.

P/109. Pivnik, D.A. & Khan, M.J., 1996. Transition from foreland- to piggyback-basin deposition, Plio-Pleistocene Upper Siwalik Group, Shinghar Range, NW Pakistan. Sedimentology 43, 631-646.

Plio-Pleistocene synorogenic deposits of the Upper Siwalik Group in the Shinghar Range (Trans-Indus Salt Ranges) of north-western Pakistan record the transition from foreland-basin to piggyback-basin deposition on the hangingwall of the Salt Range thrust. The Siwalik and Upper Siwalik Groups are over 4 km thick in the Shinghar Range. The lower 3 km consists of the Miocene Siwalik Group, which was deposited by a south-flowing foreland trunk stream, the palaeo-Indus River. The upper 1·5 km consists of the Upper Siwalik Group, which is herein divided into three members. The lowest member includes deposits of the south-flowing palaeo-Indus River and is distinguished from the underlying Siwalik Group by the first appearance of conglomerate. The transition from the lower member to the middle member is interpreted as recording uplift on the Salt Range thrust. As the Salt Range thrust was active, the palaeo-Indus River was bifurcated to the east and west around the embryonic Shinghar Range and overbank and lacustrine deposition occurred, represented by the middle member. When the Shinghar Range achieved significant topography, the upper member was deposited by streams transporting gravel and sand that flowed north and west out of the range and into a piggyback basin that formed on the hangingwall of the Salt Range thrust. New and previously published palaeomagnetic stratigraphy and fission-track ages from volcaniclastic deposits within the Upper Siwalik Group provide tight constraints on the chronology of sedimentary-facies transitions and timing of uplift of the Shinghar Range. The integration of sedimentological and geochronological data indicates that motion on the Salt Range thrust and repositioning of the Indus River began at 1·0 Ma.
Key word: Depositional environments, basin evolution, Pliocene, Pleistocene, topography, Siwaliks.

P/110. Pivnik, D.A., Qayyum, M., Lawrence, R.D. & Beck, R.A., 1997. The edges of the Himalayan Suture, western Pakistan and Myanmar. Abstract volume, 12th Himalaya-Karakorum-Tibet International Workshop, Rome, Italy, 189-190.

The western and eastern edges of the Himalayan suture, located in western Pakistan and western Myanmar respectively, are complexly deformed zones that have experienced multiple phases and styles of deformation and sedimentation. These include ophiolite emplacement, subduction, strike-slip faulting, compressional faulting, and flysch- and molasse-type deposition. The two edges of the suture are in many ways geological mirror images, but also have contrasting histories and resultant structural geometries. Western Myanmar has not experienced the intense collisional deformation that western Pakistan has, thus may serve as an analogue for the depositional and tectonic evolution of the western edge of the suture.

The western edge of the Himalayan suture, in western Pakistan and eastern Afghanistan, consists of, from hinterland to foreland: a plate bounding strike-slip fault (Chaman Fault); a deformed Tertiary sedimentary basin (Katawaz Basin); ophiolites; a belt of intensely deformed “melange” deposited in a foredeep (Kahi Melange); a major transpressional fault (Zhob Fault); telescoped Indian continental-margin deposits (Sulaiman Range); and an undeformed foreland basin (Indus Plain). The most recent interpretations of the structural and depositional history of the western edge of the suture involve Late Cretaceous obduction of ophiolites, Paleocene collision of India with Asia (Beck and others, in press), and Miocene to Quaternary compressional and transpressional deformation (Pivnik, 1995). During the Eocene, the Kohat Basin formed as a restricted marine evaporite basin on the formerly stable Indian continental shelf (Pivnik and Wells, 1996). The Katawaz Basin was formed by Eocene-Oligocene transtension, and hosted fluvio-deltaic and marine deposition that took place on transitional crust between the colliding landmasses. The sedimentary rocks in the basin record southward progradation of the paleo-Indus fan and river system, which presumably flowed south from the Himalayas (Qayyum and others, 1996). The course of the Indus shifted eastward to its present position during the Miocene, when northwest India moved past the Kabul block and the Katawaz Basin was crushed.

The eastern edge of the Himalayan suture, in western Myanmar, consists of, from hinterland to foreland; a plate bounding strike-slip fault (Sagaing Fault); a mildly deformed Tertiary sedimentary basin (Central Basin); ophiolites; a belt of “melange” deposited in a foredeep (Indo-Burman Ranges); an oblique subduction zone (Andaman Trench); and an undeformed foredeep basin (Bengal Fan). Although interpretations vary, it is generally recognized that a north-south striking subduction zone was established by the end of the Cretaceous, and that ophiolite obduction took place during the Eocene (Bhattacharjee, 1991; Brunnschweiler, 1966; Duarah and others, 1983; Mitchell, 1993; Sengupta and others, 1990; Srivastava and others, 1978). This, and subsequent deformation, is most likely related to collision of the northeastern edge of the India Plate with the Burma Plate. The Central Basin has hosted fluvio-deltaic and marine deposition throughout the Tertiary, recording southward progradation of the Irrawaddy deltaic and fluvial system. The basin has not been sutured closed, thus the present-day Irrawaddy Delta represents the recent expression in a continuum of deposition. Phases of deformation were distinct in the Central Basin, with extensional deformation occurring in the Miocene and compressional deformation occurring in the Plio-Pleistocene (Pivnik and others, in press).

The main difference between the two edges of the Himalayan suture is that the western edge has experienced intense collisional deformation, and the eastern edge has experienced a combination of collisional deformation, dominant in the north, and extensional deformation, dominant in the south. This has influenced the development and preservation of sedimentary basins and controlled the position of Tertiary volcanic arcs.

Key word: Tectonics, sedimentation, suture, Himalaya, Pakistan, Burma.

P/111. Pivnik, D.A. & Sercombe, W.J., 1992. Out-of-sequence, evaporite-controlled faulting and folding in the Kohat Plateau, NW Pakistan. Abstract Volume, 7th Himalaya-Karakoram Workshop, Department of Earth Sciences, Oxford University, England, p.71.

Detailed surface mapping and recently acquired subsurface data in the Kohat Plateau of northwestern Pakistan show complex structural styles created by the overprinting of transpersonal structures on pie-existing compressional structures and the presence of a mid-level shale and evaporate decollment horizon. The Kohat Plateau is roughly divided into two regions; a northwest region (NW) and a southeast region (SE), Surface structural styles in the NW region include doubly-overturned anticlines (shishtaray structures) and synclines involving a lower Eocene through Pleistocene stratigraphic succession. Intensely folded (and locally overturned) with the stratigraphy of the NW region is a relict, southward-verging thrust belt, the Mir Khweli Sar I Thrust Belt (MKSTB), that involves mostly middle Eocene to Miocene aged rocks. What were originally low-angle thrust faults of the MKSTB can be traced for 10’s of kms along the limbs of folds with lateral ramps exposed in numerous locations. The SE region of the plateau also contains shishtaray structures, however, many of these have had either their southern or northern limbs faulted

out along a lower Eocene shale and gypsum decollment, presumably in the latest stages of fault-propagation folding. Recent structural models of fault-propagation folds with boundary layers similar to gypsum have produced structures very much like those seen in the SE region. The MKSTB is not present in the SE region, and evaporate-floored thrusts are not present in the NW region. The absence of gypsum in the NW region is believed to have limited the propagation of faults, leaving unfaulted detachment folds exposed at the surface.
Newly acquired subsurface data from the Kohat Plateau indicate that previous models of duplex formation and typical foreland thrusting applied to adjacent areas do not apply to this section of the foreland. Instead, steeply dipping strata at depths of over 10,000 ft, steeply dipping faults that become shallow near the surface forming flower structures, and large vertical I displacements across faults suggest transpressional rather than purely compressional deformation. The near-surface, shallow thrusts form flats in lower Eocene shales resulting in detachment folds in the NW region. Localized ramps in lower Eocene gypsum and limestone allow the faults to surface in the SE region. Since low-angle thrusts of the MKSTB have been folded with the rest of the structures in the Kohat Plateau, an out-of-phase sequence of deformation is proposed, which involves the formation of a thrust belt (MKSTB) and subsequent deformation of this thrust belt by younger transpression-related folding and faulting. Based upon sedimentary-facies changes, compositional changes and unconformities within chronologically-constrained molasse deposits in and adjacent to the Kohat Plateau, it is believed that the transpressional phase of deformation occurred from approximately 2.6 to 1.8Mya, while the earlier formation of the MKSTB probably occurred between 3 and 8Mya.
Key word: Structure, salt tectonics, Kohat plateau.

P/112. Pivnik, D.A. & Sercombe, W.J., 1993. Compression- and transgression-related deformation in the Kohat Plateau, NW Pakistan. In: Treloar, P.J. & Searle, M.P. (Eds.), Himalayan Tectonics. Geological Society of London, Special Publication, 74, 559-580.

Key word: Deformation, Kohat plateau.

P/113. Pivnik, D.A. & Wells, N.A., 1996. The transition from Tethys to the Himalaya as recorded in northwest Pakistan. Geological Society of America Bulletin 108, 1295-1313.

Early Cenozoic sedimentary rocks exposed in the Kohat Plateau of northwestern Pakistan record tectonic closure of the Tethys sea and development of a restricted marine basin that formed during Himalayan collision between India, Asia, and a series of microplates. In the Paleocene, initial subsidence of the basin was caused by the downward deflection of the Indian plate in response to loading of the Asian plate. The western margin of the early Eocene basin was dominated by deposition of shale, sandstone, and conglomerate derived from microplates located to the north and west of the Indian continental margin. The eastern margin of the basin was a carbonate shelf and sabkha flat. Salt deposition occurred subaqueously in the central parts of the basin. In the late early Eocene, redbeds derived from the northwest were deposited by a fluvial and/or deltaic system. This influx of clastic sediments marks the earliest record of terrestrial foreland-basin deposition in northwest Pakistan. During the middle Eocene, the basin was reflooded and a carbonate shelf developed. Relative sea-level rise may reflect subsidence of the Indian plate in response to continued crustal loading in the Himalayan suture zone. Uplift and erosion occurred between the late Eocene and Miocene, possibly related to a peripheral bulge south of the Himalayan suture zone. The main phase of Himalayan foreland-basin fluvial deposition began in the Miocene. Renewed uplift related to final collision of India and Afghanistan during the Pliocene is recorded by a thick sequence of conglomerate in the western Kohat Plateau. Correlation with Eocene sedimentary rocks from southern Pakistan to northern India delineates the depositional systems that developed as the Tethys sea closed during Himalayan convergence.
Key word: Basin evolution, tectonics, Tethys closure, Himalayan tectonics, Kohat plateau.

P/114. Pognante, U., 1991. Different P-T-t paths along the High Himalayan Crystallines: constraints on the formation and distribution of Miocene leucogranites. Abstract Volume, 6th Himalaya-Karakoram-Tibet workshop, Auris, France, 65-66.

On the ground of previous studies of the P-T metamorphic conditions and of new data emerged recently on the High Himalayan Crystalline (HHC), this paper suggest that different P-T-t paths exist not only in N-S cross sections, as usually described, but also along the belt from western to eastern Himalayas. In the Kaghan nappe of northern Pakistan, the P-T-t path with an early (M1) eclogite-facies metamorphism (P> 13kbar, T=650±50oC; Pognante and Spencer, in prep.) and a later exhumation at decreasing temperatures (Greco, 1989), are typical of subducted and collided tectonic sheets with low initial heat supply which were uplifted very rapidly and/or were imbricated with other nappes. In northern Pakistan the minerals give prevalent pre-Miocene cooling ages (Treloar et al. 1989).

East of Pakistan, occasional granulites formed during stage M1 (Burg et al. 1987. Pognante and Lombardo, 1989) instead of eclogites and relatively slow uplift rates are suggested by the prevalent Miocene cooling ages of minerals. The decompression path occurred at uniform or increasing temperatures which produced anatexis and formation of leucogranitic melts during stage M2 (e.g. Caby et al., 1983; Staubli, 1989; Pognante et al., 1990;) P=4-7 kbar, T=600-750oC). This is typical of rocks involved in a continental event and derived from crust with normal or high initial heat supply (Thompson and England, 1984). The stage M3 produced an incipient retrograde recrystallization in Zanskar. In contrast, anatexis continued during stage M3 in Buthan and Nepal where leucogranite melts were produced also in the corderite-andalusite field (Brunel and Kienast, 1986; personal observations in the Everst-Makalu area;) P=3-5 Kbar, T=600-650oC). From the available data along the HHC also emerges that close relations exists between P-T-t paths and distribution and characters of the Miocene crustally derived leucogranites.

Intrusive leucogranite bodies are subordinate in western Himalayas. In the Khagan nappe, the lack of a heating stage during uplift and the crossing of the granite melting field only at medium-/high pressures, all should be responsible for the formation of small amounts of melt.

In Zanskar, extensive anatexis occurred during stage M2 (in the sillimanite±kyanite field) but relatively small amounts of melt were produced. In the middle structural levels, collection and ascent may have been partly inhibited by high, viscosity of the dispersed melt which chiefly freezed “insitu” as migmatites and anatectic leucogranites (Pognante, in prep.). In Buthan and Nepal, anatexis continued after stage M2 with the production of more significant amounts of melt. In fact relatively low amounts of H_2O (or micas in case of dehydration melting) are required to produce a granitic melt at the low-pressure conditions of stage M3. Large portions of this melt were extracted and intruded to high structural levels (Le Fort et al., 1987) where they coalesced to form large lens-shaped leucogranite bodies.

Key word: Metamorphism, P-T-t paths, Zanskar, Kaghan, Azad Kashmir.

P/115. Pognante, U., Benna, P. & Le Fort, P., 1992. High-Pressure metamorphism in the High Himalayan Crystallines of the Stak Valley (North-Eastern Nanga Parbat-Haramosh Syntaxis, Pakistan). Abstract Volume, 7th Himalaya-Karakoram Workshop, Department of Earth Sciences, Oxford University, England, p.120.

After the pioneering work of Zanettin (1964), the NE termination of the High Himalayan Crystallines (HHC) in the Haramosh syntaxis has been studied during a geological expedition in the Stak and Turmik valleys (NW Skardu, Pakistan). The eastern boundary of the HHC with the overlying low-grade sedimentary, metabasic and minor ultrabasic rocks of the Ladakh Unit (Le Fort et al., this vol.) is defined by a shear zone dipping toward east.

The HHC consists of paragneiss, orthogneiss, metabasic rocks derived from original dykes and rare calc-silicate rocks and marbles. Leucogranitic dykes are lacking or very rare, while deformed pegmatitic dykes are common at the uppermost structural levels. The rocks of the HHC show rather homogeneous metamorphic assemblages: Qtz-Pl-Or-Bt-Ms-Grt-Ky in the gneisses and Grt-Aug(Xrd <0.14)-Pl-Rt-Qtz in the metabasic rocks. Except for the later growth of amphiboles (hornblende and actinolite) and biotite in the metabasites, apparently related to H_2O-infiltration along discrete fractures, evidence of decompressional re-equilibrations are rare. Only in the uppermost levels (a few tens of meters below the shear zone) an obvious metamorphic zonation and a pervasive greenschist-facies re-equilibration have been observed. Green amphiboles, albite, clinozoisite porphyroblasts and chlorite are widespread near the upper shear zone.

Grt-Cpx geothermometer and Grt-Pl-Cpx geobarometer in the Grt-granulites of the middle structural levels indicate T=700±500C at P=8-10 kbar and T=600±800C at P=7-8 kbar for cores and rims, respectively. Grt-Bt geothermometer and Grt-Pl-Ky geobarometer in the associated gneiss give comparable estimates with T=650±300C at P=9-12 kbar and T=590±300C at P=7-8 kbar for cores and rims, respectively. An incipient migmatization with formation of Ky-bearing leucosomes has been observed at these structural levels. In the gneiss of the upper levels, Grt-Bt geothermometry and Grt-Pl-Ky geobarometry give T=580±300C and P=6-9 kbar.

The lack of a pervasive low-P re-equilibration of the high-P assemblages, the thermobarometric data and the study of garnet zoning profiles, all suggests that exhumation of the HHC occurred at decreasing T and, perhaps, at high rates. The metamorphic zonation with upward I decrease and the pervasive low-T recrystallization near the

extensional shear zone were probably induced by conductive cooling and shearing along the boundary with the "cold" Ladakh Unit.
These data are consistent with the evolution proposed for the eclogitic rocks recently found in the HHC of the upper Kaghan valley (SW Nanga Parbat-Haramosh syntaxis). For the Kaghan eclogites, petrological and geochronological data suggest rapid cooling and exhumation after the eclogitic peak (Tonarini et al., this vol.). In contrast, exhumation paths at increasing T and extensive anatexis with formation of leucogranite plutons characterize the HHC in eastern Himalayas (e.g. Pognante and Benna, this vol.).
Key word: High-P metamorphism, High Himalayan Crystallines, Stak valley, Nanga Parbat Haramosh.

P/116. Pognante, U., Benna, P. & Le Fort, P., 1993. High-pressure metamorphism in the High-Himalayan crystalines of the Stak valley, northeastern Nanga Parbat-Haramosh syntaxis, Pakistan Himalaya. In: Treloar, P.J. & Searle, M.P. (Eds.), Himalayan Tectonics. Geological Society, London, Special Publications 74, 161-172.

The High Himalayan Crystallines (HHC) from the little-known NE termination of the Nanga Parbat-Haramosh syntaxis (Stak and upper Turmik valleys, Pakistan) consist of kyanite-bearing gneiss with minor garnet-granulite and garnet-amphibolite. The HHC underwent a Himalayan metamorphism with a peak at high pressure (8–13 kbar) and high temperature (650–700° C). During exhumation the HHC rocks followed a rapid exhumation path at high temperature with little or no medium to low pressure re-equilibration. These lines of evidence, combined with geochronological and petrological data from Eocene eclogites recently found in the Kaghan nappe, indicate that, after subduction and high to very high pressure metamorphism, part of the HHC from northern Pakistan underwent very rapid cooling and exhumation. By contrast, exhumation along paths of increasing temperature are recorded by the HHC from regions located east of Pakistan (e.g. Nepal). These differences along strike in the HHC suggest that, during the Eocene collision between India and Eurasia, subduction and exhumation occurred at higher rates in northwestern than in central-eastern Himalaya. Additional information can be obtained in the preceding account.
Key word: High-P metamorphism, High Himalayan Crystallines, Stak valley, Nanga Parbat Haramosh.

P/117. Pognante, U. & Spencer, D.A., 1991. First report of eclogites from the Himalayan belt, Kaghan Valley (Northern Pakistan). European Journal of Mineralogy 3, 613-618.

Eclogite characterized by omphacite – garnet – quartz – rutile ± phengite assemblage are reported for the first time in the Himalayan belt. They occur in the High Himalayan Crystallines (HHC) and Tethyan metamorphic units of northern Pakistan. The eclogites formed at ~650 ± 50C and P ~ 13–18 Kbar, and represent the deepest rocks derived from the Indian plate known so far. They show an incipient decomprsssional constant or increasing temperature of the HHC in India and Nepal.
Key words: Eclogite, Ultra high-P metamorphism, Kaghan, Himalaya.

P/118. Pogue, K.R., DiPietro, J.A., Hughes, S.S., Dilles, J.H., Rahim, S. & Lawrence, R.D., 1992. Late Paleozoic rifting in northern Pakistan. Tectonics 11, 871-883.

Late Paleozoic rifting in northern Pakistan was investigated using stratigraphic, structural, geochemical and radiometric analyses of samples and sites in the area. Derived clasts from Jafar Kandao is indicative of extensional tectonics that took place in the Early Carboniferous. The area underwent uplift during the early Permian and Carboniferous periods accompanied by magmatism. The tectonic history in the north parallels that of central Pakistan indicating continuity of the two areas before the Neo-Tethys opened up.
Key word: Rifting, stratigraphy, structure, geochemistry, Paleozoic.

P/119. Pogue, K.R., DiPietro, J.A. & Khattak, W., 1996. Precambrian stratigraphy and the Foreland-Hinterland transition in the Himalayan thrust belt of Northern Pakistan. Abstract volume, 11th Himalaya-Karakoram-Tibet Workshop, Flagstaff, Arizona, USA, 118-119.

Recent investigation in the Indus syntaxis between Tarbela Lake and Besham have revealed critical relationships that permit the reconstruction of the pre-Himalayan configuration of the Precambrian of northern Pakistan which, in general, consists of Proterozoic and Archean (?) crystalline basement rocks overlain y a Proterozoic sedimentary and metasedimentary cover sequence. Both the thickness and metamorphic grade of the cover sequence increase to the north. South of the Main Mantle Thrust (MBT) Upper Proterozoic evaporites (the Salt Range Formation) unconformably overlie Proterozoic gneiss and granite (Gee, 1989). Between the MBT and the Panjal-Khairabad thrust (PKT), the Proterozoic sedimentary cover is represented by siltstone, argillite, slate and limestone of the Hazara Formation and its western equivalent, the Dakhner Formation. Gypsum intervals in the Hazara Formation imply that the Hazara and Salt Range Formations are lateral equivalents. The crystalline basement for the Hazara and Dakhner Formations is not exposed. Between the PKT and Tarbela Lake, the oldest exposed Precambrian rocks are slate and phyllite of the Manki Formation, which are interpreted as the metamorphosed equivalent of the Hazara/Dakhner Formation. The Manki Formation is overlain by stromatolitic limestone of the Shahkot, Utch Khattak, and Shekhai Formations. These limestones thin northward to be replaced by quartzite and argillite of the Tanawal Formation. Near Tarbela Lake, the Tanawal Formation overlies marble and graphitic schist of the Gandaf Formation, which is interpreted as a higher-grade equivalent of the Manki Formation. Northwest of Tarbela Lake, in Swat, higher-grade equivalents of the Tanawal Formation are mapped as the Manglaur Formation. The Gandaf Formation thickens northward in the Indus syntasix and the deeper levels expose intervals of gneiss and sheared monzonite interpreted as a Proterozoic intrusive complex (the Kotla complex). North of Tarbela Lake, Gandaf Formation lithologies are included in the Karora Formation. In the northern part of the Indus syntaxis, the Karora Formation overlies the Besham Complex. The Besham Complex consists of gneisses that record early Proterozoic metamorphism (Baig, 1990; Baig and Snee, 1989; Treloar and Rex, 1990) that are intruded by granitic rocks and mafic dikes of Proterozoic and Paleozoic age. Near Besham, the unconformity of the Karora Formation with underlying early Proterozoic gneiss of the Besham Complex is marked by a conglomerate. However, at other locations, granitic rocks of the Besham complex intrude the basal part of the Karora Formation, obscuring this unconformity. The entire Precambrian sequence north of Tarbela Lake is extensively intruded by Cambrian granodiorite (the Mansehra and Swat Granites), Late Paleozoic alkaline granitoids (the Ambela intrusive complex), and Permian mafic dikes and sills. Precambrian rocks exposed north of Besham in the Nanga Parbat area are divided between the Iskere Gneiss, Shengus Gneiss, and Haramosh Schist (Madin, 1986). Radiometric dating implies that these units are equivalents of the Besham Complex, Mansehra-type granites, and the Karora Formation (Zeitler and others, 1989).

The relationships outlined above indicate that while the demarcation between basement and cover within the Precambrian can be defined in the southern part of the Pakistan Himalaya, it is obscure to the north. North of the PKT, much of the Precambrian sections were subjected to pre-Himalayan metamorphism and north of Tarbela Lake the entire section is extensively intruded by granitic plutons. Mechanically, these rocks would behave as basement, not as cover. Exposures of Proterozoic gneisses in the Indus syntaxis indicate that the Himalayan basal decollement must have stepped downward into crystalline basement south of Tarbela Lake. Involvement of the basement in thrusting probably first occurs at the PKT, which forms the southern limit of exposures of extensively metamorphosed rocks. The PKT thus forms the boundary between the foreland and hinterland in the Himalayas of Pakistan.

Key word: Stratigraphy, foreland-hinterland, Precambrian, Indus syntaxes, Himalaya thrust belt.

P/120. Pogue, K.R. & Hussain, A., 1986. New light on the stratigraphy of Nowshera area and the discovery of Early to Middle Ordovician trace fossils in NWFP, Pakistan. Geological Survey of Pakistan, Information Release, 135, 15p.

Key word: Stratigraphy, fossils, reef complex, Ordovician, Nowshera.

P/121. Pogue, K.R., Hylland, M.D. & Yeats, R.S., 1993. Stratigraphic and structural framework of Himalayan foothills, Northern Pakistan. Abstract, Volume, 8th Himalaya-Karakoram-Tibet Workshop, Vienna, p.73.

The integration of new paleontological, stratigraphic, and structural data permit analysis of the pre-Himalayan configuration of the Indian plate passive margin in northern Pakistan. Thick sections of Paleozoic metasediments exposed in the Peshawar basin were preserved in half grabens created during Late Paleozoic rifting. Rift highlands were largely stripped of Paleozoic cover in Swat where Permian metabasalts overlie the Piotetozoic Manglaur Formation and in the Attock-Cherat Range where Jurassic and Cretaceous rocks overlie the Proterozoic(?) Dakhner Formation. In the absence of a fossiliferous Paleozoic section, lithologic correlation of Proterozoic units is crucial to retro deformation and estimates of Himalayan shortening. The Proterozoic Salt Range Formation, Hazara (Dakhner) Formation, Manki Formation, Gandaf (Salkhala) Formation, and Karora Group are interpreted as a formerly continuous northward-deepening sequence.

The Khairabad and Nathia Gali-Hissartang faults divide the foothills region into three stratigraphically distinct structural blocks. The northern block consists of the Proterozoic Gandaf and Manki Formations overlain by younger Proterozoic (?) formations and fossiliferous Paleozoic and Mesozoic strata. The metamorphic grade in the northern block gradually increases northward from lower greenschist facies near the Khairabad fault to upper amphibolite facies in central Swat. The central block consists of weakly metamorphosed Proterozoic Hazara (Dakhner) Formation and locally Cambrian and younger Paleozoic(?) strata overlain by Cretaceous and Paleogene marine strata. The southern block consists of unmetamorphosed fossiliferous strata of Triassic to Eocene age. Proterozoic rocks in the subsurface of the southern block are probably transitional between the evaporite dominated Salt Range Formation and the shallow marine clastics of the Hazara (Dakhner) Formation.

Key word: Stratigraphy, structure, palaeontology, Paleozoic sediments, Himalayan foothills.

P/122. Pogue, K.R., Hylland, M.D., Yeast, R.S., Khattak, W.U. & Hussain, A., 1999. Stratigraphic and structural framework of Himalayan foothills, northern Pakistan. In: Macfarliane, A., Sorkhabi, R.B. & Quade, J. (eds.), Himalaya and Tibet: Mountain root to mountain tops. Geological Society of America, Special Papers 328, 257-274.

We present a geological synthesis of northern Pakistan between the Main Boundary and Main Mantle thrusts based on new stratigraphic and structural information. The Hazara (Dakhner) Formation and its metamorphosed equivalents form the basal Proterozoic sedimentary sequence in the Himalayan foothills of northern Pakistan. These units were deformed and metamorphosed prior to the deposition of the overlying Phanerozoic section. The Paleozoic section of the Peshawar basin was preserved in a half graben created during late Paleozoic rifting. Paleozoic rocks were mostly removed from elongate northeast-trending highlands bounding the half graben on the north and south. Whereas the northern highland was submerged by the Late Triassic, large parts of the southern highland remained subaerial until the Middle Jurassic.

The Hissartang fault of the Attock-Cherat Range is interpreted as being continuous with the Nathia Gali fault of Hazara. Both are the first faults north of the Salt Rang thrust to expose Proterozoic rocks in their hanging walls. The Panjal fault of Hazara and Khairabad fault of the Attock-Cherat Range are also interpreted to be single continuous fault. The Panjal-Khairabad fault forms the southern limit of rocks that were metamorphosed by the Himalayan collision. Between the Panjal-Khairabad fault and Main Mantle thrust, there is now evidence for a Himalayan fault comparable to the Main Central Thrust of the central Himalaya of India and Nepal. The absence in Pakistan of a Main Central Thrust analog as well as other stratigraphic and structural contrasts precludes the extrapolation of central Himalayan tectonic subdivisions to northern Pakistan.

Key word: Stratigraphy, structure, MBT, MMT, Hazara Formation, Himalaya foothills.

P/123. Pogue, K.R., Quade, J., Hussain, A., Hinz, N. & Wright, H., 1999. Isotopic constraints on the age of metasedimentary rocks of the Peshawar basin, Pakistan. Terra Nostra 99, Abstract Volume, 14th Himalaya-Karakoram-Tibet Workshop, Kloster Ettal, Germany, 117-118.

The ages of many of the metasedimentary formations exposed in the Himalayan foothills that surround the Peshawar Basin have long been the subject of debate. The Manki, Shahkot, Utch Khattak, Shekhai, Dakhner, Darwaza, and Hissartang Formations and Inzari Limestone of the Attock-Cherat and Gandghar Ranges, the Khyber Limestone and Ali Masjid Formation of the Khyber region, and the Ambar, Tanawal, and Gandaf Formations of the northern Peshawar Basin (fig. 1) have been assigned inferred ages based largely on lithologic correlation. Early workers correlated these rocks with unmetamorphosed Paleozoic and Mesozoic rocks of similar lithology exposed to the south (e.g. Calkins et al., 1975). However, they were not aware of the significance of the intervening Panjal-Khairabad fault, a thrust fault with large displacement that is largely concealed beneath Cenozoic basin fill. Later studies (e.g. Pogue et al., 1992) described stratigraphic contrasts across this fault that are similar to those observed on either side of the Main Central Thrust (MCT) of India and Nepal.

An upper age limit of Early Ordovician on the Ambar Formation and stratigraphically lower units was established through the discovery of fossils in the overlying Misri Banda Quartzite (Pogue et al., 1992) and radiometric dating of the Mansehra Granite (Le Fort et al., 1980) which intrudes the Tanawal Formation. Rocks of the Attock-Cherat and Gandghar Range have been considered to be older than these units by most workers even though stratigraphic relationships are obscured by faulting and basin fill. Most recent workers infer a Proterozoic age for the majority of the rocks of the Gandghar and Attock-Cherat Ranges based on the presence of pronounced unconformities at the base of dated Paleozoic rocks and Late Proterozoic whole rock Rb-Sr model age dates on the Hazara Formation near Abbottabad (Crawford and Davies, 1975). These dates were interpreted by Baig et al., (1988) to represent the provenance age of Hazara Formation clastic material. Outcrops of the Hazara Formation however, are confined to the south side of the Panjal-Khairabad thrust and are never in depositional contact with the inferred Proterozoic rocks of the Gandghar or Attock-Cherat Ranges.

Until recently, it has not been possible to further constrain the ages of the undated Peshawar Basin formations. The only associated igneous rocks are ubiquitous diabase dikes of Permian age and the only fossils reported have been stromatolites. Since many of the undated units are carbonates, we concluded that it might be possible to collect samples suitable for stable strontium isotope analysis. Initial seawater ratios are best preserved in unmetamorphosed pure limestone from each undated formation at its southernmost exposure. All of the sampled formations lie in the hanging wall of the Panjal-Khairabad thrust. The metamorphic grade of rocks within this tectonic block increases dramatically northward.

As expected, many of the samples appeared to have acquired excess 87Sr from silicates during metamorphism and wee thus too altered to permit correlation with published seawater curves. However, five samples from the Attock-Cherat and Gandghar Ranges have 87Sr/86Sr ratios below 0.7065 indicating a minimum age of approximately 750 Ma. A ratio of 0.7074 for one sample from the Inzari Limestone in the southern tectonic block of the Attock-Cherat Range rules out the correlation of this unit with Paleozoic rocks exposed near Nowshera proposed by Pogue et al. (1999). This ratios gives an ambiguous age as it is shared by Late Proterozoic, Late Permian, and Mesozoic age for the Inzari Limestone based on the absence of fossils which are generally common in the Permian and Mesozoic carbonates of northern Pakistan. Samples of the Khyber limestone from near the Khyber Pass road yielded ratios as low as 0.7064 which indicates an unambiguous Proterozoic age.

These new data have important implications for the stratigraphy of northern Pakistan. All rocks stratigraphy below the Shekhai Formation, including the widely exposed Manki Formation, are at least 750 Ma in age. A Proterozoic age is also confirmed for the thick Khyber Limestone which crops out extensively in the Khyber region. Similarities in both age and lithology strongly imply a direct correlation between the Khyber Limestone and the Shahkot, Utch Khattak, and Shekhai Formation of the Attock-Cherat Range. Based on these constraints, the Precambrian/Cambrian boundary must lie somewhere between the Shekhai Formation and the Misri Banda Quartzite within the stratigraphic interval represented by the Ambar and Tanawal formations. The Proterozoic rocks of the Peshawar Basin region are probable correlatives with the upper part of the Vindhyan Supergroup of Peninsular India. The new age information also indicates a correlation of the Peshawar Basin Proterozoic section with recently dated protoliths for the Greater Himalayan sequence exposed in the hanging wall of the MCT in Nepal (Parrish and Hodges, 1996).

Key word: Stratigraphy, structure, metasedimentary, chronology, isotopes, Peshawar basin.

P/124. Pogue, K.R., Sak, P.B. & Khattak, W.U., 1995. A Geological Reconnaissance of the Indus Syntaxis, Northern Pakistan. Abstract Volume, 10th Himalaya-Karakoram-Tibet Workshop, (ETH Zurich) Switzerland.

The Indus syntaxis is an elongate north-striking faulted anticlinorium centered in the valley of the Indus River between the northern Gandghar Range and the Besham area. At its southern extremity near Tarbela dam, northeast-striking rocks in the Gandghar Range are separated from northwest-striking rocks across the river by a complex fault zone marked by pervasively sheared and mineralized graphitic schist (figure 1). Calkins (1975) mapped this fault zone as the Darband fault. Recent activity along the Darband fault is indicated by offset Indus River gravels in drill cores and tilted terraces near the dam site (Yeats and Hussain, 1989). The Gandghar Range southeast of the dam site is composed of low-grade Proterozoic metasediments in two structural blocks separated by the Baghdarra fault. The southeastern block exposes the slates and phyllites of the Manki Formation overlain by a thick limestone interval that is divided between the Shahkot, Utch Khattak, and Shekhai Formations. A relatively thin section of Tanawal Formation quartzite overlies the limestone. The oldest rocks in the northwestern block are graphitic schist and minor marble exposed along the Baghdarra fault. The schist has a gradational contact with the overlying Manki Formation. A thick interval of Tanawal Formation quartzite is separated from the underlying Manki Formation by limestone of

the discontinuous Tobrah Formation. North of the Indus River, the oldest rocks are graphitic schist and marble that were mapped by Calkins (1975) as Salkhala Formation. Due to the ambiguity of the term "Salkhala" with regard to lithologic content, unit boundaries, and type section in Kashmir, these rocks will be referred to as Gandaf Formation in this study. The Gandaf Formation is overlain unconformably by the Tanawal Formation. A relatively complete Paleozoic and Mesozoic section overlies the Tanawal Formation in the Peshawar Basin to the west.
North of Tarbela Dam, the strike of rocks on either side of the syntaxis abruptly swings from east-west to north-south near Tarbela Lake. Rocks in the core of the syntaxis exposed along the lake shore consist of quartzo-feldspathic gneiss intruded by granite bearing characteristic blue-gray microcline. The upper part of the gneiss contains discontinuous intervals of marble. At many localities the basal gneiss unit and granite is pervasively sheared. Based on its stratigraphic position, grade of metamorphism, and lithologic similarity, the basal unit is correlated with Indian plate basement rocks of the Besham Group. The gneiss passes gradationally into a northward-thinning interval of Gandaf Formation schist and marble. The Gandaf Formation is overlain by an enormous thickness of quartzite and quartz-mica schist of the Tanawal Formation. On the east side of the syntaxis, the Tanawal is intruded by porphyritic granodiorite of the Mansehra Granite. On the west side of the syntaxis, similar rocks belonging to the Ambela Granitic Complex intrude the Tanawal. The belt of granitic rocks on the west side of the syntaxis narrows and becomes increasingly mylonitized to the north. Where the belt crosses the Barundu River it is a 2 km-wide mylonitic gneiss. It is presumed that this narrow belt of granitic rock continues northward to join the Choga granitic gneiss. East of Tarbela Lake, the Tanawal Formation is unconformably overlain by lower Paleozoic dolomite and quartzite in the Sherwan synclinorium. The youngest rocks of the synclinorium are burrowed feldpathic quartzites similar to the Ordovician Misri Banda Quartzite of the Peshawar Basin. West of Tarbela Lake, the Tanawal Formation is overlain by a thick sequence of marble with interbedded amphibolite that may correlate with parts of the Peshawar Basin Paleozoic section.
Key word: Stratigraphy, reconnaissance, Indus river valley, Indus syntaxis, Gandghar Range, Besham.

P/125. Pogue, K.R., Wardlaw, B.R., Harris, A.G. & Hussain, A., 1992. Paleozoic and Mesozoic stratigraphy of the Peshawar basin, Pakistan: Correlations and implications. Geological Society of America Bulletin 104, 915-927.

The most complete Paleozoic sequence described from Pakistan is exposed in bedrock inliers and in ranges fringing the eastern Peshawar basin. Interbedded quartzite and argillite of the Precambrian and Cambrian Tanawal Formation is overlain unconformably by the Cambrian(?) Ambar Formation. The Misri Banda Quartzite unconformably overlies the Ambar and contains Ordovician Cruziana ichnofossils. New conodont discoveries restrict the ages of overlying formations as follows: Panjpir Formation, Llandoverian to Pridolian; Nowshera Formation, Lochkovian to Frasnian; and Jafar Kandao Formation, Kinderhookian to Westphalian. The Karapa Greenschist, consisting of metamorphosed lava flows, separates the Jafar Kandao from Upper Triassic (Carnian) marbles of the Kashala Formation. The Upper Triassic and Jurassic(?) Nikanai Ghar Formation forms the top of the section.
Correlatives to the Peshawar basin stratigraphy are present locally in the Sherwan synclinorium of Hazara and in the Khyber Pass region. The sequence contrasts markedly with the Paleozoic and Mesozoic section exposed south of the Khairabad thrust in the Attock-Cherat Range. This thrust and its northeastern continuation in Hazara north of Abbottabad thus form the boundary in Pakistan between the Lesser Himalayan and Tethyan Himalayan sections, a function performed by the Main Central thrust (MCT) in the central Himalaya of India and Nepal.
The newly dated Carboniferous to Triassic horizons provide the first firm age constraints on the protoliths of the high-grade Swat metasediments. The dating of the metasediments has, in turn, provided age constraints on pre-Himalayan tectonism and associated intrusions. Two major tectonic episodes during the Late(?) Cambrian and Carboniferous produced positive areas north of the Peshawar basin that provided coarse detritus to the Misri Banda Quartzite and Jafar Kandao Formation.
Key word: Stratigraphy, structure, Peshawar basin.

P/126. Poretti, G., 1983. Geomagnetic profiles along the Karakorum Range. Bollettino di Geofisica Teorica ed Applicata, Pamir-Himalaya, 25, 317-328.

Key word: Geophysics, geomagnetism, Karakoram range.

P/127. Porter, S.C., 1970. Quaternary glacial record in Swat Kohistan, West Pakistan. Geological Society of America Bulletin 81, 1421-1446.

During three Pleistocene glaciations, large valley glaciers originating at altitudes of 12,000 ft or more occupied the northern part of the Swat River drainage basin and terminated at altitudes as low as 5800 ft. Discrimination and subdivision of the three principal drift sheets is based on various relative-age criteria, including moraine and terrace morphology, weathering characteristics of surface stones, and degree of soil development. The areal and altitudinal distribution of the three drifts, which are designated Laikot (oldest), Gabral, and Kalam, indicates a less extensive glacier cover during each successive glacial age (510 mi2, 473 mi2, and 430 mi2, respectively). Laikot Drift is poorly preserved, strongly weathered, and retains little or no depositional morphology. Moraines and outwash terraces built during the Gabral and Kalam advances are well preserved in two intermont valleys at Kalam and Utror and permit subdivision of the two younger drifts into two and three units, respectively, of lesser stratigraphic rank. Moraines of Gabral age tend to be broad and smooth and have few surface stones, whereas those of Kalam age are bouldery and sharp-crested.
The altitude of the equilibrium-line (ELA) for existing glaciers in Swat Kohistan ranges from 13,000 to 14,000 ft. Assuming accumulation-area ratios of 0.6 ± 0.1 for Pleistocene glaciers in this region, steady-state ELA's during former glaciations are estimated to have been some 3000 to 3600 ft below their present levels.
Key word: Glaciers, Quaternary, Pleistocene, Swat.

P/128. Potts, G.J., Treloar, P.J. & Wheeler, J., 1992. Faulting history of the Nanga Parbat Syntaxis, Northern Pakistan; Constraints from modern earthquake data. Abstract Volume, 7th Himalaya-Karakoram Workshop, Department of Earth Sciences, Oxford University, England, p.73.

Faults and fault rocks have been examined along a 40 km traverse of the Indus gorge through the Nanga Parbat syntaxis of Northern Pakistan. Using field evidence the direction and sense or displacement have been determined for many of these. From this analysis hypothetical fault plane solutions have been derived and compared with published solutions obtained from modern earthquakes. The comparison shows that, of the faults observed in the field, only those, which display reverse oblique-slip displacement, have counterparts that are seismically active. The remaining faults must be considered either aseismic or inactive. Without geodetic information there is no way to test if the faults are moving aseismically and therefore the second possibility is considered in greater detail. Geometrically the “inactive” faults can be grouped into two sets of normal faults (with associated strike-slip faults). Thus it is necessary to consider the possibility that a period of normal faulting preceded the current regime of thrusting in the Nanga Parbat region and that the exhumation of this portion of the Himalayas was achieved by a combination of normal faulting and erosion.
Key word: Structure, earthquake, Nanga Parbat syntaxis.

P/129. Poupeau, G., Pecher, A., Benharbit, M. & Noyan, O.F., 1991. Ages traces de fission sur apatites et taux de denudatin Plio-Quartarnaires au Karakorum central. Comptes Rendus de l’Academie des Sciences, 313, 917-922.

Key word: Chronology, fission track ages, denudation, Pliocene, Quaternary, Karakoram.

P/130. Powell, C.McA., 1979. A speculative tectonic history of Pakistan and surroundings: Some constraints from the Indian Ocean, In: Farah, A. & DeJong, K.A. (eds.), Geodynamics of Pakistan. Geological Survey of Pakistan, Quetta, 5-24.

The position of India relative to Africa since the mid-Cretaceous, recently determined from ocean-floor magnetic-anomaly patterns between India and Madagascar, is traced from 80 my to the present. Three stages can be identified: I) Rapid northward flight of India from Late Cretaceous to Early Eocene: II) Small counterclockwise rotation of India about a close pole during the Eocene, and 111) Slower northward movement from the Oligocene to the present. Using geological arguments, the various tectonic elements of the Late Mesozoic and Cenozoic fold belts

from Iran to western Tibet are positioned palinspastically relative to India and Africa at 70, 55, 40 and 20 m.y. before the present. From these reconstructions the history of the major tectonic elements is then traced from the Late Cretaceous to the present.
The tectonic history of the region is modelled in terms of two major convergence zones; a-northern one, the Albon-Hindu Kush convergence zone bordering the southern edge of the stable Eurasian plate, and a southern one, the Zagros Chitral convergence zone, lying at the southern edge of a complex of microcontinents, island arc and ocean-floored basins which is preserved at present as a wide orogenic belt in Iran and Afghanistan. The Eocene counterclockwise rotation of India, following its probable Late Cretaceous or Palaeocene collision with the Zagros-Chitral convergence zone, initiated the north-northeastward trend of the Pakistani fold belt. Continued convergence choked the Zagros-Chitral convergence zone, and a new intra-continental convergence zone on which the Himalayas grew was developed during the Oligocene and Miocene. The Pakistan fold belt is not a simple oroclinal bend of Himalayan structure, but has evolved as a consequence of the shape of the northwestern comer of India. The Salt Range, Tram-Indus Salt Range and Sulaiman fold-festoon structures may all be currently moving on shallow decollements as the Indo - Pakistani shield continues its northward convergence with Eurasia.
Key word: Tectonics, structure, Indian Ocean, Pakistan.

P/131. Powell, C.McA. & Coneghan, P.J., 1973. Plate Tectonics and the Himalayas. Earth and Planetary Science Letters 20, 1-12.

The Himalayas, commonly taken as the type example of continent-continent collision, have developed in two stages. The first stage involves convergence of the northward-drifting Indian subcontinent with a proto-Tibetan landmass during Late Cretaceous and Palaeocene, with collision before Middle Eocene. The second stage involves formation of a fundamental crustal fracture within the Indian block during Late Eocene and Oligocene, and underthrusting of the Indian subcontinent along this fracture from Miocene to Recent. The present elevated Himalayan mountain chain is not a direct result of the continent-continent collision, but of uplift during underthrusting along the deep crustal fracture.
Key word: Plate tectonics, Himalaya.

P/132. Powell, C.McA. & Vernon, R.H., 1979. Growth and rotation history of garnet porphyroblasts with inclusion spirals in a Karakorum schist. Tectonophysics 54, 25-43.

Idioblastic garnet porphyroblasts in the metapelitic layers of a Cenozoic garnet-staurolite-biotite-muscovite-plagioclase schist from the Hunza valley, Karakoram Mountains, Pakistan, contain both quartz and graphite inclusion spirals. Growth-zones within the crystals enable reconstruction of the growth and rotation history of each porphyroblast. All the observed microstructural features are adequately accounted for by the model of Schoneveld (1977), which involves growth of the porphyroblast during rotation relative to the matrix. Apparent rotation angles up to 540° have been found. In contrast, xenoblastic to sub-idioblastic garnet porphyroblasts in adjacent metapsammitic layers have only slightly curved inclusion trails.
The quartz spirals appear to have developed by the garnet overgrowing quartz concentrated in “pressure-shadow” domains around the growing porphyroblasts. However, none of the quartz spirals reach the margins of the final crystal outline, and the present “pressure-shadow” domains contain little or no quartz. Furthermore, microprobe analyses of growth-zones within the garnet crystals show a relatively abrupt change in the concentrations of MnO, MgO and FeO across a boundary coinciding approximately with the disappearance of quartz from the inclusion spirals. These changes may be related to a change in metamorphic reactions during garnet growth.
Key word: Metamorphism, tectonic history, garnets, Hunza valley, Karakoram.

P/133. Powell, D., Technical Services Limited, 1959. Report on the production and utilization of coal in Pakistan. 2nd Report to the Government of Pakistan, 136p, Final Report 238p.

Key word: Coal.

P/134. Powell, J.L., & Deans, T., 1968. Trace elements and Strontium isotopes in Carbonatites, Flourites and Limestones from India and Pakistan. Nature, 218, 750–752.

Carbonatites discovered in south-west Asia have typical trace elements, but some have unusually high ratios of strontium-87 to strontium-86. Related hydrothermal fluorites have quite different strontium isotope ratios and no distinctive trace elements, emphasizing difficulties in identifying ultimate sources of fluorites.
Key word: Carbonatites, fluorites, Sr-isotopes, India, Pakistan.

P/135. Preiswerk, H., 1921. On the geological features of the oil region in the northern Punjab (British India). Geological Magazine 58, 3-21.

In the great chains of mountains belonging to the alpine system, stretching from the Armenian upland throughout Eastern Mesopotamia, Western and Southern Persia, and Baluchistan up to the Indus, then in a great curve encircling the Indian tableland in the Kirthar and Suleiman ranges and the Himalayas, then in the east turning south to Burma there are several regions rich in oil, following the foot of the mountain-ranges on the border of the plains extending in front to the south. The most important of these oil-regions arrange themselves into three chief groups: the Mesopotamian-Persian region, the Baluchistan-Punjab region, and the Burmese region.
Key word: Hydrocarbons, Kirthar, Suleiman range, Punjab, Himalaya.

P/136. Preller, C., 1924. The glacier period in the valleys of Upper Indus and Kashmir. Scottish Geographical Magazine, 40, 20-27.

Key word: Glaciation, Indus valley, Kashmir valley.

P/137. Premoli, S.I., 1965. Permian fossils from the upper Hunza valley. Italian Expedition to the Karakorum and Hindu Kush (Desio, A., Leader), vol.4, 89-113. Brill, Leiden.

Key words: Palaeontology, Permian, Hunza, Karakoram.

P/138. Priest, J.E., 1962. Snow surveys in West Pakistan. Pakistan Geographical Review 17, 43-49.

The ultimate development of water resources in an area requires that all factors of the hydrologic cycle be investigated and evaluated. The Indus Waters Treaty of 1960 envisages the construction of two large dams on the Indus River System. These dams, which are a big step towards the full utilization of the waters of the Indus Basin, will provide storage to assure irrigation and power supplies at all times of the year. The water which will enter these reservoirs comes from two sources: the melting of snow and ice and monsoon rainfall. Melt supplies are most important the first half of each year, and rainfall assumes most importance from the beginning of July. Therefore the irrigation water supply necessary for maturing the rabi crop and for planting the kharif crop is derived from melt water. It is important to determine the comparative magnitude of this melt runoff.
The Jhelum River upstream of the proposed Mangla Dam (See figure 1), in which catchment snow studies have begun, is a good example. Its melt runoff derives primarily from snow fields as opposed to the huge ice fields which feed the Upper Indus River. The snow field in the Jhelum catchment represents at any one time during the spring, a reservoir of about five million acre feet. This is the equivalent of the Mangla first stage storage capacity. To manage intelligently the Mangla reservoir, it is obviously desirable to have knowledge of snow conditions prior to the melt season. By using techniques developed in other snowy regions it may be possible to predict subsequent runoff by knowing the winter and spring snow conditions.
Key word: Hydrologic cycle, Indus river system, dams.

P/139. Prior, D.J., 1985. Uplift evolution of the Hunza valley metasediments. Abstract Volume, 1st Himalayan Workshop, Department of Geology, University of Leicester.

In the Hunza Valley, N Pakistan, a suite of metasediments outcrops between the Northern Suture and the Karakoram Batholith. The metasediments sub-divided into two units: a phyllitic melange and a group of interbedded schists and

marbles. Metamorphic grade increases from south to north. The structure is dominated by one pervasive foliation. Parallels to this foliation are numerous shear zones and thrusts.
Porphyroblast textures indicate that the main period of metamorphic growth occurred during foliation development. Development of foliation ceased shortly after or coincidentally with the end of the metamorphic episode. Deformation of the main foliation is rare, except in the shear zones where complex progressive crenulations are developed. Porphyroblasts become deformed without retrogression in the shear zones and syntectonic garnets are sometimes present.
Across one shear zone, staurolite-garnet schists contact metamorphose chlorite-garnet schists to an andalusite-biotite hornfelse. This shear zone juxtaposed material of differing metamorphic grade whilst still close to peak metamorphic conditions. The hornfels assemblage indicates that uplift occurred at this time. This uplift is interpreted as the result of shear zone/thrust movement in lower grade rocks to the south.
Differential uplift, caused by shear zone movement, over the whole belt of metasediments is responsible for the present distribution of metamorphic assemblages. Younger K/Ar ages (4-5 Ma: Rex perss comm) in higher grade rocks result from their excavation from deeper hotter levels than their low grade equivalents which yield ages of c.30Ma (op cit).
Fission track ages (1-2Ma: Zeitler, 1985) of high and low grade rocks are comparable suggesting that there was little differential uplift across the metasediments at this stage. Considerable homogenous uplift recorded by combining zircon, apatite and sphene fission track ages (op cit) was probably all accommodated by movement on the Northern Suture. Uplift evolution is dominated by a complex interaction of deformation and metamorphism. Movement on shear zones and faults is the most important uplift mechanism. Tectonic uplift is an important control on the thermal evolution of this belt.
Key word: Metasediments, tectonic uplift, thermal evolution, Northern suture, Hunza, Karakoram batholith.

P/140. Prior, D.J., 1987. Syntectonic porphyroblast growth in phyllites: textures and processes. Journal of Metamorphic Geology, 5, 27-39.

Porphyroblast textures in a Karakorum phyllite reveal that porphyroblast growth was syntectonic with respect to a cleavage forming deformation. During and after porphyroblast growth it partitions the deformation such that zones of intensified cleavage are developed which wrap around the porphyroblast whilst the porphyroblast and its strain shadow undergo little deformation. Porphyroblast strain shadows comprise quartz, calcite and feldspar with little mica, and are probably formed by solution transfer during deformation. Unless the deformation is so strongly partitioned that no deformation of the porphyroblasts and their immediate surrounds occurs, inequidimensional porphyroblasts will rotate. Porphyroblasts undergo some dissolution after they have finished growing.
Key word: Petrography, porphyroblasts, syntectonic, Karakoram.

P/141. Prior, D.J., 1989. Metamorphism, deformation and uplift of the Hunza valley, Karakorum, N. Pakistan. Journal of Metamorphic Geology, 7, 47-54?

Key word: Metamorphism, deformation, Hunza valley, Karakorum.

P/142. Pschichholz, D., 1980. Smaragde aus Indien und Pakistan.

Key words: Gemstones, emerald.

P/143. Pudsey, C.J., 1982. Arc-related and continental margin sedimentation in Kohistan, W. Himalayas. 11th International Congress of Sedimentology, Hamilton, Ontario, p.37.

For further information, consult Pudsey 1986.
Key word: Sedimentation, continental margins, arcs, Kohistan.

P/144. Pudsey, C.J., 1986. The Northern Suture, Pakistan: Margin of a Cretaceous island arc. Geological Magazine 123, 405-423.

The Northern Suture is a fault separating the Cretaceous Kohistan island arc terrain (northwest Himalayas) from Palaeozoic sediments of the Asian Plate to the north. The Kohistan arc includes volcanic and sedimentary rocks (andesitic lavas, tuffs, volcaniclastics, slates and limestones), metamorphosed to greenschist facies and intruded by the two-phase Kohistan Batholith. Asian continental margin sediments are mainly of shelf type, are variably metamorphosed and intruded by the Karakoram Batholith. The Northern Suture is a zone of melange from 150 m to 4 km wide, and contains blocks of volcanic greenstone, limestone, red shale, conglomerate, quartzite and serpentinite in a slate matrix. It has a strong planar fabric; but in many places bedding is preserved in blocks and matrix, and depositional rather than tectonic contacts are seen between the two. The melange is inferred to be an olistostrom largely derived from the Kohistan arc, formed in a small back-arc basin between Kohistan and Asia. Limestone blocks in the melange are dated as Aptian–Albian; post-tectonic intrusions yield radiometric ages from 111 to 62 Ma. The Northern Suture therefore probably formed in the early Late Cretaceous during closure of the back-arc basin. The Tethys ocean lay south of Kohistan, where the Main Mantle Thrust represents the westward continuation of the Indus - Tsangpo Suture.
Key word: Tectonics, structure, Northern Suture, Kohistan arc, Himalaya.

P/145. Pudsey, C.J., Coward, M.P., Luff, I.W., Shackleton, R.M., Windley, B.F. & Jan, M.Q., 1985. Collision zone between the Kohistan arc and the Asian plate in NW Pakistan. Transaction of the Royal Society of Edinburgh, Earth Sciences 76, 463-479.

Key word: Collision, deformation, Kohistan arc, Asian plate.

P/146. Pudsey, C.J. & Gupta, V.J., 1985. Stratigraphic position of the Darband Formation, Kohistan, northern Pakistan. Research Bulletin of Punjab University (Chandigarh) 36, 57-60.

Key word: Stratigraphy, Darband Formation.

P/147. Pudsey, C.J. & Maguire, P.K.H., 1986. Magnetic profiles across the northern suture, Kohistan, NW Pakistan. Geological Bulletin, University of Peshawar 19, 47-60.

The northern boundary fault (Northern Suture) of the Kohistan island arc terrain separates Cretaceous arc sediments and volcanics from Palaeozoic shelf sediments of the Asian plate. Arc rocks are more magnetised than Asian plate rocks, and ultramafics along the suture are very strongly magnetised. Four magnetic profiles across the suture show the following features:
A gradual north to south decrease in total field of about 15 nT/km. Asian plate sediments are magnetically quiet and in only one profile does the Northern Suture have a magnetic anomaly. Within the arc sequence, anomalies are associated with the sediment / volcanic boundary and large anomalies occur over granodioritic plutons. We have modelled the best-defined anomaly across the arc sediment / volcanic boundary using a cartoon structure consistent with the surface geology.
Key word: Geophysics, magnetic profiles, Northern Suture, Kohistan arc.

P/148. Pudsey, C.J., Schroeder, R., & Skelton, P.W., 1985. Cretaceous (Aptian/Albian) age for island arc volcanics, Kohistan, N. Pakistan. In: Gupta, V.J. (ed.), Geology of the Western Himalayas, Contributions to Himalayan Geology 3, 150-168. Hindustan, New Delhi.

The authors describe the Aptian-Albian fossils from the volcanic rocks and associated sediments occurring along the northern margin of the Kohistan magmatic arc. The host Yasin Group has been known for long time for its fossil-rich character.
Key words: Palaeontology, Island arc volcanics, Cretaceous sediments, Kohistan,