O/1. O'Brien, P.J., Zotov, N., Law, R., Khan, M.A. & Jan, M.Q., 1999. Coesite in eclogite from the upper Kaghan valley, Pakistan: a first record and implications. Terra Nostra 99, Abstract Volume, 14th Himalaya-Karakoram-Tibet workshop, Kloster Etta, Terra Nostra 99, 109-111.

Coesite, recognized petrographically and confirmed by in situ Raman microprobe spectroscopy, is reported from an eclogite from the Upper Kaghan Valley, Pakistan and represents the first record of Ultra-High Pressure (UHP) metamorphism in the Himalaya. The formation conditions >25 kbar, implied by the presence of coesite, are also supported by garnet-pyroxene-phengite barometry. The mafic bodies of the Upper Kaghan Valley have been interpreted as the metamorphic equivalents of mafic lavas, dykes and sills of Permian age (Panjal Trap volcanics). The important implication is, therefore, not only that the leading edge of the Indian plate, i.e. continental crust, was subducted to extreme depths (<90-km) during the Himalayan collision phase but that part of it was also quickly exhumed. The coesite-bearing eclogite was discovered in the Loihalol Nala, north of Gittidas, opposite the settlement Faqir Shah di Baihk. This location lies only a few kilometers from the Indus Suture. The macroscopically fresh eclogite exhibits a massive, fine grained (mostly less than 1mm), red garnet and dark green omphacite matrix, sprinkled with mm-sized white mica grains and overgrown by randomly oriented, black amphibole crystal up to 1cm in length. The body is also cut by quartz-white mica veins. Microscopically, anhedral garnet, mostly under 0.5 mm and with conspicuous darker cores, sits with a weakly-defined foliation defined by elongate omphacite (mostly 0.5-1.5mm and commonly dusted with tiny rutile inclusions), phengitic white mica (0.5-1mm), aggregates of quartz, and chains of rutile (rimmed by titanite). The large amphiboles grow across the fabric and enclose garnet, phengite and rutile but only scarce omphacite. Regression is extremely minor. The coesite (largest grain is 60 microns) occurs as inclusions in omphacite and shows the characteristic breakdown to radiating (palisade-texture) quartz as well as the typical radiating network of fractures in the host pyroxene. Inclusion with just palisade quartz are also present as are omphacites with more than one coesite inclusion preserved. Optically, coesite shows a higher relief than its surrounding quartz as well as a lower birefringence. Microprobe analysis showed a pure SiO_2 composition for both phases of the inclusions and by use of raman spectroscopy, including a two-dimensional mapping technique, it was very easy to distinguish between clinopyroxene, quartz and coesite spectra. The distinct color zoning of garnet is reflected in compositional zoning. Element distribution maps allow distinction of a relatively Ca-rich core (Alm_{50} Prp_{18} Grs_{29} Sps_3), surrounded by zone with lower Ca (Alm_{50} Prp_{21} Grs_{21} Sps_1) and followed by a narrow- but distinct- overgrowth where Ca is again higher than Mg. The jadeite content of omphacite ranges between 25 and 33 mol% (aegirine content 4-13 mol% from charge balance) but individual grains appear to be unzoned. Phengite shows a maximum Si per formula unit of 7.2 (Mg/Mg+Fe=074) in grain interiors with both values falling towards the margins of grains. The large amphiboles are Mg-hornblende, zoned to barroisite close to garnet, whereas younger amphibole formed as a breakdown product of garnet plots in the field of sub-silicic ferroan paragasite. The geothermobarometric methods that would most commonly be applied to an eclogite of this kind are the garnet-clinopyroxene and garnet-phengite Fe-Mg exchange geothermometers and geobarometer based on the reaction albite + adeit + quartz. Unfortunately, the jadeites geobarometer, in the absence of plagioclase (as is the case in eclogites), can only yield a minimum pressure. From these 'traditional' methods alone, equilibrium conditions of around 650ºC and 14 kbr were estimated: values perfectly in line with what previous workers in the area have deduced. An additional, and very useful geobarometer, is that based on the reaction between garnet, omphacite and phengite described by: Pyrope (in garnet)+Grossular (in garnet) = Diopside (in omphacite)+inverse Tschemaks ($=Al_2Mg_{-2}Si_{-1}$) (in phengite). The inverse Tschemaks activity is derived as Muscovite/Celadonite). This water-absent geobarometer reaction, calibrated initially by waters and Martin (1993), has been successfully tested in the Dabie Mountains, China by Carswell et al. (1977), to distinguish phengite-bearing eclogites that formed in the quartz stability field. It was results from the application of this geobarometer to data from Kaghan Valley eclogites (taken from Spencer 1993). i.e. pressures well above 20 kbar, that prompted the new field work in this area. Interestingly, some of the eclogite samples described from the Tso Morari area of Ladakh by de Sigoyer et al., (1977) also yield pressures in the coesite field. For the coesite-bearing sample described here, the estimated equilibrations fall on the coesite-quartz curve at around 27 kbar, 680ºC. This first discovery of coesite, combined with the new pressure estimates obtained from garnet-clinopyroxene-phengite geobarometry, are strong evidence that at least this corner of the Indian Plate has been subducted to considerable depth (27 kbar is equivalent to 90-100 km i.e.

almost three times the normal thickness of the continental crust). More important for the tectonic interpretation, however, is that rocks from this depth have managed to reach the surface again without being completely overprinted. Exhumation rates and exhumation model for the various metamorphic rocks in this area had been estimated, before, the discovery of eclogites, based on the maximum pressure conditions deduced for garnet-kyanite-staurolite-bearing assemblages in metapelites-parameters not significantly modified if the conservative minima estimated for the eclogites (Spencer, 1993) were taken into consideration. Model parameters must now be corrected as the pressure (or depth) deduced from this study is greater by at least a factor of 2. As the age constraints on the timing of collision, metamorphism, exhumation and cooling are entirely unaffected by these results, the only possible conclusion is that exhumation of rocks from coesite-forming depths, and more importantly the metastable preservation of coesite in such rocks, may well be entirely due to the buoyancy of the relatively low density (compared to the mantle) subducted continental crust slice hosting the eclogites. Tectonic models promoting this aspect, such as that proposed by Chemenda et al. (1995), may therefore be directly applicable to the early part of the Himalayan collision event. The first definite eclogites in the Himalayan were reported only in the early 1990’s and there are still only very few areas where eclogites (or their retrograded or overprinted equivalents) have been identified. In comparison to European continental collision belts such as the Alps, Variscides, or Caledonides, eclogites are extraordinarily scarce in the Himalayas and other characteristic high-pressure rocks, such as garnet peridotite, are completely unknown. Is this just a product of the lack of investigation or is the lack of high-pressure rocks a function of the pervasive amphibolite facies event? One thing is certain: the eclogites were encased in continental crust at these mantle depths and it is only a question of time before a high-pressure evolution is confirmed in these rocks as well. It should not be forgotten that easily accessible rocks preserving relics of ultra high-pressure metamorphism in the Dora Maira Massif, Western Alps, had been completely overlooked by generations of geologists before their true worth was discovered.
Key words: Eclogite, UHP metamorphism, tectonics, Kaghan, Kohistan.

O/2. O’Brien, P.J., Zotov, N., Law, R., Khan, M.A. & Jan, M.Q., 2001. Coesite in Himalayan eclogite and implications for models of India-Asia collision. Geology 29, 435-438.

Coesite, recognized petrographically and confirmed by in situ Raman microprobe spectroscopy, is reported from an eclogite from the Kaghan valley, Pakistan, and represents the first record of ultrahigh-pressure metamorphism in the Himalaya. The formation conditions of >27 kbar implied by the presence of coesite are supported by garnet-pyroxene-phengite barometry (27-29 kbar, 690-750 C). If, as seems likely from previous field and geochronologic studies, the eclogites represent metamorphosed dikes, sills, and lava flows of Permian age within the granitic gneiss-metapelite-marble sequence of the Higher Himalayan crystalline nappes, then continental crust-the leading edge of the Indian plateaus also have been subducted to coesite-forming depths (90-100 km). This more than doubles previous depth estimates and, on the basis of available geochronological data for this area, requires average exhumation rates at least twice as fast (-10 mm/yr) as previously imagined. A further implication, based on interpretations of deep seismic data, is that the present-day shallow angle of subduction of Indian plate lithosphere beneath Tibet represents a significant change from an initially much steeper angle.
Key words: Eclogite, Coesite, collision, Kaghan.

O/3. Odell, N.E., 1983. On the occurrence of granite in the Himalayan mountains. In: Shams, F.A. (ed.), Granites of Himalayas, Karakorum, and Hindu Kush. Institute of geology, Punjab University, 1-10.

The varying occurrences of granite in the principal regions of Himalaya proper and the Karakorum – Hindu Kush are considered and contrasted. Professor A. Desio’s important work in the Karakorum in particular is cited. The older concept of there being on an ‘axial granite core” in the Great Himalaya range is shown to be erroneous. Instead, later exploration and mountaineering in the main ranges have revealed that a large proportion of the high peaks are composed of sedimentary rocks, with intrusive granite appearing only very locally, while most, if not all, occurrences of granite, whether of the older granite gneiss or the newer

intrusives, are considered to be magmatic in origin, the special case of Nanga Parbat, claimed by Mish to be metasomatic and a major example of granitization is briefly discussed. The recent extensive geological survey of Nepal by Magen is touched upon and details given of important work in the area of Mount Everest and Makalu; with emphases made upon the earlier and significant studies of Wager in the injected granite sheets of Everest and vicinity, their role and their radiometric ages. Gansser's current work in Bhutan is also cited, apart from references to his outstanding and comprehensive studies of the better-known portions of the main Himalaya.
Key words: Granite, Nanga Parbat, Karakorum, Hindu Kush, Himalaya.

O/4. Oestreich, K., 1912. Der tschochogletcher in Baltistan. Zeitschrift fur Gletscherkunde 6, 1-30.

Key words: Baltistan.

O/5. Offield, T.W., 1964. Preliminary bibliography and index of the geology of Pakistan. Geological Survey of Pakistan, Records, 12(1), 54p.

This is a compilation of contributions to the geology of both East Pakistan (now Bangla Desh) and West Pakistan (the present day Pakistan). A useful index accompanies the document for ready access to the contributions. The bibliography has been incorporated in subsequent bibliographies, such as that compiled by I. A. Khan et al., 2002.
Key words: Bibliography.

O/6. Offield, T.W. & Abdullah, S.K.M., 1968a. Reconnaissance geology of the Balakot and Mahandri quadrangles, Hazara District, West Pakistan. US Geological Survey/Geological Survey of Pakistan, (IR) PK-34, 41p.

Key words: Reconnaissance, Balakot, Mansehra.

O/7. Offield, T.W. & Abdullah, S.K.M., 1968b. Reconnaissance geology of the Darband quadrangle, Hazara District, West Pakistan. US Geological Survey/Geological Survey of Pakistan, (IR) PK-35, 24p.

Key words: Reconnaissance, Darband, Hazara.

O/8. Offield, T.W., Abdullah, S.K.M. & Khan, M.S.Z., 1966. Reconnaissance geology of the Mansehra quadrangle, Hazara District, West Pakistan. US Geological Survey/Geological Survey of Pakistan, (IR) PK-10, 31p.

Key words: Reconnaissance, Mansehra, Hazara.

O/9. Offield, T.W., Calkins, J.A. & Ali, S.T., 1964. Reconnaissance geologic map and cross section of Tarbela area, Pakistan. US Geological Survey, Geologic Map Series 1109, PP716C, Plate 3, 94, (43 B/2).

Key words: Reconnaissance, mapping, structure, Tarbela.

O/10. Offield, T.W., Calkins, J.A. & Ali, S.T., 1968. Reconnaissance geology of the Tarbela quadrangle, Hazara District, West Pakistan. US Geological Survey/Geological Survey of Pakistan, (IR) PK-37, 37p.

Key words: Reconnaissance geology, Tarbela.

O/11. Ogasawara, M., 1998a. Interpretation of JERS-1 remote sensing data on Karakoram, northern Pakistan. Geological Bulletin, University of Peshawar 31 (Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop. Abstract Volume, Geological Bulletin, University of Peshawar 31, 143-144.

Remote sensing data obtained by JERS-1 (Japanese Earth Resources Satellite) have been evaluated for lithological and structural interpretations in areas from the Karakoram, northern Pakistan. A comparison has also been made with similar images from Landsat TM. JERS-1 carries an optical sensor (OPS) which records seven spectral bands. Three bands around 2.2 micron wavelength have been designed to provide valuable information for lithological discrimination. The spatial resolution of JERS-1 (18m) is better than that of the Landsat TM (30m), and provide very detailed topographical and geological information [11. One scene of JERS - 1 covers an area of about 75 * 75 km, and for the purposes of this study, twenty scenes of JERS-1 data were examined. Excellent data have been obtained along two strips of JERS-1, i.e. paths 183 and 188 (Fig. 1).

Among the factors limiting the use of remote sensing data in the high mountain terranes are the snow cover and the cloudy weather. For instance, the Karakoram Ranges is largely covered by snow in the winter, but the highest mountains are also covered in the summer. An image of northern Karakoram, north of Gilgit, taken in middle of November, shows that more than 90 % of the area is covered by snow. The images of the similar area in the northern Karakoram taken at the end of June still indicates that it is covered by snow. Thus, in order to have a minimum snow cover, it is necessary to select appropriate remote sensing data, for instance, these obtained at the end of summer (e.g., from the end of August to early September). In addition to problem by the snow cover, cloud cover also provides limitation on the image selection. Despite the problem of the snow covers, the Karakoram range is an ideal area for interpreting the remote sensing data, since it is characterized by a scarsity of vegetation mainly due to the relatively dry weather conditions. The different rock types are easily distinguished using JERS- 1 data.

Four scenes of JERS-1 Path 183, covering the area from Nanga Parbat to Khunjerab pass, were collected at the end of September, and they contain excellent geological information. The Karakoram Highway runs in the middle of the images. These show very detailed topographic features and fine geological structures. The high spatial resolution of JERS-1 data is very useful especially in areas where there are no good topographic maps or air-photos. The JERS-1 images can be enlarged into 1/100,000 scale without the loss of image quality.

Distribution of carbonate rocks and acidic granitic rocks [2] in the area is clearly shown in the images. The carbonate horizons which are several tens of meters thick, can be easily detected. These horizons are important key beds for the structural interpretation of the area. The black slate formations, e.g., Misgar slate, can also easily traced because they are appeared with a distinct black tone on the false color image.

In conclusion, the satellite images with the high spatial and spectral resolutions are useful for making geological survey in the area with difficult access. Geological information of several limited traverse can be correlated on a regional scale by using remote sensing data. Although Landsat TM data provide useful geological information, remote sensing data with even higher spatial resolution, JERS-1 or possibly SPOT, can be utilized in the area like the Karakoram.

This study was supported by joint research program between Geological Survey of Japan and Earth Resources Satellite Data Analysis Center.

Key words: Remote sensing, tectonics, structure, Karakoram.

O/12. Ogasawara, M., 1998b. New muscovite Rb-Sr ages of mylonite from the Misgar Shear Zone, in northern Karakoram: implications for late Cretaceous tectonism in the

Eurasian plate. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 144-145.

The mylonite was found near Misgar in the northern Karakoram which consists largely of Permian to Jurassic sediments. The mylonite is well exposed on the road cut of the Karakoram Highway at a distance of about 5-km upstream of the Khunjerab River from the Khunjerab-Kilik Rivers junction with a width of 900m. It continues 7km northwest to north of Misgar with a N70°W trend. The mylonite separates the Misgar Slate to the north from the Kilik Formation to the south. The occurrence of such wide zone of the mylonite could indicate the presence of a major shear zone, Ogasawara et al. proposed to use the term Misgar Shear Zone (MSZ) to describe it. The MSZ consists of mylonitic rocks, gneiss and schist originated from granodiorite, granite, limestone, sandstone and mudstone. Cataclasites after the mylonite are also present. Pseudotachyite veins are found in the cataclastic rocks. Mylonite of plutonic origin is dominant in the northern portion of the MSZ, and augen texture is commonly observed in it. Calcareous and pelitic schists are present in the southern portion. A narrow calcareous mylonite with a width of 15m bounds the southern margin of the MSZ. The mylonitic foliation mostly dips 70-80' to the south. Horizontal to southeast shallow plunging lineation is commonly observed on the foliation plane. Several types of asymmetric microstructures, e.g. asymmetric pressure shadows, are observable in the mylonite and pelitic schist in the MSZ All the asymmetric microstructures demonstrate a dextral strike-slip shear.
K-Ar ages of the muscovite and biotite of the mylonite are 66.±53.3 and 63.4±3.4 Ma, respectively. New muscovite Rb-Sr ages of mylonite are 69.9±1.7 and 66.6±1.5 Ma. Though, these are slightly older than the K-Ar ages, all the ages obtained are clearly indicating that the mylonite was formed by a late Cretaceous tectonic event in the Eurasian plate.
The Kohistan-Ladakh arc collided with the Eurasian plate before the collision of India to Eurasia, and the northern suture is thought to have closed during late Cretaceous time between 95 and 75 Ma. Therefore, the late Cretaceous age of the MSZ suggests that the dextral strike-slip displacement of MSZ in the Karakoram terrane may be related to final movement of the collision of the Kohistan-Ladakh arc to the Eurasia. On the other hand, Klootwijk et al. suggested an early India-Asia contact before 55N1 (as early as 70Ma) from paleomagnetic constraints. Such early India-Asia contact may have led to deformation of the Eurasian continent even in the late Cretaceous. Late Cretaceous radiometric ages of the mylonite from MSZ could support this model.
The presence of cataclastic and pseudotachylite with dextral strike-slip sense of shear indicates that the dextral strike-slip displacement continued after several Milometers uplift of Karakoram terrane from the depth of mylonite formation. The dextral strike-slip Misgar fault which occurs at a distance of about 5 km south of the MSZ at Khunjerab River and merges into MSZ near Misgar, also records the same strike-slip displacement. Therefore, the continued convergence of the Indian and Eurasian plates led to the strike-slip displacement of the crust within the Eurasian plate and it started from the late Cretaceous.
Key words: geochronology, Rb-Sr dating, K-Ar dating, mylonite, Misgar shear zone, Hunza, Karakoram.

O/13. Ogasawara, M., Watanable, Y., Khan, F., Khan, T., Khan, M.S.Z. & Khan, K.S.A., 1992. Late Cretaceous igneous activity and tectonism of the Karakoram block, Northern Pakistan. Abstracts, First South Asia Geological Congress, Islamabad, p.31.

Consult the following account for further details.
Key words: Tectonics, granites, Geochronology, K-Ar dating, Cretaceous, Tirich Mir, Khunjerab, Karakoram.

O/14. Ogasawara, M., Watanable, Y., Khan, F., Khan, T., Khan, M.S.Z. & Khan, K.S.A., 1994. Late Cretaceous igneous activity and tectonism of the Karakoram block in the Khunjerab valley, Northern Pakistan. In: Ahmed, R. & Sheikh, A.M. (eds.), Geology in South Asia--I. Proceedings of the First South Asia Geological Congress, Islamabad, 1992. Hydrocarbon Development Institute of Pakistan, Islamabad, 203-207.

In the Karakoram block of the Eurasian plate to the north of the Northern Suture in Pakistan, the Karakoram Batholith is a major body of granitic rocks. However, several smaller granitic bodies are present to the north of the Karakoram Batholith, which comprise the Khunjerab-Trich Mir granite belt. Some of the granitoids of this belt which occur in the Khunjerab Valley have been investigated. The Khunjerab pluton consists of hornblende-biotite granodiorite and granite. Its K-Ar hornblende and biotite ages are 107±5 Ma and 96.9±4.8 Ma, respectively. The K-Ar hornblende and biotite ages of 105±5 Ma, and 95.0±4.7 Ma respectively, for the Girag syenite are not different from the ages of the Khunjerab pluton. Slightly younger K-Ar biotite ages of 84.2±4.2 Ma and 85.9±4.3 Ma have been obtained for the North Sost pluton. These data and the age of the Tirich Mir pluton from the reference indicate that plutonism of the Khunjerab-Trich Mir granite belt took place during 120-85 Ma. The age is similar tot he ages of the older plutonism found in the Karakoram Batholith. That plutonism could be generated by the northward subduction of the oceanic crust, which was present between the Kohistan Island Arc and the Karakoram Block.
Key words: Tectonics, Cretaceous granites, geochronology, K-Ar dating, Tirich Mir, Khunjerab, Karakoram.

O/15. Ogasawara, M., Watanabe, Y., Khan, F., Khan, T., Khan, M.S.Z., & Khan, K.S.A., 1997a. Late Cretaceous igneous activity and tectonism of the Karakoram block in the Khunjerab valley, northern Pakistan. In: Research on Geology and Mineral Resources of the Collision Zone in Pakistan International Research and Development Coop. ITIT Project, Japan, Rep 87(1–2), 42–62.

Consult the preceding account.
Key words: Tectonics, Cretaceous granites, geochronology, K-Ar dating, Tirich Mir, Khunjerab, Karakoram.

O/16. Ogasawara, M., Watanabe, Y., Khan, F., Khan, T., Khan, M.S.Z. & Khan, K.S.A., 1997b. Mylonite of Misgar Shear Zone, in northern Karakoram: Evidence for late Cretaceous dextral strike-slip displacement in Eurasian plate. In: Research on Geology and Mineral Resources of the Collision Zone in Pakistan International Res and Development Cooperation, ITIT Project No. 87–1–2, Japan, Rep., 63–79.

Consult Ogasawara et al., 1994 for further details.
Key words: Shear zone, Karakoram, Cretaceous, Eurasian Plate.

O/17. Oil and Gas Development Corporation of Pakistan 1987. Natural oil and gas resources of mountainous regions of Pakistan. In: Shams, F.A. & Khan, K. (Eds.), Resources Potential of Mountainous Regions of Pakistan. Centre for Integrated Mountain Research, Punjab University, Lahore, 45-54.

Key words: Hydrocarbon potential, Himalaya.

O/18. Okimura, Y. & Fatmi, A.N. (eds.), 1988. Tectonics and sedimentation of the Indo-Eurasian colliding plate boundary region and its influence on the mineral developments in Pakistan. Hiroshima University, 1-31.

Key words: Tectonics, sedimentation, mineral potential, collision, plate boundaries.

O/19. Okrusch, M., Bunch, T.E. & Bank, H., 1976. Paragenesis and petrogenesis of a corundum-bearing marble at Hunza (Kashmir). Mineralium Deposita 11, 278-297.

A calcite-marble containing gem-quality ruby is exposed in the Hunza Valley, northwestern part of the Karakoram Mountains, Pakistan zone of Kashmir. The marble forms concordant intercalations within sillimanite- and garnet-bearing biotite-plagioclase gneisses and mica schists. The metamorphic sequence is cut by discordant aplite and pegmatite dikes. The following mineral assemblages are recognized in the marble:
1) Calcite+corundum+phlogopite±margarite±sheridanite±Al-rich pargasite±anorthite (An 96.7),
2) calcite+spinel±corundum+phlogopite+sheridanite.
Microprobe analyses are given for the essential minerals including corundum (ruby) and three different colour varieties of spinel. On the basis of recent experimental data, especially in the system CaO - Al_2O_3 - SiO_2 - H_2O -CO_2 (and related subsystems), we assume that, during the regional metamorphism, temperatures of about 600 – 620°C and a water vapour pressure of about 6 kb were realized in part of the Hunza area. The gas phase must have contained roughly 20 mole-% of CO_2. Thus the total fluid pressure may have reached about 7 kb. Presumably, temperatures increased in northwest direction, perhaps up to about 700°C. The estimated P-T conditions are consistent with a geothermal gradient of about 25°C/km.
Key words: Paragenesis, geothermobarometry, petrogenesis, corundum, marble, Hunza.

O/20. Oldham, R.D., 1884. On the re-discovery of certain localities for fossils in the Siwalik beds. Geological Survey of India, Records 17, Part 2.

Key words: Paleontology, fossils, Siwaliks.

O/21. Oldham, R.D., 1887. Notes on some points in Himalayan geology. Geological Survey of India, Records 20 (4), 155-161.

Key words: Himalayan geology.

O/22. Oldham, R.D., 1888. Some notes on the geology of the North West Himalayas. Geological Survey of India, Record 21(4), 149-159.

Key words: Himalayan geology.

O/23. Oldham, R.D., 1891. Preliminary report on the oil locality near Moghal Kot in the Shirani country, Sulaiman Hills. Geological Survey of India, Records 24(2), 83-84.

Key words: Hydrocarbons, Shirani area, Sulaiman Hills.

O/24. Oldham, R.D., 1893. Encyclopedia of Indian geology. 2nd edition, Government of India Press, Calcutta, 543p.

This is an edited and revised version of the manual of Indian geology by H.B. Medlicott and W.T. Blanford (1879-1887). It is based on all the data (essentially generated by the Geological Survey of India) up to 1892. The two volumes comprise 19 chapters containing many tables, 19 illustrations and 27 figures. The various chapters are titled as: I. Physical geography, II. Metamorphic and crystalline rocks, III. Transition systems, IV. Older Paleozoic (Cuddapah and Vindhyan) systems of the peninsular, V. older Paleozoic systems of the extra peninsular area, VI. Carboniferous and Triassic rocks of extra peninsular India, VII. The Gondwana system, VIII. Homotaxis of the Gondwanic system, IX. Marine Jurassic rocks, X. Marine Cretaceous of the Indian Peninsula, XI, Deccan trap, XII. Cretaceous rocks of the extra peninsular India, XIII. Tertiary deposits, XIV. Tertiary of the Himalayas, XV. Laterite, XVI. Pleistocene and recent deposits, XVII. The Indo-Gangetic plane, XVIII. The age and origin of the Himalaya, XIX. Geological History of the Indian Peninsula. These are followed by 14 pages of subject index. References to source literature are given in foot notes. Available information of the geology of the area of our compilation has been included. This manual is a valuable compilation and easy reference to the earlier publications of the GSI.

Key words: Books, geology, India.

O/25. Oldham, T., 1868. Memorandus on the results of cursory examination of the Salt Range and parts of the Districts of Bannu and Kohat, with a special view to the mineral resources of those districts. Selection from the Records of the Government of India, 64, 126-156.

Key words: Mineral resources, Salt Range, Bannu, Kohat.

O/26. Oldham, T., 1882. Thermal springs of India. Geological Survey of India, Memoirs 19(2), 63p.

No abstract could be obtained by the authors about this account. But other authors (e.g. THERMAL SPRINGS OF DAKSHINA KANNADA - K.R. Chandrashekar , K.R. Sridhar , M. Rajashekar and K.M. Kaveriappa, Indian institute of Science 2000) have referred to Oldham, T. as follows.
T. Oldham, a veteran geologist, catalogued the thermal springs of India as early as 1882. He located a thermal spring in a remote and inaccessible part of Puttur taluk in South Kanara district (cf. Radhakrishna, 1971). This spring, referred to as "Bendre Thirtha" by the locals, is located on the south bank of the Badantadka river, which emerges after the confluence of two tributaries, Balakku and Ermati (12° 43' N, 75° 13' S) (Fig. 1). The spring is located on a private areca garden. There are very few trees surrounding the spring viz., Ficus benghalensis L., Mangifera indica L., Artocarpus heterophyllus Lam., Cocos nucifera L.,and Areca catechew. L. Waring (1965) referred to the existence of this spring in U.S.G.S. Publication "Thermal springs of the United States and other countries of the world". Radhakrishna (1971) was impressed by a beautiful description of this spring in the Kannada novel "Karulina Kare" written by the noted Kannada writer Dr. Shivarama Karanth who had woven a beautiful story around this thermal spring. He carried out preliminary investigations on the geology of this thermal spring. Later, Chandrashekar et al. (1991) did some investigations on the aquatic hyphomycetes occurring in this spring.
Key words: Thermal Springs, India

O/27. Olson, T.M., 1982. Sedimentary tectonics of the Jalipur sequence, northwest Himalaya. Pakistan. M.A. Thesis, Dartmouth College, Hanover, New Hampshire, 152p.

This is a study of the young molasse sediments along the Indus River on the western flank of the Nanga Parbat massif. These rocks are dominantly immature sandstones with fragments of metamorphic rocks and feldspar derived from the massif and mafic rocks of the Kohistan arc. The observed tectonic deformation is interpreted as gravity collapse structures induced by uplift of the adjacent massif. Extensive soft sediment deformation, sandstone dikes, and deposits representing catastrophic events suggest deposition of the units of the sequence in an active tectonic environment. The presence of the once-buried Jalipur sequence and the overlying undeformed sediments on the flanks of the rapidly uplifting Nanga Parbat massif suggests that uplift is sporadic rather than continuous uplift would inhibit accumulation of a significant amount of sediment.
The Jalipur sequence consists of a series of alluvial fan, lacustrine, and braided stream deposits in the middle Indus Valley in the northwest Himalaya. Units in the sequence are similar in character to recent sedimentary deposits but have undergone extensive deformation. Stratigraphic relationships indicate a very young age for the sequence a conclusion which was suggested previously by fission-track dating of detrital zircons from a sandstone unit in the sequence.
The intermontane setting of the deformed sedimentary sequence and the proximity of the sequence to a branch of the Himalayan suture zone provided the initial framework for the study of these late-orogenic sedimentary rocks. Recent work on regional thermal history has indicated that the dominant structural element of the region, the Nanga Parbat- Haramosh Massif, is undergoing very rapid uplift.
A geologic map of the region was produced through a combination of field mapping and computer classification of digital Landsat spectral data. The dual approach to mapping proved effective in this area,

where ground access is difficult and air photographs and accurate topographic maps are not readily available.
No coherent structural style, such as might be expected in a thrust-dominated suture zone setting, is apparent in the deformation of the young Jalipur sequence. The observed tectonic deformation is interpreted as gravity collapse structures induced by uplift of the adjacent massif. Extensive soft sediment deformation, sandstone dikes, and deposits representing catastrophic events suggest deposition of the units of the sequence in an active tectonic environment.
Sandstones in the sequence are immature and contain large amounts of metamorphic rock fragments and feldspar grains. The petrology and heavy mineral compositions of these sandstones indicate that the detrital components were locally derived; sandstone composition was strongly influenced by the granitic rocks and metasediments of Nanga Parbat and by pyroxene granulite, the other major local bedrock type. The degree of lithification and the microstructures are evidence for some degree of burial of the sequence.
The presence of the once-buried Jalipur sequence and the overlying undeformed sediments on the flanks of the rapidly uplifting Nanga Parbat massif suggests that uplift is sporadic rather than continuous uplift would inhibit accumulation of a significant amount of sediment.
Key words: Sedimentation, tectonics, Quaternary, Jalipur, Chilas, NW Himalaya.

O/28. Omodei, D., 1911. Relazione sulle osevazioni meteorologichefatte dalla spedizione S.A.R. il Duca degli Abruzzi nel Karakoram ed Imalia Occidentale e calculi altimetrichi. In: F. De Filippi. La Spedizione di S.A.R. il Prinipe Luigi Amedeo e calculi altemetrichi.

Key words: Meteorology, altimetry, Italian expedition, Karakoram.

O/29. Opdyke, N.D. (ed.), 1982. The geochronology and biochronology of the Siwalik Group, Pakistan. Palaeogeography, Palaeoclimatology, Palaeoecology 37, 1-130.

Key words: Geochronology, paleomagnetism, Siwaliks.

O/30. Opdyke, N.D., et al., 1977a. The magnetic polarity stratigraphy of the Upper Siwalik sediments of northeast Pakistan and the age of the transition between Pinjore and Tatrot land mammal faunas. Geological Society of America Abstract with Program, 9, 1120-1121.

Key words: Paleomagnetism, Upper Siwaliks, Potwar, Kashmir.

O/31. Opdyke, N.D., Johnson, N.M., Johnson, G.D., Lindsay, E.H. & Tahirkheli, R.A.K., 1977b. Paleomagnetism of the Upper Siwalik sediments of Pakistan. Transactions American Geophysical Union, 58, p.379.

Key words: Paleomagnetism, Upper Siwaliks, Pakistan.

O/32. Opdyke, N.D., Johnson, N.M., Lindsay, E.H. & Johnson, G.D. & Tahirkheli, R.A.K., 1982. Paleomagnetism of the middle Siwalik formations of northern Pakistan and rotation of the Salt Range decollement. Palaeogeography, Palaeoclimatology, Palaeoecology 37, 1-15.

Sampling for paleomagnetic study has been carried out at seven localities in the Potwar Plateau region of Pakistan in the vicinity of the Salt Range. In all, 253 sites, consisting of three samples per site, were studied. The sites were taken from the Chinji, Nagri, Dhok Pathan and Upper Siwalik formations which span the last 14 m.y. of Earth history. The formations have been deformed in the ongoing Himalayan orogeny and are exposed today in sections which dip at angles of from 10° to 90° in different directions.

A characteristic direction of magnetization was isolated at all sections by thermal demagnetization at temperatures of from 550° to 650°C. The sediments have been folded within the last 2 m.y. and because of a positive fold test it can be shown that the characteristic magnetization of these sediments was acquired before folding. Four of the sections have directions of magnetization which have been rotated in a counter-clockwise fashion up to 40°; however, sections taken along the Indus River, the north flank of the Soan syncline and the south flank of the Salt Range show small counter-clockwise rotations of under 10°. These observations are in agreement with previous suggestions that strata in the Salt Range have been moved to the south and rotated in a counter-clockwise fashion. The observations reported here indicate that the paleomagnetic poles derived from Cambrian and Permian formations within the Salt Range have probably also suffered rotation and should be removed from consideration in Gondwanaland reconstruction of the Paleozoic.

Key words: Paleomagnetism, structure, Siwaliks, Northern Pakistan.

O/33. Opdyke, N.D., Lindsay, E.H., Johnson, G.D., Johnson, N.M., Tahirkheli, R.A.K. & Mirza, M.A., 1979. Magnetic polarity stratigraphy and vertebrate paleontology of the Upper Siwalik Sub Group of northern Pakistan. Palaeogeography, Palaeoclimatology, Palaeoecology 27, 1-34.

Two hundred and fifty three sites consisting of three samples per site were taken from eight separate stratigraphic sections from sediments of the Upper Siwalik subgroup of northern Pakistan. All samples have been partially demagnetized in alternating fields of from 150 to 300 ^{0}c. The sediments are dipping at angles of up to 75° in a variety of directions, and the locality mean directions improve significantly after correcting for bedding attitude, providing a statistically significant fold test at the 95% level.

The magnetic stratigraphy was obtained based on the statistically significant well-grouped partially demagnetized data. Two prominent bentonitized tuffs occur in several sections above and below a prominent reversal of the earth's magnetic field. Radiometric dates of 2.3 ± 0.4 m.y.B.P. and 2.5 ± 0.4 m.y.B.P. have been obtained by fission track on zircons from these tuffs. This allows the magnetic stratigraphy to be correlated to the standard reversal chronology of the Pliocene and Pleistocene. The longest stratigraphic section (1.87 km in thickness) can be shown to span the time between 0.6 m.y.B.P. and 5.5 m.y.B.P.

The individual stratigraphic sections can be correlated on the basis of magnetic stratigraphy. All sections contain important vertebrate fossil localities which can be placed relative to each other in the time stratigraphic framework provided by the magnetic stratigraphy.

The change from the Pinjor fauna to the Tatrot fauna occurs at about 2.47 m.y.B.P. (the Gauss/Matuyama boundary) based on the simultaneous occurrence of Equus-Elephas, Bos and cervids with antlers. Hipparion, the three-toed horse, persists to the lowermost Pleistocene just after the termination of the Olduvai event. The ranges of other important vertebrate faunas are also discussed.

The folding of the eastern Salt Range has been very recent, beginning within the Brunhes normal magnetic epoch, since sediments of lower Brunhes age are folded on the flanks of the Pabbi and Rohtas anticlines and on the flanks of Chambal Ridge. The rate of uplift of these structures above the present base level is estimated to have a minimum rate of four meters per thousand years for the Rohtas anticline and three meters per thousand years for the Pabbi Hills. The rates of subsidence (i.e., rates of sedimentation) of the various sections are estimated to range from 0.35 m/103 yr to 0.50 m/103 yr. The first occurrence of conglomerate-containing clasts derived from the Himalayan uplift occurs just prior to the Olduvai event at the base of the Pleistocene.

Key words: Vertebrate paleontology, stratigraphy, Siwaliks.

O/34. Orlando, M. & Laffi, F., 1985. K2 La montagna degli italiano. Ed. Yak, 240p. Fiesso d’Artico.

Key words: K2, Karakoram.

O/35. Osmaston, H.A., 1986. The Siachen and Terong Glaciers, East Karakoram. Himalayan Journal 42, 87-96.

Key words: Glaciers, Siachen, Terong, Karakoram.

O/36. Oswald, G.K.A., 1984. Ice-depth echo-sounding techniques employed on the Hispar and Ghulkin glaciers. In: Miller, K.J. (ed.), The International Karakoram Project, Volume 2, 86-99. Cambridge University Press.

The impulse radar technique used originally to sound the temperate Vatnajokull, Iceland ice cap and successfully employed on the Hispar and Ghulkin glaciers during the Karakoram Project is reviewed. Possible improvements to the system are discussed, with particular reference to the transmitting and receiving systems and to their implementation in the 'Subscan' impulse radar system. Attention is given to techniques for integrating successive output signals in order to reduce the effective noise level, and the statistical theory of a fast and simple digital integration technique is given. A brief description of the Subscan digital signal discrimination and recording systems concludes the paper.
Key words: Glaciers, Hispar, Gulkin, Karakoram.

O/37. Ottiger, R., 1985. Rocks of the Murree Formation: indicators of a descending foreland basin of lower to middle Eocene age. Abstract Volume, 1st Himalayan Workshop, Department of Geology, University of Leicester.

The red clastic sand and shale deposits of the Murree Formation have been regarded as continental deposits of Miocene age. A new and more detailed sedimentological and micropaleontological survey on a profile of fifteen-kilometer length, in the apex region of the Hazara-Kashmir Syntaxis in Northern Pakistan, has shown that these rocks were deposited in a very shallow marine (sub-supratidal) environment, on a 5tidal flat. This hypothesis is based on a reinterpretation of the cyclic sedimentation seen in these rocks. One can interpret a single cycle as the product of meandering tidal channels in a continuously descending foreland basin. Each cycle starts with typical channel fill deposits (microconglomerates, crossbedded sandstone) and passes upwards into tidal flat deposits (laminated and strongly bioturbated sand and siltstones). The uppermost part of a cycle is composed of red clayey silt with local horizons containing calcareous concretions and which are interpreted as a type of fossil Caliche. Evidence is presented that the formation of single cycle, of an average thickness of ten meters, lasted about 8-10000 years. It would take about 13.5 million years for the deposition of the complete fifteen-kilometer thick sequence. This deduction fits very well with age determination based on syndepositional Nummulites and Assilines. These fossils indicate an age of upper Illerdien (lowermost Eocene) at the base of the Murree Formation (Balakot region) and upper middle Lutetien at Kawal, at a position some two thirds from the base of the profile. In the North, the Murree Formation is therefore much older than it is in the South (Kohat, Potwar) where data suggest a lower Miocene age.
Key words: Foreland basin, Eocene, Murree formation.

O/38. Ottiger, R., 1986. Einge Aspekte der Geologie der Hazara-Kashmir Syntaxis (Pakistan). Dissertation ETH Nr. 8083, Zurich.

Key words: Hazara Kashmir syntaxis, geology.

O/39. Owen, L.A., 1988a. Terraces, uplift and climate, the Karakoram Mountains, Northern Pakistan: Ph.D. thesis, Univ. Leicester, 399p.

For some information readily available, see Owen, 1989.
Key words: Terraces, climate, uplift, sedimentation, geomorphology, Karakoram.

O/40. Owen, L.A., 1988b. Wet-sediment deformation in Quaternary and recent sediments in the Skardu Basin, Karakoram Mountains, Pakistan. In: Croot, D. (ed.), Glaciotectonics. Balkema, Rotterdam, 123-147.

Key Words: Sedimentation, deformation, Quaternary, Skardu basin, Karakoram.

O/41. Owen, L.A., 1989a. Neotectonics and glacial deformation in the Karakoram Mountains and Nanga Parbat Himalaya. Tectonophysics 163, 227-265.

The Karakoram Mountains and the Nanga Parbat Himalaya are one of the most rapidly rising mountain areas in the world with uplift rates in the order of 2 mm/yr. Large-scale regional warping is the most likely form of uplift with the greatest rates around the Nanga Parbat-Haramosh Massif. Only two active faults have been recognised in the Pakistan Karakoram, the Rakhiot and the Misgar valley fault. The Rakhiot fault zone is a neotectonic expression of the rapid uplift centred around the Nanga Parbat syntaxis. Deformation structures in Quaternary and Recent sediments in the Rakhiot area are not produced solely by neotectonic processes but also by processes in the glacial depositional environment and slope related processes. Structures present vary from neotectonic shear zones, folds, thrusts and high-angled faults; glacially produced folds, thrusts, shears and joints; and debris slides bounded by discrete shear zones.
The distinction between these structures is vital in making valid neotectonic models for high active mountain belts.
Key Words: Neotectonics, glaciation, deformation, Karakoram.

O/42. Owen, L.A., 1989b. Terraces, uplift and climate in the Karakoram Mountains, Northern Pakistan: Karakoram intermontane basin evolution. In: Derbyshire, E. & Owen, L.A. (eds.), Quaternary of the Karakoram and Himalaya. Zeitschrift fur Geomorphologie 176, 117-146.

Key Words: Tectonics, uplift, geomorphology, Karakoram, Himalaya.

O/43. Owen, L.A. 1991. Mass movement deposits in the Karakoram Mountains and western Himalayas. Zeitschrift fur geomorphologie 35, 401-424.

Mass movement is a major process in the valleys of the Karakoram Mountains. Here very long and steep slopes, resulting from tectonically induced fluvial and glacial incision, and intense weathering help induce slope failure. These include rockfalls, avalanche, debris slides and rockslides, creep, rotational slips, debris flows and flowslides. Processes vary in scale from isolated small failures to extensive areas of complex movements. The most common and important processes are debris flows and flowslides. Sediments deposited by these processes are highly variable, consisting dominantly of coarse diamictons. These form a major component of the valley fills which frequently exceed several hundreds of metres in thickness. Distinctions between the different debris deposits and landforms are difficult to make in the Karakoram Mountains because of the polygenetic origin of many of these mass movement sediments.
However, distinctions can be made using their sedimentary characteristics including: sedimentary structures, microstructures, grain size characteristics, clay mineralogy, degree of compaction and petrology. Correct identification of sediments is particularly important in reconstructing accurate Quaternary histories and palaeoenvironments. Many of these deposits have originated from the resedimentation of glacial and non-glacial diamictons by debris flow and flowslide processes. A major phase of resedimentation occurred soon after the last major glaciation in the Karakoram Mountains (c. 50,000 years B.P.) resulting in thick deposits and creating many of the present valley landforms, such as fans and terraces. These processes are important in reconstructing the evolution of the Karakoram landscape.
Key Words: Mass movement, Karakoram.

O/44. Owen, L.A. 1993. Glacial and non-glacial diamictons in the Karakoram Mountains. In: D. Cropts & W Warren (eds.)., The deposition and deformation of tills. Balkema, Rotterdam, 9-29.

Key Words: Diamicton, deformation, Karakoram.

O/45. Owen, L.A. 1996a. High roads, high risks. The Geographical Magazine. 118. 12-15.

Key Words: Geomorphology, geohazards.

O/46. Owen, L.A. 1996b. Quaternary lacustrine deposits in a high energy semi-arid mountain environment, Karakoram Mountains, northern Pakistan. Journal of Quaternary Science, 11, 461-483.

Impressive Quaternary lacustrine deposits are present as terrace remnants throughout the Karakorum Mountains, northern Pakistan. They are mainly the result of damming of drainage systems during glacial advances or by catastrophic mass movement deposits. The longevity of most lakes is relatively short, in the order of years to tens of years, but sedimentation rates are extremely high as a consequence of the high sediment loads within the rivers. This results in deposits that frequently exceed 10 m in thickness. The sediments comprise dominantly planar bedded, massive and, less commonly, planar laminated, silts, comprising detrital quartz, feldspar, mica, calcite, chlorite and illite. A facies model for lacustrine sedimentation in a high energy semi-arid high mountain region is presented, using case studies from a glacially dammed palaeolake (Glacial Lake Gilgit) and a debris-flow dammed palaeolake (Lake Serat). The rapid deposition and absence of organic material restricts the usefulness of these lacustrine Sediments as proxies for palaeoenvironmental reconstruction, but they are helpful in reconstructing the former extent of glaciers and illustrating the importance of high-magnitude-low-frequency events, such as landsliding, as formative processes contributing to the evolution of the Karakoram landscape.
Key Words: Sedimentology, glaciation, landslide, dammed lakes, Karakoram.

O/47. Owen, L.A. & Derbyshire, E., 1988. Glacially deformed diamictons in the Karakoram Mountains, northern Pakistan. In: Croots, D.G. (ed.), Glaciotectonies. Balkema, Rotterdam, 149-176.

Key Words: Glaciation, deformation, diamictites. Karakoram.

O/48. Owen, L.A. & Derbyshire, E., 1989. The Karakoram glacial deposition system. In: Derbyshire, E. & Owen, LA. (Eds.), Quaternary of the Karakoram and Himalaya. Zeitschrift fuer Geomorphologie 76, 33-73.

The Karakoram glaciers are among the largest outside the polar regions. They are glaciologically complex with thick and steep glaciers of high activity Alpine type. Large quantities of debris are supplied to the surface of the ice by avalanching, with the result that the supraglacial debris path is dominant. Glacial deposits are thus deposited mainly by melt out with an important input from supraglacial sliding. The basal debris zone is relatively thin, and observed lodgement tills rarely exceed a few metres in thickness. Two main types of glaciers can be differentiated based on the landforms in their lower reaches:
1. Ghulkin type, dominated by ice-contact fan landforms;
2. Pasu type, dominated by hummocky moraines and glaciofluvial outwash plains.
Ancient examples of the glacial sediments and landforms and the sedimentary characteristics of these deposits are described. The sedimentary characteristics are used to compare the different types of tills and to compare sediments deposited during the Pleistocene with those of the Holocene.
Key Words: Glaciation, sedimentary deposits, geomorphology, Karakoram.

O/49. Owen, L.A. & Derbyshire, E. 1993. Quaternary and Holocene intermontane basin sedimentation in the Karakoram Mountains. In: Schroder, J.F. (ed.), Himalayas to the Sea: Geology, Geomorphology and the Quaternary, Routledge, London, 108-131.

Key Words: Sedimentation, intermontane basin, quaternary, Karakoram.

O/50. Owen, L.A., Derbyshire, E., White, B.J. & Rendell, H., 1992. Loessic silt deposits in the western Himalayas: their sedimentology, genesis and age. Catena, 19: 493-509

Loess is abundant in the foreland basins of the Himalayas. However, it is poorly developed within the intermontane basins of the western Himalayas and Karakoram. Selected sections were studied from the Swat Himalaya and the Karakoram Mountains. Fieldwork and sedimentological analysis including grain size, mineralogy and microfabric showed that the loessic sediments have been reworked and some have undergone weak pedogeneses. These silts are not true loess, rather a “loessic colluvium”. Thermoluminescence (TL) dates from the loessic sediments in sections from the Swat valley provided younger ages than earlier workers had suggested. This is consistent with reworking of the loess in these areas. It is concluded that care must be taken when using loessic silts for TL in similar mountainous terranes.
Key Words: Loessic silt, sedimentology, thermoluminescence dating, intermontane basins, Swat.

O/51. Owen, L.A., Finkel, R.C., Caffee, M.W. & Gualtieri, L., 2001.Timing of multiple late Quaternary glaciations in the Hunza Valley, Karakoram Mountains, northern Pakistan: Defined by cosmogenic radionuclide dating of moraines. Geological Society of America Bulletin 114(5), 593-604.

Moraines and associated landforms in the upper Hunza Valley, Karakoram Mountains, northern Pakistan, provide an excellent record of multiple glaciations. During the late Quaternary, glaciers advanced at least eight times. By using 10Be and 26Al surface-exposure dating on moraine boulders and scoured bedrock, we determined the timing of glaciation for four of these glacial advances: ca. 54.7–43.2 ka (Borit Jheel glacial stage), ca. 25.7–21.8 ka (Ghulkin I glacial stage), ca. 18.4–15.3 ka (Ghulkin II glacial stage), and ca. 10.8–9.0 ka (Batura glacial stage). For two of the older advances, the Yunz and Shanoz glacial stages, our data set a limit of >60 ka. Although, at present, the uncertainties in dating make it impossible to describe unequivocally the climate processes controlling glaciations in the Hunza Valley, the results suggest that precipitation changes related to oscillations in the southwest Asian monsoonal system combine with cooling that is broadly associated with Heinrich events to cause glacial advances in this region.
Key Words: Glaciation, Late Quaternary, Hunza, Karakoram.