L/1. Labonne, B., 1995. Geological endowment and mining potential of Pakistan: An overview. Proceedings, International Round Table Conference on Foreign Investment in Exploration and Mining in Pakistan, Islamabad, October 16-18, 1994, 31-42.

Key words: Mineral deposits, exploration, mining,

L/2. La Fortune, J.R., 1989/8. Geology and geochemistry of Indian plate rocks south of the Indus suture, Besham area, northern Pakistan. MS Thesis, Oregon State University, Corvallis, 70p.

Consult the following account for further information.
Key words: Geochemistry, structure, Indian Plate, Indus Suture, Besham.

L/3. La Fortune, J.R., Snee, L.W. & Baig, M.S., 1992. Geology and geochemistry of Indian plate rocks south of the Indus suture zone, Besham area, Northwest Himalaya, Pakistan. Kashmir Journal of Geology 10, 27- 52.

The Himalayan mountains are the geologic manifestation of continental collision, and in North Pakistan the Main Mantel Thrust (MMT) is major suture along which the collision occurred. The basement rock near Besham Village in southern Kohistan, adjacent to MMT, are bounded on the east and west by north-trending high-angle faults. These basement rocks that are significantly different from any of the other plutonic and metamorphic rocks of the southern Kohistan and that are not seen elsewhere in the Pakistan Himalaya west of the Nanga Parbat-Haramosh massif (NPHM).
Rocks of the Besham area are subdivided from oldest to youngest into five groups. The oldest rocks of the Besham area are; (1) the metasediments and heterogeneous gneisses of the Besham group. In conjunction with field evidence, major, trace and rare earth element analysis of Besham gneisses suggest that the quartzofeldspathic gneisses formed in situ from a sedimentary protolith. The presence of both quartzofeldspathic gneiss and sodic quartzofeldspathic gneiss in the Besham group may be attributable to variable protolith composition or more likely, the sodic gneiss was derived from intrusive protolith that was strongly transposed during deformation. These sodic gneisses are equivalent to the previously named Lahor granite. The Besham group was intruded by (2) mafic dikes that were subsequently metamorphosed to amphibolites. Geochemical data suggest that these tholeiitic dikes have island arc geochemical affinities. (3) The third group rocks comprise cogenetic, small granitic intrusions and associated pegmatites; the Shang granite, the Dubair granodiorite and the Shorgara pegmatite. Unconformably lying upon these three units is (4) the Karora group, which comprises conglomeratic, calcareous and carbonaceous sedimentary rocks. The Karora group provides evidence for more than one metamorphic event in the Besham area, i.e., the Karora group is metamorphose to lowergreenschist facies, in contrast, the underlying Besham group is metamorphosed to epidote amphibolite facies. The youngest unit observed in the Besham area is (5) a relatively undeformed leucogranite that intrudes both the Karora group and the Besham group. The metamorphic and granitic rocks of the Besham area may be correlative with the basement rocks of the Nanga Parbat-Haramosh Massif. Specifically, the quartzofeldspathic gneisses of the Besham group may correlate with the Nanga Parbat gneisses and the amphibolites found in the Besham area may correlate with mafic dikes of the massif. Further study of both the Besham area and the Nanga Parbat-Haramosh Massif can provide a better understanding of Precambrian basement rocks of northern Pakistan.
Key words: Stratigraphy, geochemistry, structure, Indian Plate, Indus Suture, Besham.

L/4. Laghari, A., 1945. The occurrence of bitumen in the Punjab Salt Range and the Kohat area and its bearing on the age of Saline Series. Proceedings, Indian National Academy of Sciences, Section B, Volume 14(6), 329-333.

Key words: Coal, Kohat, Salt Range, Punjab.

L/5. Landis, E.R., Reinemund, J.A., Cone, G.C., Schlick, D.P. & Kebblish, W., 1971. Analyses of Pakistan coals. USGS Project/GSP Information Release, PK-58, 71p.

Between 1952 and 1969, a total of 71 samples of Pakistan coals were collected, described, and analyzed by standardized methods and procedures. Descriptions of all the samples as reported by the collectors and complete coal analyses as reported by the U. S. Bureau of Mines are presented in this report.
Key words: Coal, Pakistan.

L/6. Latham, M.H., 1939. Some Eocene ostrocoda from North West India. Proceedings, Royal Society of Edinburgh 59(1), 38-84.

Key words: Ostrocoda, Eocene.

L/7. Latif, A., 1977. Groundwater conditions in Paharpur area, District Dera Ismail Khan. M.Sc. Thesis, Peshawar University.

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

L/8. Latif, M. & Fayaz, A., 1987. Road alignment studies along Gilgit-Gupis road, Northern Areas. Geological Survey of Pakistan Information Release 292.

Road alignment and related studies along Gilgit – Gupis roads were carried out during the field season of 1986. The road which 110 km long is jeepable in fair weather conditions. Geological mapping and study of seven bridge sites from the engineering geological point view was done. The entire road was devided into 20 sectors and a comparative statement showing the material exposed, problems, remedial measures and blasting pattern was prepared. At certain places realignment of road was also proposed. proper execution and implementation of recommendation made, may help to great deal in construction, of better road and bridges.
Key words: Engineering geology, Gilgit-Gupis road.

L/9. Latif, M. & Hussain, H., 2002. Limestone quarry sites around Islamabad and Kohat. Geological Survey of Pakistan Information Release 721.

The beautified and green Margalla Hills of Islamabad are being eaten up by limestone mining and crushing which in addition to the destruction of the natural landscape, is causing large scale environmental degradation and air pollution. To find out the alternate limestone reserves, the investigation in the surrounding areas of Islamabad was carried out in April, 2000. As a result of this investigation six different sites have been identified. These new sites are Khairi Murat, Kala Chitta Pathargarh Khanpur, Ganghar and Kohat ranges.The Margalla range which is already being mined has been studied as a reference site, The new sites have been selected in view of their relatively more favorable occurrences in sufficient quantity and their easy accessibility. Brief description of locations, accessibility, reserve estimates and geology of the six new sites and the existing mining area of the Margalla Hills range are given in the report.
Key words: Limestone quarry, Margalla hills, Islamabad, Kohat.

L/10. Latif, M. & Khan, N.A., 1999a. Geological Map of Gahkuch-Roshan quadrangle (Toposheet No. 42 H/12, Scale 1:50,000) District Ghizer, Northern Areas, Pakistan. Sheet No. 1227, GSP. Geological Map Series.

Key words: Geology, Gahkuch, Ghizar.

L/11. Latif, M. & Khan, N.A., 1999b. Geological Map of Bara Pani quadrangle (Toposheet No. 43 M/8, Scale 1:50,000), District Skardu, Northern Areas, Pakistan. Sheet No. 1404, GSP. Geological Map Series.

Key words: Geology, Bara Pani, Skardu.

L/12. Latif, M., Khan, T., Fayaz, A. & Shah, S.H., 1998. Geology of Kargah quadrangle, District Gilgit, Northern Areas of Pakistan. GSP Information Release 675.

The KarGah quadrangle (43 1/1) lying in the district Gilgit has been mapped on 1:50,000 scale. Mapped area shows variety of rocks including metasedimentary, metavolcanic and plutonic. Metasedimentary and metavolcanic rocks are classified as Gilgit formation (parapeisses and schists together with amphibolites), Thelichi formation (turbidites, marble, green schist and basic dyke) and Greenstone complex (metavolcanics and metatuffs). The plutonic rocks are named as the Kohistan batholith which consists of diorite, granodiorite, granites aplite and pegmatite.
Structure of the mapped area is depicted by a syncline which is occupied by the rocks of the Thelichi formation. The mapped area contains mineral showings of insignificant economic importance.
Key words: Mapping, Kargah, Gilgit.

L/13. Latif, M.A., 1962. An Upper Cretaceous limestone in the Hazara District. Geological Bulletin, Punjab University 2, p.57.

In the Hazara District of West Pakistan, there occurs a limestone, 300 to 400 feet in thickness, above the Giumal Sandstone and below the un-doubted Tertiary sequence. It was described by Middlemiss (pp. 39-40) who was not sure of its age, but placed it at the base of his Nummulitic Series (Eocene), primarily for the convenience of mapping. At the base of the limestone is a bright orange yellow sandy limestone, about 6 to 10 feet thick, which contains a rich assemblage of definite Cenomanian fossils (op. cit. pp. 35 - 38). The top of the limestone is strongly lateritized, generally to a depth of 5 feet, and even more; and usually marks the small time-break to the overlying carbonaceous shales with inferior coal bands of early Tertiary age.
The limestone is very fine grained and pale grey on the freshly broken conchoidal fracture surfaces. It usually weathers creamy white, and occasionally dark grey. It is more thickly bedded at the base than the top, where it develops an uneven platy appearance due to the frequent alternations of limestone and very thin marly layers. This gives the rock a rather distinctive appearance compared with other limestones in the succcssion.
During the recent remapping of the region, a rich assemblage of small pelagic Foraminifera was found at a number of localities (Darband 33 56', 72 19' : Dungagali 34 3', 73 22': and Khan 34 8', 73 19').
Detailed work on these microfossils is in progress and the results will be published in full later. From the preliminary investigations of thin sections, however, the Foraminifera Globotruncana, Heterohelix, Rugoglobigerina and Pseudotextularia have been seen to occur, frequently, particularly in the upper part of the limestone. These genera are characteristic of the Upper Cretaceous, and, therefore, the limestone may be assigned definitely to this Series. It is interesting to note that the Parh Limestone of Baluchistan is of same age, and bears a striking similarity in the field.
Key words: Limestone, Cretaceous, Hazara.

L/14. Latif, M.A., 1963. Stratigraphy of the Hazara District, West Pakistan. 15th All Pakistan Science Conference, Lahore, p.15.

Key words: Stratigraphy, Hazara.

L/15. Latif, M.A., 1964. Criteria used in identification of various limestones in Hazara. 16th All Pakistan Science Conference, Lyallpur.

Key words: Limestone, Hazara.

L/16. Latif, M.A., 1968. Contributions to the geology and micro-palaeontology of Hazara, West Pakistan. Sond. Verh. Geol. Bund. Austria 3, 92-94.

Key words: Palaeontology, Hazara.

L/17. Latif, M.A., 1969. The stratigraphy of southeast Hazara and parts of the Rawalpindi and Muzaffarabad districts of West Pakistan and Kashmir. Ph.D. Thesis, London University, England.

Key words: Stratigraphy, Hazara, Rawalpindi, Muzaffarabad.

L/18. Latif, M.A., 1970a. Micropaleontology of the Chanali Limestones. Upper Cretaceous of Hazara, West Pakistan. Jahrbuch der Geolgische Bundesansatalt (Wien) 15, 25-61.

A sequence of limestones, considered as the basal beds of Eocene, have been identified as a mappable, lithostratigraphic unit and given a new formation name, the Chanali Limestone. The microfaunal studies of 5 samples, further reveal the presence of more than 30 species, 16 belonging to planktonic and 15 to benthonic foraminiferida and 3 to Ostracoda. An Upper Coniacian to Campanian age for the formation is established.
Key words: Micropaleontology, Chanali Limestones, Cretaceous, Hazara.

L/19. Latif, M.A., 1970b. Explanatory notes on the geology of southeastern Hazara, to accompany the revised Geological Map. Wein Jahrb. Geol. Bundasant, Sonderb. Austria 15, 5-19.

This is a brief account of the stratigraphy of over 1000 square miles of south eastern Hazara, West Pakistan, supported by a geological map on a scale of one inch to one mile. The mapping is based on the recognition of lithostratigraphic units, which are briefly described with modernization of nomenclature. The rocks are divided into 7 groups and subdivided into 21 formations, some provisional. The strata range from Eo-Cambrian?/Cambrian to Recent. Diagnostic fossils evidence wherever available is given. A correlation with adjoining areas is attempted.
Key words: Geology, geological map, Hazara.

L/20. Latif, M.A., 1970c. Micropalaeontology of the Galis Group, Hazara, West Pakistan. Wein Jahrb. Geol. Bund. Austria 15, 63-66.

Key words: Micropaleontology, Galis group, Hazara.

L/21. Latif, M.A., 1970d. Lower Carboniferous rocks near Nowshera, West Pakistan. Geological Society of America, Bulletin 81, 1585-1588.

No abstract available for this account.
Key words: Carboniferous, Nowshera.

L/22. Latif, M.A., 1972a. Lower Palaeozoic (? Cambrian) hyolithids from the Hazara Shale, Pakistan. Nature, Physical Science 240(100), 92-93.

The age of rocks forming the Lower Himalayas of Nepal and of the Kumaon, Garhwal, Simla, Kashmir and Hazara areas in the northwestern part of the Indo-Pakistan subcontinent has long been the subject of considerable controversy. The rocks include the Simla Slates, the Chandpur and Nagthat beds, as well as the Hazara Group and Tanol Formation of the Hazara District in northern Pakistan, which are separated from the overlying clastic and carbonate sediments by a disconformity marked by a glacial conglomerate known as the Blaini boulder bed in Nepal

and India and the Tanakki boulder bed in Hazara, Pakistan. The post-Blaini or post-Tanakki sequence is known as the Infra-Krol and Krol beds in Nepal, Kumaon and Simla, and as the Abbottabad Group in Hazara1,2. In the absence of fossil evidence, both the Blaini and Tanakki boulder beds have been correlated with the fossiliferous Talchir boulder bed and, accordingly, considered to be of Upper Carboniferous-Permian age.
Key words: Palaeontology, Hazara.

L/23. Latif, M.A., 1972b. An occurrence of Paleozoic phosphate rocks in Hazara District, West Pakistan. Transaction Institute of Mining and Metallurgy (Section B: Applied Earth Sciences) 81, 850-853.

Key words: Paleozoic, phosphate, Hazara.

L/24. Latif, M.A., 1973. Partial extension of the evaporite facies of the Salt Range to Hazara, Pakistan. Nature, Physical Science 244(138), 124-125.

The age of the Salt Range Formation (formerly the Saline Series of Wynne) has long been controversial. The problem of age has revolved around two factors-the fossil evidence and the contact with the overlying Palaeozoic sequence. A third factor-the presence of Slate Series in other areas of the Indo-Pakistan subcontinent-has not been considered, despite the fact that both the Salt Range Formation and the Slate Series mark the oldest known rocks of enormous thickness and with an unknown base6,7 in their respective areas of development.
Key words: Evaporites, Salt range, Hazara.

L/25. Latif, M.A., 1974a. A Cambrian age for the Abbottabad Group of Hazara, Pakistan. Geological Bulletin, Punjab University 10, 1-20.

The Lower Himalayas all along are dominantly composed of a thick sequence of quartzites, sandstones and dolomites overlying what are known as Slate Series named variously at different localities. One such sedimentary sequence mapped earlier (1970) by the author as Abbottabad Group is the subject of study in this article. Like similar other rocks sequences in other parts of Indo-Pakistan the age has been unknown for want of fossil evidence. The majority of previous workers have for reasons of glaciated Tanakki conglomerate proposed a post carboniferous age for the problematic sequence. The rock sequence has been described starting with the Hazara Group followed by the Tanol Formation. These are considered to be from Eo-Cambrian to Basal Cambrian. Abbottabad Group follows after a break marked by Tanakki Conglomerate followed by Sangargali Member, Mahmadagali Member and Mirpur Member all belonging to Kakul Formation. These are followed by a dolomite sequence, the Sirban Formation, which in upper parts is cherty and phosphatic. After a break, said to be gradational in few sections, (?), the Abbottabad Group is followed by Tarnawai Formation composed of Galdanian and Hazira members, known to be facies equivalents of each other. Galdanian Member is composed of red haematitic mudstones, clay-stones etc. and Hazira Member of yellowish sandstone and siltstone rich in glauconite in lower parts. The Tarnawai Formation is followed by the Thandiani Group of Jurassic age.
Fossil, Hyoliths and Chencelloria have been recorded from the Hazira Member and a Cambrian age is assigned to the rock sequence lying above Tanol Formation and below Hazira Member. The sequence has been correlated partly with the Cambrian sequence of Salt Range and Iran. The lithologically similar sequence in other parts of Indo-Pakistan are suggested to be the possible equivalents of Abbottabad Group.
Key words: Cambrian, Abbottabad, Hazara.

L/26. Latif, M.A., 1974b. A review of the study of phosphatic rocks in Hazara District, Pakistan. Geological Bulletin, Punjab University 10, 91-94.

Key words: Phosphates, Hazara.

L/27. Latif, M.A., 1974c. A new evidence to solve the controversy of paleo-glaciation in Indo-Pakistan. Geological Bulletin, Punjab University 11, 1-6.

Evidences show that unconformity is not restricted to Tanaki Member horizon; the conglomerate occurs at levels other than Tanakki Member; the Tanakki Member is composed entirely of rocks of local origin, mainly sedimentary, as against Talchir Boulder Bed where these have been transported from far off distances and are mainly composed of crystalline rocks; the red and purple sandstones, quartzites add dolomites always occur younger than Tanakki Member whereas lithologically identical rock units always occur older than Talchir Boulder Bed; fossil Hyolithes, Chancelloria etc. of Cambrian age are found to occupy a younger position in sequence than Tanakki Member and there is a possibility of the presence of globular organisms of Algonkian affinities in the Blaini Beds of Simla India. It is suggested that Tanakki Member and Talchir Boulder Bed belong to two different phases of glaciation, the former being older, possibly Cambrian or topmost Pre-Cambrian.

Key words: Paleo-glaciation, Tanakki conglomerate, Cambrian.

L/28. Latif, M.A., 1976. Stratigraphy and micropaleontology of the Galis Group of Hazara, Pakistan. Geological Bulletin, Punjab University 13, 1-64.

The Galis Group is composed of 6 distinct mappable units recognized as formations. The gray limestone considered as Eocene by Middlemiss (1896) in fact of Upper Cretaceous age and has been separated as Kawagarh Formation at the top of the Hothla Group. The contact between Hothla and Galis groups is marked by a break in deposition followed by laterite/limonite/hematite/ and coal/bituminous shales. The group contains 75 species of Foraminferida and genera of Ostracoda, recorded and described from Hazara for the first time. The Group ranges in age from Lower Paleocene to basal Middle Eocene. The southeastern parts of the area indicate relatively shallower conditions of deposition. During the deposition of the Galis Group, intermittent phases of transgression and regression are recorded with a tendency towards a complete withdrawal of marine conditions upward in the succession.
Key words: Stratigraphy, micropaleontology, Galis Group, Hazara.

L/29. Latif, M.A., 1980. Overstep by Thandiani Group, Jurassic over older rock sequences in Hazara. Contributions to the Geology of Pakistan 1, 1-8.

Of the seven unconformities recorded in the sequence of rocks in Hazara the lower three disconformities merge into one composite unconformity. This leads to an overstep by Toarcian rocks over, the Eo-Cambrian rocks. An attempt has been made to elaborate the varied effect of various unconformities on the underlying sequences in various parts of Hazara which led to the formation of the composite unconformity.
Key words: Stratigraphy, Thandiani, Hazara.

L/30. Latif, M.A., 1992. Tectonic control of stratigraphic and facies variations in the Mesozoic and Paleogene rocks, in Hazara, Islamabad & Kashmir. Abstracts, First South Asia Geological Congress, Islamabad, p.26.

Key words: Tectonics, stratigraphy, facies, Mesozoic, Hazara, Kashmir.

L/31. Latif, M.A., Afzal, M.S., Qureshi, M.N., Munir, M.H. & Ahmed, N., 1991. Geological setting and landslide Hazara at Kalabun and Riala south-east Hazara, NWFP. Kashmir Journal of Geology 8 & 9, 133-138.

Location of Kalabun and Riala in the vicinity of regional thrusts; presence of extensive faulting and folding; very high relief; denudation of softer shales at the toe of high ridge by local streams and chemical and mechanical action together seem to be responsible for sliding in the area.
Key words: Structure, geography, hazards, landslides, Hazara.

L/32. Latif, M.A., Lodhi, S.A.K., Qureshi, M.N. & Munir, M.H., 1991. Geological, mineralogical and geotechnical investigations of laterite from Changlagali area of Hazara division. Kashmir Journal of Geology 8 & 9, 165-172.

Indian plate movement after the deposition of Cretaceous Kawagarh Formation and prior to the Paleogene deposition created conditions suitable for the formation of Hangu Formation which the product of lateritization of old limestone surface. The laterite beds exposed near Changlagali, on Murree-Abbottabad road were measured and sampled for this study. The samples dominantly consist of gray colored pisoliths embedded in a gray to creamish brown matrix. Mineralogically, geothite and boehmite are the two distinct phases in laterite. Geochemical analyses show that the percentage of alumina decreases in the upper parts of the beds, whereas, the percentage of iron increases with the decrease of alumina in the beds. The general trend is desilicification in the middle of the beds. In the upper part of the beds the percentage of silica is increasing because of leaching out of the elements due to weathering phenomenon. The firing of samples at above 900 °C produces beautiful red colors. It is deducted that materials are suitable for the manufacturing of surface tiles.
Key words: Mineralogy, petrology, laterite, Changlagali, Hazara.

L/33. Latif, M.A., Munir, M.H., Qureshi, M.A., Ahmed, N. & Tareen, M.S., 1992. The facies control of mineralization of the Hangu Formation in Hazara, Islamabad and Azad Kashmir. Kashmir Journal of Geology 10, 161-168.

The Hangu Formation (Paleocene) reveals a range of lithologies in Hazara – Islamabad, northern Rawalpindi District and Azad Kashmir areas. Five lithologies comprise, the Hangu Formation i.e., bauxite facies (Azad Kashmir), laterite facies (Southern Hazara), haematite facies (central regions of Hazara), laterite cum arenaceous facies (mid northwestern Hazara region) and arenaceous/quartzite facies (northwest Hazara region). The five facies are delimited by thrust and have been recognized as the member of the Hangu Formation.
Key words: Mineralogy, lithology, Hangu Formation, Hazara.

L/34. La Touche, T.D., 1892. Report on the oil springs at Moghal Kot in Shirani Hills. Geological Survey of India, Record 25(4), 171-175.

Key words: Hydrocarbons, oil, Shirani Hills.

L/35. La-Touche, T.D., 1893. Geology of the Shirani Hill. Geological Survey of India, Record 26(3), 77-96.

Key words: Geology, Shirani Hills.

L/36. La Touche, T. D., 1917. Bibliography of Indian Geology and Physical Geography; with an Annotated Index of Minerals of Economic Value, 2 Vols: 571 + 490 + 143 p. Geological Survey of India, Calcutta.

Key words: Bibliography, geography, economic minerals.

L/37. Laurs, B.M., Dilles, J.H. & Snee, L.W., 1996a. Geologic origin of gem-bearing pegmatites, Stak Nala, Haramosh massif, Pakistan. Abstract volume, 11th Himalaya-Karakoram-Tibet Workshop, Flagstaff, Arizona (USA), 83-84.

Gem-bearing pegmatites and associated leucogranite bodies are widely distributed in rocks of the Pakistan Himalaya, within both the Nanga Parbat-Haramosh Massif of the Indian Plate and in the Asian Plate to the north. The Stak Nala pegmatites are located (ca. 35°59′; 75°02′E) near the eastern portion of the massif, where late tectonic

Himalayan leucogranites (U/Pb zircon ages of 2 to 13 Ma) were emplaced during late Neogene uplift (Zeitler and Chamberlain, 1991). The pegmatites are hosted by granoblastic-textured ortho-and para-gneiss (Shengus gneiss of Verplanck, 1986) metamorphosed at granulite facies (8 to 13 kb, 650-700°C) (Pognante et al., 1993). In the mine area, cm- to m-scale banded biotite-muscovite±garnet granitic gneiss dominates.

The Stak Nala pegmatites contain the only known economic concentration of gem quality pink-green tourmaline in the region. The pegmatites are mined west of and 400 m above the Stak Nala valley over a 0.5 km distance, but similar pegmatites extend 3 km south. Pegmatites are typically <1-m thick and locally up to 5-m thick. Most pegmatites are emplaced along the gently dipping S1-foliation (& F1 folds with top-to-south shear) of the Shengus gneiss, but in detail are slightly discordant sills. The pegmatites also cross-cut a series of N60°W striking, 60°N-dipping monoclinal F2-flexural shears with gneissic layers attenuated within the dipping limbs. These fold-shears are interpreted to be deep, ductile normal faults related to Neogene uplift of the massif. The pegmatite emplacement locally deforms gneissic wall-rock foliation and hence occurred while the gneiss was hot enough to allow ductile deformation of quartz (>300°C). Late brittle normal faults reactivate the F2-shears, offset pegmatites, and contain local sericite-pyrite hydrothermal alteration inferred to have formed at ca.250°C. Two 40Ar/39Ar plateau ages on white micas (closure temperature ca. 325°C) yield 5.80±0.05 Ma for wall-rock gneiss and 4.63±0.12 Ma for the pegmatite. If the micas have the same structural state, these data suggest the gneissic wall-rock cooled to 325°C at 5.8 Ma slightly prior to pegmatite emplacement.

In the mine area, at least six pegmatites separated by 3 to 20m occur within a 100m section of gneiss. All these pegmatites have complex mineralogic zonation, microlitic cavities, coarse grain-size, and quartz, orthoclase, sodic plagioclase, muscovite, and schorl tourmaline. The most productive pegmatite has been mined in a zone 100m by 60m. The thickest portion of the pegmatite (1.0 to 1.2 m) is most productive; the northern thin (<0.7 m) portion in non-productive. The productive zone is bounded on the north by an F2 fold, which forms an anticline that may have trapped volatile components to produce gem tourmaline. The pegmatites display a simple internal zonation from the wall-rock contact inward; border and intermediate zones symmetrically enclose a central core zone (Fig. 1). The border zone is ca. 10 cm thickened characterized by coarse-grained (1 to 7 cm) albite, orthoclase, and quartz, and medium-grained schorl, garnet, and loellingite. Large (15 to 30 cm) perthite crystals nucleate within the border zone and flare into the intermediate zone, accompanied by locally abundant schorl prisms. Schorl, albite and quartz form irregular coarse-grained intergrowths which are rarely graphic in texture; loellingite (<0.1 vol.%) is widespread. The core zone is at or slightly above the pegmatite centerline, and is marked by an abrupt increase in blocky, commonly albitized, and perthite crystals. Albite, quartz, schorl, muscovite (rare lepidolite), and green fluorite of variable grain size (1 mm to 10 cm) are essential.

Gem tourmaline-bearing pockets occur sporadically within the core zone. The pockets range in size up to 2*3*0.5 m, and are lined by albite (wedge-shaped crystals and cleavelandite), topaz, green fluorite, and pink-brown fluorapatite; columbite-tantalite, pyrochlore, and hambergite form rarely. A thin layer of hypogene fine-grained illite partially covers pocket minerals, and together with soil fills the remaining pocket cavity. Associated with some pockets are irregular bodies of sugary albite, garnet, and tourmaline, which locally extend into the surrounding intermediate zone. These may be pressure-quench aplite derived from abrupt fluid escape during pocket rupture, as described at pegmatites in San Diego County, California (Ford, 1976).

The wall-rock is bleached up to 7 cm from the pegmatite and contains metasomatic albite, muscovite, and tourmaline. Wall-rock alteration increases with pegmatite thickness and amount of pocket mineralization, and is most extensive in biotite-rich gneisses where tourmaline extends up to >50 cm along foliation. Pegmatite-derived fluids have added, B, Fe, Rb, Zn, Zr, and Nb, and leached K, Ba, and Sr from the wall-rocks.

We conclude that pegmatite gem mineralization at Stak Nala formed during the late Neogene uplift of the Nanga Parbat-Haramosh Massif, probably after the granulite-facies host rocks has cooled to 300 to 350°C at pressures of <2 kb (based on miarolitic cavities). The pegmatites are derived from leucogranite magmas enriched in Si, Al, Na, K, B, F, Li, Rb, and H2O that formed from low degrees of partial melting of a metapelite source during decompression (?). The high concentration of rare elements in the narrow pegmatite dikes is probably due to extreme fractionation of vapor-saturated magma.

Key words: Gems, pegmatites, granites, Stak Nala, Nanga Parbat-Haramosh.

L/38. Laurs, B.M., Dilles, J.H. & Snee, L.W., 1996b. Emerald mineralization and metasomatism of amphibolite, Khaltaro granitic pegmatite-hydrothermal vein system, Haramosh Mountains, northern Pakistan. Canadian Mineralogist 34, 1253-1286.

Emerald mineralization is found within 0.1- to 1-m-thick hydrothermal veins and granitic pegmatites cutting amphibolite within the Nanga Parbat-Haramosh massif, in northern Pakistan. The amphibolite forms a sill-like body within garnet-mica schist, and both are part of a regional layered gneiss unit of Proterozoic (?) age. The $^{40}Ar/^{39}Ar$ data for muscovite from a pegmatite yield a plateau age of 9.13+ or -0.04 Ma. Muscovite from mica schist and hornblende from amphibolite yield disturbed spectra with interpreted ages of 9 to 10 Ma and more than 225 Ma, respectively, which indicate that peak Tertiary metamorphism reached 325 to 550 degrees C prior to 10 Ma. Pegmatites were emplaced after peak metamorphism during this interval and are older than pegmatites farther south in the massif. At Khaltaro, simply zoned albite-rich miarolitic pegmatites and hydrothermal veins containing various proportions of quartz, albite, tourmaline, muscovite, and beryl are associated with a 1- to 3-m-thick heterogeneous leucogranite sill, that is locally albitized. The pegmatites likely crystallized at 650 to 600 degrees C at pressures of less than 2 kbar. Crystals of emerald form within thin (<30 cm) veins of quartz and tourmaline-albite, and more rarely in pegmatite, near the contacts with altered amphibolite. The emerald-green coloration is produced by Cr and Fe. The Cr and total Fe contents, expressed as Cr_2O_3 , and Fe_2O_3 , respectively, decrease systematically from emerald (>0.20, 0.54-0.89 wt%), to pale blue beryl (< or = 0.07, 0.10-0.63%), to colorless beryl (<0.07, 0.07-0.28%). The amphibolite is metasomatized in less than 20-cm-wide selvages that are symmetrically zoned around veins or pegmatites. A sporadic inner zone containing F-rich biotite, tourmaline, and fluorite, with local albite, muscovite, quartz, and rare beryl, gives way to an intermediate zone containing biotite and fluorite with local plagioclase and quartz, and to an outer zone of amphibolite containing sparse biotite and local quartz. The inner and intermediate zones experienced gains of K, H, F, B, Li, Rb, Cs, Be, Ta, Nb, As, Y and Sr, and losses of Si, Mg, Ca, Fe, Cr, V and Sc. The outer alteration zone has gained F, Li, Rb, Cs, and As. Oxygen isotope analyses of igneous and hydrothermal minerals indicate that a single fluid of magmatic origin with delta 18 OH 2 O = 8 per mil produced the pegmatite-vein system and hydrothermal alteration at temperatures between 550 and 400 degrees C. The formation of emerald result from introduction of HF-rich magmatic-hydrothermal fluids into the amphibolite, which caused hydrogen ion metasomatism and released Cr and Fe into the pegmatite-vein system.
Key words: Emerald mineralization, amphibolites, metasomatism, pegmatites, granites, Stak Nala, Nanga Parbat Haramosh.

L/39. Laurs, B.M., Dilles, J.H., Warraich, Y., Kausar, A.B. & Snee, L.W., 1998. Geological setting and petrogenesis of symmetrically zoned, miarolitic granitic pegmatites at Stak Nala, Nanga Parbat-Haramosh massif, northern Pakistan. Canadian Mineralogist 36, 1-47.

Miarolitic granitic pegmatites in the Stak valley in the northeast part of the Nanga Parbat-Haramosh Massif, in northern Pakistan, locally contain economic quantities of bi- and tricolored tourmaline. The pegmatites form flat-lying sills that range from less than 1 m to more than 3 m thick and show symmetrical internal zonation. A narrow outer or border zone of medium-to coarse-grained oligoclase--K-feldspar-quartz grades inward to a very coarse-grained wall zone characterized by K-feldspar-oligoclase-quartz-schorl tourmaline. Radiating sprays of schorl and flaring megacrysts of K-feldspar (intermediate microcline) point inward, indicating progressive crystallization toward the core. The core zone consists of variable mixtures of blocky K-feldspar (intermediate microcline), oligoclase, quartz, and sparse schorl or elbaite, with local bodies of sodic aplite and miarolitic cavities or "pockets". Minor spessartine-almandine garnet and lollingite are disseminated throughout the pegmatite, but were not observed in the pockets. The pockets contain well-formed crystals of albite, quartz, K-feldspar (maximum microcline+ or -orthoclase overgrowths), schorl-elbaite tourmaline, muscovite or lepidolite, topaz, and small amounts of other minerals. Elbaite is color-zoned from core to rim: green (Fe^{2+} and Mn^{2+}) -bearing), colorless (Mn (super 2+) -bearing), and light pink (trace Mn (super 3+)). Within approximately 10 cm of the pegmatites, the granitic gneiss wallrock is bleached owing to conversion of biotite to muscovite, with local quartz and albite added. Schorl is disseminated through the altered gneiss, and veins of schorl with bleached selvages locally traverse the wallrock up to 1 m from the pegmatite contact. The schorl veins can be traced into the outer part of the wall zone, which suggests that they formed from aqueous fluids derived during early saturation of the pegmatite-forming leucogranitic magma rich in H 2 O, F, B, and Li. Progressive crystallization resulted in a late-stage sodic magma and abundant aqueous fluids. Two late stages of volatile escape are recognized: the first stage caused pressure-quenching of the last magma, which produced aplite and caused albitization (An 3 to An 8) of earlier crystallized K-feldspar and oligoclase. The second stage, released during the rupture of miarolitic cavities, produced platy albite ("cleavelandite," An 1) locally associated with F-rich muscovite and elbaite. Albitization is likely due to cooling of alkali-fluoride-dominated fluids at less than 2 kbar pressure. The pegmatites are derived from Himalayan leucogranitic magma emplaced prior to 5 Ma into granulitic gneiss that was at 300 degrees to 550 degrees C and 1.5

to 2 kbar. The pegmatites were emplaced during uplift of the Haramosh Massif, since they cross-cut ductile normal faults but are cut by brittle normal faults. Economically important pink tourmaline mineralization formed in pockets concentrated near the crest of a broad antiform, as a result of trapping of late magmatic aqueous fluids that had become Fe-poor owing to the prior crystallization of schorl.
Key words: Petrogenesis, zoned pegmatites, granites, Stak Nala, Nanga Parbat-Haramosh.

L/40. Lawrence, L. & Malinconico, Jr., 1989. Crustal shortening in the west Himalaya. Geological Bulletin, University of Peshawar 22, 55-64.

The main collision between the Indian and Asian lithospheric plates occurred during the late Eocene (40 million years ago) and continued closure at the rate of 5 cm/yr has resulted in approximately 2000 km of crustal shortening between the two plates (Molnar and Tapponnier, 1975; Molnar, 1984). In northern India it has been suggested that while some of the shortening is by underthrusting (Molnar and Tapponnier, 1975) much may be the result of diffuse deformation in China (Tapponnier, 1982). However, in northern Pakistan the problem is complicated because there is no Tibetan plateau analog and no evidence of strike-slip structures that could have removed significant amounts of crustal material.
In order to place tighter constraints on tectonic models for the Indian-Asian collision in the western Himalaya it is important to be able to estimate the amount of crustal shortening that has occurred. Current estimates of 500 to 700 km of convergence in northwestern Pakistan (Butler, 1986), are calculated from balanced cross-section methods. This is significantly less than the 2000-km required by closure models based on paleomagnetic data (Powell, 1979, Molnar and Tapponnier, 1975; Molnar, 1984).
An important step in estimating the amount of shortening that has occurred is to determine the volume of crust that remains in the orogen. The crustal models based upon observed gravity profiles presented in this paper suggest that there may be enough crustal volume to account for between 550-1100 km of shortening. This is still significantly less than the 2000 km of closure that has presumably occurred. The balance of the closure might be account for by erosion and/or diffuse deformation or it might suggest that less than 2000 km of closure has occurred in the northwestern Himalaya.
Key words: Structure, tectonics, collision, Himalaya.

L/41. Lawrence, R.D., 1982. West and Tibetan collision zone in Pakistan. EOS 63, p1112.

The northwestern margin of the subcontinental India in Pakistan is characterized by two major suture zones. The one on the west juxtaposes the Afgan block with India. That in the north (commonly referred to the Indus Suture) juxtaposes the Kohistan island arc terrain against India. These are described in this note. Major tectonic features record the transition from convergence in the Himalaya and Tibet to transform on the Chaman fault system in northern Pakistan. The Main Boundary thrust can be traced to the south side of the Safed Koh where it overrides the Sulaiman fold belt. It ends abruptly where the Sarubi tear fault abuts the Heart fault. The Main Central thrust becomes obscure in eastern Kashmir. Beyond the Hazara-Kashmir Syntaxis (HKS) its only possible expression is a deep seismic zone (IKSZ) under “flack tectonic” thrust sheets of Kohistan & Swat (Kohistan flakes). The Indus suture continues as the Main Mantle thrust to the Kunar fault, reappears around the Kabul block, and into the Quetta line; all marked by latest Cretaceous/Paleocene obduction. The Kabul block is a fragment of Lesser Himalayan terrain of the Indian subcontinent displaced by interactive motion on the Herat & Chaman faults. Significant stratigraphic contrasts subdivide the Lesser Himalayan terrain. The HKS & Nanga Parbat loop are neotectonic features on the eastern border of the Kohistan flakes with centers of rotation at their apices. Microplate line of Afghanistan-Nuristan-Pamirs-South Tibet is wrapped around the Kohistan flakes by rotation in the west, thrusting in the north (Pamir thrusts), & right-lateral translation in the east (Karakorum fault). Unscrambling of tectonic development requires (1) reverse translation and rotation of relatively rigid blocks, (2) unfolding and thrusting of marginal belts, and (3) reconstruction of areas concealed by over-thrusts. Key is reversal of motion on Chaman & Herat faults and reversal of rotation of Kohistan flakes.
Key words: Collision zones, tectonics, Tibet, Pakistan.

L/42. Lawrence, R.D., 1984a. An expedition to Pakistan. Science 226, p.1414.

This gives a brief account of the two volumes of the International Karakoram Project (K.J. Miller editor, 1984). Papers in these are annotated at appropriate places in this work.
The International Karakoram Project, K. J. Miller, Ed. Cambridge University Press, New York 1984. In two volumes. Vol. 1, xxx, 412 pp., Vol. 2, xxviii, 635 pp., From two conferences, Islamabad, June 1980, and London, Sept. 1981.
This two volume set contains papers delivered at conferences which that took place before and after the International Karakoram Project (IKP). The IKP was a major expedition into the remote Karakorum Mountains of northern Pakistan using the recently completed Karakorum Highway, which follows the old silk road between India and China. The project was undertaken, in a two-month period, during the summer of 1980s as part of the Royal Geographic Society’s 150th anniversary celebration. It brought together earth scientists mainly from three cooperation nations, the United Kingdom, Pakistan, and the People’s Republic of China. The principal studies involved glaciology, topography, seismology, housing as it relates to natural hazards, geomorphology, and geology.
The first volume contains papers delivered at the conference preceding the expedition. About a third of the volume is thus devoted to descriptions of techniques for gathering desired data. About a fourth is devoted to descriptions of the results of studies in distant areas that used techniques intended to be used in the IKP. The remainder of the book mainly describes projects planned in Pakistan and neighboring areas. Six papers report new results from previous work in Pakistan that are of lasting value. Four papers report the results of glaciological studies by Chinese scientists. Israr-ud-Din of Pakistan reports the results of his studies of house construction in Chitral in relation to the geographic setting. H. M. Rendell reports new work on the Quaternary history of the Potwar plateau. This volume is largely superseded by the second volume.
The second volume contains the results obtained by the IKP, Much information is published here for the first time and not all of it can be reviewed. One of the most ambitious efforts of the IKP was a resurvey of the 1913 triangulation connection between India and Russia in an effort to detect tectonic deformation across the Karakoram. This effort entailed major mountaineering, for the stations to be reoccupied were mostly mountain peaks between 4000 and 6000 meters high. The survey itself was successfully accomplished, but significant tectonic deformation was not detected. A substantial effort was made in glaciology, and many new data were obtained that will be increasingly useful as these baseline studies are replicated. A micro-earthquake survey was made with a portable seismic network. Most of the seismicity was under the Hindu Kush to the west. However, important seismicity was observed for the first time in the Kohistan area of northern Pakistan (south of Karakorum) and will provide guidance to future neotectonic studies. A large part of the volume is devoted to the study of housing and natural hazards. Many data on house construction and family use of homes were gathered that will interest ethnologists and anthropologists. A key element of the success of these studies was the presence of a female, F. D’Souza, for non-family males are not allowed inside the homes in this area. The housing team devoted considerable effort to attempts to determine the role of natural hazards in locating houses. Surprisingly in this area of very great natural hazard, they found that agricultural considerations, specifically preservation of cultivatable land and availability of irrigation supplies, essentially exclude natural hazards such as rock-fall, mudflow, flood, and earthquake from consideration when new houses are located.
The longest part of the volume deals with geomorphology. Extensive data on current processes are reported. Perhaps the most unexpected result here is that a dissolved load yielding sediment of 90 tons per square kilometer per year was measured on the Hunza River, indicating that substantial chemical weathering occurs even in a high, cold, arid area where it had always been considered to be negligible. One of the best papers in the collection deals with the Quaternary history of the Hunza Valley. Eight separate glacial phases are recognized, the older of them more than 139,000 years old. The oldest stages are recorded by remnants several thousand meters above the Hunza Valley floor. The sole weakness of the study is a failure to consider the effects of tectonic uplift interacting with glacial episodes. With uplift rates of over 1’ centimeter per year recorded in the area, the interaction must be significant. This is the first modern study of glacial chronology in northern Pakistan and will be of great value to other workers.
The IKP was an ambitious undertaking. Much was accomplished, but the project has the inherent weaknesses of short-term projects. In numerous in stances previous work is not adequately recognized. Little effort was apparently made to assist Pakistani colleagues to continue the studies, particularly those that established baseline data. These proceedings volumes are not as tightly edited as one would wish, but they do contain substantial amounts of valuable information.
Key words: Reconnaissance, expedition, Karakoram.

L/43. Lawrence, R.D., 1984b. Suture tectonics in Pakistan. Abstracts, First Pakistan Geological Congress, Lahore, p.49.

In Ladakh the Indus suture divides. A minor northern suture, the MKT, records a back arc basin north of the Kohistan-andesite arc. The major suture, which records the location of the Neotethys, is south of the arc. It is made up of a complex set of terrains and structures. Ultramafic rocks of three derivations can be distinguished in this suture, namely: (1) those emplaced by obduction, (2) those imbricated into subduction zones, and (3) those basal to the arc complex. Obducted material is present as an infolded klippe at Dargai and associated with emerald mineralization from Mohmand to Mingora. Subduction complex with blueschist, serpentinite, piedmontite schist, and phyllite is preserved at Shangla. Fossils of probable early Cretaceous age are present in subduction material near Mingora. Initial emplacement of subduction and abduction material in Swat occurred prior to continental collision. Ophiolite material of diverse origin is mingled by collision and its complex earlier history is obscured. This is demonstrated better in Pakistan than elsewhere in the world. As the suture is followed west and south from Swat, the subduction and obduction complexes become separated by the Khojak flysch. Subduction melange occurs at Khost, in the Altimur Range, and in the southern Ras Koh. Obduction masses occur at Waziristan, Muslimbagh, and Las Bela. The enormous Khojak flysch mass separates these, and collision has not gone to completion as is the case in the Himalayan Ranges.
Key words: Structure, tectonics, ultramafics, MKT.

L/44. Lawrence, R.D., Baig, M.S., Dilles, J.H., Lafortune, J.R., DiPeitro, J., Huges, S.S., Palmer.Rosenberg, P.S., Pogue, K., Snee, L.W., Tahirkheli, R.A.K., Ghauri, A.A.K., Jan, M.Q., Ahmad, I., Rafiq, M., Kazmi, A.H. & Hussain, A., 1989. Tectonics south of the Suture, northern Pakistan. Geologique Internationale Resumes – 28th International Geological Congress Section 2. No. 28, p.265.

In Pakistan the Indus suture zone is known as the Main Mantle Thrust zone (MMT) and separates the Kohistan andesitic arc complex from rocks of the Indian subcontinent portion of Gondwana. The latter, south of the MMT, are the hinterland of the Himalayan thrust system in Pakistan. In Swat and Besham areas prehimalayan deformation and early Himalayan metamorphism complicate interpretation of these rocks.
The MMT zone contains three separately mappable melanges in the Swat region. Mingora melange consists of ophiolite blocks and slabs in or on a metamorphosed talc-arbonate or serpentinite matrix that is tectonically interleaved with graphite schists at the base. Klippe of Mingora melange may be found 40 km south of the MMT. Charbagh melange is composed of greenschist of possible andesitic arc origin. The Shangla melange contains blueschist, serpentinite, and other exotic blocks in a sheared matrix of low grade metasediments and metavolcaoclastics. On the Indus River north of Besham the MMT is a fault at the base of the Jijal complex (peridotites and pyroxene granulites of the base of the Kohistan arc); suture melanges are absent. In Allai Kohistan east of the Indus River, blueschist and serpentinite melanges similar to those of southern Swat reappear in southern Swat the rocks under the MMT are stratigraphically divided by a significant unconformity. Below the unconformity are quartzofeldspathic and calc-silicate metasediments, Manglaur schist (MS). Above mi· the unconformity are the members, quartz-mica schists, amphibolites, calc-schists, marbles, graphite schists, etc. of the Alpurai formation (AF) of late(?) Paleozoic age. Member 5 maps south to stratigraphically overlie conodont-bearing lower Carboniferous rocks near Rustum. This Rustum Paleozoic section is fossiliferous from Ordovician to Carboniferous. The Paleozoic section of the SE Peshawar basin margin overlies with angular unconformity Precambrian Tanawal formation, a largely quartzose sequence probably correlative with MS. Granitic rocks of the Swat region were intruded at several different times. The Swat porphyritic granites (SPG) are unconformable beneath AF and intrude MS. These are peraluminous coarse-grained granites containing biotite, muscovite garnet. SPG correlates (?) with Mansehra granites east of Indus River (516 My Rb/Sr isochron). Small bodies of syntectonic Swat tourmaline granite (STC) intrude mainly along major contacts. These are peraluminous non-porphyritic rocks containing muscovite, tourmaline, epidote group minerals. STG REE patterns are similar to those of the SPG, but a factor of 5-10 less enriched; this is compatible with partial melting of the SPG to form the STG. About 20 km south of SPO outcrops, the Ambela granite (AG), associated with numerous small bodies of alkaline granites (Rb/Sr isochrons of about 300 My) intrudes Carboniferous sediments. These granites may reflect late Paleozoic rifting along northern Gondwana. Major and trace element chemistry confirm that the STO, AO, and STG are distinct magmatic entities. The youngest granites Include the small post-tectonic Malakand biotite granite whose Intrusive contacts cross cut Himalayan age metamorphic foliation. The upper rocks of Swat probably form a roof thrust 7S km. Marker units can be traced In overlapping sequence from the MMT to the Swabi region. AF Member 2 forms a regional marker

allowing detailed analysis of folding within this unit. The first two fold sets are synmetamorphic at or before Ar closure in hornblende at about 40 My. and have north-south or northwest-southeast axes. The first set is recumbent and west verging; the second set upright and west verging. Neither comprises sheath folds or other structures rotated into the direction of elongation; their axes do not define a stretching lineation. They occur only in the 20-30 km wide zone of high grade metamorphism, are associated with initial collision, and suggest left lateral strike slop along the suture with limited west-directed overthrusting (50 - 30 My). The youngest set of folds in the Swat area has eastwest axes associated with the onset of major south-directed thrusting. Folds of this pattern are present from the MMT south to the Salt Range. East of the Indus River stratigraphy and intrusive history are similar to Swat, but an imbricate pattern of south-directed thrusts developed in the Hazara Hills east of the Indus River. The most probable interpretation is an extensive roof thrust in Swat that overlies the imbricate duplexes revealed by deeper erosion to the east in Hazara. The Besham block is a stratigraphically and structurally distinct block along the Indus River. North-south, steeply dipping faults separate this block from its neighbors. Reconnaissance mapping suggests 'that these faults also cut the MMT itself and separate the portion of the MMT marked by the Jijal complex from the Swat and Allai Kohistan melange-bearing portions of the MMT.

Bresham block stratigraphy consists of heterogeneous quartzofeldspathic banded gneisses and metasediments, the Besham Group (BG), representing early Proterozoic(?) crystalline basement. Major and trace element variability in the gneisses suggests both paragneisses and in situ anatectic melts of pelitic sediments as the origin of these rocks. The BG is intruded by Labor granite (LG) which is clearly crustal melt. Pegmatites of LG intrude all lithologies of the BG. BG gneissic foliation and LG pegmatites are truncated by an angular unconformity at the base of marine metasediments of the Karora Group (KG). Fragments of all basement lithologies are found in the Karora Group (KG). Fragments of all basement lithologies arc found in the basal conglomerate of the KG. Above this unit the KG consists of graphitic phyllite overlain by siliceous dolomite. Metamorphic grade of the KG is middle greenschist. The higher metamorphic grades and anatectic events of the BG developed before the unconformity between these units. The KG can probably be traced into equivalent Precambrian phyllites unconformable under the Tunawal near Turbela. A common structural history for Besham and Swat blocks probably began with the younger north-south fold set. Recently the entire area was arched on a north-south axis to form the syntaxial bend of the MMT. The limbs of this structure are partly formed by brittle motion on steeply dipping northsouth trending faults. Some of these faults contain mafic and ultramafic slivers derived from suture melanges. In summary the Swat and Besham regions record different structural and metamorphic histories: in the former, late Precambrian to Paleozoic granites and sediments are deformed and intruded by tourmaline granites during Himalayan metamorphism and deformation; in the latter, an earlier Proterozoic metamorphism and magmatism are preserved below the suture.

Key words: Tectonics, Southern Suture, Himalaya.

L/45. Lawrence, R.D. & Ghauri, A.A.K., 1983a. Observations on the structure of the Main Mantle Thrust at Jijal, Kohistan, Pakistan. Geological Bulletin, University of Peshawar 16, 1-10.

Structures in the lower plate of the MMT at Jijal include a blastomylonite zone, Z-folds in the blastomylonite, and abundant slickensides in a breccia block. Blastomylonite foliation is cross-cut by intermediate granitic intrusive. A multi-stage history of the MMT involving (1) SE thrust motion on a deep shear zone, (2) uplift and granitic intrusion, (3) renewed thrust faulting and breccia formation at a shallow crustal level, and (4) folding of the MMT and cessation of thrust motion is suggested.

Key words: Tectonics, structure, MMT, Jijal, Kohistan, Himalaya.

L/46. Lawrence, R.D. & Ghauri, A.A.K., 1983b. Evidence of active faulting in Chilas District, northern Pakistan. Geological Bulletin, University of Peshawar 16, 185-186.

About 10km northeast from the town of Jalipur, a zone of breccia, 5-10km thick, is located along the Karakorum Highway. The breccia is found in Holocene fan-gravels developed at the foot of the Nanga Parbat massif. It is present at several locations along the road up to Raikot bridge, and also north of the confluence of the Indus and Astor River, Slickensides are developed in this breccia zone. Most of these appear to plunge along the dip of fault surfaces on which they are found. The trace of the fault is delineated by a line of hot springs, some right on the road and some on the river side. The ones located along the road can be easily spotted by the rising steam. The hot springs south of Raikot bridge are closely spaced and have a definite linear arrangement.

Key words: Structure, KKH, Nanga Parbat, Nanga Parbat.

L/47. Lawrence, R.D. & Ghauri, A.A.K., 1984. Tectonics of the western Indus suture in Pakistan. EOS 65, p.1094.

The Indus suture extends from southern Tibet to northwestern Pakistan. This is a brief account of the tectonics of the western part of the suture in Pakistan. The suture is associated by mélanges at places. In Ladakh, the Indus suture bifurcates. A minor northern suture, the MKT, records a backarc basin north of the Kohistan andesitic arc. The major suture is south of the arc. It is a made up of a complex set of terrains and structures. Ultramafic rocks initially emplaced by obduction, imbricated into subduction zones, and basal to the arc complex can be distinguished. At Dargai, A klippe of obducted material is intricately infolded into metasediments. In Swat, obducted material contains emerald mineralization in ophiolite metamorphosed to talc-carbonate. Subduction complex with blueschist, serpentinite, piemontite schist, and phyllite is preserved at Shangla. From Dargai to Shangla, the southern marginal fault of the suture zone is older than the northern fault mid-Cenozoic metamorphism of the northern margin of the Indian subcontinent occurred under the overriding Kohistan arc. Three units of metasediments are tentatively recognized: twice metamorphosed crystalline schists of probable Precambrian age, once metamorphosed shelf sediments of probable Paleozoic age, and one metamorphosed possible Indus flysch equivalent. The crystalline schists are intruded by augen gneisses, and both are unconformably overlain by the metamorphosed shelf sediments. The entire complex rides south on the Himalayan sole thrust as a tectonic flake. At Jijal, peridotite and garnet granulite are basal Kohistan arc complex; other elements are completely overridden. East of Chilas, the suture complex is cut by the active Rakhiot fault which trends north-south. Plio-Pleistocene Jalipur fluvial sandstones are preserved along the fault. Talus cones, alluvial fans, and glacial sediments are cut by the Rakhiot fault. IT brings the psammitic gneisses of the Nanga Parbat-Haramosh complex to the surface It extends north-south from Sassi to Chilas and probably continues to the Hazara-Kashmir syntaxis. We interpret it as a displacement transfer structure offsetting the Himalayan sole thrust. The MCT terminates against this fault. The Indus suture reappears east of the Nanga Parbat-Haramosh massif in the relatively well known Ladakh area. Previous workers have interpreted the suture zone to loop around the Nanga Parbat-Haramosh loop; we find that it is interrupted and displaced by the loop. The Nanga Parbat-Haramosh massif is not an ancient basement high of the Indian rock, but rather an active Himalayan structure that records the offset on the Himalayan sole thrust.
Key words: Tectonics, Indus Suture, Himalaya.

L/48. Lawrence, R.D., Kazmer, C. & Tahirkhelli, R.A.K., 1983. The Main Mantle Thrust; A complex zone, northern Pakistan. Geological Society of America, Abstracts with Program 15, p.624.

The Main Mantle Thrust, northern Pakistan, brings the Kohistan andesitic arc terrain against the Indo-Pakistani subcontinent and links the Indus suture zone (east) with the paired ultramafic complexes of Waziristan/Zhob/Las Bela and Altimur/Ras Koh (west). It is composed of melange, blueschist, and ultramafic rocks between major bounding faults. Ultramafic rock of three sources is present: that (1) obducted onto the leading, rifted margin of the Indo-Pakistani subcontinent, south side of the Neotethys, in latest Cretaceous/Paleocene, (2) emplaced within the subduction margin of the Kohistan arc, north side of the Neotethys, during Late Cretaceous, and (3) formed as the base of the late Jurassic Cretaceous, 7-8 km thick, Kohistan arc slab. Examples: (1) Dargai klippe and Swat Emerald Mine talc-carbonate slab, (2) Shangla Pass blueschist and Jawan Pass area,(3) Jijal Complex. Types (1) and (2) brought in contact during middle Eocene (?) suturing. Type (3) thrust over suture later during continuing collision. Resultant MMT complex is on top of Precambrian medium-grade metasediments (Salkhala?) with no intervening shelf or deep marine sediments. West of Nanga Parbat Haramosh massif MMT complex is replaced by a single active fault that brings a Tertiary migmatized and metamorphosed slab (High Himalayan slab?) over the Kohistan area.
Key words: Indus suture, MMT, Himalaya. Pakistan.

L/49. Lawrence, R.D., Kazmi, A.H. & Snee, L.W., 1989. Geological setting of the emerald deposits. In: Kazmi, A.H. & Snee, L.W., (eds.), Emeralds of Pakistan: Geology, Gemology and Genesis, 13-38. Van Nostrand Reinhold, New York.

In Pakistan emeralds are found in fascinating surrounding. The spectacularly rugged Himalayan ranges (photo. 2.1) capped by the lofty snow-capped peaks of Nanga Parbat (8128m), Rakaposhi (7790 m) and Haramosh (7406 m) are dissected by awe-inspiring canyon of the Indus River which reaches over 6100 meters of relief in places. Farther south the verdant, picturesque Swat valley between pine-clad mountains give way to the barren, hilly and hostile terrain of the Malakand, Mohmand and Bajaur agencies. Though today the emerald occurrences are spread over a fairly extensive belt, their presence was not known until 1958 when the first emerald deposit was discovered at the northern edge of the city of Mingora in Swat (Kazmi, 1983). Since then, a number of deposits or showings of emeralds have been located in Mohmand Agency at Nawe Dand, Gandao (actually green beryl), Pranghar, Bucha, and Khanori; in the Bajaur Agency at Aman Kot and Maimola; in Swat District at Charbagh, Makhad and Gujarkili and in the Gilgit Agency at Khaltaro (fig. 2.1).
Detailed geological prospecting of the Mingora mines (Kazmi, 1983; Kazmi and others, 1984. 1986), has shown that they contain at least three distinct types of emerald deposit which differ in quality. Thus, Pakistan emeralds offer a wide range of color and quality, with the best ones coming from Gujarkili and Mingora mines (Kazmi and others. this volume).
Exquisite as these emeralds are as gems; their geological selling is also wonderful: they are the products of collision between the Indian and Asian continental crustal plates. This history has been briefly described in the previous paper (Kazmi, this volume). The present study indicates that all the emerald deposits and showing in Pakistan except the Khaltaro occurrence are located exclusively in the metamorphosed ophiolitic melange of the suture zone. Although the Khaltaro emerald occurrence is within the Nanga Parbat gneiss,it also is found in close proximity to the suture zone. The geological setting of these deposits is briefly described.
Key words: Gems, gemology, emerald, ophiolites, Swat, Mohmand.

L/50. Lawrence, R.D. & Shroder, J.F., 1984. Active fault northwest of Nanga Parbat. Abstracts, First Geological Congress, Lahore, 50-51.

The Rakhiot fault is a newly identified active fault along the western margin of the Nanga Parbat-Haramosh massif. This active fault offsets the suture zone (MMT) and produces a gap in the trace of the suture. It is an oblique fault with a combination of reverse and right-lateral slip. Active fault features include crystalline basement overriding Quaternary sediments, fault scarps in fan gravels, lines of hot springs, sheared glacial till, offset glacial terraces, and slickensides in fan gravels. The scarp of the famous 1841 landslide is along the trace of the Rakhiot fault. The landslide was triggered an earthquake, presumably associated with the fault, in December 1840 or January 1841, and it dammed the Indus into a lake up to 300 m deep that broke out in June to overwhelm the Sikh army downstream at Attock. The still fresh scar of the landslide is located on the east side of the Indus south of the mouth of the Astor River. The to on the west side of the Indus preserves pressure ridges from the high-velocity movement. The rockslide diamicton is a chaotic mixture of pulverized rock fragments in a friable sandy matrix; the larger clasts are dominantly light colored gneisses. This diamicton is quite distinct from adjacent older semi-consolidated tills and the consolidated Jalipur diamicton that it overlies. The association of massive landslides with active reverse faults is well known and suggests possible future hazard in the area.
Key words: Structure, active faulting, Nanga Parbat.

L/51. Lawrence, R.D. & Shroder, J.F., 1985. Tectonic geomorphology between Thakot and Mansehra, Northern Pakistan. Geological Bulletin, University of Peshawar 18, 153-161.

Geomorphic features between Thakot and Mansehra include, 1) bedrock terraces and an associated knickpoint on Nandihar Khwar, an Indus tributary, 2) deeply weathered residual soils on a relict upland surface called the Chattar plain, 3) an escarpment developed at the edge of headward erosion into this upland surface, and 4) an incised intermontane sedimentary basin north of Mansehra. Together these features provide new data to be used in reconstructing the history of recent uplift of the Himalaya in Pakistan. They reflect a period of relative tectonic stability during tropical soil development on a surface of rolling hills between about 25 and 5 m.y. ago followed by uplift and erosion of that surface. These residual soils may be an important sediment source for the young intermontane basins developed in association with foreland thrust fault motion during the last 5 my.
Key words: Tectonics, geomorphology, Thakot, Mansehra.

L/52. Lawrence, R.D., Snee, L.W. & Rosenberg, P.S., 1985. Nappe structure in a crustal scale duplex in Swat, Pakistan. Geological Society of America, Abstracts with Programs 17, p.640.

Key words: Structure, duplex, Swat.

L/53. Lawerence, R.D. et. al., (including Tahirkheli, R.A.K. & Ghauri, A.A.K.) 1986. Deformation of crustal rocks beneath suture in western Himalaya, Pakistan. Geological Society of America, Annual Meeting . 18.

Key words: Deformation, Indus suture, Himalaya.

L/54. Leahy, T., 1993. Fluid flow, metamorphism, and magmatism at Nanga Parbat, Pakistan Himalaya. M.S. Thesis, Dartmouth College, Hanover, New Hampshire.

Key words: Metamorphism, magmatism, Nanga Parbat, Himalaya.

L/55. Leake, R.C., Fletcher, C.N., Haslam, H.W., Khan, B. & Shakirullah, 1989. Origin and tectonic setting of stratabound tungsten mineralization within the Hindu Kush of Pakistan. Journal of the Geological Society of London 146, 1003-1016.

Key words: Tectonics, mineralization, Hindukush.

L/56. Leake, R.D., 1983a. Mineralization in the area around Besham, Kohistan, Pakistan. Natural Environmental Research Council, Institute of Geological Sciences, London, 26p. (Prepared for Sarhad Development Authority, Peshawar).

Key words: Mineralization, Besham, Kohistan.

L/57. Leake, R.D., 1983b. Mineralization within the Chitral District, and adjacent areas of North West Frontier Province, Pakistan. Natural Environmental Research Council, Institute of Geological Sciences, London, 30p. (Prepared for Sarhad Development Authority, Peshawar).

Key words: Mineralization, Chitral, NWFP.

L/58. Leathers, M., 1987. Balanced structural cross section of the western Salt Range and Potwar Plateau, Pakistan. Deformation near the strike-slip terminus of an overthrust belt. MS Thesis, Oregon State University, Corvallis, 297p.

Key words: Structure, Salt Range, Potwar.

L/59. Le Bas, M.J., Mian, I. & Rex, D.C., 1987. Age and nature of carbonatite emplacement in north Pakistan. Geologische Rundchau 76, 317-323.

The N Pakistan carbonatites of Loe Shilman, Silai Patti and those within the Ambela complex were formerly considered as comprising one alkaline igneous province associated with a Peshawar rift valley. New data show that these alkaline rocks occur in two distinct periods, Carboniferous and Tertiary, and are not related to any Tertiary rift faulting. K-Ar dates determined on biotites from the Loe Shilman and Silai Patti carbonatites reveal that the carbonatites were emplaced at 31 ± 2 Ma, and along thrust planes, not rift faults. Subsequent movement of the thrusts reset the argon contents in some biotites to indicate a deformation age of 24 ± 2 Ma for the carbonatites at

both localities. The Koga carbonatite in the Ambela complex occurs as a plug associated with nepheline syenites and ijolites, and Rb-Sr isotope determinations on the silicate rocks give dates of approximately 297-315 Ma. The study implies that there were thrust movements associated with the Indian – Asian plate collision more than 31 Ma ago, which is much earlier than the 20 Ma date previously advocated for the initiation of thrusting.
Key words: Carbonates, chronology.

L/60. Lefebvre, L.A. & Malinconico, L.L. Jr., 1989. Gravimetric methods for estimating the cross-sectional area of mass movement deposits in the Karakoram Range, Pakistan. Abstracts with Programs, Geological Society of America 21, p.20.

Key words: Mass movement, Karakoram.

L/61. Le Fort, P., 1975. Himalaya: the collided range. Present knowledge of the continental arc. American Journal of Science 275A, 1-44.

From a presentation of the geological and geophysical characteristics of the Himalayas, the author tries to draw the main features of mountain building. After a common Precambrian story, the Higher and Lesser Himalayas separate in two basins, the northern one on a continental thinned margin, the southern one intracratonic under shallow marine and continental influences. The beginning of this distinct evolution may be traced in both domains by a widespread spilite keratophyre episode. Caledonian and Hercynian periods are only marked by epeirogenic movements and limited volcanism. The four phases of deformation and the three intervenient phases of metamorphism (the third being a retrogression) all belong to the Tertiary orogeny.
The orogeny is composed of distinct cycles. The first ends with collision of the Indian and China plates at the beginning of the Tertiary; it leads to the formation of the Trans Himalaya range and probably develops the first phase of folding and metamorphism in the Himalayas. The second cycle (Miocene) is thoroughly intracontinental with a very large scale subduction along the Main Central Thrust; such movements provide a simple and elegant explanation of the inverted metamorphism observed all along the Himalayas, together with particular tectonic features.
The amplitude of the intracontinental subduction seems to be limited in time; it brings a high rate of erosion whose products are partly accumulated in the foredeep of the range. When movement resumes, after 10 m.y., it takes place along a weaker, more southerly line. The fossilized movements of the Himalayas are now in action along the Main Border Thrust.
Key words: Collision, continental arc, Himalaya.

L/62. Le Fort, P., 1989. The Himalayan orogenic segment. In: Sengor, A.M.C. (eds) Tectonic evolution of the Tethyan Region. Kluwer Academic Publishers, Dordrech, 286-289.

Four major plutonic belts are related to the Meso-Cenozoic orogenic evolution of the Himalaya-Trans Himalaya-Karakoram realm: the Trans Himalaya belt and its satellite Kohistan arc, the Karakoram batholith, the High Himalaya belt and the North Himalaya belt. A fifth one results from the lower Palaeozoic epirogenic events: the "Lesser Himalaya' belt. The tectonic settings of their production and emplacement are successively reviewed. Among the first four, two results from oceanic subduction along an Andean margin locally branching into an island arc and two result from intracontinental subduction after closure of the oceanic realm. Both Andean belts are made up of very large quantities of highly diversified granitoids produced more or less continuously during 70 Ma at least, whereas the intracontinental ones are limited to a small volume of very uniform anatectic granite produced during a 10-15 Ma period. The production and emplacement in the Andean belts is partly controlled by the obliquity of the convergence between India and Eurasia. The emplacement of the intracontinental belts is even more dependent on the regional tectonic setting. These contrasting belts are case studies probing the depths and mechanisms of their production and giving adequate models for older geodynamic frames.
Key words: Orogeny, Tethys, Himalaya.

L/63. Le Fort, P., 1996. Evolution of the Himalaya. In: Yin, A. & Harrison, M. (eds.), The Tectonic Evolution of Asia. Cambridge University Press, 95-109.

The collage of the three of the Himalaya (the Sub-Himalaya, the Lesser Himalaya, and the High Himalaya) has resulted from a long evolution starting at 50 Ma with the closure of the Tethys ocean and the collision of the Indian and Tibetan continental masses. This evolution can be divided into five periods: a prelude, three main acts, and a postlude. The prelude corresponded to the Andean-type evolution of the northern margin of Tethys during the closure of the ocean; it produced the Transhimalaya and Karakoram ranges, with abundant plutonism and volcanism. The first act was the collision of the northward drifting Indian plate with the accreted continental Eurasia. It was a progressive suturing that can be dated to around 55-50 Ma, on the basis of a survey of the Indian Ocean, the paleomagnestism of the continental masses, and stratigraphic and magmatic observations. It was accompanied by the obduction of a few ophiolitic nappes and the production of very limited eclogites in the northwestern Himalaya. The Alpine period, act 2, was characterized by the development of a large system of nappes overriding the present High Himalaya, with series more than 10-km thick issuing from the suture basin. That period induced the eo-Himalayan metamorphism best represented in the northwestern part of the range. Act 3, the Himalayan period, resulted in a doubly thickened Indian crust along the Main Central Thrust (MCT). Penetrative stretching lineation and S-C-type fabric characterize the deformation of this 5-10-km-thick zone. Gravity collapse, with kilometric folds and normal faulting, with some dextral shear component, was partly contemporaneous with the MCT. Metamorphism inverted below the MCT, and leucogranite magmatism resulted from this thrusting of hot crystalline gneisses over the cooler Lesser Himalayan formations. The protracted convergence between Indian and Asia has resulted in “hyper-convergence”, a southward sequence of younging thrusts, the MCT being replaced by the Main Boundary Thrust, itself replaced by the presently active Main Frontal Thrust. This tectonic evolution is also recorded in the sedimentation. The present situation of the postlude is not different from the preceding period, but benefits from actual observations and measurements of such mechanisms as seismicity, uplift, and erosion. With erosion and uplift rates mainly around a millimeter per year, the Himalaya has remained a prominent range since at least 17 Ma, dominating the evolution of most Asia.
Key words: Orogeny, Himalaya.

L/64. Le Fort, P. & Cronin, V.S., 1988. Granites in the tectonic evolution of the Himalaya, Karakorum and southern Tibet. Philosophical Transaction, Royal Society of London 326, 281-299.

Four major plutonic belts are related to the Meso-Cainozoic orogenic evolution of the Himalaya-Transhimalaya-Karakoram realm: the Transhimalaya belt and its satellite Kohistan arc, the Karakoram batholith, the High Himalaya belt and the North Himalaya belt. A fifth one results from the lower Palaeozoic epirogenic events: the `Lesser Himalaya' belt. The tectonic settings of their production and emplacement are successively reviewed. Among the first four, two result from oceanic subduction along an Andean margin locally branching into an island arc and two result from intracontinental subduction after closure of the oceanic realm. Both Andean belts are made up of very large quantities of highly diversified granitoids produced more or less continuously during 70 Ma at least, whereas the intracontinental ones are limited to a small volume of very uniform anatectic granite produced during a 10-15 Ma period. The production and emplacement in the Andean belts is partly controlled by the obliquity of the convergence between India and Eurasia. The emplacement of the intracontinental belts is even more dependent on the regional tectonic setting. These contrasting belts are case studies probing the depths and mechanisms of their production and giving adequate models for older geodynamic frames.
Key words: Tectonics, granites, Himalaya, Karakoram, Tibet.

L/65. Le Fort, P., Debon, F., Pecher, A., Sonet, J. & Vidal, P., 1986. The 500 Ma magmatic event in Alpine southern Asia a thermal episode at Gondwana scale. In: Le Fort, P., Colechen, M. & Montenat, C. (Eds.), Evolution des. Domaines Orogeniques d' Asia Meridionale. Science de la Terre, Memoir 47, 191-209.

Cordierite-bearing granitic plutons of about 500 Ma emplacement age occur in lesser Himalaya, including the Mansehra granite (consult the following account). Similar rocks of this age in Australia may be a continuity of these. The geodynamic implications of the Gondwana granitoids is discussed.
Key words: Granitic magmatism, Lesser Himalaya, Gondwana.

L/66. Le Fort, P., Debon, F. & Sonet, J., 1980. The ‘Lesser Himalayan’ cordierite granite belt typology and age of the pluton of Mansehra (Pakistan). Geological Bulletin, University of Peshawar 13, 51-62.

The Manserah pluton is a very typical example of the discontinuous belt of two mica-cordierite granite of the ‘Lesser Himalaya’. It is aluminous, quartz rich but feldspar and sodium deficient, and igneous ‘microgranular’ inclusions are frequent. Severely deformed to the North, the Manserah pluton has been metamorphosed and gneissified during the Himalayan orogeny. Rb-Sr whole rock isotopic data give a well-defined seven point isochron with a Cambrian age of 516 + 16 m. y. The high initial ratio of 0.7189 ± 6 implies derivation from a source containing a major and very old crustal contribution. The geodynamic framework for the genesis of this huge belt of similar plutons could be that of a simple thinning of a Precambrian shield or that of a late Pan African orogeny.
Key words: Granitic plutons, metamorphism, Mansehra.

L/67. Le Fort, P., Debon, F. & Sonet, J., 1983. The Lower Palaeozoic "Lesser Himalayan Granitic Belt": Emphasis on the Simchar Pluton of Central Nepal. In: Shams, F.A. (ed.) Granites of Himalayas, Karakorum and Hindu Kush. Institute of Geology, Punjab University, Lahore, 217-255.

Simchar pluton is the western-most of the six main granitic bodies emplaced in the Precambrian formations of the Kathmandu nappe South of Kathmandu. Made up of a dominant porphyritic, two mica, sometimes cordierite bearing granite, it is associated with a two mica lencocratic granite. Both form a very characteristic and typical quartz rich aluminous association. Considered by most authors as Cenozoic, it has been deformed and metan1orphozcd during the Himalayan orogeny by the main phase of deformation.
A Rb - Sr study on whole rock samples gives an isochron age close to the Cambro-Ordovician boundary with a rather high Sr initial ratio The petrographical, structural, geochemical and chronological characteristics of the Simchar Pluton are quite similar to the other plutons of the Kathmandu nappe, including the Palung one, as to the fifteen or so “Lesser Himalayan" plutons that stretch for 1600 km. There is a remarkable coherence within the 11Lesser Himalayan" belt. Moreover the authors have found similar rocks of similar age in the Central Mountains of Afghanistan, the Tibetan Slab of Nepal (Formation III) and Lhagoi Kangri (North Himalayan) belt of Tibet. This very large scale phenomenon seems to be independent from any true orogenesis.
Key words: Granites, Nepal, Himalaya.

L/68. Le Fort, P., Debon, F. & Stebbins, J., 1978. Mise en evidence d’une ceinture de granites a cordierite et enclaves “microgrenues” en Bas-Himalaya “Nepal, Indes, Pakistan. 6 e Reunion Annuale Science de Terre, Orsay, Societie Geologique de France, p.243.

Consult the preceding accounts for further information.
Key words: Granites, India, Nepal, Pakistan.

L/69. Le Fort, P. & Gaetani, M., 1998a. Geological map of western central Karakorum, North Pakistan, Hindu Raj, Ghamubar, and Darkot areas at 1:250,000 scale. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 108-109.

The authors have produced a new geological map at 1:250,000 scale of the mountainous region of NW Pakistan comprising the Hindu Raj and Ghamubar ranges, and the Darkot area in between. The map includes the Karakorum central granitoid belt, in the region where it is divided into two branches, and the slightly metamorphic Darkot sedimentary group.
The region of the present map covers three main units: two crystalline masses separated by a sedimentary unit: the northern crystalline masses, the Hindu Raj' unit, is mainly made up of plutonic rocks varying from diorite to granite in composition, the granite being in the center, flanked to the north and south by the mafic plutonic rocks. In general, the Chikar meta-sedimentary formations and migmatitic gneisses occur in the northern part; intruded by the

Ishkarwaz pre-Ordovician granitoid, they represent the basement of Karakorum; the middle sedimentary unit, the Darkot unit, is composed of low-grade meta-sedimentary formations, including arenites, slates, and limestones in which Upper Paleozoic bryozoans and brachiopods have been found [I]. We have also found Triassic megalodonts, and possible Cretaceous rudists;
the southern crystalline mass, the Ghamubar unit, is composed of plutonic rocks also varying from diorite to granite in composition, and intruding into a large northern stripe of Aghost gneisses and migmatites.
To the north and north-east, the area is separated by a series of folds, thrusts, and lineaments from the East Hindu Kush, in which outcrops a large Jurassic porphyritic granite outcrops. To the south, the Nialthi meta-sedimentary formation, at least Permian in age, is overlain by the Lower Cretaceous detritic and partly volcanic formations of the Yasin group. Within the Nialthi fm have discovered a separate strip of conglomerate: the Hundur formation. One of the salient feature is the presence throughout the map of extended pinched strips of sedimentary rocks (Reshun and Hundur conglomerates, Dobargar sedimentary horizons) that underline the lenticular shape of the crystalline masses.
The large-scale tectonics can be divided into three main phases: a longitudinal stretching with boudinage of the batholith, a left-lateral strike-slip that has doubled the batholith and is probably responsible for the pinched structure of sedimentary formations, and a north-south extension fast enough to produce a layer of pseudotachylite (see Le Fort & Villa, this volume) on the southern side of the 5 to 10 km wide Darkot graben.
Key words: Mapping, Karakoram.

L/70. Le Fort, P. & Gaetani, M., 1998b. Introduction to the geological map of western central Karakoram, north Pakistan Hindu Raj, Ghamubar, and Darkot areas 1:250,000 scale. Geologica 3, 1-67 (French version, p.69-93).

These notes introduce a new geological map at 1:250000 scale of the mountainous region of NW Pakistan comprising the Hindu Raj and Ghamubar Ranges and the Drakot area in between. The map includes the Karakoram central granitoid belt, in the region where it is divided into two branches and the slightly metamorphic Darkot group. The two crystalline massifs of the Hindu Raj and Ghamubar are mainly composed of dioritic to granitic plutons, often in tectonic contact, that seem to pertain to Cretaceous time. In addition, on the northern side of the Hindu Raj massif, outcrops of Ishkarwaz pre-Ordovician granitoid, overlain by lower Ordovician sedimentary series. All these granitoids are intrusive to metasedimentary formations of varied metamorphic grade, from epi-metamorphic to magmatitic, that represent the basement of the Karakoram range.
The sedimentary series of the Drakot group: at least permo-Triassic in age, have been preserved in a 5-10 Km wide grabben, filled by the sedimentary cover series of the Drakot group between the two crystalline ranges. The map also includes the Jurassic plutonic complex of shushar, intrusive into the Wakhan slates of the Hundu Kush.
The large scaled tectonics can be divided into three main phases: a longitudinal stretching, a left-lateral strike slip that has doubled the major batholithic belt of granitoid, and north south extension enough to produce a layer of pseudotachylite on the southern side of the grabben.
Key words: Geological mapping, Karakoram.

L/71. Le Fort, P., Gulliot, S. & Pêcher, A., 1997a. HP metamorphic belt along the Indus suture zone of NW Himalaya: new discoveries and significance. Comptes Rendus del' Academie des Sciences, Parsi 325, 773-778.

Key words: Metamorphism, Indus Suture, Himalaya.

L/72. Le Fort, P., Gulliot, S. & Pêcher, A., 1997b. Discovery of Retrogressed Eclogites in the Indus Suture, East of Nanga Parbat-Haramosh massif (Northern Pakistan) the HP Belt of NW Himalaya. Abstract volume, 12th Himalaya-Karakorum-Tibet International Workshop, Rome, Italy, 57-58.

The eastern contact between the Nanga Parbat Haramosh Massif and the Ladakh island arc is a north-south to NNE-SSW boundary known as the Indus Suture or the Main Mantle Thrust. It is a complex ductile shear zone with right-lateral strike-slip more recently reworked by pervasive brittle faulting. Along this contact, close from the confluence between the Stak and the Indus valleys, we have found a series of metric to decametric lenticular bodies of

serpentinized peridotites accompanied by smaller boudins of garnet bearing pyroxenites and amphibolites. These lenses only form a few percents of the 2-km thick contact zone. They belong to the Arc material.
The original parag4nesis of the metabasic rocks is clearly retrogressed; diopside clinopyroxene (Jd10) appears as symplectitic association with Na-plagioclase (Ab85), the globularization of the symplectites is typical of the destabilization of omphacites during decompression. Mg-rich garnet is surrounded by amphibole + plagioclase + biotite corona. Most samples remain fresh and are devoid of alteration and weathering. The occurrence of pyroxene inclusions in garnet and the reconstruction from the symplectites of the initial pyroxene gives a 30 to 40 mol.% jadeite. It allows us to evaluate the eclogitic conditions at a minimal pressure of 13 ± 1 kbar and 610 ± 30°C, typical of low- to intermediate-temperature eclogites. The retrogressed assemblage gives a mini0mal pressure of 8 ± 1 kbar at 610 ± 30°C.
We have tried to find similar occurrences along the Astor section across the eastern Himalaya-Arc contact, some 30-km south of the retrogressed eclogites, but only found high-pressure granulite facies assemblage in Himalayan gneissic material, a few hundred meters from the contact. The rocks are characterized by garnet + diopside clinopyroxene (Jd5-15) + plagioclase (Ab75) ± rutile primary paragenese. The retrogression is marked by the development of poekilitic ferroan pargasitic amphiboles. P-T conditions of the granulitic stage are evaluated at 10 ± 1 kbar and 700 ± 50°C whereas the retrogression is characterized by a pressure and temperature drop (6 ± 1 kbar and 570 ± 50°C). Thus, this assemblage very much resembles the HP-granulite facies occurrence of the higher Stak Valley (Pognante et al., 1993), some 20 km north of the new eclogitic occurrence. This suggests that, on the eastern side of Nanga Parbat, the Indian continental crust has been juxtaposed to the present Arc material after an eclogitic metamorphic period, and that they experienced together only the second part of the exhumation process at relatively high-temperature.
The new occurrence of eclogites is located between those reported at the Northwestern margin of the Himalaya (Kaghan Valley, Pognante & Spencer, 1991), 120 km more to the SW, the blueschists of Ladakh (Pashkyum, Shergol, Urtsi, Puga, see Honegger et al., 1989), 130 to 300 km more to the SE, and the eclogites reported in the eastern Ladakh, 400 km more to the ESE (Tso Morari, Guillot et al., 1995). The present eclogitic metamorphism, as the blueschist metamorphism from Ladakh has imprinted oceanic material from the suture, not crustal material of the northern Himalayan margin as in the Kaghan and Tso Morari occurrences. It suggests the existence of a 600-km long HP-LT belt in the northwestern part of the Himalaya probably related to subduction process.
Key words: Structure, mineral chemistry, eclogite, ultramafics, HP metamorphism, NPHM, MMT.

L/73. Le Fort, P., Lemennicier, Y., Lambardo, B., Pecher, A., Pertusati, P., Pognante, U. & Rolfo, F., 1994. Geological Map of Himalaya-Karakoram Junction in Chogo Lungma to Turmik Area (Baltistan, Northern Pakistan). Journal of Nepal Geological Society 10. Abstract Volume, 9th Himalaya-Karakoram-Tibet Workshop, Kathmandu, Nepal, 81-83.

The circa 800 km^2 of the map mostly covers the upper Chogo Lungma glacier system flowing into the Basha river, and the Turmik valley, all on the right (northern) bank of the Indus. Previously mapped schematically by Zanettin (1964) and Desio et al. (1985), it has been surveyed by three of our expeditions (1991-1993), it concerns three major units: the High- Himalayan Nanga Parbat - Haramosh crystallines, the Ladakh terrain possibly made up of a back-arc basin, and the Karakoram. These units are thrusted on each other along two major fault systems: the Main Karakorum Thrust (MKT) between Karakorum and Ladakh and the Indus Tsangpo Suture (ITS) between Ladakh and Himalaya. The ITS, described as a normal fault in lower Stak (Verplanck, 1986) with a dextral component at Stak La (Pognante et al., 1993) swirls around the Nanga Parbat - Haramosh promontory, whilst the north-dipping more brittle MKT follows a quasi planar trajectory across the entire territory. In addition a leuco-trondhjemitic pod intrudes the ITS west of Remendok.
High-Himalaya: The High Himalaya crystallines consist of kyanite grade paragneiss slightly migmatised (part of the Shengus gneiss of Macin 1986), intruded by a mass of granitic orthogneiss resembling the 500 Ma “Lesser Himalaya’ granites. Mafic dykes cutting through the gneisses retain a garnet granulite paragenesis (650-700C and 8 to 13 kbar, Pognante et al., 1993).
Ladakh: The unit comprises: (1) the Ladakh volcanic arc intruded by numerous plutons and dykes to the SW and SE, and (2) the Greenstone complex or Turmik melange to the NE. The volcanic arc (1) is limited on the map to a band of amphibolites (Askore Fm of Desio) E of Stak La and S of Chogo Lungma glacier, and a granodioritic intrusion at the Turmik-Indus confluence; it is separated at Dasu by a mass of serpentinites from (2). The Greenstone complex is a volcano-sedimentary sequence with numerous limestone horizons and a tectonic melange of meta-volcanics and -sediments. The major lms horizon (Pakora lms) has yielded post-Valanginian rudists (Le Fort et al.,

1992) and separates a southern band of tuffaceous schists from a northern bank richer in mafic material including serpentinite lenses. The complex has been strongly deformed and metamorphosed in an epidote greenschist facies. It is intruded by a granodiorite to gabbro pluton ("Tisar tonalite" of Desio, 1963) in the Shigar valley.
Karakorum: It is the most complex unit. The back bone of the mapped zone is a dome of granitic orthogneisses (Mangol Bluk dome) with an offset migmatitic core (Arandu), and an intrusive contact into the surrounding metasediments. The orthogneisses are thoroughly infolded with the Basha paragneisses bearing kyanite and sillimanite (690 C and 10 kb, Allen & Chamberlain, 1991). Isoclinal folds have been deformed by the doming. On both sides, the folded alternations of marbles, schists, quartzites and amphibolites stretch WNW-ESE, narrowing towards W. They include a few orthogneissic bands (Bolocho, Mooraine gl.) and are intruded by the Karakoram batholith (Solu granite, up Dabadas). Most of the metasediments are in the amphibolite facies with staurolite ± kyanite and andalusite. The southern limestone (Chutrun lms) follows more or less the contact with Ladakh. A unique syenitic pod (Hemasil syenite) intrudes the metasediments to the SE. In 40 km from E to W, the entire structure thins down to 1/3, as it moulds itself on the Himalayan spur.
Key words: Mapping, Baltistan, Himalaya, Haramosh, Karakoram.

L/74. Le Fort, P., Lemennicier, Y., Lombardo, B., Pecher, A., Pertusati, P., Pognante, U. & Rolfo, F., 1995. Preliminary geological map and description of the Himalaya-Karakorum junction in Chogo Lungma to Turmik area (Baltistan, Northern Pakistan). Journal of Nepal Geological Society 11, 17-38.

Some 800 km2 of the area lying between the Haramosh Spur of the Southern Karakorum Complex, centered on the Chongo Lungma glacier system, is presented on a preliminary geological map, after three expeditions. It includes three major units from SW to NE: the High Himalayan Nanga Parbat-Haramosh Crystalline (HHC), the Ladakh Paleo Island Arc, and the Karakorum Metamorphic Complex intruded by granitoids. The three units are thrust to the south. The High-Himalayan ortho- and para-gneisses are metamorphosed to granulite facies and migmatised. The Ladakh Arc is made up of two groups of formation, the Askore Amphibolite to the SW and the Greenstone Complex to the NE, separated by a screen of serpentinized ultramafics. It is intruded by numerous granitoids including a leuco-trondhjemite body cutting the horizons that have yielded post-Valanginian fossils. The Karakorum Metamorphic Complex includes orthogneisis domes of granitoids intruded into the surrounding metasedimentary formations. A syenitic dome of granitoid at Hemasil is apparently syntectonic. Two phases of deformation are observed in Karakorum and Ladakh and seem to correspond, but with different grades of metamorphism. The late doming structures are characteristic of the Karakorum. The Himalaya-Karakorum contact varies from south to north, from normal fault to a strike-slip shear zone, and finally a thrust fault. The original Ladakh-Karakorum contact (Shyok Suture) is folded and reactivated by late brittle thrusting, possibly the latest large-scale deformation of the region. The closure of the Ladakh-Karakorum back-arc basin followed by the collision of India is mostly overprinted by the recent structures.
Key words: Mapping, Baltistan, Haramosh, Himalaya, Karakoram.

L/75. Le Fort, P., Michard, A., Sonet, J. & Zimmermann, J.L., 1983. Petrography, geochemistry and geochronology of some samples from Karakorum axial batholith (northern Pakistan). In: Shams, F.A. (ed.), Granites of Himalayas, Karakorum and Hindu Kush. Punjab University, Lahore, 377-387.

Granitoid samples from the Hunza Valley have been studied and analyzed. They include dominant type of biotite - hornblende granodiorites and minor two-mica adamellites. The granodiorites are relatively rich in dark minerals, but feldspar and quartz poor; their trend is typically cafemic and calc-alkaline with subordinate subalkaline affinity. The granodiorite is always gneissic and very fresh; actually it is a metagranodiorite resulting from the high grade regional metamorphism of a previously emplaced plutonic rock. Three different methods of isotopic geochemistry have been undertaken on some of the samples. The oldest age is obtained by U-Pb on zircons with a lower discordant intersection at 95 ± 8 m.y. Four K-Ar amphiboles gather around 46 m.y. and three k-Ar biotites around 26 M.Y. Younger Rb-Sr and K-Ar mica ages form two groups: around 15 m.y. and around 6 m.y.
The initial Sr ratio appears to be high. The dispersion of ages may reflect the complex history of the Karakorum, mainly: Upper Cretaceous batholithic emplacement. Eocene regional metamorphism at the time of the Indo-Eurasian

collision, Miocene rebound of the Himalaya orogeny. Similarities with the eastern Hindu Kush and the Central Mountains of Afghanistan may help to restore the Cretaceous and subsequent geodynamics.
Key words: Petrography, geochemistry, geochronology, Karakorum axial batholith.

L/76. Le Fort, P. & Pecher, A., 1995. The Scar of the Shyok Suture between Kohistan-Ladakh and Karakoram from Hunza to Baltistan (Pakistan). Abstract Volume, 10th Himalaya-Karakoram-Tibet Workshop, (ETH Zurich) Switzerland.

There is a marked lineament, underlined by discontinuous pods of serpentinized ultramafics that can be followed from the left bank of the Shigar valley in Baltistan to the Hunza valley near Chalt along some 160 km (figure). Our fieldwork from 1991 to 1994 has enabled to follow and map this lineament linking the northern boundary of Ladakh with that of Kohistan. Typically to the north of this line, a formation of polygenic sedimentary conglomerate occurs, whereas to the south volcanic tuffs and breccias are abundant. The three formations belong to the northern suture zone of Pudsey (1986).
The serpentinite lenticular bodies have been observed at the following localities:
just E of Chalt along the Karakorum highway (KKH), an outcrop mapped by Pudsey (1986),
cutting the crest on the right bank of the Pisan glacier (Askoro pass) providing boulders on the right lateral moraine of the Minapin glacier, issued from the region of the pass leading to Bualtar valley, between the Sumayar and the Diran peaks, as big boulders on the left bank of the Chogo Lungma glacier, as pebbles in the river bed of Burimis (a right bank tributary of the Chogo Lungma), as boulders in the river cone of Brag Zago (a left bank tributary of the Turmik), forming a 40 in thick lenticular band crossing the Pakore valley, north of the summer huts of Pakore, as two pods described and mapped by Hanson (1989) on the north-eastern slopes of the Shigar.
The polygenic sedimentary conglomerate contains mainly ill-rounded pebbles of recrystallised quartz-arenite and limestone, reaching up to 50 cm in diameter. It is poorly sorted and the matrix is made up of Limy sandstone. Volcanic contribution seems to increase progressively towards the south, as shown on the left bank of the Minapin glacier. The outcrops include, from E to W:
outcrops of the Mayon valley (Pudsey, 1986), a thick band of massive outcrops crossing the Minapin glacier around its lower bend, a large formation forming massive peaks on both sides of the Miar glacier, cliffs on the northern side of the pass between the Chogo and Barpu basins, feeding the upper moraines of both glaciers, outcrops of the Spantik base camp, a series of outcrops on the left (northern) bank of the Turmik valley, in particular, 100 m thick north of the summer huts of Pakore, screes on the left bank up Tisar.
The southern conglomerates, tuffs and volcanic breccias belong to the Greenstone complex of Tahirkheli & Jan (1979), Rakaposhi volcanic complex (Tahirkheli, 1982), or Turmik formation of Desio et al. (1985) (cf Le Fort et al., in press; Rolfo et al., this volume). They are made up of varied mixtures of volcano-detrital rocks, with a constant imprint of mafic volcanism, almost impossible to map in detail. At the foot of the northern crest of the Diran a formation of quartz arenites show beautiful sedimentary features of prodelta distributary channel deposit (graded bedding, climbing ripples, according to G. Allen personal communication); it forms blocks in the moraines of the Minapin glacier.
Change in thicknesses is particularly conspicuous for the northern conglomerate that varies from a few meters, and may even lack in places, to more than a kilometre on the left bank of the Miar glacier. All three formations are deformed and metamorphosed. The deformation of the conglomerates on both sides of the lineament is heterogeneous, mainly of flattering plus constriction type (cigar-like shaped). The metamorphism is of low grade greenschist facies with typical chlorite, biotite, epidote, and acicular amphibole (see also Rolfo et al., this volume).
The lineament is almost vertical and rectilinear through the entire zone, oblivious of any Nanga Parbat-Haramosh Himalayan indenter. The slight bulge to the south that it shows in the eastern portion looks like moulding around the two gneissic domes of Mangolbluk and Dassu (cf Le Fort et al., in press; Lemennicier et al, this volume).
As already emphasized by Hanson (1989), the lineament cuts across tectonic and metamorphic structures. Its age has to be fairly young, most likely contemporaneous of the end of the doming structuration known to be less than 7 Ma (Smith, 1993; Villa personal corn.). The lineament cannot represent the original suture between Karakorum and Ladakh-Kohistan arc, bracketed between 102 and 85 Ma (Petterson & Windley, 1985), but only the trace of a recent reactivation.
Key words: Ultramafics, structure, Shyok Suture, Kohistan, Ladakh, Karakoram, Baltistan.

L/77. Le Fort, P. & Pecher, A., 1998. A new map of Hunza to Baltistan at 1:150,000 scale, northern Pakistan. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 112-113.

The authors are finalizing a new geological map at 1: 150,000 scale of the mountainous region joining Hunza and Baltistan. The map includes the central granitoid belt and the southern metasedimentary complex of the Karakorum range, volcano-sedimentary and igneous formations of the Kohistan and Ladakh island-are units, and the northern tip of the gneissic Himalayan spur. Some of the salient features evidenced during mapping include:
Lithology: The very continuous marble horizons of the Karakorum metamorphic complex (KMC), some of them of Permian age (see Rolland et al., this volume). The existence of long stripes of orthogneissified granitoid in Karakorum. The reconnaissance of terrigenous formations in south-western KMC. The continuity of the Kohistan to Ladakh formations, limestone horizons in particular. some of them dated as Cretaceous. The existence of ultramafic lineament that separate the island-arc in two domains.
Tectonics: The large isoclinal folding of the Karakorum metamorphic complex (KMC), underlined by very continuous marble horizons. The folding of the Karakorum granites in the isoclinal folds. The presence of a mélange zone along the MKT, north of it (Karakorum side) to the west. south of it (Ladakh side) to the east. Folding of the boundaries between the three units, MKT and MMT. Likeliness that some traditionally described formations may actually belong to the neighbouring unit (e.cr.: amphibolites in the Himalayan unit). The pervasive doming structure in a band, east of the Raikot fault, cutting across Himalaya-Ladakh and South-Karakorum. The northern tip of the Raikot fault, presently the most active fault, corresponding to the north-western edge of the NPHM dome.
Key words: Structure, mapping, Hunza, Baltistan.

L/78. Le Fort, P., Pognante, U. & Benna, P., 1992. The Himalaya-Karakoram contact: eastern termination of the Nanga Parbat spur (Pakistan). Abstract Volume, 7th Himalaya-Karakoram Workshop, Department of Earth Sciences, Oxford University, England, p.48.

The contact of the Nanga Parbat High-Himalayan crystallines (HHC) with the surrounding low-grade metamorphic rocks has been studied during a geological expedition in the Turmik valley (NW of Skardu in Pakistan). On the HHC side, para- and ortho-gneisses show rather homogeneous high-pressure amphibolite facies assemblages (see companion abstract, Pognante et al., this vol.). The metamorphic foliation, strongly underlined by the banding of the gneisses, dips some 450 east and lies parallel to the contact in the upper Stake and Turmik valleys.
The surrounding rocks belong to the Greenstone complex of Tahirkheli & Jan (1979) and Hanson (1986). It is made up of a melange of greenschists, amphibolites, conglomerates and marbles, all more or less lenticular, strongly deformed and metamorphosed in a epidote greenschist facies. The size of the lenticular bodies varies from several meters to a few kilometers in thickness. In the northern tributary valley of Pakora on the way to the Gonto-La, we have found fine grained black muddy limestone containing deformed recrystallized white shells of rudists. At least three different shapes of rudists are present, the age being most likely post-Valanginian, possibly Barremo-Aptian ? (J.P. Masse pers. comm.).
The Greenstone complex comprises tuffaceous schists, banded amphibolites, volcanic breccias and conglomerates, and at least one large occurrence of a body of gabbro. In addition, several screens of serpentinized ultramafics are distributed in the Turmik mélange, the major one underlining its southern boundary with a plutonic member of the Ladakh batholith, at the lower end of the valley (Dasu). Going up the Turmik valley, the foliation rotates from a northern to an eastern dip. In the upper reaches of the valley, the foliation is strongly refolded by a crenulation that has accompanied, under greenschist metamorphic conditions, the differential rise of the HHC gneisses.
Key words: Structure, mapping, Hunza, Baltistan.

L/79. Le Fort, P., Pognante U. & Rolfo F., 1995. Preliminary geological map and description of the Himalaya-Karakorum junction in Chogo Lungma to Turmik area, Baltistan, Northern Pakistan. Journal of Nepal Geological Society, 11**,** special issue, 17-38.

Key words: Mapping, Himalaya, Karakoram.

L/80. Le Fort, P., Tongiorgi, M. & Gaetani, M., 1994. Discovery of crystalline basement and Early Ordovician marine transgression in the Karakoram mountain range. Geology 22, 941-944.

A granite pluton intruding low-grade quartzites and migmatites lies north of the Karakorum axial batholith of Cretaceous to Miocene age. The pluton is covered by transgressive litharenite and slate that contain a fairly rich assemblage of acritarchs of Arenigian age (Early Ordovician), belonging to the Peri-Gondwana biogeographic province. This is the first time that crystalline basement has been found in Karakorum and acritarchs in central Asia. These discoveries add new evidence that the Karakorum microplate, together with the Helmand block of central Afghanistan and the Lhasa block of Tibet, belongs to a Cimmerian domain at the northern fringe of Gondwana.
Key words: Ordovician, marine transgression, granite pluton, Karakoram.

L/81. Le Fort, P. & Villa, I., 1998. Pseudotachylites at crustal scale in Karakorum: the Thui pseudotachylite, northern Pakistan. Geological Bulletin, University of Peshawar 31 (Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop), 114-115.

The Karakorum mountain belt is typically divided into three main units: a northern sedimentary belt (NSB) and a southern metamorphic complex (KMC) separated by a central granitoid batholith (CGB) often referred to as the Axial batholith. In the western part of the Karakorum Mountain, two crystalline belts occur: a northern Hindu Raj belt, that includes Darkot pass and Garmush crystalline masses, and a southern Gamubar belt, that are separated by the Darkot unit of mildly metamorphosed sedimentary series (see Le Fort & Villa, this volume).
In 1996, during the course of our regional reconnaissance and mapping of north-western Karakorum, with Maurizio Gaetani, we have discovered that the northern side of the Ghamubar belt is profusely invaded by a band of pseudotachylite. From north to south, the generally north-dipping section comprises:
the 4 to 7 km wide Darkot unit that had yielded Permian fossils and where we have retrieved Triassic megalodonts, and possible Cretaceous rudists (Gaetani, pers. comm., 1996); a tightly folded and metamorphosed contact zone, about a 100 m thick, mainly made up of black silicic schists at the top and quartzites at the base; the km-thick zone of Aghost banded gneisses, mostly granitic, but also containing very dark biotite and/or amphibole gneisses, as well as several group of layers of marble, presenting tight isoclinal folds usually north-verging. The Thui pseudotachylite fringes the northern boundary of this Aghost formation; a several km thick and massive zone mainly composed of biotite-garnet-sillimanite gneisses interlayered with granitic gneisses and partly migmatised. To the south, this zone is intruded by the Ramach granodiorite and the Ghamubar porphyritic granite (Ghamubar plutonic unit).
We have followed the Thui pseudotachylite for more than 40 km East-West, between Gazin glacier (Yarkhun valley), and summer settlement of Ghamubar (Darkot valley) at the eastern foot of the Ghamubar pass. More to the east, the pseudotachylite seems to pass to ultramylonitic bands within the Aghost gneiss. Vertically, it extends for nearly 3 km. The best set of outcrops is located in the upper Kerun Bar valley where the pseudotachylite forms most of the southern slope, and has a total thickness probably exceeding 10 m.
In the field, the rock appears as centimeter- to millimeter-thick black streaks anastomoziner within the Aghost gneiss, disregarding the orientation of the metamorphic foliation. The disposition of the veinlets reminds of the hydraulic fracturation. The intruding dark veins have a glassy appearance, a conchoidal fracturation, and contain many cataclastic disrupted remains of the enclosing rock. Under the microscope, the veins have an isotropic texture.
In the "basal shales" of the overlying Darkot group, the pseudotachylite develops a few meters thick "contact metamorphism" with micas and, occasionally, garnet. It is very little deformed: on a unique outcrop, we found it to be folded at 50 cm-scale. For the moment, $^{39}Ar/^{40}Ar$ dating by stepwise heating shows the predominance of inherited clasts from an older protolith. This apparently largest so far discovered pseudotachylite, is related to the fast collapse of the sedimentary cover along the top of the southern crystalline mass. One of the latest tectonic movement of the region, it has produced the Darkot graben.
Key words: Tectonics, Karakorum.

L/82. Leghari, A.L., Khan, I.H., Khan, F. & Wazir, A.K., 1986. Occurrence of sulphide mineralization in Nomal area (Toposheet 42 L/8), Gilgit District, Pakistan. Geological Survey of Pakistan, Information Release 268.

Massive sulphide mineralization zone have been found in volcanics and metasediment arc rocks (Greenstone Complex) of Lower Cretaceous age in Nomal area about 25 km north of Gilgit (toposheet No.42 L/8). The mineralization is exposed in an area of 7.5 sq.km approximately. This sulphide zone is recognized as highly weathered and altered product of original rocks being pale, brownish, reddish and black in colour in the upper portion of the outcrop. During geological mapping of the area, 29 samples were collected and chemically analysed.

Majority of samples show very encouraging anomalies of massive sulphide mineralization. The metallic content of analysed samples (Table l) shows that out of 29 samples, all samples contain Fe (averaging 4.17%), 27 samples with Mn (944 ppm), 25 samples have Cu, (353 ppm), 22 samples average in Zn (108 ppm), 6 samples with Pb (550 ppm), 2 samples show content of Au (as 0.65 and 1.03 ppm), two samples have Ag (one with 69 ppm content and other with traces) and finally 9 samples show traces of Mo. Two samples collected from Naltar Gah, northwest of Nomal where volcanics are exposed contain Mn (as 848 and 986 ppm) and Cu (as 7900 and 350 ppm), (Table-1). This report is based on field investigations and chemical analyses, and will be followed by a more comprehensive account of field work and laboratory studies which may prove the area promising for further study of sulphide mineralization.

Key words: Sulphide, mineralization, Nommal, Gilgit.

L/83. Leghari, M.B., 1990-91. The geology, stratigraphy, sedimentation and micro-paleontology of Jabri area District Haripur Hazara (NWFP), Pakistan. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 106p.

The project area is located in district Haripur (N.W.F.P). It covers about 60 sq. km. It is the part of topographic sheet No.43 G/1 published by Survey of Pakistan at the scale of 1: 50000. Geological map at the scale 1:12500 of Jabri, Akhora, Faqir Muhammad, Lassan and Dunna Naurl area is presented along with complete record of Pre-Cambrian to Eocene rock units especially, Hazara Formation, Samana Suk Formation, Chichali formation, Lumshiwal Sandstone, Kawagarh Limestone, .Margala Hill Limestone, Chorgali Formation, exposed in the area. On the basis of field observations and petrographic studies the depositional environments of rock units have been interpreted. The formations exhibit varying fauna and lithology and microfacies from bottom to top.

Basal unit i.e. Hazara Formation which is predominantly slates and Samana Suk Formation which is mainly oolitic Limestone and shows shallow marine environment. The Chichali Formation which is dominantly Black slates with Iron Pyrite nodules, is the result of anaerobic conditions (lagoona1 environments) Glauconitic and ferrogenous Sandstone of Lumshiwal Formation shows open marine shelf environment. Kawagarh Formation possess mainly, fine grained micritic Limestone, which show deep sea environment.

Hangu Formation having laterite Bauxite, limonite, quartzite, red clays, Oolitic Haematitic sandstone and Carbonaceous shales which represent facies change and shows that the area was eroded during that lime of deposition and marks unconformity between Cretaceous to lower Paleocene which is the result of regression of the sea for long period. Lockhart Limestone is mainly nodular, Limestone, medium to find grained with bituminous smell having shales and marl at various places which shows shallow marine environment.

Patala Formation having Khaki shales with fossiliferous Limestone and marl which shows that the environment is shallow marine (Circa litoral sub zone).

Margala Hill Limestone is fossiliferous, nodular Limestone, which also shows shallow marine depositional environment. Chorgali Formation consists of Limestone flaggy marly having abundance of fossils of larger sized forams. It shows shelf environment. The thin section slides from Jurassic to Eocene rock units have been studied. Petrographically Samana Suk Formation (Jurassic) Lockhart Limestone (Paleocene) and Margala Hill Limestone (Eocene) have been studied in detail.

Samana Suk Formation is normally wack to pack stone, according to Dunham's classification, fossiliferous to packed biomicrite, according to Folk's classifications, Lockhart Limestone is normal to wackstone according to Dunham's classification and biomicrite according to Folk's classification. Margala hill Limestone biomicrite, biosparite and spary biomicrite according to Folk (1962) according to Dunham (1962) it is dominantly wackstone, grain stone and pack stone. The measured stratigraphic section of the rock units from Pre-Cambrian to Eocene is presented in Lithology. No. 5 (Pocket). Tectonically the area is highly disturbed, being involved in Himalayan Orogeny. Geological sub surface structures are described with the help of cross section, Almost all the structures follow the general trend NE-SW. From the cross section line along AB shows that intensive deformation in the area.

Some important folds are Dunna Naural anticline, Dotara anticline and syncline, Dubran anticline, Langrial syncline. The project area is highly faulted, the major faults are Karral Haro thrust fault, Langrial Thrust fault, Kohala Lasan fault, Jabri fault, Dubran fault. The Economic potential of Limestone of various rock units, laterite and aggregate have been discussed.

Key words: Stratigraphy, sedimentation, paleontology, Haripur, Hazara.

L/84. Lemennicier, Y., 1996. The south Karakorum metamorphic complex in the Chogo Lungma area (Baltistan, N. Pakistan). Structural, Metamorphic, Geochemical and radiochronological study. Geologie Alpine. Universite de Grenoble, Memoir 26, 171p.

Key words: Structure, metamorphism, geochemistry, chronology, Karakorum, Baltistan.

L/85. Lemennicier, Y., Le Fort, P., Lambardo, B., Pecher, A. & Rolfo, F., 1995. Tectonometamorphic evolution of the central Karakoram (Baltistan-Northern Pakistan). Abstract Volume, 10th Himalaya-Karakoram-Tibet Workshop, (ETH Zurich), Switzerland.

The tectonometamorphic history of the Karakorum has already been considered by several workers, e.g., Bertrand et al (88), Allen & Chamberlain (91), Searle & Tirrul (91), but timing and interpretation of this evolution are still discussed. We present here new structural and metamorphic data from the Chogo Lungma glacier area and Basha valley, at the northeastern side of the Nanga Parbat - Haramosh spur.

A multi-stage structural evolution has been observed, including a first cryptic tectonometamorphic event (not visible at field scale but deduced from the mineral fabric and chemical zoning of minerals), followed by two main syn-metamorphic episodes plus a late folding event.

The first event (we may call it D0, the first event recognized in the field being referred to as Dl), is defined by a metamorphic cleavage within garnet porphyroblasts, underlined by quartz and opaque inclusions, and only visible in the innermost part of garnet. This cleavage is oblique on the main foliation, which at turn can be overprinted by the later garnet rims.

The main tectonometamorphic event (Dl) is characterized by south vergent 61 isoclinal folds (Fig.1-a) at all scales (plurimillimetric to plurihectometric), associated with a metamorphic axial-plane cleavage Si. The axial planes of those folds always strike around N110ºE, with a dip of 60º to 70º northward. The plunges of the fold axis are dispersed in the average axial plane, and are usually steep (pitches from 70ºNW to 60ºSE). It indicates that the folds were probably formed in response to a high flattening rate of deformation, with vertical extrusion of the pinched material. The predominantly flattening regime of deformation is also emphasized by the dispersion of boudin axes in the flattening plane, the presence of circular flattened enclaves, as well as the scarcity of coherent shear criteria. A medium pressure / medium to high temperature peak metamorphism (Mi) with Grt-Bt-Mu-Ky paragenesis corresponds to Dl (620 to 730ºC and 7.5 to ii Kbar; Fig. 2).

The D2 tectonometamorphic event corresponds to the development of several conical dome structures, in which Di isoclinal folds are refolded. The dome structures, drawn by the main metamorphic cleavage inherited from Dl, have N110ºE to N140ºE elongations. The S_2 cleavage is scarcely individualized as it usually corresponds to a reworking of Si. For this reason, it is often difficult to interpret metamorphic fabrics. In some areas, late evolution of the D_2 doming deformation is marked by a crenulation. Petrologically, D_2 is characterized by shearing and boudinage of Ml minerals, and by development of sillimanite. Thus, M2 corresponds to a retrograde evolution in the sillimanite field, with slight changes in temperature, but with a pressure decrease (from more than 7.5 Kbar down to 4 Kbar; Fig.2).

The interpretation of the dome structures can also be debated. The diapiric model, which may be now suitable to explain Archean domes (Choukroune et al, 1994), appears to be very much dependent of the rheology of the crustal component involved. The Metamorphic Core Complex model, associated with extensional mechanisms (Brun & Van Den Driessche, 94), fits rather well with the observed regional pattern, and could apply to the Panmah dome described by Bertrand et. al. (1988) north of Korophon. However, in the Chogo Lungma area, we have no evidence of extensional ductile fabrics or of normal faulting. For Ramsay (1987), doming can be due to heterogeneous shortening. Such heterogeneous strain is easily obtained around an indenter, such as the Nanga Parbat - Haramosh spur.

The D3 event corresponds to large undulations and open folds, as, e.g., the Spantik fold, which affect the D2 crenulation. Actually, 03 seems to be the continuation of D2. The complex tectonometamorphic evolution described here has also been observed by previous workers, but different interpretations have been proposed:

-For Bertrand et al. (1988), the evolution is a two-step's evolution, with (i) the main metamorphic episode related to the Dl isoclinal folds, predating the emplacement of the Mango Gusor granite, dated at 37±0,8 Ma (U-Pb datation on zircon, Parrish & Tirrul, 1989), and (ii) a distinct Miocene metamorphism and deformation, with open folds and doming;
-For Allen and Chamberlain (1991), the whole tectonometamorphic evolution predates the Mango Gusor granite emplacement. They consider that the main metamorphic imprint was acquired earlier than the main deformation, and for them, the observed metamorphic pattern is mainly due to the stacking of two nappes, separated by a thrust.
In the Basha and Chogo Lungma area, the metamorphism is clearly synchronous with the deformation: kyanite grows in the Si foliation plane and the sillimanite development corresponds to the doming deformation. This evolution can also be seen in the garnets associated with sillimanite, in which transects indicate a retromorphosis of the rim. Considering the timing of the tectonometamorphic events, for the doming phase (D2), preliminary 40Ar/39Ar results on amphibole and biotite (I. Villa, personal communication) give very young ages (<10 Ma), in good accordance with the- Miocene ages proposed by Bertrand et al. (1988) for their second metamorphic and tectonic event. We have no good constraints for the Dl age. If we consider the interpretation of the previous authors, it could predate the Mango Gusor granite, and be related to the main continental collision. However, the pattern of the metamorphic PT path (Fig.2) corresponds to rapid exhumations' rates which do not fit quite well with a long gap of time between Ml and M2. The different phases could be part of a continuum of deformation.
We have not been able to define clearly the western prolongation of the Gama Sokha Lumbu thrust described by Bertrand et al (1988). However we have mapped orthogneiss sheets intercalated in the metasedimentary formations, north of Chogo Lungma glacier. They could indicate nappe stacking, but we have not found shear criteria at their contacts. They could also be interpreted as laccolitic intrusions of granites into the sedimentary pile, previous to the main Dl isoclinal folding and metamorphism. The occurrence of retromorphosed chiastolitic andalusite (relics of contact metamorphism?) could validate this second hypothesis.
Altogether, the tectonometamorphic evolution of central Karakoram remains difficult to set into a global geodynamic frame. The recent age of the D2 event implies that most of the observed tectonometamorphic evolution is fairly young. The early evolution of this portion of crust may still be blurred by this more recent activity. If this is true, central Karakoram offers the possibility of being a young collision range.
Key words: Tectonometamorphism, Karakoram.

L/86. Lemmenicier, Y., Le Fort, P., Lombardo, B., Pêcher, A. & Rolfo, F., 1996. Tectonometamorphic evolution of the central Karakoram (Baltistan, northern Pakistan). Tectonophysics 260, 119-143.

New structural and metamorphic data from the Chogo Lungma glacier area and Basha valley enlighten the polyphased tectonometamorphic evolution of the Metamorphic Complex of Karakorum. A pre- to early D1 event is defined by a metamorphic cleavage in the core of some zoned garnet and staurolite porphyroblasts. The main tectonometamorphic event (D1) is characterized by N110°E south-vergent isoclinal folds associated with a metamorphic axial-plane cleavage formed in a predominantly flattening regime of deformation. It corresponds to a Grt-Bt-Mu-Ky peak metamorphism (M1: 620–730°C and 7.5–11 kbar). The D2 tectonometamorphic event corresponds to the development of several conical domes elongated striking N110°E to N140°E. The S2 cleavage is seldom individualized as it usually corresponds to a reworking of S1. In some areas, late evolution of D2 doming deformation is marked by a crenulation. Petrologically, D2 is characterized by shearing and boudinage of M1 minerals and by development of sillimanite. It corresponds to a decompressional evolution (7.5 down to 4 kbar) with only slight changes in temperature. A late event corresponds to large undulations and open folds which affect the D2 crenulation. We propose here a model of vertical plus dextral extrusion of the middle crust to explain the dome structures in Karakorum. The steep pattern of the metamorphic *P-T* path implies rapid exhumation rates and suggests that the different phases could be part of a continuum of deformation. Preliminary results by $^{40}Ar/^{39}Ar$ method give young cooling ages (<10 Ma) for the D2 event (Villa et al., 1996, this issue). Thus, most of the observed tectonometamorphic evolution in central Karakorum could be fairly young.
Key words: Tectonics, metamorphism, Karakoram.

L/87. Lemennicier, Y., Le Fort, P., Pecher, A., Lapierre, H. & Rolfo, F., 1996. The Hemasil Syenitic Dome: An example of Miocene Syn-Orogenic Alkaline Magmatism, Karakoram-N

Pakistan. Abstract volume, 11th Himalaya-Karakoram-Tibet Workshop, Flagstaff, Arizona (USA), 85-86.

The Hemasil syenite is a small pluton intrusive in the continental formations of the Karakoram metamorphic complex near its southern contact with the Ladakh-Kohistan island arc formations. The syenite is emplaced in late Miocene times (Villa et al., in press) as a dome–shape pluton during the last tectonometamorphic event affecting the area in a compressive + transcurrent context associated with high denudation rates (Lemennicier et al. in press). It is a leucocratic rock with a fK-P1-B±Am±Sph main paragenesis and rare feldspathoids (sodalite). It is ferriferous and extremely potassic (7.0 to10.6 wt% K2O), with K2O/Na2O ratios from 1.15 to 5.24. La/Lu ratios are high (60.0 to 117.2). However, it shows a strong heterogeneity in trace elements composition with two main populations: population 1 enriched in MREE, Ba, Sr, V and slightly depleted in U, Th, Hf, Zr; population 2 normal in MREE, slightly enriched in HREE, enriched in U, Th, Hf, Zr, and strongly depleted in Ba. The same heterogeneity is observed in isotopic data recalculated at t=10 Ma (Fig. 2): population 1 has eSr = -2.3 and 3Nd = +4.3, whereas population 2 has positive eSr (+8.1 +/- 14.7) and slightly lower eNd (+3.0 to + 3.6). There is no isotopic correlation between the tow populations. The variation cannot be explained by simple fractionation processes nor by alteration phenomena (very fresh rocks), but is more probably reflecting source heterogeneities or contamination processes. Whole rock isotopic ratios suggest a slightly depleted mantle source, mainly for population 1, but slightly enriched in strontium for population 2. However, trace elements indicate an obvious contamination, but different for each population. In addition, the trace element composition resembles that of the lower crust, except for incompatible elements. Lower crust can thus represent the (or a) contaminant. Actually, the Hemasil syenite, though it is emplaced in a continental collision chain, would result from partial melting of a mantle source contaminated, during its ascent, by a limited addition of lower crust material.
Key words: Syenitic dome, Miocene, alkaline magmatism, Karakoram.

L/88. Lemennicier, Y., Villa, I.M., Le Fort, P., Pecher, A. & Briner, A., 1997. New $^{40}Ar/^{39}Ar$ age constraint on the metamorphic evolution of Karakoram metamorphic complex in Braldu and Chogo Lungma Areas, NW Pakistan. Abstract volume, 12th Himalaya-Karakorum-Tibet International Workshop, Rome, Italy, 171-172.

The Karakorum Metamorphic Complex (KMC), the northern margin of the Cretaceous Neotethys, is composed of amphibolite facies gneiss (ortho- and para-) domes and metasedimentary formations. Its tectono-metamorphic evolution includes a first phase of south vergent isoclinal folding of unknown age and a second phase of doming considered as Tortonian (see Le Fort et al., 1995; Lemennicier et al., 1996; Villa et al., 1996).
Ten new samples from the KMC have been analyzed by 40Ar/39Ar stepwise heating: 4 amphiboles from the Basha-Chogo Lungma area and 6 micas from the Braldu valley on the Dassu dome, east of the Basha valley.
All amphiboles have been separated from orthogneisses, viz. mafic dykes or layers. The first amphibole (Moraine gl), collected far from the dome area in the isoclinally folded metasedimentary formations, is recrystallized. It gives a little-disturbed age spectrum around 55-60 Ma. The three other amphiboles come from the Mangol Block dome sector and give well-resolved mixed-phase degassing, with the younger amphibole generation ≤20 Ma and the older one >120 Ma for two samples.
From five granitic orthogneiss samples of the Braldu valley we dated five biotites and one muscovite. The biotites yield ages between 4 and 8 Ma, although they have been collected in similar structural position within the dome. The muscovite shows a clear mixed-generation spectrum with a young generation around 7 Ma and an old generation certainly >35 Ma.
Interpretation
The amphibole from the metasedimentary formations is sufficiently far from the dome area to be not affected by their thermal effect. Its age could be interpreted as the age of the amphibolite-facies isoclinal folding, and be related to the India-Asia continental collision for the western part of the Himalayan orogenesis. However, the span of some 45 Ma between folding and doming questions the continuum of metamorphism between the two phases (as had originally been proposed by Lemennicier et al., 1996).
The young amphibole generation of the three samples from the dome is compatible with our identification of a -10 Ma doming event in that area (Villa et al., 1996), and of a partial overgrowth of the amphibole, without rejuvenation of the old cores. The old amphibole generation suggests a minimum Jurassic age for the protolith of the KMC.

The ages of the micas from the Dassu dome confirm the already published data (~5 Ma: Searle & Tirrul; 1991; Smith, 1993). They show that the Miocene evolution of the Dassu dome and Basha valley domes is similar, and emphasize the 10 Ma event. The data scatter between 4 and 8 Ma for the biotites is difficult to interpret. Numerous (up to 10 Vol %) pegmatitic dykes cutting the foliation are present in this area, and they possibly have an influence on the age of the orthogneiss biotites. The mixed-generation muscovite gives informations similar to the amphiboles from the Basha domes.
These new data seem to point to a Paleocene metamorphism linked to south vergent isoclinal folding, but this age needs to be confirmed by a larger sampling in areas not affected by the doming. The second tectonometamorphic event results in neoformation of micas and (incompletely resolved) amphibole overgrowth between 10 and 4 Ma. Thus, the development of the KMC crust is not just a simple high-grade metamorphism followed by "episodic uplift", but a more complex geological evolution comprised of a Mio-Pliocene shearing causing recrystallization of micas and amphiboles under amphibolite grade conditions.
Key words: Chronology, metamorphism, evolution, Karakoram, Chogo Lungma, Braldu.

L/89. Li, J., Derbshire, E. & Shuyina, X., 1984. Glacial and paraglacial sediments of the Hunza valley, North West Karakoram, Pakistan - A preliminary analysis: In: Miller. K.J. (ed.), The International Karakoram Project 2, 496-535. Cambridge University Press.

The tills of the upper Hunza region include both lodgement and meltout types. Particle size analysis shows them to be relatively coarse-grained and somewhat positively skewed. There is evidence of modification of the particle size distribution by melt water eluviation, especially in the case of the Ghulkin and Pasu glacier deposits by the role of bedrock lithology and glacier size is also discernible. Tills currently being deposited are predominantly of meltout type: these have diffuse fabrics, rather granular matrixes and contain evidence of eluviation and collapse. Re-deposition of the abundant coarse supraglacial debris by sliding under gravity is common. The thickest exposures of compact and sheared lodgement till, on the other hand, are of Pleistocene age, especially those of the main valley (t2), diffluence col (t3) and expanded foot (t4) stages. There is no evidence of direct deposition of till by viscous flow either during or since the Pleistocene although the abundant debris flows do contain glacial material. It appears likely that the present combination of high-activity glacial regimes and arid to semi-arid valley floor climatic conditions have prevailed since at least the beginning of the late Pleistocene. The distribution of the dense, jointed lodgement tills of Pleistocene age is consistent with their deposition in generally free-draining environment beneath thick glaciers. The genetic classification of tills based on field relationships is generally confirmed by laboratory-derived data on particle size, particle shape, stone orientation and fabric.
Key words: Sedimentology, glacial till, Hunza, Karakoram.

L/90. Lillie, R.J., 1991. Evolution of gravity anomalies across collisional mountain belts: clues to the amount of continental convergence and underthrusting. Tectonics, 10 (4), 672-687.

A series of density models illustrates the gross form of free air and Bouguer gravity anomalies anticipated during ocean basin closure and consequent development of collisional orogens. When compared to gravity anomalies observed across some mountain belts, the hypothetical anomalies provide a clue to the degree of under thrusting of crust associated with one lithospheric plate beneath crust of the opposing plate margin. The results of the study suggest very early stage collision in the Ouachita Mountains of Arkansas and the Sulaiman Range of Pakistan, with thin transitional or oceanic crust still intact on the lower plate. In contrast, the Himalaya of Pakistan represent a much more advanced stage of collision, where continental crust may have underthrust the mountains for 600 km.
Key words: Collision belts, orogeny, geophysics, Suleiman Range, Pakistan.

L/91. Lillie, R.J., 1996. Foreland Fold-and-Thrust Belts of the Western Himalaya: diversity due to differing stages of continental collision. Abstract volume, 11th Himalaya-Karakoram-Tibet Workshop, Flagstaff, Arizona (USA), 87-88.

The active foreland fold-and-thrust belts of western India and Pakistan show a variety of deformational styles that relate to the type of crust beneath the decollement. Studies incorporation surface, drill hole and seismic reflection profiles reveal differences in thickness of strata, lithology, and overthrust wedges taper; the differences relate to varying degrees of underthrusting of the Indian continental margin.

In India and northern Pakistan, there have been several hundred km of convergence since collision, so that the full-thickness craton India constitutes the underthrusting plate in the Sub-Himalaya (Duroy et al., 1989). The pre-collisional (Mesozoic and older) strata associated with the craton are only about 1 km thick; the buoyancy of the thick craton limits the thickness of post-collisional molasse to only 5 km. In the Sulaiman Range to the southwest, convergence since collision has been minor, so that the Mesozoic passive margin of India constitutes the lower plate. Seismic reflection profiles show that the undeformed sedimentary strata in from of the Sulaiman Range are 10 km thick (Humayon et al., 1991); cross-section balancing suggest that the deformed sedimentary package in the Sulaiman interior may be considerably thicker (Jadoon et al., 1994). These thicknesses are possible because the sediments rest upon thin crust of the continent-to-oceanic transition; the thick sediments are compensated by shallow mantle of the Mesozoic passive margin.
The nature of the crust of the Indian Plate influences the thickness and composition of overlying strata, thereby affecting the critical taper angle (basement + topographic slope) necessary for overthrusting (Davis and Lillie, 1994). The thin sedimentary package that overlies the Indian craton generally deforms in a brittle regime. Beneath the Sub-Himalaya of India there is strong coupling between sediments and basement, so that a broad critical taper angle (>5º) is observed. An exception occurs in Pakistan, where evaporites of the Salt Range Formation behave ductilly; the necessary critical taper angle is narrow (≈1º; Jaume and Lillie, 1988). Beneath the central Salt Range and Potwar Plateau, seismic reflection profiles (Lillie et al., 1987) reveals that the basement slope alone is sufficient to provide critical taper; not topography slope is required, so that the region is translated southward with little internal deformation. In the eastern Potwar Plateau the basement slop is less than 1º, so that distributed deformation builds the topography necessary for critical taper (Pennock et al., 1989). In the Sulaiman region, carbonates of the Mesozoic passive margin may be buried so deeply that they are ductile, producing a narrow critical taper angle.
Along virtually all the deformation front of the Sub-Himalaya, only very young molasse is exposed. The notable exception occurs where the entire sedimentary section (Eocambrian to Recent) is brought to the surface along the Salt Range Thrust. Reflection profiles reveal that ramping occurs where the salt decollement is offset by a basement normal fault (Baker et al., 1988). The normal fault, within the underthrusting craton, was apparently caused by flexure of the Indian Plate as it was loaded by weight of the Himalaya. The modern expression of the flexural bulge is the Delhi-Sargodha Ridge, revealed by Precambrian outcrop in the Kirana Hills of Pakistan.
Key words: Foreland basin, seismology, structural geology, collision, Himalaya.

L/92. Lillie, R.J., Johnson, G.D., Yousaf, M., Zamin, A.S.H. & Yeats, R.S., 1987. Structural development within the Himalayan foreland fold-and-thrust belt of Pakistan. In: Beaumont & Tankard (eds.), Sedimentary basins and basin-forming mechanisms: Canadian Society of Petroleum Geologists, Memoir 12, 379-392.

For further information, consult the preceding work.
Key words: Foreland basin, structural geology, Collision, Himalaya.

L/93. Lillie, R.J. & Yousaf, M., 1986. Modern analogs for some mid crustal reflection observed beneath collisional mountains belts. Reflection Seismology Geodynamics Series 14, 379-392.

Key words: Reflection seismology, collision belts, orogeny, Suleiman Range, Himalaya.

L/94. Lindsay, E.H., 1987. Cricetid rodents of Lower Siwalik deposits, Potwar Plateau, Pakistan and Miocene mammal dispersal events. Evk Magy All Foldt Intez [Budapest] 70, 483-488.

Key words: Paleontology, rodents, siwaliks, Potwar.

L/95. Lindsay, E.H., 1988. Cricetid rodents from Siwalik deposits near Chinji Village. Part I: Megacricetodontinae, Myocricetodontinae and Dendromurinae. Palaeovertebrata, 18 (2), 95-154.

Key words: Palaeontology, rodents, Chinji Formation, siwaliks.

L/96. Lindsay, E.H., 1994. The fossil record of Asian Cricetidae with emphasis on Siwalik cricetids. In: Tomida, Y. & Setoguchi, C.K.L.T. (eds.), Rodent and lagomorph families of Asian origins and diversification. National Science Museum, Tokyo, Monographs, 8, 131-147.

Key words: Palaeontology, rodents, siwaliks.

L/97. Lindsay, E.H., 1996. A new eumyarionine cricetid from Pakistan. Acta Zoological Cracoviensia, 39 (1), 279-288.

For further information, consult the following.
Key words: Palaeontology, rodents, siwaliks.

L/98. Lindsay, E.H., 1997. A new eumyarionine cricetid from Pakistan. Abstracts, 3rd GEOSAS Workshop on Siwaliks of South Asia, Islamabad. Geological Survey of Pakistan, Records 109, 57.

Miocene deposits in four areas of Pakistan (Potwar Plateau, Trans-Indus area, Sulaiman foothills, and Balochistan) have produced a rich and diverse record of cricetid rodents that spans an interval of about 12.5 my (20 to 7.5 Ma). This interval apparently spans the "cricetid vacuums" of Europe (about 18-20 Ma) and North America (about 17-19 Ma); the Pakistan record fills a critical gap the history of Palearctic cricetid rodents and enriches our understanding of their evolution. A new species of Eumyarioninae cricetid, Eumyarion kowalskii, n.sp. is reported from the Sulaiman foothills of Pakistan. E. kowalskii probably gave rise to Prokatzisamys and the rest of the Rhizomyidae. In addition to Eumyarion, the Eucricetodontinae cricetids are represented in Pakistan by two species of Primus; the Democricetodontinae are represented by three species of Spanocricetodon and eight species of Democricetodon. The Megacricetodontinae are represented in Pakistan by four species of Megacricetodon and two species of Puiyabemys. The Myocricetodontinae are represented in Pakistan by two species of Myocricetodon and three species of Dakkamyoides. The Dendromurinae are represented by one species of Potwarmus, one species of Paradakkamys and two species of Dakkamys. The Miocene record of these six informal groups of cricetid rodents in Pakistan represents an important chapter in the history of muroid rodents.
Key words: Palaeontology, siwaliks.

L/99. Lindsay E.H. & Downs, W.R., 1998. Cricetid rodents from Miocene deposits of Pakistan, 35-47. In: Ghaznavi, M.I., Raza, S.M. & Hasan, M.T. (eds.), Siwaliks of South Asia. Geological Survey of Pakistan, Islamabad.

Key words: Palaeontology, Miocene, rodents, siwaliks.

L/100. Lindsay, E.H., Johnson, N.M. & Opdyke, N.D., 1980a. Correlation of Siwalik faunas. In: Jacobs, L.L. (ed.), Aspects of vertebrate history; essays in honor of Edwin Harris Colbert: 309-319. Museum of North Arizona Press, Flagstaff.

Key words: Paleontology, faunas, siwaliks.

L/101. Lindsay, E.H., Opdyke, N.D. & Johnson, N.M., 1980b. Pliocene dispersal of the horse Equus and late Cenozoic mammalian dispersal events. Nature, 287, 135-138.

The Cenozoic history of land mammals is marked by brief periods of intercontinental dispersal, termed dispersal events. One of these dispersal events includes the horse *Equus*, that evolved in North America, dispersed to the Old World in the Pliocene, and became a prominent member of Old World Pleistocene communities. *Equus* was derived from a species of the single-toed horse *Pliohippus*, known only from North America3. Timing for the Pliocene

dispersal of *Equus* into Europe was questioned4 following resolution for the appearance of *Equus* into the Siwalik sequence of Pakistan5. It seems that there were at least three major dispersal events of large mammals during the Pliocene (at 1.9, 2.6 and 3.7 Myr). We now report new data that limit the time of *Equus*' dispersal and into Europe to the 2.6 Myr dispersal event.
Key words: Palaeontology, Pliocene, mammalian dispersal, siwaliks.

L/102. Liu, G., 1980. The climate of the Batura Glacier and its adjacent areas. In: Shi, Y. (ed.), Professional Paper on the Batura Glacier and Karakoram Mountains, 99-110. Science Press, Beijing.

Key words: Climate, glaciology, Batura, Karakoram.

L/103. Loewe, F., 1923. Die Eiszeit in Kashmir, Baltistan and Ladakh, Zs. Gesell. Erdk, Berlin, 42–53.

Key words: Kashmir, Baltistan, Ladakh.

L/104. Loewe, F., 1961. Glaciers of Nanga Parbat. Pakistan Geographical Review 16, 19-24.

Key words: Glaciers, Nanga Parbat.

L/105. Lombardi, F., 1991. Geodatic and topographic survey of Desio's 1954 Expedition. Italian Expedition to the Karakorum (K2) and Hindu Kush (A. Desio leader). I-Geography, volume 1, 125-141, ISMEO, Milano (Scientific Reports 1-Geography).

The 1954 expedition was engaged in multi-faceted studies. Important contribution was made in geodesy and topography, especially of the high peak areas and major glacial valleys. This paper deals with the methodology and results of the survey. Contribution include four excellent topographic maps in the pocket of the volume: 1) 1: 12,500 scale of the K2 area, 2) 1:50,000 scale of the Stak valley, and 3) 1:100,000 scale of Baltoro Glacier and Stak-Turmik valleys.
Key words: Italian Expedition 1954, geodesy, topography, Karakoram.

L/106. Lombardo, B., Borghi, A., Rolfo, F. & Visona', D., 2001. Formation and exhumation of eclogites and HP granulites in the Himalaya. Journal of Asian Earth Sciences 19, p.42.

Key words: Eclogite, granulite, exhumation, Himalaya.

L/107. Lombardo, B., Le Fort P., Lemmenicier Y., Pecher A., Pertusati P., Pognante U. & Rolfo, F., 1995. The Ladakh Terrain at the Karakorum-Nanga Parbat-Haramosh junction, Baltistan, Northern Pakistan. International Ophiolite Symposium, Pavia, September 1995.

Key words: Tectonics, Ladakh terrain, NPH, Karakoram.

L/108. Lomdardo, B. & Rolfo, F., 2000. Two contrasting eclogite types in the Himalayas: implications for the Himalayan orogeny. Journal of Geodynamics 30 (1-2), 37-60.

The metamorphic evolution of granulitized eclogites recently discovered in the Eastern Himalaya compared to that of the eclogites of the Northwestern Himalaya (upper Kaghan Nappe and Tso Morari Dome) suggests the possibility of a Himalaya-wide eclogitic metamorphism of Early Tertiary age. Eclogites from the Northwestern Himalaya record peak metamorphic temperature of 580-600 °C at metamorphic pressures in excess of 23-24 kbar. They have glaucophane as a retrograde phase and followed a nearly isothermal decompression path into the field of epidote amphibolite facies. In contrast, the Eastern Himalaya eclogites have a strong granulite-facies overprint at metamorphic temperatures of about 750 °C and pressures of 7-10 kbars, and followed a clockwise decompression path strongly convex toward high metamorphic temperatures. The main difference between the crystalline nappes of the Northwestern Himalaya and those of the East Himalaya appears to lie in the different P-T path they followed during exhumation. In particular the Northwestern Himalaya crystalline nappes lack the Miocene high temperature and low pressure overprinting which is characteristic if the Eastern Himalaya, where thermal relaxation of the thickened continental crust erased almost completely the mineralogical record of the early stage of continental collision.

Key words: Metamorphic evolution, eclogites, Kaghan valley, Himalaya.

L/109. Lombardo, B., Rolfo, F. & Compagnont, R., 1998. Glaucophane and barroisite eclogites from the High Himalayan Crystallines of the Kaghan valley, Pakistan Himalaya. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 116-118.

This report presents preliminary results of a petrographical and mineralogical study of the eclogite samples from the High Himalayan Crystallines (HHC) of the upper Kaghan valley in which Pognante discovered the presence of glaucophane.

The eclogites described here were collected by U. Pognante in 1991 just south of Babusar Pass, close to the summer settlement of Gittidas. They belong to the same suite as the garnet-omphacite-phengite-quartz-Futile eclogites dated as Eocene. The Gittidas eclogites show differences in mineralogy which reflect compositional differences in the protolith and were apparently equilibrated in different stages of the metamorphic history. In addition to omphacite, garnet and accessory rutile, most samples contain a significant amount of quartz (up to 15% vol.). The peak assemblage may also include kyanite, zoisite and ankerite or phengite. Poikioblasts of blue-green or blue amphibole are conspicuous in thin section. In Fe-rich eclogite the amphibole is glaucophane, with high Al^{iv} (up to 0.2 atoms p.fu.) and Ca in M4 (up to 0.4 atoms p.fu.), whereas in more magnesian varieties it is barroisite with high Na in M4 (up to 0.7 atoms p.fu.). Paragonite may be present either as part of the peak assemblage or as a retrogression phase after kyanite. A reddish epidote of allanite composition was found in the glaucophane eclogite.

Garnet is only slightly zoned in the glaucophane eclogite but displays strong prograde zoning in more magnesian varieties, with Fe decreasing and Mg increasing from core to rim. The iron-rich core is usually crowded with minerals of the peak assemblage, but locally inclusions of green and blue-green amphibole were also found. In foliated eclogites the garnet inclusions often define an internal foliation, commonly discordant to the main external foliation. In some garnet crystals, retrograde biotite appears to develop from the Mg-rich rim inwards, producing an atoll-like structure. Omphacite is frequently crowded with very small rutile needles, suggesting replacement of a former Ti-bearing igneous (?) pyroxene.

During retrogression garnet develops a thin corona of green amphibole, omphacite is replaced by a symplectite of albite + amphibole and phengite by a symplectite of biotite + feldspar.

The Gittidas eclogites are associated with a metasedimentary sequence of paragneiss with the high-pressure assemblage garnet-K-white mica-plagioclase-kyanite-staurolite-zoisite and accessory rutile, with retrograde margarite and biotite. Garnet is zoned, with Fe-rich cores and Mg-rich rims, its chemical composition and zoning being comparable with those found in the barroisite eclogites. This suggests that the quartzofeldspathic country rocks probably suffered the same high-pressure metamorphism as the eclogites did.

Equilibration conditions in the Gittidas barroisite eclogites have been estimated at T=600±30°C and P > 13 kbar from Fe/Mg partition in garnet-omphacite and garnet amphibole pairs, and from the jadeite content of omphacite (X_{Jd} UP to 0.42). This estimate is close to temperature conditions estimated for the eclogites and high pressure metapelites of the North Himalayan Tso-Morari Dome (580±60°C and 550±50°C, respectively). However, the Tso Morari metapelites have jadeitic pyroxene, and hence this unit is believed to have equilibrated at metamorphic pressures significantly higher than the Kaghan HHC.

At the regional scale, metamorphic peak temperature recorded by both the Kaghan and Tso Morari eclogites during the Eocene high pressure event appear to be significantly different from those recorded by metabasaltic and metadoleritic garnet granulites in the HHC of the northeastern Nanga Parbat-Haramosh Massif, where geothermobarometry of the peak assemblage clinopyroxene-plagioclase-garnet-quartz-rutile suggests temperatures around 700'-800'C and pressures around 12-14 kbar for a younger (Miocene?) high pressure metamorphism affecting the High Himalayan Crystallines of the North Western Syntaxis.

Key words: Petrography, alkali amphiboles, eclogites, Kaghan valley, Himalaya.

L/110. Lombardo, B., Rolfo, F. & Compagnoni, R., 2000. Glaucophane and barroisite eclogites from the Upper Kaghan nappe: implications for the metamorphic history of the NW Himalaya. In: Khan, M.A., Treloar, P.J., Searle, M.P. & Jan, M.Q. (eds.), Tectonics of the Nanga Parbat Syntaxis and the Western Himalaya. Geological Society, London, Special Publication 170, 411-430.

This paper presents the results of a petrographical and mineral chemical study of glaucophane- and barroisite-bearing eclogites from the Upper Kaghan nappe in the Higher Himalayan Crystalline of the Pakistan Himalaya, and discusses the implication of the P-T path recorded in such rocks for the tectonic and metamorphic history of the NW Himalaya. The eclogites described here come from a previously undescribed outcrop at Gittidas, but belong to the same suite as the garnet-omphacite-phengite-quartz-rutile eclogites previously described elsewhere in the Upper Kaghan nappe. The metamorphic peak assemblage is garnet-omphacite-rutile-quartz in glaucophane eclogite and garnet-omphacite-zoisite-rutile ± kyanite ± phengite ± ankerite in barroisite eclogite. Most samples contain a significant amount of amphibole, white mica and quartz. White mica may be present either as part of the peak assemblage (phengite) or as a retrogressive phase after kyanite (paragonite). Amphibole is later than the metamorphic peak assemblage and is barroisite in most samples, but in relatively Fe-rich eclogite it is glaucophane with significant Na in the A SIT, Ca in the M4 sit and tetrahedral Al. Garnet displays strong prograde zoning in the barroisite eclogites, with Mg increasing and Fe decreasing from core to rim. The iron-rich core is crowded with mineral inclusion of the peak assemblage, but inclusion of earlier pargonite, green and blue-green amphibole was also found. Peak metamorphic conditions in the barroisite eclogites have been estimated at T=610 ± 30ºC and P=24 ± 2 kbar from Fe/Mg partition in garnet-omphacite pairs, and from the garnet-omphacite-phengite barometer. These values are close to the equilibration conditions estimated for the eclogites of the NORTH Himalayan Tso-Morari Dome. Strong similarities between metamorphic evolution of the Upper Kaghan nappe and metamorphic evolution of the eclogite-bearing units in the Neelum Valley just to the east of the Kaghan Valley indicate that the eclogite extent, which was subjected to high pressure metamorphism in middle Eocene times. A comparison of the metamorphic evolution recorded in the eclogites of the NW Himalaya with that of the granulitized eclogites recently discovered in the E Himalaya suggests the possibility of a Himalaya-wide eclogitic metamorphism of pre-Miocene age. Therefore, the main difference between the Higher Himalayan Crystalline nappes of the NW Himalaya and those of the E Himalaya appears to lie less in the early part of their metamorphic evolution than in the different P-T paths they followed during exhumation.
Key words: Petrology, mineralogy, eclogites, Kaghan valley, Himalaya.

L/111. Loprete, E., 1995. Studio geochimico e microtermometrico delle inclusioni fluide, in marmi e rubini del Surgun Group (Himalaya, Pakistan nord-orientale). MS Thesis, Dipartimento di mineralogia e petrografia, Facolta di Scienze M.F.N., Torino.

Key words: Geochemistry, fluid inclusions, marbles, ruby, Himalaya.

L/112. Luff, I.W., Rex, D.C., Guise, P.G. & Windley, B.F., 1985. K-Ar and Ar-Ar dating of the Kohistan arc sequence, Northern Pakistan. Abstract Volume, 1st Himalayan Workshop, Department of Geology, University of Leicester.

The geological evolution of Kohistan is characterized by two stages of crustal accretion punctuated by a major tectono-metamorphic event. The initial island arc stage of Kohistan is represented by a sequence of dominantly meta-igneous rocks, which as a result of deformation and uplift provide a virtually complete section through the island arc. The arc sequence comprises, from north to south, the Aptian-Albian Yasin Group of upper-arc sediments, underlain by the island arc Chalt Volcanic series. The middle and lower crustal levels of the arc are represented by the mainly meta-volcanic Kamila Amphibolites, which are intruded by the Chilas Complex, an enormous mafic/ultramafic body which probably formed near the base of the arc. Metamorphic grade increases from greenschist in the north to granulite in the Chilas Complex. K-Ar dates from metamorphic mineral phases (mainly hornblende) range from 7 to 340 Ma Ar-Ar studies have shown that the oldest dat4es are due to excess Ar, with Ar-Ar patterns being generally U-shaped with minima in the range 70 to 80 Ma. The oldest r3eliable ages for pre-tectonic metamorphic rocks or post-tectonic intrusives are around 95 Ma, suggesting that the major deformational event took place shortly before this time.

Post-tectonic rocks in Kohistan are mainly represented by the Kohistan Batholith, a major I-type cordilleran plutonic suite forming the westwards continuation of intrusives in Ladakh and Tibet. The batholith has been dated using samples from three main areas: the northern margin gives ages in the range 32-95 Ma; the Karakoram Highway section southeast of Gilgit gives ages in the range 17-39 Ma, while at the southern margin of the batholith the 58 Ma Kalam andesitic Volcanics both overlie and are intruded by batholith rocks ranging in age from 40 to 94 Ma. In addition, an extensive post-tectonic dyke suite in the Hunza River section north of Gilgit gives Ar-Ar ages in the region 70-80 Ma. Young ages, down to 7 Ma obtained from rocks in the Indus Valley Section probably reflect recent uplift centered on the Nanga Parbat massif, as documented by Zeitler using fission track methods.

The major deformation event affecting the original island arc sequence in Kohistan must have taken place after the deposition of the Yasin Group sediments but before the oldest undeformed plutonics of the batholith at 95 Ma. This event is correlated with the formation of the Northern Suture and implies that the Kohistan Arc originally formed near the southern margin of the Asian Continent and was generated above a northwards-directed subduction zone. Continued northwards subduction following the initial collision with the Asian Continent led to the development of the Kohistan Batholith at an Andean-type margin. Major magmatism ceased around 40 Ma, close to the age of final collision with the Indian Continent, though the youngest intrusive rocks were emplaced close to 30 Ma.

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

L/113. Loucks, R.R., Ashraf, M., Awan, M.A., Khan, M.S. & Miller, D.J., 1992. Subdivisions of the Kamila amphibolite belt in southern Kohistan island arc complex, Pakistan. Kashmir Journal of Geology 10, 147-152.

Previously known Kamila Amphibolite Belt has been studied further now in details and found to consist of three principal subdivisions. These are Dasu, Kayal and Patan complexes underplated successively. They are composite of several mafic-ultramafic cumulate intrusions that vary in degree of metamorphic hydration and deformation. The Dasu Complex Indus Valley consist of extremely deformed, polymetamorphosed, epidote-garnet amphibolite banded gneisses. These record metamorphic P-T conditions averaging 5.5-6.5 kb and 520-580ºC the Kayal Complex consists chiefly of garnet-epidote amphibolites with strong foliation but only rare gneissic segregation banding with igneous hornblende and layering. Metamorphic assemblages record P-T conditions of about 7 kb and 620ºC near base. The Patan Complex is massive to modally layered and locally crossbedded gabbronorite at base to hornblende-gabbronorite and diorite in the upper part with magmatic-epidote tonalite adjacent to its roof. Mineral geobarometry yields a pressure of 7.5 kb near roof. The stacking thus formed by a process whereby a thick crust of continent-like thickness and composition developed by repeated episodes of igneous intrusion along Moha.

Key words: Ultramafics, metamorphisms, Kamila amphibolites, Kohistan island arc.

L/114. Loucks, R.R., Miller, D.J., Ashraf, M., Awan, M.A. & Khan, M.S., 1990. The Jijal complex: Layered mafic-ultramafic arc accumulates from the crust-mantle boundary Pakistani Himalayas. EOS, 71, p 664.

The mafic to ultramafic rocks of the Jijal complex are cumulates that have formed under high pressure granulite facies conditions. These rocks crystallized from magma at the crust-mantle boundary.

Key words: Ultramafic-mafic rocks, Jijal complex, Kohistan.

L/115. Loucks, R.R., Miller, D.J., Ashraf, M., Awan, M.A. & Khan, M.S., 1992-93. Principal subdivisions of the southern amphibolite belt in southern Kohistan. Regional Postgraduate Training Course in Plate Tectonics, Punjab University, 37-38.

We have mapped the principal lithologic units and structural features of southern Kohistan along a succession of north-south traverses in the valleys of the Panjgora River (Dir), Swat River, Indus River (Besham northward), and another north and south from Chilas. Each traverse extends from the Main Mantle thrust northward to the southern

part of the Kohistan batholith. We have found that the region previously referred to as the "Southern Amphibolite Belt" or "Kamila Amphibolites" is in fact a composite of several mafic - ultramafic cumulate intrusions that vary in degree of metamorphic hydration and deformation, and can be correlated east-west from one traverse to another to develop a consistent "stratigraphy" of layered cumulate complexes in the lower crust of the Kohistan arc. From the deepest level upward, the four principal cumulate intrusions are the Jijal Complex which is overlain by the Patan Complex that is in turn overlain by the Kayal-Chilas Complex, which is overlain by the Dasu Complex. The contact of the Jijal Complex with the Patan Complex is everywhere a thrust fault contact. The contact Of the Patan Complex with the Kayal-Chilas Complex is an igneous intrusive contact where exposed in the village of Khwazakhela in Swat and along the Karakoram Highway (KKH) 9 km north of Patan village. The roof of the Kayal-Chilas Complex intrudes the gneissic Dasu Complex in upper Swat 18 km north of Bahrain, and along the Karakoram Highway 31 km north of Patan, and in Kiner Gah 5 km north of Chilas town.
Key words: Southern amphibolite belts, Kohistan.

L/116. Loucks, R.R., Miller, D.J., Ashraf, M., Awan, M.A. & Khan, M.S., 1992-93. Platinum group element mineralization in high-pressure, layered, ultramafics-mafic cumulates of the Jijal complex, Pakistani Himalayas. Regional Postgraduate Training Course in Plate Tectonics, Punjab University, 38-39.

For more information, consult the preceding account.
Key words: Platinum group elements, ultramafic-mafic rocks, Jijal complex, Kohistan.

L/117. Lydekker, R., 1876. Notes on the geology of the Pir Panjal and neighboring district. Records of the Geological Survey of India 9, 4, 155-160.

Brief mention is given of Murree, Rawalpindi and Punch section together with brief description of Murree beds and structure in the rocks.
Key words: Mapping, Murree, Rawalpindi.

L/118. Lydekkar, R., 1879. Notes on the geology of Kashmir, Kishtwar and Pangi. Geological Survey of India, Records 11, 20-63.

Key words: Geology, mapping, Kashmir.

L/119. Lydekker, R., 1879. Geology of Kashmier (3^{rd} notice). Records of the Geological Survey of India 12, 1-15.

Treats mainly of the Mesozoic ellipse of Sonamarg and the upper Kishanganga valley, and is illustrated by a small map. A notice of the old glaciation of the Kashmir valley is appended.
Key words: Geology, mapping, Kashmir.

L/120. Lydekker, R., 1880. Geology of Ladakh and neighbouring districts, being fourth notice of geology of Kashmir and neighbouring territories. Geological Society of India, Records 13, 10-304.

Key words: Geology, mapping, Kashmir.

L/121. Lydekker, R., 1881a. Geology of part of Dardistan, Baltistan, and neighboring districts, being fifth notice of the geology of Kashmir and neighboring territories (with map). Geological Survey of India, Records 14 (1), 1-56.

Gives map and sections of the above-mentioned districts, with a general description of their geology. Gneiss belonging to two geological epochs is described, sometimes penetrated by intrusive granite. The limestone rocks of the Kashmir valley are more closely examined, and shown to be in part of Triassic age. The paper concludes with a notice of the ancient and modern glaciation of Baltistan, and of the thermal springs of the same district.
Key words: Geology, mapping, glaciation, Dardistan, Baltistan, Kashmir.

L/122. Lydekker, R., 1881b. Geology of north-west Kashmir and Khagan (being sixth note on the geology of Kashmir and neighbouring territories). Geological Survey of India, Records, 15(1), 14-24.

Key words: Geology, mapping, Kaghan, Kashmir.

L/123. Lydekker, R., 1882. Geology of North-West Kashmir and Khagan etc. Geological Survey of India, Records 15, 1.

A paper, illustrated with a map and section, describing the geology of a great part of the Kishanganga and Khagan valleys; various errors connected with the north-westerly termination of the sub-Himalayan territories are corrected.
Key words: Geology, mapping, Kashmir, Kaghan, Himalaya.

L/124. Lydekker, R., 1883. The geology of the Kashmir and Chamba territories, and the British District of Khagan. Geological Survey of India, Memoirs 22, 1-344.

This exhaustive volume gives details of physical features. The various geological formation (ranging from recent alluvium to Precambrian) and economic geology of the area. Beside, this volume contains a geological map of the area, and figures and description of paleontology. The paper also lists all the previous publications on the geology of Kashmir together with brief summaries.

TABLE OF GEOLOGICAL FORMATIONS IN THE NORTH-WEST HIMALAYA.

Kashmir Territory		European Equivalent	Spiti	Simla District
Alluvial system				
Low-level alluvia, etc.		Prehistoric	The Same	The Same
High-level alluvia, glacial, lacustrine, and known series.		Pleistocene	The Same	The Same
Tertiary system				
Siwalik series	outer Inner	Pliocene	____	Siwalik series
			____	Dugshai and Kasauli groups
Sirmur series	Murree group	Miocene		
	Subathu group	Eocene	____	Subathu group
	Indus tertiaries			

Zanskar system			
Chikkim series	Cretaceous	Chikkim series	____
Supra-Kuling series	Jura and Trias	Gieumal group Spiti group Tagling group Para group Lilang group	Krol series Infra-Krol series
Kuling series	Carboniferous	Kuling series	
Panjal system (not generally subdivided	Silurian Cambrian?	Muth series Bhabeh series	Blaini series Infra-Blaini series
Metamorphic system Metamorphosed Panjal, etc.; Central gneiss	Paleozoic and Archean	Central	Chor gneiss

Key words: Geology, mapping, geomorphology, palaeontology, Precambrian, Kashmir.

L/125. Lyman, B.S., 1872. The topography of the Punjab oil region. American Philosophical Society Transactions, New Series 15, 1-14.

The Punjab oil region is in the corner between Cashmere and Cabul, and wholly between north latitude 32 31', and 33 47', and east longitude (from Greenwich) 71^0 18, and 73^0 5'; a nearly square space about a hundred miles long east and west by ninety miles wide, north and south.
Just inside the northeast corner of this square is Rawul Pindee, the largest town of the region, with about twenty thousand inhabitants; just inside the southwest corner is Pind Dadun khan, a town of about twelve thousand inhabitants; and just inside the southwest corner is the ancient uninhabited ruin of a walled town, now called Kafir Kot. Just within the northwest edge of the region, and less than twenty miles from its eastern edge, stands the little village of Shah kee Dheree, on the site of the ancient capital Taxila, where the king Taxiles hospitably entertained Alexander the Great. The small town of Attok, where Alexander crossed the Indus into India, is only ten miles north of the middle of the northern edge of the square. The famous Muneekyala Tope, built by king Kanishka, about the Christian Era, to mark the spot where Booddha in compassion gave his own flesh to satisfy the hunger of a starving tiger, stands a little outside the square, fifteen miles southeast of Rawul Pindee.
The river Indus enters the square about the middle of the northern edge, and leaves it at the southwest corner. The Jhelum River (the "fabulosus Hydaspes" of the ancients), one of the five rivers that gives its name to the Punjab, flows across the southeast corner, past Pind Dadun Khan, southwesterly towards the Indus. The centre of the region is drained by the Sohan, which rises near Rawul Pindee, and flows west southwest to the Indus.
The region lies, then, mostly between the Indus and Jhelum, in what is called the Sind Sagur Doab (two rivers), and it is mainly in the mountainous or hilly part (Kohistan) of the Doab.
Key words: Topography, geology, hydrocarbons, oil, Punjab, India.

L/126. Lynam, J.O.F., 1965. Rakaposhi, the North-West Ridge. Himalayan Journal, XXVI, p.70.

Key words: Rakaposhi, Karakoram.