W/1. Waagan, W., 1872. Rough section showing the relations of the rocks near Murree (Mari), Punjab. Geological Survey of India, Records 5(1), 15-18.

This note gives a brief description of nummulitic limestone with some shales overlain by reddish sandstone and slates. Presence of main faults is also mentioned. Describe section from Khera Gali to Murree.
Key words: Limestone, shale, sandstone, Murree.

W/2. Waagan, W., 1879. Note on the Attock Slates and their probable geological position. Records of the Geological Survey of India 12(4), 183-185.

The first page of the article: In the "Records of the Geological Survey of India, Vol. XII, pt. 2, there is a paper by Mr. Wynne, entitled "Further notes on the geology of the Upper Punjab," which bears a special interest on account of the general views on the geology of that country. As many of the points treated of in the paper are yet to be considered as open questions, it seems not advisable to pronounce any opinion on them until further materials have been collected, but it may not be useless to notice some points which might be of value towards the elucidation of the questions discussed by Mr. Wynne.

There is before all the age of the "Attock slates." Mr. Wynne is quite right when he considers the evidence upon which the opinion of their being of Silurian age is founded very scanty indeed; and only the absence of any other clue towards the determination of the age of those slates could at the time justify the opinion expressed in our joint memoir on Mount Sirban, that the occurrence of lower Silurian fossils in gravels in the Kabul river, which lay approximately in the strike of the " Attock slates," would make a Silurian age probable also for the latter.

It is very much to be regretted that to the careful search of Mr. Wynne the slates have proved absolutely unfossiliferous up to the present. Yet this sterility in fossils seems not to prevail at all localities. Among the materials which have been most liberally sent to me by the Geological Society of London, there are about a dozen specimens of a Spirifer, which bear, however, only the label "Punjab." These specimens are preserved in a black slate, which, if the specimens came really from the Punjab, " and there is no reason why this should be doubted, " must have belonged to the Attock slates, as there is no other rock known to me in that part of India which would bear similar petrographical characters, and from which the specimens could have come.

Though these fossils are more or less deformed by oblique pressure, yet the species can without difficulty be determined. All the specimens belong to one and the same species, and cannot be distinguished from Spirifer keilhavi, Buch., (8p. Bajah, Salt.). As this species is one of those most characteristic of the carboniferous formation in the Himalaya, and as thus the determination of the age of the rocks from which these fossils came considerably differs from the age hitherto attributed to the Attock slates, it is necessary to be doubly cautious in accepting the current opinion regarding these slates.

The rock in which the fossils are preserved is, as stated above, a black, not very hard slate, such as I have seen to occur at many places in the Attock slates; but there are also outside of the Punjab some localities where similar slates occur. I have myself seen similar slates from the Milam pass which seem also to belong to the carboniferous formation, and seem to be there inferior to white limestones, also full of carboniferous fossils, the latter, however, of a much more recent type. Similar slates have been described by Lydekker from Eishmakam. in Kashmir, whilst at other places in the same territory the carboniferous formation is composed nearly entirely of thick limestones. The slates of Eishmakam have been compared by Lydekker to the "Kiol group" and the limestones to the "Great limestone" of the outer Himalaya. Thus it might be very possible that in the Himalaya the carboniferous formation should present two sub-divisions, one older slaty, and one younger calcareous sub-division. This, however, does not prevent that at many localities the whole formation might be made up of massive limestones.
Key words: Limestone, petrography, palaeontology, stratigraphy, Attock slates.

W/3. Waagen, W., 1884. Section along the Indus from the Peshawar valley to the Salt Range. Records of the Geological Survey of India 17(3), 118-123.

Key words: Mapping, Indus, Peshawar valley, Salt Range.

W/4. Waagen, W., 1887. Die carbone Eis zeit, Karakoram. Geologie Reichsantalt (Vienna). Jarbusch 37, 143p.

Key words: Ice time, Karakoram.

W/5. Waagen, W. & Wynne, A.B., 1872. The Geology of Mount Sirban, in the Upper Punjab. Memoirs of the Geological Survey of India 9, 331-350.

The paper describes the geology of the area together with the description of the rock and fossils. The following succession in the area has been established.

6.-NUMMULITIC: Thick limestones with some shales-fossils in places.
5.-Cretaceous: a.-Thin-bedded limestones-without fossils apparently, b.-Impure ferruginous sandy limestone, weathering rusty-fossils
4.-Jurassic: Black Spiti shales.
3.-Triassic a.-Thin-bedded limestones and slaty shales, b.-Dolomite, limestone; fossiliferous (Megalodon and other) bes.
2.-BELOW THE TRIAS: Hematite, dolomite, quartzite, sandstone and breccia.
Unconformity.
1.-SEMI-CRYSTALLINE: Attock (?) slate.
Key words: Stratigraphy, fossils, geology, Abbottabad.

W/6. Wadia, D.N., 1928a. The geology of the Poonch State (Kashmir) and adjacent portions of the Punjab. Geological Survey of India, Memoir, 51(2), 371-413.

Key words: Geology, mapping, Poonch, Kashmir.

W/7. Wadia, D.N., 1928b. Siwaliks of Potwar and Jammu Hills. Geological Survey of India, Memoirs, 51 (2), 334-362.

Key words: Mapping, siwaliks, Potwar.

W/8. Wadia, D.N., 1929. North Punjab and Kashmir. Geological Survey of India, Records, 62, 152-156.

Key words: Mapping, Kashmir.

W/9. Wadia, D.N., 1930. Hazara-Kashmir syntaxis. Geological Survey of India, Records 63, 1: 129-138.

Key words: Mapping, structure, Hazara-Kashmir syntaxis.

W/10. Wadia, D.N., 1931. The syntaxis of the northwest Himalaya; its rocks, tectonics and orogeny. Records of the Geological Survey of India, Records 65(2), 189-220.

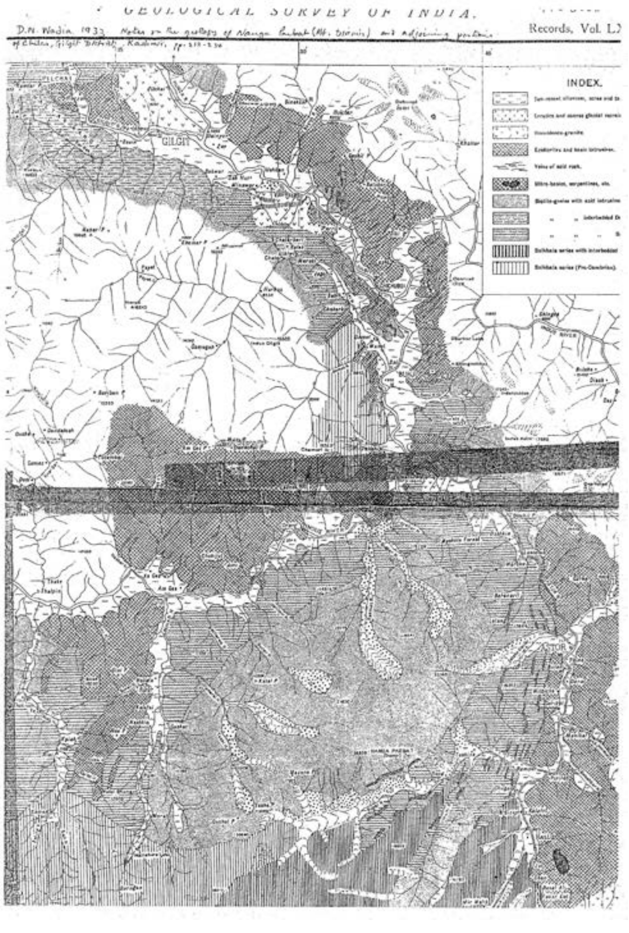
Wadia noted strong folding in the form of a hair-pin bend in the rocks of the Hazara Kashmir area. The bend was called as Hazara-Kashmir Syntaxis. He described the stratigraphy, lithology, tectonics and orogeny of the area. The peculiar syntaxisial bend attracted many geologists in the years to come.
Key words: Mapping, structure, tectonics, Himalaya.

W/11. Wadia, D.N., 1932. The Tertiary geosyncline of north west Punjab and the history of the Quaternary Earth movements and drainage of the Gangetic trough. Geological, Mining, Metallurgical Society of India, Quarterly Journal 4(3), 70-95.

Key words: Structure, Quaternary, drainage, Punjab, India.

W/12. Wadia, D.N., 1933. Notes on the geology of Nanga Parbat (Mt. Diamir) and adjoining portions of Chilas, Gilgit District, Kashmir. Records of the Geological Survey of India 66, 212-234.

Wadia made pioneering studies in the Nanga Parbat – Diamir area. He described gneisses and granitic rocks of the Nanga Parbat as well as their associated metasedimentary rocks. The Chilas-Bunji area rocks were also described by him some of which were called as epidiorites. Further information can be seen in his attached geological below.



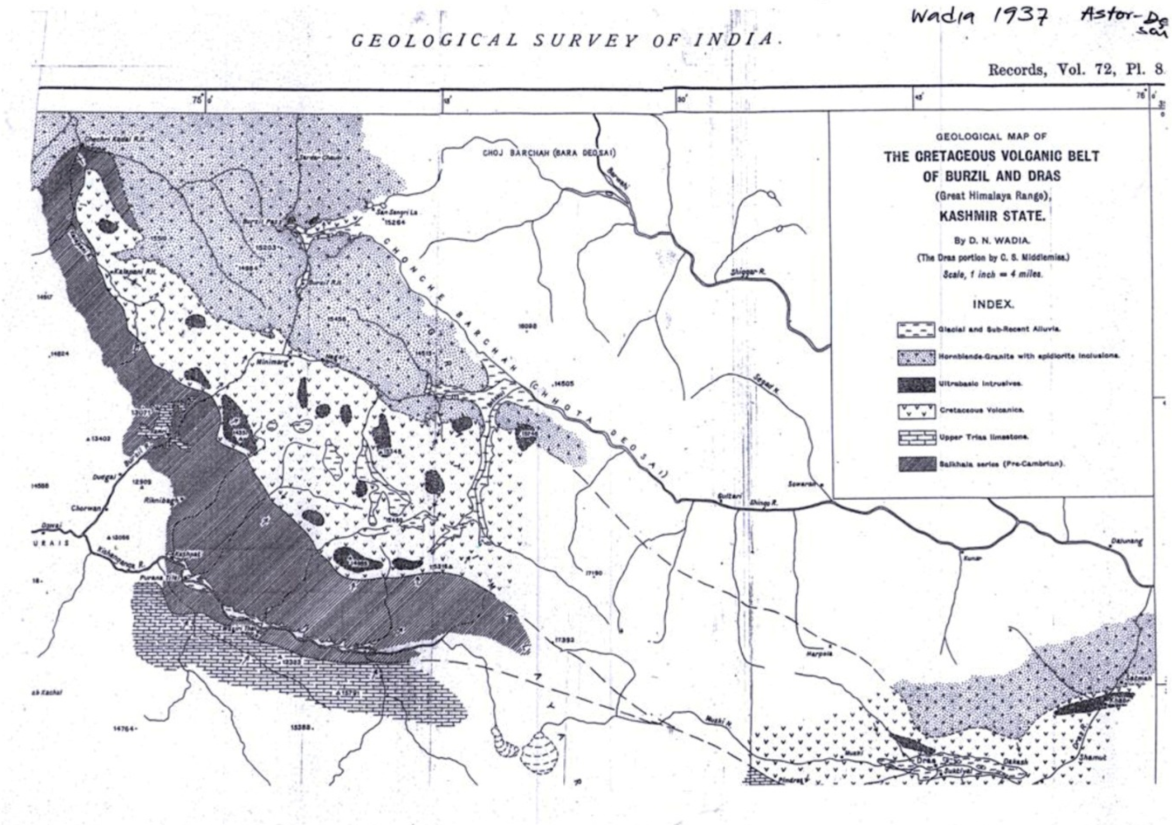
Key words: Igneous rocks, gneisses, Nanga Parbat, Diamir.

W/13. Wadia, D.N., 1934. The Cambrian-Triassic sequence of north-west Kashmir (parts of Muzaffarabad and Bara Mula district). Geological Survey of India, Records 68(2), 121-176.

Key words: Stratigraphy, Cambrian-Triassic, Kashmir.

W/14. Wadia, D.N., 1937a. The Cretaceous volcanic series of Astor-Deosai, Kashmir and its intrusions. Geological Survey of India, Records 72(2), 151-161.

Granitic rocks, a volcanic series, and sedimentary rocks from the south western part of the Deosai plateau and the adjacent Kishan Ganga valley were mapped and briefly described. The complexly folded and some 20 km broad volcanic belt, presumably occupying a synclinal flexure was shown to extend NW to SE toward Dras. Wadia noted that the volcanic series consist of a sequence of well stratified ash beds with some silicious bands, grity siliceous toughs, slates (some agglomeritic), agglomerates and flows. The ash beds and agglomerates are each several hundreds meters thick and the volcanic series contains intercalated sediments of Cretaceous age and scattered masses of ultramafic, mafic and granitic rocks.



Key words: Stratigraphy, volcanics, Cretaceous, Astore, Deosai, Kashmir.

W/15. Wadia, D.N., 1937b. An outline of the geological history of India. Indian Science Congress Association, Calcutta, 26p.

This account gives a brief of the geological history of India which includes some parts of present day Pakistan.
Key words: Geological history, maps, India.

W/16. Wadia, D.N., 1938a. The structure of the Himalayas and of the North Indian Foreland. 25th Indian Science Congress, Presidential address, 28p, 1 pl.

Key words: Tectonics, structure, Indian foreland, Himalaya.

W/17. Wadia, D.N., 1938b. Deposits of Ice Age in Kashmir. Geological, Mining, Metallurgical Society of India, Quaternary Journal, 10(4), 191–200.

The only accessible and legible records of the Pleistocene glacial epoch so far studied in India are those met with in the Kashmir Himalayas. A wide extent of the country above the latitude of 33°N and lying between the parallels of 73° and 78°E., especially the parts above an altitude of 6,000 ft. contain abundant proofs of ice-erosion and ice-borne debris covering hill slopes, valleys, cirques, glacial lakes and building terraces and mounds. At lower levels than 5,000 ft. ice-action is likewise indicated by copious occurrences of reassorted moraines, fluvio-glacial drift, lake-deposits and erratics. Many important details and even fundamental data, however, yet remain to be investigated about the Ice-Age in Kashmir and the problem may be said to have only just begun to receive the attention it deserves. Although of late years a large volume of evidence has been obtained proving the importance and extent of the post-Tertiary Ice-Age in Kashmir, precise data of its commencement in terms of the Siwalik sequence, its main fluctuations, or the date of its termination in reference to the Indo-Gangetic alluvial deposits, yet remain to be obtained by long and patient field work. Although, for many parts of Kashmir, the body of evidence is voluminous, no detailed investigation has been possible so far by the Geological Survey of India because of its preoccupation with the more vital stratigraphic and tectonic questions; and their classification and the determination of the sequence of even the major glacial and inter-glacial phases still remain for the future and will supply to the local geologists and naturalists of Kashmir a fascinating occupation. One unique circumstance which has supplied Kashmir Ice-Age with a recording chronometer of its principal episodes is the contemporaneous existence of a great lake, the Karewa lake, which filled the present valley basin of Kashmir, and which in the height of the Pleistocene glacial age must have been no less than 3,000 sq. miles in area. The vicissitudes through which this lake, a true tectonic synclinal basin, with only a single outlet, has passed, the alternations of freezing and non-deposition during the glacial phases and of basin-filling with active deposition during the inter-glacial phases, these alternations going on simultaneously with the intermittent uplift of the Western Himalayas, are registered in the alluvial strata of this lake, designated as the *Karewa Series.* The lake's existence must have been an intermittent one, attaining maximum extent during the warm inter-glacial pauses, succeeded by periods of minima, draining and .refilling. Nearly half the area of the present Kashmir valley basin is covered by deposits of the Karewa Series which range in altitude to-day from the level of the Jhelum, 5,200 ft., to over 11,000 ft. on the slopes of the bordering mountains. Both in respect of their horizontal extent and the length of Pleistocene stratigraphic record they represent, the Karewas contain materials for a detailed systematic study of the Ice-Age in the Western Himalayas. Evidence is certain to come to light yielding results in Pleistocene orography, human paleontology and anthropology, besides purely glacial geology. Broadly speaking, four main oscillations of climate have been detected in the glacial cycle of Kashmir, by Dainelli (1913), De Terra (1938) and lately by myself, but it would be premature to try to correlate the Kashmir glacial and interglacial periods with the four main glaciations of the Alpine Ice-Age, nor have sufficient data been yet discovered to allow us to attempt anything more than a broad classification of the glacial formations of Kashmir. The glacial cycle of Kashmir proves to be a highly complex one, displaying varying interrelations of great mountain-building uplift movements, climatic and hydrographic changes, with at least three, or four, advances and retreats of the ice. The deposits formed under these various conditions during the whole glacial period in the Kashmir Himalayas, and which constitute our principal source of information of post·Pliocene geology, may be classified under the following five heads. These are of unequal applicability and reliability for different regions of the mountains, but each class of deposit is of value in throwing light on some particular aspect of the problem:- Moraines of different glaciations at various levels.
Key words: Glaciers, moraines, Pleistocene, Kashmir.

W/18. Wadia, D.N., 1943. The Pliocene Pleistocene boundary in Northwestern India. Proceedings, National Institute of Sciences, India, 9(1), 37-42.

Key words: Pliocene, Pleistocene, structure, stratigraphy, India.

W/19. Wadia, D.N., 1951. The transitional passage of Pliocene into the Pleistocene in the Northwestern Sub-Himalayas. International Geological Congress, 17th Great Britain, Part 11, 43-84, p107.

Key words: Pliocene, Pleistocene, structure, stratigraphy, India.

W/20. Wadia, D.N., 1957. Geology of India. 3rd edition (revised). Macmillan & Co., London, 531p. 19 pls.

This is a revised edition of the very popular and informative book on geology of India by the great Himalayan geologist D.N. Wadia. The book covers all aspects of geology and stratigraphy of the region stretching from Burma to Pakistan. Stratigraphic and lithologic descriptions and mineral deposits have been given, along with a colored map in the pocket.
Key words: Books, geology, stratigraphy,

W/21. Wadia, D.N. & Davies, L.M., 1926. Note on the occurrence of gypsified marl and alveoline-bearing limestone beds in the gypsum zone overlying the salt deposits of Bahadur Khel. Asiatic Society of Bengal, Indian Science Congress, 13th, p.255.

Key words: Sedimentary rocks, limestone, marl, gypsum, Bahadurkhel, Karak, Kohat.

W/22. Wadia, D.N. & Davies, L.M., 1929. The age and origin of the gypsum associated with the salt deposits of Kohat, North West Frontier Province. Mining and Geology Institute, India, Transactions 24, 202-222, Pl. 9 - 14.

Key words: Salt, gypsum, Kohat, NWFP.

W/23. Wadia, D.N. & West, W.D., 1964. Structures of the Himalayas. 22nd International Geological Congress, New Delhi, 1-10.

This is a regional account of the structure and tectonics of the Himalaya. There is a brief description of the Hazara-Kashmir Syntaxis in the context of NW Himalaya, the syntaxis is considered to result from a tongue like projection of the Gondwana massif.
Key words: Structure, Hazara-Kashmir Syntaxis, tectonics, Himalaya.

W/24. Wagner, H.G., 1962. Diamir valley and Diamir glacier (Translated from German). Mitteilungen der Geographischen Gesellschaft Munchen 47, 157-192.

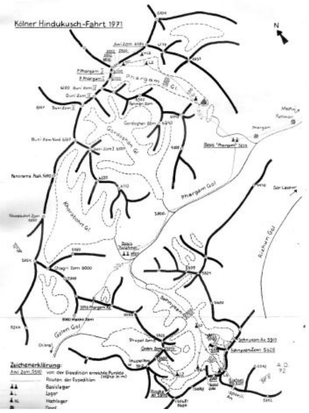
Key words: Glaciers, Diamir.

W/25. Wagner, R. & Wachten, A., 1971. Exploration and ascents in the Buni group. Himalayan Journal, 31.

We planned the Kolner Hindu Kush Expedition 1971 on the assumption that sensational discoveries and explorations m large areas of the Hindu Kush could hardly be a target for expeditions in the 'seventies' any more. Besides, for a group of nine climbers, all of amateur status, a too ambitious aim could spell disaster. For this reason we decided on a range which is somewhat away from the spectacular seven-thousanders of the Hindu Kush and had not been explored much; the Buni Zom group in Chitral, south of Buni and Awi, on the Mastuj river. From expedition results in the years 1957, 1965 and 1967, 6 Section Graz ', under the leadership of Dr. Gruber, had worked at sub-dividing the whole Buni Zom group. In 1970 a work was published in which Dr. Gruber differentiates between the North Buni Zom group, situated between Mastuj valley and the Phargam Gol, with the Khorabohrt, Gordoghan and Phargam glaciers and the South Buni Zom group, south and south-west of Phargam Gol, with the mountain areas around the Rizhun, Sohnyoan, Golen, Rinzho, Shiak, Shachiokuh, Isporili, etc., glaciers. C The Buni Zom Group in Chitral'—O.A.Z., Vol. 1370; reprinted in #./., Vol. XXX, 1970). Since our team of nine-eight men and one woman-constituted a rather large group, we decided on a double expedition, i.e. division into two groups ; George Holtmann, Herbert Hoven, Christoph Meizka and Albert Wachten were to attempt through a steep climb the difficult-to-reach Phargam glacier and into the untrodden basin to investigate and climb the virgin Awi Zom, the second highest summit of the whole of Buni Zom group; Heinz Dieter Bohme, Anno Diemar, Manfred Heintz, Erika and Robert Wagner had the task to get a clear picture of the Sohnyoan glacier which had been reached for the first time in 1970 by two Japanese groups. Thus we planned to investigate the glaciers which debauched into the

Phargam Gol and which had hardly been given any attention so far. Both groups started from the Phargam Gol with its ideal situation for a Base Camp which was established at 3,987 m. on high ground of the valley at Kulakmali. In order to investigate the approach routes to the Buni Zom group, as also to ease the problem of porters, we set out in separate groups for the Base Camp. The possibility that the Base Camp would be unreachable by one route was also eliminated, and besides the ever- changing composition of the groups helped to overcome and lessen the usual strain of the expedition members. In three mini buses we set out over the route which is to some extent also used by tourists ; through Istanbul, Ankara, Tehran, Kabul, Peshawar and on 4 August we reached Chakdara. Here we parted—one group went in its own conveyance over Saidu to Kalam in the Swat valley; the other group went to Dir and from there on to Chitral by jeeps. The difficulties which the ‘Chitral group’ expected with the authorities did not occur. After a 70 mile jeep ride through the Mastuj valley up to Miragram, they quickly reached the Base Camp at Kulakmali with the porters and pack animals through Mastuj, Rahman and Phargam. The approach route through Kalam took a few days longer. Besides the collapse of a bridge which hampered our provision of petrol and the difficulties with the authorities, the main problem was to find 40 porters for the loads. In the end the porter team consisted of inhabitants from Kalam and Matiltan in equal proportions. There emerged some unhappy strains of competition between these two teams but we were fortunate to commence the eight-day march through the richly vegetated Ushu Gol over the Kachhikhani An (4,766 m.). After a climb up to a height of 4,805 m., immediate east of the pass, the path leads down north through Sor Laspur and Harchin to Kulakmali. Due to worries and shrinkage in our expedition kitty we had to rearrange the porters in Sor Laspur and Rahman. During the month from mid-August to mid-September our exploration worked out as planned concerning the Sohnyoan and Phargam glacier basins. The settled condition of the glaciers permitted a quick erection of camps in both areas. Each group had the help of two high-altitude porters-Tschapir from Sor Laspur and Seraman from Rahman for the Phargam glacier; Mir Alam from Matiltan (Ushu Gol/ Swat) and Nigaban Shah from Phargam for the Sohnyoan glacier. While the group 'Sohnyoan' began from Kulakmali with the transport of the loads, the other group 'Phargam' erected a further Base with the material which had been already deposited there during the approach march. Besides the rapid glacier stream which descends from the Khorabohrt glacier and which had to be traversed west of the Kulakmali camps, the Sohnyoan group found no difficulties in reaching the Sohnyoan glacier. The glacier which entered the Phargam Gol without any step was reached effortlessly over the western moraine; a steep step between 4,500 m. and 4,650 m. at the foot of the ENE. ridge of the Shupel Zom E. was also easily traversed and thus after ten days all material had been moved from the Base Camp to Camp I (4,700 m.). On account of the huge stone falls along the flanks, the camp was erected in the middle moraine of the glacier. The aim of activities from Camp I for the next 2/3 weeks was the exploration of the routes to the neighbouring valleys, the Rizhun Gol, the Rinzho Gol and the Golen Gol as also the possibilities of climbing the boundary walls of the Sohnyoan glacier which showed a prominent salient to the west.For this reason we climbed Pt. 5,625 m. which the Japanese reached in 1970 and which they named 'Sohnyoan Zom'. Once we did this over the north flank and the SW. ridge and another time over the NE. ridge. The climb up the highly glaciated North wall was interesting and not too difficult. The descent though took up much time due to great amount of stone fall so that we were forced into a bivouac at 5,100 m. The descent over the NE. ridge is recommended. A wonderful view offered itself from the lower summit west of the 4 Sohnyoan Zom' which we named 6 Kolon Zom This flat summit gives an uninterrupted view of the Sohnyoan glacier (9 km. long) beyond the place where it turns north—also an interesting view into the Khorabohrt glacier basin.The result of these climbs showed that the route from the Sohnyoan glacier into Rizhun Gol, either through the north-east pass or the south-west pass, was possible only with the greatest difficulty. The climb of the mighty massif south of the upper Sohnyoan basin seemed possible either over the heavily glaciated north flank or over the rocky ESE. ridge. The last possibility proved objectively too dangerous as we witnessed, after a climb of the pre-summit (Pt. 5,700 m.), the enormous crevasses and dangerous stone falls of the ridge.Investigations into the upper Sohnyoan basin showed that one could reach the Rinzho Gol without difficulty over a high saddle (Rinzho An, 5,343 m.). On the other hand, a climb of this chain from the west should hardly be considered. There remains the above-mentioned north flank which rises 1,100 m. high from the Sohnyoan glacier towards the eastern corner-stone of the massif which has been shown on the half-inch map of 1954 as Ft. 6,100 m. and which was measured by Gruber from the Khorabohrt glacier as 6,000 m.An attempt was made on this flank but time was against us i we gave up at the steep pure ice passages at the beginning of the second half of the wall. The route for the most favourable climb in this chain was found but it would require the climb of Pt. 6,100 m. and the traversing of the ridge for which we had, in September, no more time.Considerable additions could be made to the map of the northern boundary of the upper Sohnyoan glacier, i.e. to the southern slope of Shupel Zom massif. Contrary to the markings in the half-inch map, the glacier-arm goes direct southward between Shupel Zom West and East and only shortly before it enters the Sohnyoan glacier does it bend towards the east. Over this route we reached the 5,650 m. saddle which we named c Shupel An \ Here we discovered, south of the Shupel Zom E., a summit of 5,810 m. which one ascends by a prominent west ridge. After climbing this we gave it the name ' Golen Zom' and noted that Shupel An from the Sohnyoan glacier as well as from Golen Gol offers an ideal starting point for the three summits of the Shupel Zom group.We did not attempt to climb the eastern boundary of the lower Sohnyoan glacier since the constant stone fall in the exceedingly broken chain made it appear rather unrewarding. An exception is probably the glacier-arm which descends from Pt. 5,909 m. to Pt. 5,824 m.The Base Camp of the ‘Phargam' group is just above Phargam at a height of about 3,300 m. It stands sloping on the moraine in an awkward position. Towards the north one views from here direct into the steep icefalls of the Phargam glacier ; the view and the route to Awi Zom (6,484 m.) are yet hidden. The main object of this group was to find a route into the glacier on which no one as yet had set foot; it would be for our own use or it could be of help to any future expeditions. After a march on foot for one and a half hours, at a height of about 3,700 m., a great gorge is formed by the mountains which frame the Phargam glacier. The glacier-tongue plunges over a large rock-fall into the depths ; it is impassable as is also the orographic left boundary wall. The only possible ascent is offered by the orographic right rock wall (600 m. height) at the foot of which we erect a provisions depot. The climb now is not difficult; however, one has to be careful about stone falls and we reach the glacier floor at 4,300 m. One hour's advance on to the glacier and then we erect Camp I at 4,584 m. We now transport provisions and equipment from the Base Camp over the steep step to Camp I. From here we view Awi Zom for the first time. Two further crevasses present some difficulties (the first is traversed on the orographic right side and the second on the orographic left) and then we are able to erect Camp II at 5,265 m. in close proximity to the mighty SW. wall of Awi Zom hardly a fortnight after arrival at the Base Camp. Now we can start on its climb. To attempt to climb the deterring SW. wall does not seem advisable and we plan to reach the ridge connecting Awi Zom with Buni Zom so that from there we may attempt the climb over the West ridge. The only possibility to reach this connecting ridge is over a broad sloping rubble band which traverses at the lower end of the SW. wall and ends in a steep groove which leads on to the ridge. At the mercy of the stone falls we cross this strip-we name this crossing 'Crossing of the gods'—and we reach the ridge where we erect at 5,889 m. a high-altitude Camp I. This is l he lowest point of the west ridge of Awi Zom. We name the ascending ridge to Buni Zom IV the ‘Fairy Tale Ridge’ Frightful descents on the Awi Zom west ridge towards our high camp frustrate a climb of the ice-giant. However, the 'Fairy Tale Ridge' with its average height of 6,000 m. offers a demanding and strenuous traverse. We surmount six humps on it which to date have not been mapped, and which no one has yet climbed ; the most prominent ones quite close to Buni Zom IV we name: k P. Phargam I and P. Phargam II' (both about 6,000 m.).We return to Camp II. It appears that the only approach to Awi Zom is the above-mentioned SW. wall. A spur runs through the wall and we think it is possible to erect an intermediate camp on it. We keep towards the right (in the direction of the ascent) and in the late afternoon we start (on account of the lessened danger of stone falls) and with the darkness we reach a well-formed saddle on the spur on which we can erect our bivouac tents. But even this place is not absolutely safe of falling stones. From here ascends obliquely to the west ridge, a furrowed snow-field. Next day we cross this snow-field in the morning and also after sunset and now and then some stones fall from the summit wall but they fortunately do not hit us. At about 6,150 m. we at last reach the secure West ridge. Over snow and over rocks we proceed rather effortlessly and reach on 3 September 1971 at 12.45 p.m. the summit of Awi Zom which had not been climbed previously. We would not recommend our route of ascent Our undertaking had extended up to the last days of summer. Already on the morning of our combined departure from Kulak- mali over Phargam and II to Chitral it was snowing up to the Base Camp.

We were quite aware that we had not returned with any sensational climbs and explorations. Yet, we knew that our stay and work in the Buni Zom area tallied with what we had set out to do. We do hope that the report of our expedition will be a useful addition to the knowledge of this area. [The authors are unduly modest of their achievement, both in climbing activity and exploration. All this is most valuable information and is complementary to the research of Dr. Gruber and other earlier visitors to the area.—Eds.]



KOLNER HINDUKUSH- FAHRT 1971

Key words: Expedition, exploration, Hindukush.

W/26. Wahab-Ud-Din, 1999-2000. Structure, stratigraphy, micropaleontology and petroleum geology of Kotli-Tattapani area, District Kotli, Azad Jammu & Kashmir (Pakistan). M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 217p.

Key words: Structure, stratigraphy, palaeontology, hydrocarbons, Kashmir, Himalaya.

W/27. Wahrenberger, C., 1992. The geology of the Higher Himalaya in upper Kaghan valley, NE Pakistan (Aspects of Metamorphism). Thesis (Diplomarbeit), ETH, Zurich.

Key words: Tectonics, structure, stratigraphy, Kaghan valley, Himalaya.

W/28. Wake, C.P., 1987a. Spatial and temporal variations of snow accumulation in the Central Karakoram, northern Pakistan. M.Sc. Thesis, Wilfred Laurier University, Waterloo, Ontario.

Key words: Glaciers, snow accumulation, Karakoram.

W/29. Wake, C.P., 1987b. Glaciochemical investigation as a tool to determine the spatial variation of snow accumulation in the central Karakoram, Northern Pakistan. Annals of Glaciology 13. 279-284.

Between 70 and 80% of the total annual run - off from the upper Indus Basin originates from heavy snowfall and glacierized basins at elevations greater than 3500 m a.s.l. However, very little is known concerning the mountainous headwaters of the Indus. This is especially true with respect to the amount of snowfall in the major source area, the high Karakoram. Recent studies of high -altitude alpine glaciers indicate that geochemical dating techniques can accurately and confidently identify seasonal and annual stratigraphy within snow pits and ice cores, and thus can be used to determine the seasonal and annual rate of snow accumulation. In addition, chemical records can usually be employed to determine sources of precipitation. Six snow pits, each 5- 0 m deep, were investigated in the accumulation zones of the Biafo and Khurdopin Glacier basins. Both accumulation zones are characterized by broad, open basins separated by steep, narrow ridges in which direct precipitation is the dominant form of nourishment.

Seasonal stratigraphy is delineated through an analysis of the seasonal variation in the chemical and physical characteristics of the snow-pack. Annual snow accumulation in the Biafo Glacier basin ranges from 0.9 to 1.9 m water equivalent: maximum accumulation occurs in the elevation band 4900-5400 m asl. Roughly one- third of this snow accumulation occurs during the summer.

Key words: Glaciers, chemistry, snow accumulation, Karakoram.

W/30. Wake, C.P., 1987c. Snow accumulation studies in the Central Karakorum, Pakistan. In: Lewis, J., (ed.), Proceedings of the 44th Eastern Snow Conference, Frederikton, NB, 19-33.

Key words: Glaciers, chemistry, snow accumulation, Karakoram.

W/31. Wake, C.P. & Searle, M.P., 1993. Rapid advance of the Pumarikish Glacier, Hispar Glacier Basin, Karakoram Himalaya. Journal of Glaciology, 39, 204-206.

Pumarikish Glacier is approximately 7 km long and flows south from the main crest of the Karakoram. It is one of the main transverse tributaries feeding into the northern margin of Hispar Glacier, which is 62 km long and flows west from Hispar Pass (5150m) and eventually drains into the Hunza River (Fig.1). Hispar Glacier flows roughly parallel to the southern contact of the Karakoram granite batholith, which corresponds to a belt of mountains with the highest average elevation and the fastest uplift-erosion rates anywhere in Asia (Searle, 1991). Pumarikish Glacier is fed predominantly by avalanches, which originate from the north faces of Pumarikish (7429m) and Khinyang Chhish (7854m) on the northern and western edges of the basin, and from the lower unnamed peaks of the eastern margin. The granite headwall of Pumarikish Glacier is over 2500m from the summit icefields to the upper glacial cirque. The avalanches deposit snow, ice and debris in a small gently sloping basin at 4600-4700m. The lower 4km of Pumarikish Glacier descend gradually from this small accumulation basin to 4000m in a well-defined trough less than 500m wide.

Recorded observations of Pumarikish Glacier are few. Conway traversed and surveyed Hispar Glacier in 1892. From observations of tributaries on the north side of Hispar Glacier, Conway (1894) noted that:

"It is remarkable that whereas the Lak Glacier. has so greatly shrunk of later years, this Chur Glacier [Pumarikish Glacier on our map], its immediate neighbor, and which drains another flank of the selfsame mountains, should, on the contrary, have greatly swollen. It overflows all its moraines and pours in a broken spreading wave on to the surface of the Hispar."

Hayden (1907) made no mention of the north-bank tributaries of Hispar Glacier. Dr Kooncza and Dr Caliati, two surveyors who accompanied the 1908 Workman expedition to Hispar Glacier, found that Pumarikish Glacier was "connected by terraces" to the main body of Hispar Glacier (Workman and Workman, 1910). Their map shows a relatively direct crossing of Pumarikish Glacier at the snout. The map produced by Eric Shipton's Karakoram Expedition of 1939 (Mott, 1950) also shows an apparently straighforward crossing of the snout. No account was mentioned of difficulties encountered while crossing this glacier. No mention was made of Pumarikish Glacier in published reviews by Mason (1930), Hewitt (1969), Mercer (1975) or Mayewski and Jesclike (1979).

Our own observations of the glacier began on 19 August 1985 when it was crossed during a reconnaissance of the Hispar Glacier Basin as part of the Snow and Ice Hydrology Project. At that time, the glacier was easy to cross. There was a well-marked path on both lateral moraines and across the glacier used by shepherds to bring their yaks to summer pastures further up the margin of Hispar Glacier. The surface of the glacier showed only mild undulations and was covered in debris which ranged in size from large boulders to silt and mud. The surface was several tens of metres below the top of the lateral moraines. The appearance of the glacier had changed little when it was crossed on 8 August 1987 en route to Hispar Pass. However, by 29 June 1988, the snout of the glacier had thickened by at least 20m. The surface was still debris-covered but now also showed large debris-covered hillocks and deep valleys. There was no path or obvious route across the glacier. The eastern margin of the glacier was defined by a vertical ice cliff 1520 in high which descended to a narrow defile bordered on the far side by the lateral moraine. Steps had to be cut in the ice and the porters were belayed down this section. The upper surface of the glacier was approx. 10-20m below the top of the lateral moraine (Fig.2a).

Further observations were made during July and August 1989, when a base camp was established at Bitanmal, 3 km west of Pumarikish Glacier. The snout of Pumarikish Glacier had thickened so dramatically that the upper surface of the glacier was 16-22m above the top of the lateral moraine (Figs.2b and 3). The glacier had also advanced I km, reaching almost the middle of the 2-2.5km wide Hispar Glacier (Fig.4). The entire length of Pumarikish Glacier was now heavily crevassed and impossible to cross at any point (Fig.5). The regular path up to Hispar Pass was now cut off and to continue up-glacier it was necessary to circumnavigate the advancing snout by travelling out into the middle of Hispar Glacier and around the front of the Pumarikish Glacier ice. This diversion added about 4-6h on to the journey. The pastures along the ablation valley beside Hispar Glacier upstream of Pumarikish Glacier were cut off, and the Hispar yaks now grazed mostly at Bitanmal. A brief reconnaissance up Pumarikish Glacier failed to reveal any snow, ice and/or rock deposits which would have been indicative of a major avalanche or landslide.

It is clear from Conway's observations in 1892 that the upper level of the glacier surface was above the top of the lateral moraines so that ice flowed over them, and that Pumarikish ice flowed well out on to Hispar Glacier. Furthermore, Conway's observation that Khiang Glacier had thinned in the years prior to 1892 indicates that the advance and thickening of Pumarikish Glacier was an isolated event and not characteristic for the north-bank tributaries of Hispar Glacier. The swollen nature of Pumarikish Glacier described by Conway appears strikingly similar to our observations during the summer of 1989, suggesting that the glacier had experienced at least two periods of rapid advance separated by approximately 100 years.

Several glaciers in the Karakoram have been known to surge in the past (Hewitt, 1969; Gardner and Hewitt, 1990). The majority of documented surging glaciers in the Karakoram are concentrated along the main range. In the summer of 1989, Pumarikish Glacier exhibited features characteristic of a glacier in surge: rapid advance of the snout unrelated to activity of nearby glaciers, exceptional rates of advance and the formation of new surface features. In addition, Pumarikish Glacier displays basin-morphology features described by Hewitt (1969) as characteristic of surging glaciers in the Karakoram: medium size for the region, nourishment predominantly via avalanching, and steep tributary glaciers and snow avalanches which supply relatively small, low-angle accumulation zones. While the observational record of Pumarikish Glacier over time is limited, the morphological changes and repetitive nature of rapid advances over the past century, combined with basin morphology which is characteristic of surging glaciers in this region, suggest that Pumarikish Glacier can be added to the list of documented surging glaciers in the Karakoram.

Key words: Glacier advance, Pumarikish, Hispar, Himalaya, Karakoram.

W/32. Walton, J.L.W., 1984. Special techniques for surveying on mountain terrain. In: Miller, K.J., (ed.), The International Karakoram Project, 1, Cambridge University Press.

At some stage in almost all land surveying projects a network of fixed or "control" points has to be set up. When the area being studied involves moving terrain, such as a glacier, special survey techniques have to be used either to eliminate errors incurred by the moving control points, or to actually determine their velocity. This paper contains a review of a number of these special techniques ranging from simple "by eye" approximations to complex methods requiring extensive computer facilities. Some of these techniques may be applied to problems involving infinitesimal velocities such as the tectonic plate movement studies planned for the 1980 international Karakoram Project.

Key words: Survey, tectonics, Karakoram.

W/33. Wang, W., Huang, M. & Chen, J., 1984. A surging advance of Balt glacier, Karakoram mountains. In: Miller, K.J., (ed.), The International Karakoram Project, 1, 76-83. Cambridge University Press.

In November 1977, it was discovered that the Balt Bare Galcier's terminus had moved downwards 1.6-km since 1974. This movement took place mainly in 1976. During the investigation in October 1978, it was found that the terminus had further advanced a distance of 0.4-km but had begun to thin. The glacier terminus, 2.5-km in length, was surveyed and mapp3ed at a scale of 1:5000 and a short-term measurement of surface velocity and temperature on the glacier was taken. We believe that the temperature in the surveyed section is high, and at melting point on its bottom. When the thickness and the basal sliding velocity of the glacier are estimated, one would consider that basal sliding was the dominant mechanism of the surge. It was predicted that the glacier would be thinner in the near future and that this surging advance would arrest.

Key words: Glacier advance, Balt, Karakoram.

W/34. Wang, Y., Peng, Q. & Feng, Y., 1980. The cartographic methods of the map of the Batura Glacier. In: Shi, Y. (ed.), Professional Papers on the Batura Glacier in the Karakoram Mountains. Science Press, Beijing.

Key words: Mapping, Batura glacier, Karakoram

W/35. WAPDA (Water And Power Development Authority, Pakistan), 1962. 1961 snow surveys. WAPDA, Lahore.

For more than 50 years, Water and Power Development Authority (WAPDA) has spearheaded investigations in Water Resources, Water Logging & Salinity, Engineering Geology, Reservoir Engineering, Dam-site Investigation, Hydropower, etc., in Pakistan. In several of the projects, WAPDA also involved technically skilled personnel and specialized organizations from abroad. A wealth of data in the form of reports is available in WAPDA Headquarters in Lahore and in its Regional Offices. These data are not freely available, but can be accessed through proper channel by those engaged in academic and applied research. In the following are given the titles and key words of a number of these reports under the name WAPDA. Others, having authorships, are given in appropriate places. We would like also to mention that there are many more unpublished reports of WAPDA that might be of interest to geoscientists.
Key words: Mapping, snow survey.

W/36. WAPDA, 1965. Reconnaissance report of Kabul-Swat-Chitral Basin. Appendix A. Directorate of Planning and Investigation, Lahore.

See WAPDA, 1962.
Key words: Reconnaissance, Kabul, Swat, Chitral.

W/37. WAPDA, 1970. 1968 Annual report of rivers and climatological data of West Pakistan, 1, 309p.

See WAPDA, 1962.
Key words: Rivers, climate data, West Pakistan.

W/38. WAPDA, 1976. Sediment appraisal of West Pakistan Rivers, 1966-1975: Surface Water Hydrology Project, Lahore.

See WAPDA, 1962.
Key words: Sediments load, rivers.

W/39. WAPDA, 1979. Sediment appraisal of West Pakistan Rivers, 1960-1972: Surface Water Hydrology Project, Lahore.

See WAPDA, 1962.
Key words: Sediments load, rivers.

W/40. WAPDA, 1989. Snow and ice hydrology project, upper Indus Basin-Karakoram Himalaya. Final Report. Wilfried-Laurier University, Waterloo, Ontario.

See WAPDA, 1962.
Key words: Snow, hydrology, Indus basin, Karakoram, Himalaya.

W/41. WAPDA, DAMES & MOORE, 1986. Mineral sector development study, N.W.F.P., Pakistan. Report submitted to Ministry of Planning and Development, Government of Pakistan, Islamabad, 73p.

Key words: Mineral development, NWFP.

W/42. WAPDA, Dams Monitoring Organization, 1967. Memorandum on the geology of Khanpur Main Dam. Dams Monitoring Organization, Report, 11p.

See WAPDA, 1962.
Key words: Engineering Geology, Khanpur Dam, Haripur

W/43. WAPDA, Dams Monitoring Organization, WAPDA, 1979. Warsak power house slide area, Geological Report. Dams Monitoring Organization, Report, 15p.

See WAPDA, 1962.
Key words: Engineering geology, Warsak Dam, Peshawar

W/44. WAPDA, Dams Monitoring Organization, WAPDA, 1980. Memorandum on the geology of spillway. Dams Monitoring Organization, Report, 11p.

See WAPDA, 1962.
Key words: Engineering geology.

W/45. WAPDA Dams Monitoring Organization, WAPDA, 1981. Stability of hill slopes. Dams Monitoring Organization, Resort, 22p.

Key words: Engineering geology, slope stability.

W/46. WAPDA Dams Monitoring Organization, WAPDA, 1981. Cracks in power station buildings, Volume I, additional investigation and exploratory works. Dams Monitoring Organization, Report 143, 14p.

Key words: Engineering geology, Warsak Dam, Peshawar

W/47. WAPDA Dams Monitoring Organization, WAPDA, 1981. Warsak dam cracks in power station buildings, Volume II, exploratory drilling. Dams Monitoring Organization, Report, 143, 21p.

Key words: Engineering Geology, Warsak Dam, Peshawar.

W/48. WAPDA Dams Monitoring Organization, WAPDA, 1981. Khanpur dam faults across spillway and its probable extension under the dam. Dams Monitoring Organization, Report 157, 7p.

Key words: Engineering Geology, structure, Khanpur Dam, Haripur.

W/49. WAPDA Dams Monitoring Organization, WAPDA, 1982. Sedimentation in Tarbela dam reservoir, exploration and testing of sediments. IM-E-151, 42p.

Key words: Sedimentology, Tarbela Dam

W/50. WAPDA Dams Monitoring Organization, WAPDA, 1983. Analysis of the consequences of potential flow slides of sediments at Tarbela dam. Volume I and II, IM-E-162.

Key words: Sedimentology, Engineering Geology, Tarbela Dam

W/51. WAPDA 2001. Booklet on hydrogeological map of Pakistan, scale 1:250,000. Hydrogeology Directorate, WAPDA Lahore.

This 22 page booklet comprises introduction, hydrogeological maps, hydrogeological setup of Pakistan, physiography, groundwater potential in Pakistan, groundwater potential in Baluchistan, Hydrogeological in investigations in Punjab, Hydrolgeological investigations in N.W.F.P., Hydrolgeological investigations in Sind, conclusions and recommendations, and bibiliography.

Key words: Hydrogeology, groundwater maps.

W/52. Waqarullah, A.F. & Ahmad, A., 2000. One dimensional (1-D) basin modeling of north-eastern portion of Kohat region, N.W.F.P., M.Sc. Thesis, University of Peshawar, 55p.

Key words: Basin modeling, Kohat.

W/53. Warner, L.F., 1993. Variable denudation of the Nanga Parbat-Haramosh massif: A fission-track study of the Tato valley, Pakistan. B.S. Thesis, Leigh University, Bethlehem, Pa.

Key words: Denudation, Geochronology, Fission Track dating, Nanga Parbat, Himalaya.

W/54. Warraich, M.Y., Zafar, M., Hassan, S., Aslam, A., Ahmad, M.N., Ali, M., Karim, T., Naka, T. & Herayama, J., 1993. Geology of the northwestern part of Abbottabad quadrangle, Abbottabad, Hazara Division. Proceedings of Geoscience Colloquium, Geoscience Lab, GSP, Islamabad, 7, 5-15.

Geology of the northwestern part of Abbottabad quadrangle, Abbottabad has been described. The area is occupied by, from bottom to top, Abbottabad formation (Early Cambrian) and Hazira formation unconformably overlain by the Samana Suk formation (Jurassic), and Cretaceous Chichali and Kawagarh formations. Brief descriptions of the rocks are given together with a colored geological map and seven colored field photographs. The Abbottabad formation is represented by Saraban Dolomite member which is divided into Lower, Middle and Upper units.
Key words: Stratigraphy, geology, Abbottabad, Hazara.

W/55. Wartho, J.A., 1991. Argon isotope systematics and mineralogy of metamorphic hornblendes from the Karakoram. Unpublished Ph.D. dissertation, The University of Leeds, Department of Earth Sciences, 255p.

Key words: Mineralogy, geochemistry, Ar isotopes, metamorphism, hornblende, Karakoram.

W/56. Wartho, J.A., Dodson, M.H., Rex, D.C. & Guise, P.G., 1991. Mechanisms of Ar release from Himalayan metamorphic amphiboles. American Mineralogist 76. 1446-1448.

Changes in hornblende samples that occur during stepwise 39Ar/40Ar analysis were studied experimentally and mineralogically. A complex succession of reactions was seen (hornblende - oxyhornblende - clinopyroxene-structured phase - fine-grained reaction products + glasses) in the temperature range 750-1300C. The release of Ar from hornblende in the vacuum furnace appeared to occur by fundamentally different processes from those resulting in Ar loss during metamorphism. Simple diffusional interpretations of the release patterns are, therefore, not capable

of revealing the thermal history of samples. In principle, some useful information may be obtained if long-standing fractures and other defects control both natural Ar loss and mineral reactions within the laboratory.
Key words: Geochemistry, Ar isotopes, metamorphism, amphibole, Himalaya.

W/57. Wartho, J.A., Rex, D.C. & Guise, P.G., 1996. Excess argon in amphiboles linked to greenschist facies alteration in the Kamila Amphibolite Belt, Kohistan Island Arc system, northern Pakistan: insights from ^{40}Ar/^{39}Ar step-heating and acid leaching experiments. Geological Magazine, 133, 595-609.

A mineralogical and ^{4O}Ar/^{39}Ar study of 13 amphibole samples in the Kamila Amphibolite Belt and Kamila Shear Zone in northern Pakistan has found a correlation between the degree of greenschist facies alteration and quantity of excess ^{40}Ar. Additionally, there is a north–south divide with amphibole samples from the northern region showing larger degrees of green schist facies alteration, brittle deformation, and excess ^{40}Ar incorporation compared to the predominantly plastically deformed, less altered, amphibole samples from the Kamila Shear Zone in the south. Acid leaching of two amphiboles from the Kamila Amphibolite Belt indicates that a large proportion of the excess 40Ar is correlated with later greenschist facies alteration phases, and can be easily removed by acid etching, thus revealing acceptable regional ^{40}Ar/^{39}Ar plateau ages.
Key words: Geochemistry, Ar isotopes, greenschists, Kamila amphibolite, Kohistan arc.

W/58. Warwick, P.D. & Hussain, F., 1990. Coal fields of Punjab, North-West Frontier Province and Azad Kashmir. In: Kazmi, A. H. & Siddiqi, R. A. (eds.), Significance of Coal Resources of Pakistan. Geological Survey of Pakistan, Quetta, 15-26.

Key words: Geology, hydrocarbons, coal, NWFP, Azad Kashmir, Punjab.

W/59. Warwick, P.D. & Shakoor, T., 1988. Preliminary report on coal deposits of the Salt Range area, north-central Pakistan. US Geological Survey Project Report PK-88, 333p.

Key words: Geology, hydrocarbons, coal, Salt Range.

W/60. Warwick, P.D. & Wardlaw, B.R., 1992. Paleocene-Eocene Stratigraphy in Northern Pakistan: Depositional and Structural Implications. 7th Himalaya-Karakoram-Tibet International Workshop.

The Paleocene-Eocene strata of northern Pakistan are found in a northeast-trending trough that is well preserved south of the Main Boundary Thrust (MBT) but is structurally disrupted to the north of the thrust (fig. 1). The depositional trough south of the MBT can be reconstructed along a northwest-southeast cross section from lithofacies of the upper Paleocene Lockhart Limestone and associated Hangu and Patala Formations, the upper part of the lower Eocene Panoba Shale, and the uppermost lower Eocene Kuldana Formation. The Lockhart Limestone was deposited throughout most of the trough and is predominately red algal nodules in skeletal mudstones to packstones in the northwest (Hangu area), foram muds in skeletal mudstones to wackestones (packstones rare) in a central area (Makarwal), and foram-dasyclad sands in skeletal wackestones and packstones (mudstones rare) in the southeast (Salt Range). The southeastern facies of the Lockhart Limestone shows a gradual facies change shoreward to clastics that are indistinguishable from the underlying Hangu Formation and the overlying Patala Formation. During the deposition of the upper part of the Panoba Shale and equivalents, deltaic sands and muds are in the northwest, marls and shales in a central area, and nodular-bedded carbonates in the southeast. The Kuldana Formation is represented by red beds in the northwest and northeast (northern Potwar) and by evaporites and various marine units in the central area (Karak, north of Makarwal). North of the MBT, but south of Khairabad Thrust, where only the foram mud facies is present in the Lockhart Limestone, three sequences are recognized: Hangu missing below, Lockhart, and a Patala marl and shale sequence above, Hangu missing below, Lockhart, and Patala red beds above, and Hangu below (mostly mudstones rather than sandstone as it is south of the MET), Lockhart, and Patala red beds above. The Patala red beds north of the MBT indicate probable terrestrial and marginal marine

deposition during the upper Paleocene-lowermost Eocene, well before the generally widespread, younger Kuldana was deposited south of the MBT.
It appears the "red" Patala is generally present in structurally higher thrust plates north of the MET, suggesting that sequences and are not on the same thrust plate as mapped. The structurally juxtaposed stratigraphies north of the MBT are significantly different than those south of the MBT and are composed of marginal marine to terrestrial. Study Area in sediments that probably represent northern Pakistan. A general shoaling area at the northern end of the Paleocene-Eocene trough that presaged the continental collision.
Key words: Stratigraphy, Paleocene, Eocene, structure, North Pakistan.

W/61. Washburn, A.L., 1939. Karakoram glaciology. American Journal of Science 237, 138-146.

Key words: Glaciology, glaciers, Karakoram.

W/62. Wasson, R.J., 1979. Stratified debris slope deposits in the Hindu Kush, Pakistan. Zeitschrift fur Geomorphologie 23, 301-320.

Key words: Debris flow, debris deposits, Chitral, Hindukush.

W/63. Wazir, M.Y. & Masood, Allauddin, 1983. Petrology of part of North Waziristan Agency, including Khaderkhel, Datta Khel, Kaniro-Ghamanzar Khel and Dagan areas, NWFP., Pakistan. M.Sc. Thesis, Peshawar University, 80p.

Key words: Petrology, mapping, North Waziristan.

W/64. Weerth, A., 1991. Neu mineralfunde aus den beruhmten Pakistani shen edelsteinpegmatiten. Lapis 16(1), 36-37.

Key words: Gems, pegmatite, Pakistan.

W/65. Weerth, A., 1991. Neufunde aus dem Himalaya und Karakorum. Lapis 16(10), 45-46.

Key words: New mineral finds, Himalaya, Karakoram.

W/66. Weerth, A., 1992. Die aktuellen mineralfunde aus dem bereich des Hunza-Tals in Nord-Pakistan. Lapis 17(10), 38-44.

Key words: Minerals, Hunza.

W/67. Weerth, A., 1994. Krieg und steine. Ein aktueller situationsbericht uber neufunde aus Pakistan und Afghanistan. Lapis 19(10), 27-30.

Key words: Gems, Afghanistan, Pakistan.

W/68. Weerth, A., 1997. Alpine Neuheiten aus dem Karakorum. Lapis 22, 13-22.

Describes newly discovered gemstones from the Karakoram Mountains.
Key words: Karakorum.

W/69. Weerth, A., 1988. Edelsteinvorkommen im schatten der achttausender: Beshreibung der mineralvorkommen im norden Pakistans. Lapis 13, 11-28.

Describes the general geology and other information on localities of various gem minerals and collectable specimens in northern Pakistan.
Key words: Gems,

W/70. Weinberg, R.F., Dunlap, W.J. & Whitehouse, M., 2000. New field, structural and geochronological data from the Shyok and Nubra valleys, northern Ladakh: linking Kohistan to Tibet. 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, 253-275.

The Nubra-Shyok confluence in northern Ladakh is a key area for understanding the tectonic evolution of NW Himalaya and provides the basis for linking the geology of Pakistan to that of Tibet. The geology of the confluence area has been the subject of much speculation centered mainly on the existence of ophiolites and their regional significance. These ophiolites are thought to represent the eastward extension of the Shyok Suture Zone (SSZ), which separates the Dras island arc from the southern margin of Eurasia, and which was overprinted by movement along the Khalsar Thrust (often thought to represent the eastern continuation of the Main Karakoram Thrust). The geology of the area is relatively complex and the little information available has hampered regional geological correlations. The Khalsar Thrust (KT) and the dextral Karakoram Fault (KF), two regional tectonic features of NW Himalaya, merge at the confluence defining a triple point and three block; the Ladakh block to the south, the Saltoro block to the northwest, and the Karakoram block to the northeast. Close to the triple point, the KF changes strike and movement direction. Movement vector analysis of the triple point indicates that the KT and the two parts of the KF could have moved contemporaneously, and allows prediction of the movement vectors across the faults. The KT and KF shear preferentially volcano-sedimentary rocks of the Shyok and Nubra formations, respectively. Contrary to previous interpretations, these sheared rocks do not represent disrupted ophiolites. Regional tectonic reconstructions, however, require suturing between the Ladakh block and Eurasia and the strike of the SSZ in Baltistan suggest that the suture zone might crop out north of the KT, either along the southern slopes of the Saltoro Range or further north along the Saltoro valley. In the few outcrops of the Saltoro block we were able to visit, we found no evidence of ophiolitic rocks. Instead we found outcrops of the calc-alkaline Tirit batholith. Although our observations do not confirm the presence of the suture-related rocks in the southern Saltoro block, this possibility cannot be ruled out. Zircons from a sample of Tirit granite (U-Pb ion-microprobe age) yielded an age centered at 68 ± 1 Ma. The similar range of modal composition and age of the Tirit and Ladakh batholiths suggest that they are part of the same magmatic event. This result and a number of other observations indicate that the post-75 Ma geology of the Ladakh and Saltoro blocks is similar. Thus, if there is a suture zone in the southern Saltoro block, suturing must have occurred before 75 Ma, as concluded by others along the same tectonic boundary to the west in Pakistan. The KF represents a much younger terrane boundary, juxtaposing rocks of the Ladakh and Saltoro blocks to those of the Karakoram terrane. Rocks related to suturing of continents were not found along the KF. Karakoram leucogranites cropping out in the southern part of the Karakoram terrane yielded a U-Pb zircon age centered at 15.0 ± 0.4 Ma (2σ). Because these leucogranites were not found south of the KF, this fault must have initiated after leucogranite intrusion and must therefore be younger than 15 Ma old. At the confluence the KF cuts across the regional rocks sequence than can be followed from Kohistan into Baltistan and into the confluence area. Movement on the fault displaces the sequence by approximately 150 km to southern Tibet was the regional rock sequence could be regained.
Key words: Structure, geochronology, Shyok, Nubra valleys, Shyok suture, Karakoram fault, Ladakh, Kohistan, Tibet.

W/71. Wells, N.A., 1984. Marine and continental sedimentation in the early Cenozoic Kohat Basin and adjacent northwestern Indo-Pakistan. Ph.D. dissertation, University of Michigan, 465p.

Key words: Sedimentation, continental, Cenozoic, Kohat basin.

W/72. Wells, N.A. & Gingerich, P.D., 1983. Review of Eocene Anthracobunidae (Mammalia, Proboscidea) with a new genus and species, Jozaria Palustris from the Kuldana Formation of Kohat (Pakistan). University of Michigan, contributions from the Museum of Paleontology, 26, 117-139.

Anthracobune and its primitive bunodont-bilophodont herbivorous allies from the Eocene of Indo-Pakistan are grouped together in a new family, Anthracobunidae. Anthracobunids are interpreted as basal "tethytheres" that are probably broadly ancestral to proboscideans, sirenians, and desmostylians. The family includes five genera and species: Anthracobune pinfoldi Pilgrim, 1940; Lammidhania wardi (Pilgrim, 1940); Pilgrimella pilgrimi Dehm and Oettingen-Spielberg, 1958; Ishatherium subathuensis Sahni and Kumar, 1980; and Jozaria palustris (new genus and species). Anthracobunidae may be ancestral to Moeritheriidae among primitive proboscideans and Prorastomidae/ Protosirenidae among primitive sirenians; they resemble both groups in size and general cheek tooth morphology, and they appear earlier in the fossil record. Anthracobunids are primitive in having four premolars and in lacking the tusks and specialized rostra seen in moeritheriids and protosirenids. Desmostylia may also be derived from Anthracobunidae. Jozaria appears to have fed on soft aquatic vegetation in brackish to freshwater marshes. Some Pilgrimella and Ishatherium specimens have been found in marine deposits. These observations are consistent with the postulated amphibious habits of moeritheres and the shallow-water littoral-marine habitats of sirenians and desmostylians.
Key words: Palaeontology, mammals, Eocene, Kuldana Formation, Kohat.

W/73. Wells, N.A. & Gingerich, P.D., 1987. Paleoenvironmental interpretation of Paleogene strata near Kotli, Azad Kashmir, Northeastern Pakistan. Kashmir Journal of Geology 5, 23-42.

In the Kotli area of east central Pakistan, the Subathu Formation was deposited by a single cycle of transgression and regression during the early Eocene. The marine Subathu section, which is developed on a pre-Eocene bauxite, records the successive passage of a coastal coal swamp; a very muddy shoreline; shallow and highly turbid but quiet offshore waters depositing unfossiliferous green mud and organic debris; clear and probably deeper but still occasionally turbid wear over fetid muds and marls beyond the coastal turbid zone; progressively shallower water depositing shales and higher energy limestone; an oyster bank; a delta-related submergent sand-bar complex; and a back-bar bay or lagoon that trapped river muds. Finally, progradation of a brackish coastal marsh across the bay is inferred from the succeeding slowly accumulated and completely pedogenized onshore clays. The topmost marine shale is inferred to correlate with a regional regression at the end of the early Eocene.
Key words: Paleoenvironments, Paleogene, Azad Kashmir.

W/74. Werdin, J., 1998. Gletscherverbreitung und-dynamik im Hunza-Karakorum. Thesis (Diplomarbeit), Geograpisches Institut, Universitat Bonn.

Key words: Glaciers, Hunza, Karakoram.

W/75. Wessels, W., 1997. Myocticetodontinae from the Miocene of Pakistan. Koninklijke Nederlandse Akadamie van Wetenschaft, Proceedings, Series B, 99, 253-312.

Key words: Palaeontology, Miocene, Pakistan.

W/76. Wessels, W., Bruijn, H.D., Hussain, S.T. & Leinders, J.J.M., 1982. Fossil rodents from the Chinji Formation, Banda Daud Shah, Kohat, Pakistan. Koninklijke Nederlandse Akadamie Van Wetenschaft, Proceedings, Series B, 85, 337-364.

Key words: Fossils, rodents, Chinji Formation, siwaliks, Karak, Kohat.

W/77. Wessels, W., Unay, E. & Tobien, H., 1987. Correlation of some Miocene faunas from northern Africa, Turkey and Pakistan by means of Myocricetodontinae. Koninklijke Nederlandse Akadamie van Wetenschaft, Proceeding, Series B, 90, 65-82.

Key words: Palaeontology, Miocene, Africa, Turkey, Pakistan, siwaliks.

W/78. West, R.M., 1980. Middle Eocene large mammal assemblage with Tethyan affinities, Ganda Kas region, Pakistan. Journal of Paleontology 54, 508-533.

A new collection of fossil mammals from the vicinity of Ganda Kas, along the southern edge of the Kala Chitta hills, Pakistan, provides new insights into the Paleogene faunas of southern Asia. Nineteen genera are now known from Ganda Kas, one described here as new. In addition, several taxa are referred to the Cetacea, Khirtharia is returned to the Helohyidae and shown to be a senior synonym of Bunodentus, and Pilgrimella pilgrimi is a junior synonym of Anthracobune pinfoldi which is a tethythere closely allied to the Moeritheriidae. The excellent new material of Khirtharia, Anthracobune and Lammidhania allows more complete description of their dentitions and, in the case of Khirtharia, the skull, than was previously possible. The abundance and diversity of cetaceans and tethytheres at Ganda Kas suggests marked affinities of South Asian faunas with the other major Tethyan Eocene assemblage at Fayum, Egypt. Other affinities are with eastern Asia through the brontotheres and artiodactylis. Lammidhania is retained in the Anthracotheriidae, although it surely is atypical and may, when the upper dentition is known, belong elsewhere. The fossil mammals from Ganda Kas fit well with the coastal environment pos- tulated for Kuldana and Kohat Formation rocks.
Key words: Palaeontology, mammals, Eocene, Kalachitta Range.

W/79. West, R.M., 1981. Plio-Pleistocene fossil vertebrate and biostratigraphy of Bhittani and Marwat Ranges, northwest Pakistan. Neogene-Quaternary boundary, Proceedings, Field Conference, India, 211-216. Geological Survey of India.

Key words: Vertebrate palaeontology, biostratigraphy, Plio-Pleistocene, Bhittani Range, Marwat Range.

W/80. West, R.M. & Lukacs, J.R., 1979. Geology and vertebrate-fossil localities, Tertiary Continental rocks, Kala Chitta Hills, Attock District, Pakistan. Contribution in Biology and Geology 26, Milwaukee Public Museum Press, 20p.

Key words: Palaeontology, vertebrate fossils, Tertiary, Kalachitta Range, Attock.

W/81. West, W.D., 1931. Hazara Simla Hills correlations. Geological Survey of India, Record 65, 125-132.

Key words: Stratigraphy, Hazara, Simla.

W/82. Whalley, W.B., 1984. High altitude rock weathering processes. In: Miller, K.J. (eds.), The International Karakoram Project volume 1, Cambridge University Press.

High altitude rock weathering is poorly understood both in terms of processes involved and rates of activity. As well as freeze-thaw activity which produces small blocks, larger scale rock falls appear to be common. In addition, chemical processes are probably more Important at high altitude than has been generally realized. This chemical weathering can take place in either cracks or on the surface to give sand and silt-sized particles (grus). Rock surface rinds, as a form of desert varnish, appear to form where special conditions operate, although these environmental parameters are not yet elucidated. Other places show grain by grain disintegration due to weathering in micro-cracks. The varnish rinds are of complex chemical composition and show preferential enrichment of Mn and Fe over the parent rock. A variety of techniques have been used to investigate these crusts. Examples are shown of scanning electron micrographs and Mossbauer spectroscopy which suggest formation of haematite and a gel form of Fe(OH)3. The form of Mn concentration is not yet known but appears to be in small nodules (1 – 2 µm diameter) on the varnish surface.

Key words: Weathering, Karakoram.

W/83. Whalley, W.B., McGreevy, J.P. & Ferguson, R.I., 1984. Rock temperature observations and chemical weathering in the Hunza region, Karakoram: Preliminary data. In: Miller, K.J. (eds.), The International Karakoram Project 2, 616-633. Cambridge University Press.

Air, rock surface, 5 cm deep and crack temperatures were recorded around a variety of rock types at various altitudes in the Hunza Valley in July/August 1980. Clear sky and cloudy conditions were compared. Under clear skies rock surfaces can exceed air temperatures by as much 24oC with actual rock temperatures around 40oC even at 4250m. Cloudy conditions showed smaller excess. Rock surface minima reached nearly 5oC below air temperatures under clear skies but were about the same under cloudy skies. Rock cooling rate vary considerably according to cloud cover and rock color. At 4400m the effects of chemical weathering are significant in rock breakdown. Desert varnish is rare above 3000m.

Key words: Weathering, rock temperature, chemistry, Hunza, Karakoram.

W/84. Wheeler, J., Murdie, R., Potte, G.J., Prior, D.J., Treloar, P., Butler, R.H.W.H., George, M., Harris, N.B.W. & Jones, C., 1991. Structure of northern Nanga Parbat syntaxis and its relation to the Kohistan arc. Abstract Volume, 6th Himalaya-Karakoram-Tibet workshop, Auris, France, 95-96.

The Nanga Parbat syntaxis of Pakistan is a region of basement gneiss belonging to the Indian continental plate, structurally overlain by amphibolites of the Kohistan Island Arc which were emplaced along a complex set of faults, the Main Mantle Thrust (MMT). In turn, these arc rocks are bounded to the north in the Hunza region by Asian plate metasediments, the contact being the Northern Suture. The relation between the MMT and the Northern Suture, where they approach each other in an area north of the Indus gorge, is critical to understanding the relation between the formation of the Nanga Parbat syntaxis and possible late movements on the two major sutures.

They are three lithotectonic units identified within the northern part of the syntaxis. The Iskere Unit, found on the west side, consists of migmatic orthogneiss yielding Proterozoic ages. The Shengus Unit occurs on the east side of the syntaxis in the Indus gorge and further south, and contains metapelites and calc-silicate rocks, again sometimes migmatic. In the north and northeast, immediately underlying the MMT, is the Layered Unit. This is strikingly banded on the scale of 100s of metres, consisting of biotite gneiss alternating with thick sheets of orthogneiss, sometimes garnetiferous. Sheets of marble, and boudinaged sheets of amphibolite, are common.

The Shengus and Iskere units contain sheets of amphibolite, sometimes discordant to the banding in the surrounding gneisses, and inferred to be original basic dykes. The age of these is not certain; though both dykes and gneisses share a dominant N-S trending stretching lineation, and the dykes are frequently foliated parallel to their margins. Dykes were encountered in two areas.

In the Indus gorge, field relation suggests that the dykes were less ductile than gneiss during the post-dyke deformation. The main shape fabric in dykes and gneiss, and the north-south lineation, are Himalayan in age and relate to initial emplacement of the Kohistan Arc over the Indian Plate. This main fabric is folded into a broad antiform trending NNE, slightly oblique to the lineation.

Further N near the village Iskere, dykes are arched into an antiform with a roughly N-S axis and intrude the magmatites of the Iskere Unit. The dykes are foliated, but foliation in the gneiss is poorly developed and usually N-S subvertical. The migmatites were thus relatively ridged during folding, with dykes as “easily slip” horizons accommodating flexure whilst the gneiss form a crude axial-planar fabric.

A contact interpreted as the MMT is well displayed in mountain side to the N and E of the Iskere, where it separates epidotic banded greenschist and amphibolites from the gneiss of the layered unit. Banding in both units appears parallel to the contact. Where it is seen further S, bounding the E side of the syntaxis in the Indus gorge, the contact is vertical and the foliations on the both side is concordant. In contrast, on the W side of the syntaxis, at Sassi and further N, it is heavily modified by ductile and brittle dip-slip and oblique-slip movement.

At least 1-2 km of Kohistan amphibolites is seen above the MMT north of Iskere: these are upper-arc rock. However, glacial rubble includes abundant pale green phyllites with garbenschiefer amphiboles. This distinctive

lithology is characteristic of metasediments of the Asian Plate, and possibly the Kohistan amphibolites are roofed by these rocks. This would imply that the “Northern Suture” is not a strait subvertical join here, as it is further west in the Hunza area, but a N-dipping contact. Tourmaline pegmatites showing little deformation are present throughout the syntaxis. In addition larger granitic sheets are common and, NW of Iskere, an undeformed 2-mica leugcogranite intrudes syntaxis rocks.
Key words: Structure, Nanga Parbat, MMT, Kohistan arc, Himalaya.

W/85. Wheeler, J., Potts, G.J. & Treloar, P., 1990. Asymmetric structure and uplift of the Nanga Parbat syntaxis, Pakistan Himalayas. In: Abstract volume, 5th Himalaya-Karakoram-Tibet Workshop, Milano, 64.

The syntaxis is an anomalous N-S trending structure in which the Main Mantle Thrust (MMT) in an internal part of the Himalayan belt has been warped up to expose Indian Plate continental gneisses in its footwall, rimmed by ophiolitic material of the Kohistan Island Arc in the hangingwall. We studied a transect across the syntaxis in the Indus gorge to constrain its structural evolution. On the East Side, the MMT is vertical but there are no penetrative fabrics of syntaxis age, the main fabric being interpreted as of MMT age. Crossing an antiformal core region, the steep West margin contains fabrics with steep stretching lineations and shear bands indicating down-to-West movement along this margin. This uplift was accompanied by passive rotation in the East, but active shearing on the West margin. We suggest that the syntaxis formed above a deep detachment propagating westwards, perhaps a consequence of gravity spreading in the main Himalayan chain. Sticking on this led to large-scale buckle folding in metasediments now found in the east half of the syntaxis. Subsequent shortening in orthogneisses in the west was accomplished along a shear zone steeping upwards, giving overall tilting of the existing structures. Thus we predict asymmetric uplift ages due both to a west-propagating locus of uplift and to large-scale tilting of the partly formed syntaxis along a curved shear zone.
Key words: Structure, Nanga Parbat, MMT, Himalaya.

W/86. Wheeler, J. Treloar, P.J. & Potts, G.J., 1995a. Structural and metamorphic evolution of the Nanga Parbat syntaxis, Pakistan Himalayas on the Indus Gorge transect: the importance of early events. Geological Journal 30, 349-371.

For details consult the following account.
Key words: Structure, Nanga Parbat, metamorphic evolution, Indus gorge, Himalaya.

W/87. Wheeler, J., Treloar, P.J. & Potts, G.J., 1995b. Structural and Metamorphic Evolution of the Nanga Parbat Syntaxis: The Importance of Pre-Himalayan Events. Abstract Volume, 10th Himalaya-Karakoram-Tibet Workshop, (ETH Zurich) Switzerland.

The Nanga Parbat syntaxis remains a focus of scientific attention in the Pakistan Himalaya due to the rapid exhumation rates inferred for its recent history. Young fission track ages (Zeitier, 1985), recent overthrusting of lndus gorge gravels by the syntaxis gneisses (Butler and Prior, 1988), and apparently very young migmatites (Zeitler etal, 1993) have all been linked to large uplift rates with accompanying rapid erosion and perhaps tectonic exhumation. However, these basement gneisses, in common with other basement complexes in young orogens, have certainly be subject to a prolonged history, not all of which relates to the Tertiary plate collision which created the present orogen. The nearest parts of the Indian foreland exposed south of the Himalayas consist of Proterozoic gneisses, and Proterozoic zircon ages (amongst others) have been reported from the lndus gorge. The task of distinguishing recent structures and metamorphic assemblages (related to the Tertiary Himalayan history) from much older features is not trivial. In this contribution we present a summary of a detailed structural and metamorphic study of the Nanga Parbat syntaxis along the lndus gorge transect. We show how the kyanite-bearing migmatites, common in the gneisses of the lndus gorge, are pre-Himalayan: their genesis does not, therefore, relate either to the Himalayan burial/exhumation cycle or to the genesis of Himalayan granites. In contrast, the gross structure and main fabric preserved in the syntaxis is Himalayan. The gneisses in the gorge form a diverse array of ortho- and paragneisses with many textural variations. A crude subdivision into “lskere” granitoid orthogneiss in the west, and ‘Shengus” paragneiss in the east is, however, sufficient to illustrate the main features (c.f. Chamberlain et al., 1989). Most of the gneisses carry strong mineral shape fabrics and also banding, sometimes clearly migmatitic. An additional key group of rocks are sheets of amphibolite on the m- to 10 m scale. We first describe structural features as investigated in the field, and then summarise the metamorphic history of the syntaxis gneisses.

Structural history

Usually, mineral shape fabrics and banding are parallel in the gneisses. The planar composite fabric appears to define a large, tight antiformal closure in the east half of the syntaxis, and a more open closure on the west side (Fig. 1). Where gneisses are adjacent to interleavings of Ladakh island arc amphibolites on the eastern margin, LS fabrics in the two units are parallel. Since the Ladakh fabrics relate to Himalayan events, we infer that the shape fabrics in the gneisses do also. Thus, the eastern margin is the Main Mantle Thrust, rotated but otherwise unmodified. Omitting much detailed complexity (Wheeler et al., submitted), lineations throughout the syntaxis are roughly N-S and inferred to be Himalayan. The large tight antiform postdates the lineations but, as the fold axis is subparallel to them, they were not severely steepened. It is likely that the antiform affected the whole nappe pile of syntaxis gneisses and Ladakh-Kohistan island arc amphibolites, as Fig. 1 suggests.

The amphibolite sheets within the gneisses commonly carry the same LS fabric, with N-S lineation, as the adjacent gneisses. However, in some places it can be seen that the margins of the sheets truncate migmatitic banding in the gneisses. Moroever, no evidence for migmatisation of the amphibolite sheets has been observed, even when they are within intensely strained and migmatised gneisses. These two key observations show that migmatisation predated the intrusion of discordant basic sheets which now form the amphibolite sheets. This relationship is commonly obscured by subsequent deformation at amphibolite facies, which formed LS fabrics in both gneisses and basic sheets and transposed earlier structures, giving the illusion that banding and mineral shape fabrics relate to the same deformation event. There is no record of Tertiary basic magmatism within the Indian plate gneisses in the Himalayan chain or in the foreland. We infer that the basic sheets are pre-Tertiary - they may be part of the Panjal Trap magmatic event, and therefore Permian. The migmatisation of the gneisses, being still earlier than this, is therefore unrelated to the Tertiary Himalayan collision. The main fabric, often transposing migmatitic banding into parallelism with other features, is Himalayan in age.

Metamorphic history

The Shengus paragneisses contain several assemblages, but a “typical” assemblage is as follows: garnet-kyanite-orthoclase-biotite-plagioclase-quart-accessories. Garnet and orthoclase both form porphyroclasts with irregular outlines. Garnet is commonly rimmed by a corona of biotite and kyanite. The edges of such coronas are commonly streaked out into a strong shape fabric defined by quartz ribbons, aligned biotite and blades of kyanite, and streaks of polycrystalline orthoclase. The occurrence of kyanite + orthoclase shows that muscovite, which must have been present in this metapelite originally, broke down by dehydration or dehydration melting. The occurrence of garnet + orthoclase is diagnostic of more extreme conditions. Figure 2, the petrogenetic grid of Vielzeuf & Holloway (1988) shows that these two phases can only be produced on a prograde path by a biotite dehydration melting reaction above 800^0C: specifically, biotite + Al-silicate + plagioclase + quartz = garne6 orthoclase + melt PT estimates using the garnet-biotite geothermometer (Ferry and Spear, 1978) and the garnet-kyanite-plagioclase-quartz geobarometer (Koziol and Newton, 1988) also indicate these extreme temperatures, although ~ubstantial post-peak resetting has modified the relevant phase compositions. Inclusions of sillimanite in garnet show that this reaction happened in the sillimanite stability field on the prograde path. The kyanite-biotite coronas are best explained by partial back-reaction of melt with garnet and orthoclase: the reverse of the above reaction, but in the kyanite stability field. These reactions, involving melt, were part of the migmatisation event. Subsequent deformation involved the recrystallisation of the biotite-kyanite coronas and other phases, but no further reaction. As argued in the structural section, this was a Himalayan event, probably much later than the partial melting reactions and corona development which relate to the migmatisation. Sporadic late sillimanite and muscovite (due to ingress of small amounts of water in the sillimanite stability field) are the only new Himalayan phases to be developed in the gneisses. This metamorphic history is summarised in Fig. 2. The lskere orthogneisses show differences to the Shengus gneisses which are not due merely to bulk chemical differences. A typical lskere gneiss assemblages is orthoclase-biotite-muscovite-plagioclase-quartz-accessories. Assemblages including garnet and/or kyanite also occur, but never with orthoclase. Biotite and muscovite are typically strongly foliated. It would appear, then, that muscovite never broke down in these rocks, and they never experienced the same temperatures as the Shengus gneisses: yet, since in the field migmatitic tetxures are common, this poses a problem. Wet melting is one possibility, but we prefer a model in which the lskere gneisses did undergo substantial melting, perhaps at conditions comparable to those in the Shengus gneisses during migmatisation. Then, melt segregated on a small scale, but remained in chemical “communication” with the restite, enabling melt to back-react thoroughly as the migmatite complex cooled. Such a process would recreate the subsolidus amphibolite fades assemblage: any grain-scale reaction textures could then have been destroyed by the later Himalayan deformation, which gave rise to the two-mica shape fabric. Thus, we suggest that the lskere gneisses followed the same PT path as the Shengus gneisses during migmatisation, but that large-scale melt loss from the lskere migmatites was insignificant, leading to complete back-reaction. The Shengus gneisses lost substantial melt, so that back-reaction was incomplete and the granulite-facies restite assemblage was preserved.

In summary, a significant part of the lndus gorge syntaxis history relates to pre-Himalayan events, specifically a migmatisation episode. This produced the banding still seen in the gneisses, although any accompanying shape fabrics have been obliterated. The migmatisation caused partial melting in all rock types at temperatures above 800 00 Melt loss was limited, so that back-reaction was important during cooling of the migmatite complex. Subsequently, a swarm of basic sheets intruded the complex. During the Himalayan collision, the gneisses and basic sheets were intensely deformed at amphibolite facies, but there is no evidence-for any further partial melting. Thus, these kyanite migmatites differ not only in grade but also in age from the reputedly Himalayan cordierite migmatites found further south. The pre-Himalayan inheritance of the basement gneisses cannot be ignored in any model for the Himalayan evolution of the Nanga Parbat syntaxis.

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

W/88. White, M.G., 1966. Copper, lead, zinc, antimony and arsenic in West Pakistan. US Geological Survey/Geological Survey of Pakistan, (IR) PK-4, 39p.

Copper localities that merit geological investigation are found in the western Chagai district, in North Waziristan agency and in the Salt Range in Mianwali and Sarrgodha Districts. No high-grade deposits have been reported from thes areas and if deposits are developed they will likely be low-grade, high-tonnage, disseminated deposits. Those localities reported from Chitral State are too remote and inaccessible to be of interest now. All lead localities found to date are of minor importance; there has been small production at one locality in Chagai District and in the southern part of the Hazara District. Zinc, antimony, and arsenic are sparse in Pakistan and no important localities of these metals are reported. No base metals are reported in East Pakistan.

Key words: Economic geology, base metals, Pakistan.

W/89. Whittington, A., 1995. The Thermal Evolution of Nanga Parbat, Northern Pakistan. Abstract Volume, 10th Himalaya-Karakoram-Tibet Workshop, (ETH Zurich) Switzerland.

The Nanga Parbat - Haramosh Massif (NPHM) is a tongue of underthrust Indian Plate Precambrian basement exposed for 100 km protruding northwards into the Asian Plate, at the western end of the Himalaya. Geochronological studies over the past decade have shown that the whole massif has been exhumed exceedingly rapidly (up to 7 mm/y) over the past 5 Ma. In addition, Ar-Ar dating linked with detailed structural studies has shown that the recent exhumation is most rapid on the western margin, due to a combination of thrust and transpressive strike-slip faulting. This study concentrates on the southern part of the massif, around Nanga Parbat (81 25m). Here recent structures related to rapid Pliocene & Pleistocene exhumation can be observed overprinting older Main Mantle Thrust structures associated with collision and initial crustal thickening. The present study relates the various stages of metamorphism and magmatism to the structural history and tectonics of Nanga Parbat. Preliminary Ar-Ar analyses on pelitic gneisses have yielded ages of 1.8 to 2.0 Ma for muscovite, and 2.3 to 3.1 Ma for biotite. The older biotite ages imply the presence of excess argon, so that the closure ages recorded are absolute maxima. These maximum muscovite ages of 2.0 Ma imply a minimum average cooling rate of 165oC/m.y. over the past two million years. For an arbitrary geothermal gradient of 40º C/km this represents an average exhumation rate of >4 mrn/y. Initial results of thermal modeling shows that rapid exhumation can lead to very high near- surface geothermal gradients, and that the pronounced topography around Nanga Parbat may produce non-horizontal isotherms. The assumptions of horizontal isotherms and modest geothermal gradients are made in calculating exhumation rates from fission track data, and there may be significant over-estimation of these rates in the literature. The aim of future work is to integrate the results of various other techniques into a more detailed thermal model for the evolution of this part of the massif.

Key words: Structure, Precambrian basement, thermal evolution, NPHM, Himalaya.

W/90. Whittington, A. & Harris, N., 1995. Anatexis of the Nanga Parbat Massif, Northern Pakistan. Abstract Volume, 10th Himalaya-Karakoram-Tibet Workshop, (ETH Zurich) Switzerland.

An unusual thermal history of the Nanga Parbat-Haramosh Massif (NPHM) is indicated both by anatectic leucogranites of unusually young age (< 10 Ma) and by the recognition of even younger cordierite-spinel anatectic melts hitherto unknown to the Himalayan orogen. The NPHM forms a northward kink in the suture (MMT) between the Indian Plate and Kohistan Island Arc at the western end of the Himalaya. A combination of thrust and transpressive strike-slip faulting has resulted in unusually rapid exhumation rates (~7 mrn/yr) of the western margin of the massif over the past 5 Ma1,2. Recent compressional structures related to this rapid exhumation can be observed overprinting older MMT structures associated with collision and initial crustal thickening. Basement lithologies from the NPHM have undergone a complex thermal history involving at least three phases of anatexis. Migmatitic pelitic gneisses with anatectic leucosomes are cross-cut by amphibolitic sheets, probably of pre-Himalayan age3. These migmatites are intruded by tourmaline-two mica leucogranite dykes and plutons which are syn-tectonic with respect to exhumation structures. The NPHM leucogranites are similar in major-element geochemistry to High Himlayan leucogranites (intruded at ~20Ma) exposed along the length of the Himalaya4, even though much younger ages (2.3 - 7 Ma) are indicated by ionprobe studies of accessory phases from NPHM intrusives5. Trace element abundances differ from those of High Himalayan leucogranites in that Rb/Sr ratios are significantly higher as are concentrations of Y, U and Th. Ba abundances are lower in the NPHM intrusions. Such variations suggest low degree partial melts from a pelitio source of unusually radiogenic character. Melting could be induced by a combination of high internal heat production and by rapid exhumation under vapour-absent conditions. Leucogranite emplacement was post-dated by local anatexis forming granitic pods, rarely more than 50 cm in diameter, within kink bands and shear zones. Both peritectic cordierite and spinel have been observed suggesting that biotite breakdown has occurred under fluid-present conditions, presumably due to local fluid ingress along structurally favourable channels. Further studies of such melts may constrain the behaviour of crustal fluids following rapid exhumation of the massif.

Key words: Leucogranites, crustal anatexis, NPHM, Himalaya.

W/91. Whittington, A., Harris, N.B.W., Ayres, M.W. & Foster, G., 2000. Tracing the origins of the western Himalay: an isotopic comparison of the Nanga Parbat massif and Zanskar 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, 201-218.

New Sr and Nd isotope data for basement gneisses and leucogranites are presented from two contrasting areas of the western Himalaya; the Nanga Parbat-Haramosh massif (NPHM) and Zanskar. Sr-isotope systematics of metapelites and anatectic migmatites from the Zanskar Himalaya are characterized by εSr of 515-930, typical of the High Himalayan Crystalline unit as exposed for more 2000 km along strike. Moreover, Zanskar leucogranites are typical of the belt of Early Miocene granites intruding the High Himalayan Crystalline across the orogen (mean εSr =834). In contrast, the NPHM leucogranites show an elevated average εSr of 2400, and basement samples show a wide range in εSr from 1850 to 8150. Errochrons for the metasedimentary gneisses indicate isotopic homogenization of the basement at c. 500 Ma for the Zanskar samples compared with c. 1800 Ma from the NPHM, confirming that the two terrains have experienced contrasting pre-Himalayan histories. Nd isotopic data from the NPHM indicate model ages from 2300 to 2800 Ma, indicating the mean crustal formation ages of the protoliths from which the sediments were derived. A compilation of published Nd data from the Himalaya indicates average protolith formation ages of 2640 ± 220 Ma for the Lesser Himalaya lithologies, compared with 1940 ± 270 Ma for High Himalaya unit. Gneissic lithologies from Zanskar and the NPHM have previously been correlated with the High Himalayan Crystalline Series, since both display high-grade Himalayan metamorphism and are intruded by syn-to post-tectonic tourmaline-bearing leucogranites. Isotopic systematics in the Zanskar region confirms this correlation. In contrast, the NPHM basement rocks are better correlated with Lesser Himalayan lithologies, exposed south of the Main Central Thrust. We conclude that the NPHM represents either a lower structural level of the Lesser Himalaya Series, or its protolith.

Key words: Basement gneisses, leucogranites, Sr and Nd isotopes, NPHM, Zanskar, Himalaya.

W/92. Whittington, A., Haris, N. & Butler, R., 1996. Field and analytical constraints on thermal evolution of the Nanga Parbat Massif, Pakistan. Abstract volume, 11th Himalaya-Karakoram-Tibet Workshop, Flagstaff, Arizona (USA), 168-169.

In this contribution, a multidisciplinary approach elucidates the thermal and magmatic history of a rapidly exhuming terrane in the Western Himalaya. Inverse modeling allows investigation of the P-T-t path for exposed rocks from collision to exhumation constrained by geochronologic and thermobarometric data. We specifically address the problem of melt formation by considering the interaction between transient geotherms and fluid infiltration during rapid exhumation. The Nanga Parbat Syntaxis, or Nanga Parbat-Haramosh Massif (NPHM), forms a northward kink in the suture between the Indian Plate and Kohistan Island Arc at the western end of the Himalaya. A combination of thrust and transpressive strike-slip faulting has resulted in unusually young cooling rates on the western margin of the massif over the past 5 Ma (1). Recent compressional structures related to this rapid exhumation can be observed overprinting older Main Mantle Thrust (MMT) structures associated with collision and initial crustal thickening (2). The Tato Valley which runs north form the peak of Nanga Parbat to the Indus Valley at Raikot Bridge is particularly problematic for geochronological and thermal modeling studies due to (i) its exceptionally high cooling rates, interpreted to indicate rapid and increasing exhumation rates of 7mm/year (1) and (ii) its unparalleled topography of 7 km vertical relief over a horizontal distance of 21 km. The basement Indian Plate lithologies exposed in the massif have a polymetamorphic history, as indicated by pre-Himalayan amphibolite dykes cross-cutting some migmatitic fabric. Small tourmaline leucogranite plutons and sheets show sharp cross-cutting relations and are undeformed except in shear zones related to recent exhumation. All fabrics and units are overprinted in the core of the massif by cordierite-bearing granitic pods, which form preferentially in small conjugate shears with kinematics consistent with vertical stretching. Thermobarometric data from equilibrium pelitic assemblages suggest peak metamorphic conditions of 700±60ºC and 4.4±0.6kbar (3). Some assemblages record higher pressures of about 6kbar at similar temperatures, suggesting a near-isothermal decompression path during exhumation. Published U/Pb ages on accessory minerals suggest that this is latest episode of high-grade metamorphism is Pliocene in age, broadly coeval with formation of the leucogranites (4,5). In present day study, 40Ar/39Ar geochronology has been used to determine the exhumation path of these rocks, and while excess argon renders biotite ages only useful as upper limits to the timing of closure, muscovite ages suggest that these rocks cooled through about 445°C as recently as 1.8 Ma. Geochemical constraints indicate an origin for the leucogranites by fluid-absent muscovite breakdown (decompression melting) during exhumation. Accessory phase thermometry calculations indicate that melting occurred at temperatures of 710 ± 10°C, consistent with such a fluid-absent melting reaction. Sr-isotope systematics can be used to find the precise crustal source of the granites. Data from leucogranite plutons define a narrow range of ^{87}Sr/^{86}Sr ratios between 0.87 and 0.90. Samples of basement gneisses from the massif define a much broader field from 0.77 to 1.25. This wide range of isotopic ratios suggests that pervasive fluid infiltration through the basement has not occurred, and confirms that lithologies are available in the massif with sufficiently radiogenic Sr to source the granite plutons. The likely source was geochemically similar to metapelites within the outcropping gneisses but lay at greater depth than lithologies exposed at present erosional levels. The most recent melt-forming episode, associated with melting of metapelites and local formation of pneumatolytic cordierite-granite pods, resulted from biotite breakdown during infiltration of an aqueous fluid along small shear zones. The combination of geochronologic and thermobarometric results provides powerful constraints on thermal models of the evolution of the NPHM between 50 Ma and the present day. Further limits can be imposed by structural arguments which bracket total exhumation since 50 Ma as between about 30 and 35 km, and the absence of large melt volumes exposed at the surface which indicates that fertile levels of NPHM crust did not cross the vapour-absent biotite solidus for pelitic assemblages. One-dimensional thermal models indicate that the unusually young cooling ages from this area do not necessarily imply extreme or rapidly increasing exhumation rates, because the advection of heat resulting from rapid exhumation leads to a steepened near-surface geotherm. The most important control on the present-day thermal structure of the NPHM appears to be the thermal structure resulting from obduction of the Kohistan Arc some 50 million years age. Transient geotherms calculated for the past 10 Ma can only be reconciled with published geochronological and thermobarometric studies if exhumation rates lay in the range of 3 to 4 mm/year, still considerably grater than exhumation rates determined from the main Himalayan orogen. Exhumation paths fitted to the cooling age data and calculated P-T fields require leucogranite formation at realistic depths (sources 2 to 5 km below present levels of exposure) times (2 to 8 Ma). Multidisciplinary approaches on samples from a restricted spatial area allow a well-constrained thermal and metamorphic history to be inferred. At Nanga Parbat the complex magmatic history is controlled by both the evolving thermal structure, involving relaxation of transient geotherms and recent telescoping of isotherms due to rapid exhumation, and fluid infiltration at moderate depths (<10-15 km).

Key words: Thermal evolution, NPHM, Himalaya.

W/93. Whittington, A.G., 1996. Exhumation overrated at Nanga Parbat, northern Pakistan. Tectonophysics 260, 215-226.

New $^{40}Ar/^{39}Ar$ laserprobe and thermobarometric data from the Nanga Parbat-Haramosh Massif (NPHM) in northern Pakistan provide important constraints on thermal models of the evolving geotherm of the massif. Simple thermal models indicate that the unusually young cooling ages from this area do not necessarily imply extreme exhumation rates of about 7 mm/y, because the advection of heat resulting from rapid exhumation leads to a steepened near-surface geotherm. The most important control on the present-day thermal structure of the NPHM appears to be the thermal structure resulting from obduction of the Kohistan Arc some 50 m.y. ago. Transient geotherms calculated for the past 10 Ma can only be reconciled with published geochronological and thermobarometric studies if exhumation rates lay in the range of 3 to 4 mm/y, still considerably greater than exhumation rates determined from the main Himalayan orogen.
Key words: Geochronology, Ar-Ar dates, thermal evolution, NPHM, geothermometry, Himalaya.

W/94. Whittington, A.G., 1997. The thermal, metamorphic and magmatic evolution of a rapidly exhuming terrane: the Nanga Parbat massif, northern Pakistan. Ph.D. thesis. Open University, Milton Keynes.

Key words: Metamorphism, magmatism, thermal evolution, Nang Parbat, Himalaya.

W/95. Whittington, A.G., Foster, G.L., Harris, N.B.W. & Ayres, M.W., 1999. Lithostratigraphic correlation in the western Himalaya-an isotopic approach. Geology 7, 585-588.

We present the results of a whole-rock Nd isotopic study of two contrasting regions of the western Himalaya, using the neodymium model age approach on the scale of a single orogen. High-grade metasedimentary rocks from Zanskar yield model ages (TDM) that are similar to those of the High Himalayan Crystalline Series (TDM = 1.2–2.0 Ga; ϵNd = –6 to –16) and distinct from values from the Lesser Himalaya (TDM = 2.3–3.4 Ga; ϵNd = –18 to –27). Hence these two lithological sequences can be recognized for 2000 km along the strike of the orogen. Data for the basement of the Nanga Parbat massif at the western extremity of the Himalaya (TDM = 2.3–2.8 Ga; ϵNd = –18 to –30) suggest that these rocks are not equivalent to the High Himalaya, as previously supposed, but have affinities with the Lesser Himalaya. A thin metasedimentary cover sequence on the margins of the Nanga Parbat massif is isotopically indistinguishable from the High Himalaya (TDM = 1.6–1.8 Ga; ϵNd = –10 to –14). The prior misidentification of the provenance of the massif stems from its high metamorphic grade, characteristic of the High Himalaya, but in this case related to the unique Neogene history of the Nanga Parbat massif, which has exhumed a higher-grade equivalent of the Lesser Himalaya that is not seen elsewhere.
Key words: Lithostratigraphy, High Himalayan Crystallines, Lesser Himalaya, Nanga Parbat, Zanskar.

W/96. Whittington, A.G., Harris, N.B.W., Ayres, M.W. & Foster, G.L., 1998. Where did Nanga Parbat come from? Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 211-212.

The Nanga Parbat-Haramosh Massif (NPHM) is the most northerly exposure of Indian Plate basement, and forms a syntaxial loop at the northwestern end of the Himalayan orogen. It is bounded to the north by the Main Mantle Thrust (MMT), locally overprinted by more recent strike-slip and reverse faults that separate the NPHM from the Kohistan-Ladakh island arc terrane. The NPHM has long been considered to be a westward extension of the Higher Himalayan Crystalline Unit (HHC), which outcrops further east in the main orogen, in part because of its similarly high metamorphic grade, and in part because both the HHC and NPHM host tourmaline-bearing leucogranite bodies of Eocene age or younger. The leucogranites from both regions have similar geochemistry, indicating generation from a pelitic source by vapour-absent "decompression" melting (Harris and Inger, 1992). However, several discrepancies have become apparent in recent years between the P-T-t path followed by the NPHM and HHC terranes. For example, leucogranites at Nanga Parbat have crystallisation ages as young as 1 Ma (Zeitler and Chamberlain, 1991), compared to typical ages of 18 to 22 Ma for Higher Himalayan leucogranites (Harrison et al., 1997). Geochronological studies have revealed that Nanga Parbat is currently being exhumed at a rate of at least 3 mm/y (Whittington, 1996), that has resulted in an elevated geothermal gradient and exceptional topography, thus promoting vigorous fluid flux throughout the massif. These factors have in turn led to a second melting episode, generating small cordierite-bearing restitic assemblages localised in shear zones that are not observed in the main orogen (Whittington et al., 1998). Thus the timing of both exhumation and anatexis at Nanga Parbat differs from that seen in the central Himalayan orogen. Isotopic systematics of rocks of the NPHM and the HHC in Zanskar, the nearest outcrop of HHC to the NPHM, suggest different histories for the two terranes. NPHM leucogranites are exceptionally radiogenic, with (87Sr/86Sr) ratios of about 0.877 and εNd of -23 (present day), compared with (87Sr/86Sr) ratios of 0.74 to 0.78 and εNd of -13 to -17 for High Himalayan leucogranites from Zanskar (Ayres, 1997). When plotted on an errorchron diagram, Nanga Parbat basement lithologies display a trend corresponding to between 2100 and 2400 Ma, while Zanskar rocks display a trend corresponding to about 500 Ma, for both Rb-Sr and Sm-Nd systems. Supporting evidence Proterozoic events from the NPHM terrane comes from amphibolite sheets which cross-cut the oldest gneissic fabrics are characterised by Nd model age of 2200-2400 Ma; (ii) previously published zircon core ages from the NPHM cluster around 1850 Ma for the Iskere gneiss, and 500 and 2500 Ma for the Shengus gneiss (Zeitler et al., 1989; Zeitler et al., 1993). Thus isotopic evidence suggests that the NPHM basement is much older than the HHC unit, and the two cannot be correlated. These results pose the question of whether the NPHM basement unit is unique to this area, exposed locally by the exceptional exhumation history of Nanga Parbat, or does it outcrop elsewhere in the Himalayan orogen? Lesser Himalayan lithologies, exposed in the footwall of the MCT in the main orogen, are comprised of a metasedimentary succession, but have attained a much lower metamorphic grade. Published zircon ages from the Lesser Himalaya (1870 to 2600 Ma, Parrish and Hodges, 1996) are quite distinct from those found in the HHC unit (800 to 1000 Ma, ibid.), but match ages from the NPHM. While Himalayan-age granite magmatism is unknown in the Lesser Himalaya, the abundance of pelitic lithologies makes this sequence a fertile source, and the Nanga Parbat leucogranites reproduce the isotope systematics that would be expected if these rocks were melted during decompression. Cambro-Ordovician granites do occur in the Lesser Himalaya, and the leucogneisses found in the southern NPHM may represent their metamorphosed equivalents. An orogenic event of this age may also explain the presence of 500 Ma ages in some zircon cores from the Shengus gneiss, but clearly did not result in isotopic homogenisation on a bulk-rock scale. Hence in answer to the question, where did Nanga Parbat come from, it is possible that the c. 30 km of erosion experienced by Nanga Parbat in the past 10 Ma has exposed Lesser Himalayan basement rocks through the Kohistan island arc terrane. This raises a further question, what happened to the HHC rocks overlying the Lesser Himalayan sequence? Work in progress on the margins of the NPHM that seeks to address this question (Foster et al., this volume) is further complicated by the lack of a well-defined MCT in northern Pakistan, in contrast to the relatively uniform stratigraphy seen in the main orogen.

Key words: Higher Himalayan Crystallines, NPHM, Indian plate, Himalaya.

W/97. Whittington, A.G., Harris, N.B.W. & Baker, J., 1998. Low pressure crustal anatexis: the significance of spinel and cordierite from metapelitic assemblages at Nanga Parbat, northern Pakistan. In: Treloar, P.J. & O'Brien, P. (Eds.), What Drives Metamorphism and Metamorphic Reactions? Geological Society, London, Special Publications 138, 183-198.

Key words: Crustal anatexis, metapelites, NPHM.

W/98. Whittington, A.G., Harris, N.B.W. & Butler, R.W.H., 1999. Contrasting anatectic styles at Nanga Parbat, northern Pakistan. In: Macfarliane, A., Sorkhabi, R.B. & Quade, J., (eds) Himalaya and Tibet: Mountain root to mountain tops. Geological Society of America, Special Papers 328, 129-144.

Tourmaline-bearing two-mica granite plutons and sheets intruding the basement lithologies of the Nanga Parbat-Haramosh massif represent the youngest known occurrence of High Himalayan leucogranite magamatism. Trace-element modeling using Rb, Sr, and Ba indicates an origin by vapor-absent muscovite melting. Accessory phase modeling suggest that anatexis occurred at temperatures of ~720°C, and therefore depths of 20-25 km. The source of one such intrusion (the Tato pluton) is considered to be metapelitic gneiss similar to that cropping out in the massif, and isotopically distinct from the source of the Miocene Himalayan leucogranites. Initial $^{87}Sr/^{86}Sr$ ratios of ~0.88 for the Tato pluton compare with 0.74-0.78 for Miocene granites intruded into the central Himalayan orogen.

Subsequent to, or coeval with, leucogranite emplacement, small cordierite-bearing leucosomes have been generated in ductile shear zones within the interior of the massif. These are geochemically variable, but are consistently characterized by strong depletion in high field strength elements and other incompatible trace elements. Petrographic and geochemical constraints indicate that at least some seam may be restitic, following localized incongruent melting of biotite in the presence of a fluid yielding a high melt fraction (F ~0.5). Other seams may be wholly or partly subsolidus in nature. Thermo-barometric data from these seams indicate that channelled fluid migration within the massif occurred at pressures <400 Mpa and temperatures of about 630°C. Geochemical constraints on contrasting granitic rocks from the interior of the Nanga Parbat-Haramosh massif chart a changing regime from fluid-absent anatexis in the mid-crust (~20 km depth) to fluid infiltration during ductile deformation in the upper crust (~10 km depth). These findings are consistent with the rapid exhumation of the massif with more modest exhumation rate around the margins.

Key words: Crustal anatexis, trace element modeling, Sr isotopes, NPHM.

W/99. Whittington, A.G., Kelley, S.P. & Harris, N.B.W., 1998. Fluid flow in the Nanga Parbat-Haramosh Massif: the use and interpretation of argon isotopes. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 210-211.

An extensive dataset of 175 40Ar/39Ar analyses of mica separates are presented from the Nanga Parbat-Haramosh Massif, an actively deforming syntaxial region that forms the western Himalaya. Three critical areas were selected for sampling in order to distinguish genuine spatial and temporal patterns of cooling from the spurious effects caused by inherited excess argon. The majority of ages are interpreted as recording regional cooling due to rapid exhumation within the last 10 Ma. Younger ages of less than 1 Ma from leucogranite sheets and plutons approximate to intrusion ages, and support field evidence for magma emplacement into relatively cool country rocks by fracture flow rather than by diapirism. The widespread occurrence of "excess" argon, i.e. gas of unknown composition trapped at the time of closure, results in anomalously old ages that require multiple total fusion analyses of single grains to determine the true ages of geological events. The use of isotope correlation diagrams for multiple analyses enables some confidence to be placed in the resulting age, and the composition of non-radiogenic argon trapped at the time of closure may be used as a tracer of fluid pathways. In the interior of the massif, incorporation of excess argon suggests the presence of magmatic and/or metamorphic fluids at depth, while in the Liachar Shear zone on the western margin of the massif, the incorporation of argon with an atmospheric composition suggests circulation of meteoric fluids at shallower levels.

Key words: Fluid flow, Ar isotopes, NPHM

W/100. Wiche, K., 1960. Researches of climatic geomorphology in the Western Karakoram. Deutscher Geographentag Berlin 1959, Tagungsbericht und Wissenschaftliche Abhandlungen; Wiesbaden.

Key words: Geomorphology, Climate, western Karakoram.

W/101. Williams, M.P., 1989. The geology of the Besham area, north Pakistan: deformation and imbrication in the footwall of the Main Mantle Thrust. Geological Bulletin, University of Peshawar 22, 65-82.

The gneisses, granites and metasediments of the northern exposed margin of the Indian plate in the Besham antiform consist of a Precambrian crystalline basement with younger sedimentary cover. These were metamorphosed during the main fabric-forming event of the Himalayan orogeny, a ductile simple shear dominated deformation of the footwall of the MMT during southward overthrusting of the Kohistan Arc. Deformation intensity and ductility decrease southwards. Subsequent thrusting brought together internally imbricated blocks, which have different deformation/metamorphic histories. High-grade rocks thrust over low-grade rocks within each block define an inverted metamorphic gradient produced by post-metamorphic thrusting. Major cross folding producing the Besham antiform, plus brittle faults are expressions of the later N-W directed backthrusting and E-W compression and uplift of the Besham area.

Key words: Structural geology, deformation, metamorphism, Besham, Swat.

W/102. Williams, M.P., Treloar, P.J. & Coward, M.P., 1988. More evidence of pre-Himalayan orogenesis in northern Pakistan. Geological Magazine 125, 651-652.

As this article doesn't contain an abstract, and is a correspondence to other authors, giving more details about the pre-Himalayan orogenesis of the northern Pakistan.
Key words: Pre-Himalayan orogenies, deformation, Besham, Swat.

W/103. Willis, B.J., 1991. Evolution of Miocene fluvial systems in Chinji area, Potwar Plateau, northern Pakistan, Ph.D. dissertation, State University of New York, Binghamton, 297p.

For more information, see Willis (1993b).
Key words: Fluvial system, Miocene, Chingi, siwaliks.

W/104. Willis, B.J. 1993a. Ancient river systems in the Himalayan foredeep, Chinji village area, northern Pakistan. Sedimentary Geology, 88, 1-76.

The Miocene Chinji and Nagri Formations (Siwalik Group) of northern Pakistan record ancient fluvial environments in the Himalayan foredeep basin. Excellent exposures on the Potwar Plateau (Chinji Village area) allowed detailed documentation of the geometry and stacking of sediment bodies that comprise these strata, and of variation of large-scale bedding geometry, grainsize, sedimentary structures and paleocurrent orientations within such bodies.Major sandstone bodies are tens of meters thick and are continuous along strike for many kilometers. They are composed internally of interconnected channel belt deposits, each of which contain several storeys (channel bar and fill deposits). Individual storeys, defined by inclined bedsets dipping down to a major basal erosion surface at up to 11°, are only 5 to 15 m thick within the Chinji Formation but can be up to 30 m thick within the Nagri Formation. Bedsets within storeys reflect sediment accreted during individual flood events. Along-strike variation of bedsets within storeys and the stacking patterns of storeys within channel belt deposits reflect changes in the channel bed through time due to the growth of bars, migration of channels, and channel cutoff. Generally, braided channel patterns are indicated by the relatively large number of storeys within individual channel belt deposits exposed perpendicular to paleoflow, abundant evidence for channel bar superposition due to channel switching, local evidence for mid-channel bars, dominance of coarse-grained channel fills, and low paleocurrent variations.
Paleochannel reconstructions from storeys exposed within the Chinji Formation indicate that individual channel segments generally had widths of 80–200 m, maximum depths of 4–13 m, wavelengths of 1.6–2 km and discharges of 400–800 m3/s. Full channel belt widths (1–2 km) estimated from exposures perpendicular to paleoflow, and evidence for 2–3 coeval channels within channel belts, indicate full channel discharges of 1500–2000 m^3/s. Larger channel segments reconstructed from the Nagri Formation had widths of 200–400 m, maximum depths of 15–30 m, wavelengths of 3–5 km, and discharges of 3000–5000 m3/s. As Nagri Formation channel systems were also clearly braided, full channel dimensions and discharge estimates are probably at least a factor of two greater than for individual channel segments (i.e. order of 10,000 m^3/s).
Strata between major sandstone bodies are dominated by lobate and wedge-shaped bodies (crevasse splay and levee deposits), minor channel-form bodies (deposits of minor floodplain channels), laminated mudstone bodies (lake deposits) and paleosols. These strata are arranged into meters to 10 m thick stratified sequences that were rapidly deposited, bounded by well developed paleosols recording periods when deposition rates were low. The thickness and grainsize of such paleosol bounded sequences are not directly related to the proximity of a major channel deposit along strike. Instead, such sequences within overbank deposits appear to reflect local progradation of splays and levees into low areas on the floodplain.
Key words: Fluvial system, Chingi Formation, Nagri Formation, siwaliks.

W/105. Willis, B.J., 1993b. Evolution of Miocene fluvial systems in the Himalayan foredeep through a two kilometer-thick succession in northern Pakistan. Sedimentary Geology, 88, 77-121.

Sedimentological variations through a kilometer-thick coarsening-upward succession in the Miocene Himalayan foredeep basin (fluvial Chinji and Nagri Formations of the Siwalik Group) are documented in the Chinji Village area on the Potwar Plateau of northern Pakistan. From the Chinji Formation upwards into the Nagri Formation: (1) the proportion of major sandstone bodies increase relative to mudstone-dominated beds; (2) average thickness and mean grainsize of channel deposits increase; (3) sediment aggradation rates increase; (4) there is a reported change in sediment providence; (5) paleocurrents are generally to the southeast and vary little upsection; and (6) paleosols are more distinct lower in the section where there is also more evidence of ponding of water on the floodplain. Smaller-scale (100 m thick) cyclic variations in the proportion of major channel sandstone bodies also occur in both formations.

In the modern Himalayan Basin, sediment dispersal away from the mountain belt is associated with: (1) major rivers that flow along the basin axis; (2) large rivers that drain substantial areas of the mountain belt and deposit low relief sediment fans extending hundreds of kilometers into the basin; and (3) smaller rivers in fan and interfan areas that drain local areas and carry finer sediment loads. Sediment variations through the Chinji-Nagri Formation boundary can be related to a shifting of depositional environments within such fan and interfan areas. Major basin-axial rivers are not exposed in this area. It appears that kilometer-thick upsection variations in these deposits record the progradation of the sediment fan formed by a large river system (river discharge on the order of 104 m3/s) over the floodplain of a smaller river system (river discharge on the order of 103 m3/s).

Large-scale vertical sediment variations over hundreds of meters to kilometers appear to reflect changes in the basin subsidence and the rate of sediment input to the basin over time scales on the order of 105–106 years. Upsection variations can not easily be related to climatic change or eustatic variations in sea level. The most likely explanation for upsection changes is tectonism. Deposition rates and shifting positions of river systems within the basin responded more quickly to changes in basin subsidence rate, whereas increases in the proportion of sandstone bodies and increases in floodplain slopes lagged behind. Deposit variations in the Siwalik Group clearly record variations between different-scale river systems delivering sediment to the basin as well as the overall basin evolution.

Key words: Fluvial system, Chingi Formation, Nagri Formation, siwaliks.

W/106. Willis, B.J. & Behrensmeyer, A.K., 1995. Fluvial systems in Siwalik Miocene and Wyoming Paleogene. Palaeogeography, Palaeoclimatology, Palaeoecology, 115, 13-35.

The 3 km thick Miocene Siwalik Group (Himalayan foredeep in northern Pakistan) and the 2 km thick Paleogene Fort Union/Willwood formations (Bighorn Basin in Wyoming) both preserve long records of fluvial deposition adjacent to rising mountain belts. Depositional environments and associated habitats change across large basins along with changing physiography and with the location of different river systems that may have varied greatly in patterns of channel deposition and the drainage of adjacent floodplain areas. Deposits exposed in these two basins provide very different records of shifting paleoenvironments and patterns of basin filling. These differences reflect distinct patterns and scales of depositional environments. The nature of the exposures, and the types of sedimentologic studies that have been carried out in each basin.

The Siwalik Group fills a basin that extended at least 1000 km along its axis and 150–250 km away from the mountain front. Comparison of Siwalik deposits and modern drainages in the Himalayan foredeep suggests the ancient Siwalik basin was filled by large rivers that deposited low gradient sediment fans covering areas on the order of 1000 km2, and by smaller intrafan rivers with more poorly drained floodplains. Despite the scale of these river systems relative to Siwalik exposures in Pakistan, transitions between different systems have been recognized. Deposits of coeval river systems in the Siwalik Basin show pronounced differences in alluvial architecture, the character of overbank deposits, and the abundance and taphonomy of organic remains.

In contrast, the Bighorn Basin in Wyoming is a relatively small intermontane foreland basin extending 200 km along its axis and about 80 km across. Bighorn Basin strata were deposited by a river that flowed south to north along the basin axis and by smaller rivers that flowed transverse to the basin axis. Much of this basin is exposed and thus it is possible to reconstruct changing patterns of deposition and environments through time in more detail than in the Siwalik Basin. These patterns indicate changes in basin-wide drainage conditions and environments through time, but there are also important differences among coeval strata.

Upsection shifts in environments and vertebrate faunas within both the Siwalik and Bighorn Basins may reflect tectonic or climatic forcing, but this comparison emphasizes the importance of recognizing deposits from different contemporaneous river systems before inferring such large-scale controls on paleoecological change through time.

Key words: Fluvial systems, siwalik, Miocene, Wyoming Paleogene.

W/107. Willis, B.J. & Behrensmeyer, A.K., 1996. Architecture of Miocene overbank deposits in northern Pakistan. Journal of Sedimentary Research, Section B-Stratigraphy & Global Studies 65, 403-407.

The paper presents a description and analysis of the architecture of ancient overbank deposits from the Miocene Chinji Formation of northern Pakistan (see also Behrensmeyer, 1987, Willis, 1993a). The authors described meters-thick paleosol bounded sequences that are defined by an alternation of relatively mature paleosols and stratified deposits with a lesser degree of pedogenesis. They asserted that the mature paleosols represent relatively long periods of very low deposition rate, whereas the stratified deposits represent relatively short periods of high deposition rate. They proposed and evaluated five end-member hypotheses for the origin of the paleosol-bounded sequences. It is concluded that the stratified deposits were formed by local rapid filling of low areas on the flood plain, independently of the position of major channels: such filling may have been a more or less continuous process, or may have been a short-lived event associated with river-channel avulsion. They specifically dismissed the possibility that the nature of the stratified deposits was related to the proximity of major channels and the growth of alluvial ridges. They also dismissed the possibility that paleosol-bounded sequences could have been related to regional variations in sediment supply and deposition rate, or to valley incision and filling.
Key words: Overbank sedimentation, Miocene, siwaliks.

W/108. Wilson, W.E., 1984. What’s new in mineral? Mineralogical Record 15(1), 43-46.

Gives many worldwide mineral discoveries. From Haramosh in the Gilgit-Skardu area of northern Pakistan reports large crystals and aggregates of aquamarine.
Key words: Mineral discoveries, gemstones, Haramosh, Gilgit, Skardu.

W/109. Windley, B.F., 1981. Phanerozoic granulites. Journal of the Geological Society, London, 138, 745-751.

Granulites can form at every stage of the Wilson cycle: during plate accretion (Mid-Atlantic Ridge), in active plate margins of island-arc and Andean type (Ivrea Zone, main complex in Kohistan in the Karakorums), in the roots of Andean-type batholiths (Coast Range Complex, British Columbia; Santa Lucia Range of California), during the closure of a marginal basin (Aracena belt, Spain), during Himalayan-type collision (Jijal Complex in the Karakorums of N Pakistan and at I’Agly in the Pyrenees) and during post-tectonic intrusion at depth(Säo Paulo, Brazil). Himalayan-type orogenic belts may, in principle, contain any of such granulites. The majority of granulites form along active plate margins in the roots of magmatic arcs, which are the main sites of crustal growth in the Phanerozoic. Layered stratiform complexes, formed largely by cumulate processes, are common in Phanerozoic granulites (Kohistan, Ivrea, Calabria in Italy, Cabo Ortegal in NW Spain, Brittany and N Pyrenees). Their granulite-grade parageneses may have formed during cooling from an igneous temperature, or during superimposed metamorphism. Variations in the types of granulites may help in understanding how different types of lower continental crust are constructed.
Key words: Granulites, Jijal complex, Chilas, Kohistan.

W/110. Windley, B.F., 1983. Metamorphism and tectonics of the Himalaya. Geological Society London Journal 140, 849-865.

Metamorphism connected with the main growth and deformation stages of the Himalaya ranges from mid-Cretaceous to the Quaternary. Northward subduction gave rise in the early to mid-Cretaceous to an island are complex with greenschists, amphibolites, granulites and blueschists in the W (Kohistan-Ladakh) and an Andean-type margin with greenschist-amphibolite grade metamorphism in the E (India and Tibet). Ophiolitic nappes were thrust southwards over the Indian continental margin in the Palaeogene during the final stages of closure of the southern arm of Tethys. The Indus-Zangbo Suture bifurcates westwards and between the two sutures lies the Kohistan-Ladakh island arc which was converted to an Andean-type arc in the Palaeocene-Eocene. The Karakorum Range underwent northward subduction at least during the late Cretaceous to give rise to a complex and prominent calc-alkaline batholith. Post-collisional southward thrusting of crustal slabs over the Indian continental margin took place in the early Miocene with production of high-grade metamorphism, inverted isogrades and crustal melt granites. Later southward thrusting in the Pliocene to Quaternary gave rise to localized low-grade recrystallization against the thrusts.

Key words: Metamorphism, tectonics, Karakoram, Himalaya.

W/111. Windley, B.F., 1984. The Evolving Continents. Wiley, New York, 399p.

In this highly popular book there is a brief summary of the geology and tectonics of northern Pakistan.

Key words: Tectonics, continents, magma genesis, metamorphism, mineralization..

W/112. Windley, B.F., 1985. Geochemical and time constraints on the evolution of the Kohistan arc-batholith, Pakistan. Abstract Volume, 1st Himalayan Workshop, Department of Geology, University of Leicester.

The Kohistan arc-batholith went through three stages of growth. New Rb-Sr isochron dates are by M.G. Petterson, an 39Ar/40Ar date is by D. Rex and geochemical data are by I. Luff and M.G. Petterson. We do not know when the island arc began to form. The Yasin Group Sediments which were deposited in intra-arc basins (C. Pudsey) contain Albian-Aptian faunas. The arc pluton consist of a bimodal suite of low-K tonalitic and high-K diorite gneisses, one of which has a Rb/Sr age of 102±12 Ma. The overlying Chalt Volcanics comprises pillowed primitive basaltic tholeiites succeeded by andesites, dacites and rhyolites, typical of many mature island arcs. The Chilas Complex consisting of norites and layered cumulates formed by deep-level fractionation (dominated by orthopyroxene precipitation) from the magma, which gave rise to the island arc. All these rocks were deformed by major fold structures, which are correlated with the formation of the Northern Suture, after which the island arc was intruded by an Andean-type calc-alkaline batholith on the northern active continental margin of Tethys. The first expression of the I-type batholith was the intrusion of a swarm of NE-SW trending hornblende diorite dykes, one of which has a 39Ar/40Ar hornblende age of 75 Ma. The main constituent of the batholith is a suite of medium-K intrusions emplaced throughout its evolution, which ranges from gabbro to granite, though the dominant rock type is granodiorite. In the Gilgit area this suite is intruded by high-K diorite plutons. Two plutons near Gilgit have Rb-Sr isochron ages of 54±4 Ma and 40±6 Ma. Limited Sr-isotope data indicate a dominantly mantle source for the batholith and trace element patterns are typical of subduction-related magmas. The Dir-Utror Group of calc-alkaline lavas (and sediments with Eocene fossils) are probably remnants of the volcanic cover of the batholith. Following formation of the Indus Suture in the Eocene, the batholith was intruded by an intense swarm of layered aplite-pegmatite, S-type granite, sheets at 34±14 Ma and 29±8Ma, as a results of partial melting of the island arc crust thickened tectonically and/or by magmatic accretion or of the underplated Indian below the arc.

Key words: Geochemistry, evolution, Kohistan arc batholith, Himalaya.

W/113. Windley, B.F., 1988. Tectonic framework of the Himalaya, Karakoram and Tibet, and problems of their evolution. Philosophical Transactions of the Royal Society, London, A326, 3-16.

The Himalaya, the Karakoram and Tibet were assembled by the successive accretion to Asia of continental and arc terranes during the Mesozoic and early Tertiary. The Jinsha and Banggong Sutures in Tibet join continental terranes separated from Gondwana. Ophiolites were obducted onto the shelf of southern Tibet in the Jurassic before the formation of the Banggong Suture. The Kohistan--Ladakh Terrane contains an island arc that was accreted in the late Cretaceous on the Shyok Suture and consequently evolved into an Andean-type batholith. Further east this Trans-Himalayan batholith developed on the southern active margin of Tibet without the prior development of an island arc. Ophiolites were obducted onto the shelf of India in the late Cretaceous to Lower Palaeocene before the closing of Tethys and the formation of the Indus--Yarlung Zangbo Suture at about 50 Ma. Post-collisional northward indentation of India at ca. 5 cm per year since the Eocene has redeformed this accreted terrane collage; palaeomagnetic evidence suggests this indentation has given rise to some 2000 km of intracontinental shortening. Expressions of this shortening are the uplift of mid-crustal gneisses in the Karakoram on a late-Tertiary breakback thrust, folding of Palaeogene redbeds in Tibet, south-directed thrust imbrication of the foreland and shelf of the Indian Plate, north-directed back-thrusts along the Indus Suture Zone, post-Miocene spreading and uplift of

thickened Tibet, giving rise to N--S extensional faults, and strike-slip faults, which allowed eastward escape of Tibetan fault blocks.
Key words: Tectonics, Himalaya, Karakoram, Tibet.

W/114. Windley, B.F., Coward, M.P. & Jan, M.Q., 1986. The geology and tectonic evolution of the Karakoram-Kohistan range of the Himalaya of N. Pakistan. In: Huang, J.Q. (ed.), Proceedings of Symposium on Mesozoic and Cenozoic Geology. 60th Anniv. Volume Geological Society of China, 455-467.

The Indus suture in northern Pakistan splits into two branches that bring rocks of diverse nature in contact. The exact position of the northern suture is uncertain. North of it pelitic and calcareous rocks show a rapid northward increase in grade of metamorphism; in the sillimanite zone they are intruded by the Tertiary calc-alkaline Karakoram batholith. Sedimentary rocks to the north of the batholith are mostly Palaeozoic in age and are dominated by pelites, calcareous and arenaceous rocks, and extend to the Chinese border. The southern suture, with associated high-pressure granulites, meta-ultramafics and blueschists, is bordered on the south by rocks of the Indian plate consisting of a basement of late Precambrian pelites intruded by Cambrian granites and overlain by a cover of Mesozoic carbonates and shales which, with its basement, was highly folded, thrusted and metamorphosed up to sillimanite grade during the Tertiary.

Between the two sutures occur rocks of the Kohistan sequence belonging to a mid-Cretaceous island arc (formed during northward subduction) which is represented by (north to south): tightly folded pillow-bearing basic volcanics and sediments; foliated tonalites and diorites; the Chilas complex which is a stratiform cumulate body over 300 km long and 8 km thick; an amphibolitic belt of mixed lithologies; and the Jijal complex which is a 200 km2 tectonic wedge of high-pressure mafic granulites and chromite-layered ultramafics. The Chilas complex was folded by an F1 isoclinal anticline (and metamorphosed in the granulite facies) and the upper part of the Kohistan arc by a major F2 syncline; both folds formed during collision of the arc with the Indian plate in the early Eocene. The arc was upthrust on a ramp during the collision so that it is now subvertical, providing a remarkable section through the crust. The Kohistan sequence became an Andean-type are in the Eocene (during southward subduction) when calc-alkaline plutonics and volcanics were intruded and extruded. Several plate tectonic models are evaluated for the production of the Karakoram batholith and the northern suture. Factually, the Kohistan sequence (and its eastern extension in Ladakh) is a double arc with an intervening period of collision (Coward et al., 1984). From the Chinese border to the Karakoram batholith is a thick sequence of low-grade fossiliferous sediments, mostly slates, phyllites, dolomites, limestones and sandstones, ranging from Devonian to early Cretaceous (Desio and Martina, l97l; Tahirkheli, l979). The structural hiatory of this sequence of deformed sediments is unknown.

The Karakoram batholith (> 350 km long and l0 km wide) consists of a complex sequence of intrusions which can be broadly divided into two groups: early large plutons offoliated biotite or hornblende-granodiorite, adamellite and quartz diorite were intruded by small intrusions and sheets of undeformed Ieucogranite with rare garnet and tourmaline, adamellite, and pegmatite and aplite with tourmaline, garnet and beryl. Preliminary data suggest the granodiorites and granites have K/Ar ages in the range 65-5 Ma (Blasi et al., 1980; D. Rex, pers. comms). Broughton (1981) found from a chemical (XRF and microprobe) study of these rocks that they represent two distinct petrogenetic groups. The more mafic granodiorites, tonalites and diorites have a calc-alkaline chemistryo are diopside normative and contain modal hornblende, sphene, more calcic plagioclase and magnetite+/-ilmenite, in contrast to the more alkali-rich leuco-granites which are corumdum normative and contain modal garnet and tourmaline and ilmenite as an opaque phase.

South of the Karakoram batholith there is a meta-pelitic seguence which shows a marked southward decrease in grade via closely spaced isograds. Sillimanite schists in the north pass via garnet-staurolite schists, garnetchloritoid phyllites to chloritoid slates and chlorite-biotite slates at Chalt. Chloritoid schists occur in the same tectonic position in the Skardu area (Zanettin, 1964). Adjacent to the batholith there is a 4 km wide belt of corundum-bearing marbles with complex sulphide mineralisation which crystallised at 60O-700 ^{o}C and 7 kb fluid pressure (Okrusch et al., 1976).
.**Key words:** Tectonics, continents, Karakoram, Kohistan.

W/115. Winslow, D.M., Chamberlain, C.P. & Zeitler, P.K., 1995. Metamorphism and melting of the lithosphere due to rapid denudation, Pakistan Himalaya. Journal of Geology 103, 395-408.

The Nanga Parbat-Haramosh Massif of the western Himalaya has undergone a complex metamorphic and deudational history over the past 1.8 Ga. metamorphism in the Tato region is characterized by a Barrovian type metamorphism by partial melting and recrystallization along shear zones during nearly isothermal decompression while the massif was still at temperature >550^{0}C. mineralogical and textural evidence for this path imcludes garnet zoning pattern, late-stage migmatization, abundant cordierite both in schists and leucogranite dikes, replacement of high-pressure assemblages by low-pressure assemblages, and abundant low-density inclusions. Thermobarometry on the nonmigmatized gneises reveals conditions of 540-740^0 C at 7.1 – 13.1 Kbar. Thermobarometry in the migmatized rocks reveals final equilibration at 608-675^0 C aat 3.9 – 6.8 Kbar. Early fluid inclusions occur n quartz inclusions within garnet porphyroblasts that grew during decompression. The last fluid inclusions to be trapped occur in microfractures that locally crosscut several grain boundaries and, hence, record conditions after quartz grain boundary migration ceased. Examination of all the petrologic and fluid inclusion data conclusively show a very rapid denudation event late in the collisional process. Rapid denudation resulted in the advection of isotherms to shallow crustal levels causing an elevated geotherm (~60^0 C/km) in the upper crust, metamorphism along zones, and partial melting of the crust at depths of ca. 22 km.

Key words: Metamorphism, lithosphere, denudation, Himalaya.

W/116. Winslow, D.W., Zeitler, P.K. & Chamberlain, C.P., 1993. Characterization of Neogene metamorphism in the polymetamorphic Nanga Parbat syntaxis, Pakistan, Himalaya. Abstracts with Program, Annual Meeting of the Geological Society of America, p. A-123.

Pelitic units metamorphosed under upper amphibolite-lower granulite facies conditions record the complex tectometemorphic history of the Nanga Parbat Syntaxis (NPS) with peak metamorphic conditions of 145 c and 7.1 kbar, The NPS is an extension of Indian basement which has undergone rapid exhumation over the past 10Ma resulting in its exhumation from beneath the Kohistan paleoisland arc terranes. Recent geochronoligic work indicates that the massif has experienced extensive metamorphic and igneous activity coincident with rapid exhumation. Here we report petrologic and thermobarometric evidence for pollymetamorphic history within the NPS.

The first example is from a shear zone is found just south of Talo village along the Raikot valley. The shear zone which has been brought to the surface along the associated brittle fault, contains the assemblage met+ biotite + sillimanite + plagioclase + cordierite + K-feldspar + rutile + ilm. Kα X-ray maps of Ca-Mn-Mg-Fe in garnet reveal a complex porphyroblast growth history. Ca and to lesser degree Mg, Mn and Fe record an early zoned euhedral garnet with compositions mirroring presumed paleocrystal faces. This growth was followed by the growth of homogeneous garnet and latter resorptionof the garnet characterized by a Mn enriched rim as well as physical replacement of garnet by biotite. Therrnobarometry lSitlg included biotite, matrix biotite and biotite in contact with the rim of the garnet yields a increasing P-T path form 814 to 845 ± 50 C at P of 6.8 and 7.1 ±1 kbar respectively for the zoned euhedral core followed by new garnet growth at temperatures of 688 ± 50' C and P of 6.1 kbar.

The second example is a shear zone located in the Diamir traverse 3 km from the Raikot fault and may be a ductile shear associated with earlier movement along the Raikot fault. Within the mylonite are relict porphyroclasts of garnet. The garnets are almost completely replaced by cordierite, biotite and plagioclase. Garnet-biotlte in contact yield final equilibration temperature of 555°C at 2.2 kbar. While garnet cores and biotite yield temperatures of 670C at 2.2 kbar.

Cation zoning, petrography and thermobarometry suggests a complex tectonometamorphic history for the southern portion of the NPS. An early M 1 metamorphism which overgrows a relict foliation is characterized by an increasing P-T path consistent with loading of the Indian plate by the Kohistan island arc terrane. Within the past 10 My. Ml was overprinted by a distinctively lower temperature lower pressure Ml metaamorphism initialed as rocks recrystallized during decompression. Migmatization was probably aiocident with this phase. This was followed by further decompression characterized by resorption of pnet and growth of Fe-rich cordierite at the expense of garnet as rapid denudation perturbed isotherms.

Key words: Neogene metamorphism, NPHM, Himalaya.

W/117. Winslow, D.M., Zeitler, P.K. & Chamberlain, C.P., 1993a. Combined ^{40}Ar/^{39}Ar biotite cooling ages and fluid inclusion data from Nanga Parbat (Pakistan Himalaya). An indication of the depth to paleoisotherms with time. EOS 74, p.301.

Key words: Geochronology, Ar-Ar dating, cooling history, fluid inclusion, NPHM, Himalaya.

W/118. Winslow, D.M., Zeitler, P.K. & Chamberlain, C.P., 1994a. Petrology, thermo-chronology, and fluid inclusions: Implications for the denudation and metamorphic history of the Nanga Parbat region, Pakistan. EOS 75, p.186.

Key words: Petrology, thermo-chronology, fluid inclusion, denudation, metamorphic history, NPHM.

W/119. Winslow, D.M., Zeitler, P.K. & Chamberlain, C.P., 1994b. Differential cooling within the Nanga Parbat Massif, Pakistan Himalaya: Implications for syntaxial development. Geological Society of America, Abstracts with Programs 26(7), A-136.

Key words: Petrology, chronology, Fluid inclusion, Cooling history, NPHM.

W/120. Winslow, D.M., Zeitler, P.K., Chamberlain, C.P. & Hollister, L.S., 1994. Direct evidence for a steep geotherm under conditions of rapid denudation, western Himalaya, Pakistan. Geology 22, 1075-1078.

Recent fluid-inclusion and 40Ar/39Ar cooling-age data show that currently exposed basement rocks in the Raikhot glacier valley of the Nanga Parbat-Haramosh massif, Pakistan Himalaya, were at temperatures of 350 ± 50 °C at depths of 6 ± 2 km (hydrostatic pressure correction). These data imply the presence of a steep thermal gradient in the upper crust at 1 Ma (29-100 °C/km) and denudation rates over the past 1.0 m.y. of 3-6 mm/yr, providing independent corroboration of previous estimates of rapid denudation at Nanga Parbat (4.5 mm/yr over 3.3 m.y.). Our data provide direct documentation of near-surface compaction of isotherms under conditions of rapid denudation, a result that has long been supported by thermal modeling.
Key words: Geothrermometry, Rapid denudation, Ar-Ar dating, Fluid inclusions, NPHM.

W/121. Winslow, D.M., Zeitler, P.K., Chamberlain, C.P. & Williams, I.S., 1996. Geochronological constraints on syntaxial development in the Nanga Parbat region, Pakistan. Tectonics 15, 1292-1308.

^{40}Ar/^{39}Ar data (hornblende, biotite, muscovite, and K-feldspar) and U/Pb data (zircons) were obtained from the Nanga Parbat-Haramosh Massif (NPHM), NW Pakistan, along three transects in the southern regions of the NPHM. We have based our interpretations on our new data as well as geochronologic dates from previous studies in the northern regions of the massif. Geochronologic data show that the NPHM has experienced exceptionally high denudation and cooling rates over the past 10 m.y. U/Pb ages determined through sensitive high-resolution ion microprobe (SHRIMP) "depth-profiling" experiments on metamorphic zircons and conventional U/Pb monazite dates suggest that the timing of metamorphism varied across the massif. In addition, we have documented that the massif has experienced postmetamorphic, differential cooling both along and across strike. Thermochronologic data on currently exposed surface rocks suggest that cooling occurred more recently and at greater rates in the south-central regions of the massif (representing deeper crustal levels) than along the margins and northern regions of the massif. Within the Tato region, cooling following peak metamorphic temperatures of 600°–700 °C was as high as 140 °C/m.y. following partial melting of pelitic units. Biotites from this area record plateau ages of 0.9 ± 0.1 Ma. Along the Astor and Indus gorges, cooling was less rapid (approximately 70°–80°C/m.y.) following peak metamorphism as indicated by U/Pb monazite ages of 6–8 Ma and ^{40}Ar/^{39}Ar muscovite cooling ages of 2.2–3.4 Ma. Cooling over the last 3 m.y. occurred at rates of 100°–140 °C/m.y. The overall cooling age pattern within the massif is interpreted syntaxial growth through the development of north plunging antiforms prior to 3 Ma, followed by reverse faulting along east dipping fault zones. Along the Raikot River transect the biotite cooling age pattern is consistent with the folding of isotherms during folding of the foliation surfaces. The age pattern was disrupted at 1 Ma due to faulting along the Raikot and Tato faults.
Key words: Chronology, metamorphism, NPHM, Himalaya.

W/122. Wissman, H. Von., 1959. The present day glacier cover and snowline in high Asia: Abhandlungen der Akademie der Wissenschaften und der Literatur. Mathimatisch-Naturwissenschaftliche Klasse, Heft 14, 1101-1436 (in German). 335p

Key words: Glaciers, snowline, Asia.

W/123. Wood, R.M., 1985. A science of mountains. In Miller, K.J., The International Karakoram Project, Volume 2. Cambridge University Press.

This article considers the beginnings of the science of mountains and the role of the IKP in the integration of several disciplines concerned with that science. The hope is expressed that IKP may help stimulate more projects to further that integration towards a more unified approach to the study of earth sciences.
Key words: Orogeny, Kohistan arc, Himalaya.

W/124. Workman, F.B., 1899. Ascent of the Biafo Glacier and Hispar Pass: Two Pioneer ascents in the Karakoram. Scottish Geographical Magazine 15, 523-526.

This is a narrative of the earliest visit to the central Karakoram Biafo glacier and the Hispar pass housing another great glacier of this name. General information on the geography of the area is also given.
Key words: Glaciers, Biafo glacier, Hispar Pass, Karakoram.

W/125. Workman, F.B., 1901. Amid the snows of Baltistan. Scottish Geographical Magazine 17, 74-86.

Key words: Snow, Glacier, Baltistan.

W/126. Workman, F.B., 1904a. Ascent of the Great Chogo Lungma Glacier. Apalachia, 10.

Key words: Glacier, Chogo Lungma, Karakoram..

W/127. Workman, F.B., 1904b. Explorations des glaciers du Karakorum. La Geographie 9, 23-34.

Key words: Glacier, Karakoram.

W/128. Workman, F.B., 1905. From Srinagar to the sources of the Chogo Lungma Glaciers. Geographical Journal 25, 245-268.

Key words: Glaciers, Chogo Lungma, Srinagar.

W/129. Workman, F.B., 1908. Further Explorations in the Hunza Nagar and Hispar Glacier. Geographical Journal 32, 495-496.

Key words: Exloration, glaciers, Hispar, Nagar, Hunza.

W/130. Workman, F.B., 1910a. The Hispar Glacier. Its tributaries and mountains. Geographical Journal 35, 23-29.

The Hispar glacier is one of the longest of the Karakoram glaciers that ends into the Hunza River near Ganesh. The glacier is some 60 km long and is fed by many smaller glaciers of the central Karakoram. This paper provides details of the Hispar glacier, its tributaries and catchment area.
Key words: Glaciers, Hispar, Hunza, Nagar.

W/131. Workman, F.B., 1910b. The Hispar Glacier: Prominent features of its structure. Geographical Journal 35, 115-132.

Consult the preceeding account for further information.
Key words: Glaciers, Hispar.

W/132. Workman, F.B., 1913a. Expedition zum Siachen oder Rose-Gletscher im Karakoram im Jahre. Mitteilungen Geografishe Geselleschaft 56, 61-65.

Key words: Glaciers, Siachen, Karakoram.

W/133. Workman, F.B., 1913b. Some notes on my 1912 expedition to the Siachen or Rose glacier, Eastern Karakoram. Scottish Geographical Magazine 29, 13-17.

Key words: Glaciers, Siachin, Karakoram.

W/134. Workman, F.B., 1914. The exploration of the Siachen or Rose Glacier, Eastern Karakoram. Geographical Journal 43(2), 117-148.

Key words: Glaciers, Siachin, Karakoram.

W/135. Workman, F.B. & Workman, W.H., 1901. In the ice-world of the Himalaya: Among the peaks and passes of Ladakh, Nubra, Suru and Baltistan. Fisher Unwin, London.

Key words: Glaciers, Snow, Ladakh, Nubra, Suru, Baltistan, Karakoram.

W/136. Workman, F.B. & Workman, W.H., 1908. Ice-bound Heights of the Mustagh. An account of two seasons of Pioneer Explorations and high climbing in the Baltistan Himalaya. Constable, London.

Key words: Glaciers, Mustagh, Baltistan, Karakoram.

W/137. Workman, F.B. & Workman, W.H., 1917. Two summers in the ice-wild of eastern Karakoram. The Exploration of nineteen hundred square miles of mountain and glacier. Fisher Unwin, London.

The authors spent two summers exploring 1900 km^2 area of the eastern part of the Karakorum Range. The area is one of the most glaciated on earth. Descriptions have been given of the ice cover of the area with emphasis on various glaciers.
Key words: Glaciers, Eastern Karakoram.

W/138. Workman, W.H., 1910. The tongue of the Hasanabad Glacier in 1908. Geographical Journal, 36, 194-196.

Here is a copy of the account from WH Workman: In the 'Records of the Geological Survey of India,' vol. 35, p. 135, Mr. H. H. Hayden calls attention to the story of the rapid advance of the Hasanabad glacier, which he obtained from the Mir and the Wazir of Hunza, according to which the glacier advanced several miles in the course of two and a half months, though it was said to be stationary when he observed its tongue in August, 1906. It was also said to have made a similar advance on a former occasion, of which the time was not specified, after which it retreated rapidly. In the course of the expedition of Mrs. Bullock Workman and myself to the Hispar region in the summer of 1908, before reaching Nagar we camped at Dadimal, about 6 miles distant from the Hasanabad nala. Being so near to it, I decided to devote a day to a visit to the tongue of the Hasanabad glacier, to see whether any change had occurred in its position or condition since Mr. Hayden had observed it two years previously. Accordingly, accompanied by a servant and a coolie to carry my instruments, I started early the next morning to walk the 6 miles that lay between our camp and it. On my arrival at the mouth of the nala about 10 a.m., I was met by the Wazir of Hunza, the medical officer of the Aliabad Dispensary, and a dozen attendants, dispatched by the Mir of Hunza to take me in charge and conduct me to Mr. Haydenh's stations. They presented the Mir's compliments, together with a cordial invitation to our party to visit Hunza, of which, owing to other arrangements, we were unable to avail ourselves. After I had rested a short time, and quenched my thirst from a basket of delicious mulberries the Mir had thoughtfully sent over, the whole party went up the nala to the tongue of the glacier, first visiting Mr. Hayden's first station, just west of the extremity of the tongue. This was a huge granite boulder, with Mr. Hayden's inscription upon it in black letters as fresh and bright as if made the preceding day. We climbed to the top of the boulder, which was large enough to accommodate several persons. From here, station 2, marked on the
THE TONGUE OF THE HASANABAD GLACIER IN 1908. 195 rock-face of the mountain-wall opposite on the east side of the nala, could easily be seen, and the lettering on it read with the field-glass. A tripod was set up at the central point of the boulder-top, for use in sighting and photographing. A line sighted from this to station 2 passed directly over the extremity of the tongue, thus showing that, at the end of two years that had elapsed since Mr. Hayden's observation, the tongue remained in the exact position in which he found it. There was also no evidence, from the debris at the extremity, that it had moved either way during that time, one of my photographs of this portion being an almost exact reproduction of Mr. Hayden's, even the same boulders and debris-formations being seen in both. In other respects the tongue was not essentially altered in its appearance as shown in Mr. Hayden's admirable photographs. The steep, rough talus leading up to the Gamkin irrigation-canal, above which Mr. Hayden's station 3 was located, was next ascended, and the spot found where the boulder forming the station had rested, but the boulder itself was not there. It had slid down the slope to a point, below the canal, some 60 feet from its former position, where it was lying partially embedded in sand. Photographs were taken from here, as well as from station 1. The inspection being completed, the party returned to the mouth of the nala. The Wazir added nothing to the statements previously made about the glacial movement. We bade one another adieu about noon, after which I returned to Dadimal. The day was warm, the solar thermometer at 12.30 indicating 196'5? Fahr. I am not aware that the Hasanabad glacier has ever been explored by a European, or that its length is known. Its nala, as far as I could see into it, is narrow, and high snow-peaks tower above its upper portion. If, as seems probable, its length is not great, and its reservoir is large as compared with the size of the trunk, and the mountains enclosing its upper end descend sharply to it, a season or two of heavy snowfall would be likely to cause such an accumulation of snow in the reservoir as might easily induce a sudden augmentation of pressure, which would drive the trunk rapidly down the narrow nala. The last rapid advance would appear from the account to have taken place in the summer of 1903, after the stormy seasons of 1902 and 1903 in this region, when I also noticed a similar advance of a large branch of the Chogo Lungma descending sharply from the snowy Haramash mountains, which crowded the Chogo Lungma trunk bodily over for a considerable distance against its left laternal moraines, from which, in 1902, it stood well removed. The same cause might have been active on the former occasion, when the Hasanabad glacier advanced, and then retreated quickly. If the conditions I have mentioned as probable are the ones actually existing, an equilibrium of pressure having been established by the advance after stormy seasons, in succeeding seasons, without unusual or with less than the average snowfall, the tongue.
Key words: Glaciers, Hasanabad, Hunza.

W/139. Workman, W.H., 1913. Features of Karakoram Glaciers connected with pressure, especially of affluents. Zeitschrift für Gletscherkunde und Glazialgeologie, 8, 23-30.

Key words: Glaciers, Karakoram.

W/140. Workman, W.H., 1914. Physical characteristics of the Siachen Basin and Glacier system. The Geographical Journal 43, 273-292.

The first few paragraphs of the article: The term "glacier" is not sufficiently comprehensive to designate accurately the immense and, in arrangement, complicated bodies of snow, neve and ice collected in the great rock-basin extending north-west from the source of the Nubra River to Peak 23 (Hidden peak), 78.4 kilom. (49 miles), with an east and west average width for a considerable distance of 32 kilom. (20 miles), and having an area, approximately, of 2400 sq. kilom. (over 900 square miles).

The basin is crossed in various directions by many glaciers of the first order and innumerable lesser ones, fed by snow precipitated upon the mountains and slopes of its watershed, all converging on a great central trunk averaging 4 kilom. (2*5 miles) in width, that stretches the length of the basin in a north-west by south-east direction and discharges from its tongue water derived from the snow collected in all parts of this extensive region to give birth to the Nubra river. This central trunk with its multitude of affluents resembling a river-system is more fittingly styled the Siachen glacier-system. The four other great karakoram glaciers, as well as many smaller but by no means insignificant ones, are fashioned on the same plan. This type is peculiar to the Karakoram, being conditioned on the configuration of its valleys and the arrangement of its peaks. For this reason, as well as on account of certain structural features referable to existing conditions, all these glaciers merit the designation of glacier- systems or glaciers of the Karakoram type. The Siachen basin is separated by its enclosing walls, on the east, from an unexplored region containing the Remo basin, with which the Siachen probably communicates by an ice-covered pass, possibly two, leading from the head of the Tarim Shehr affluent, and further north a group of snow mountains discovered by us from the east Siachen head that give rise to a large glacier, apparently the Urdok, running north-west into Chinese Turkestan; at the north end, from a glacier-basin leading north-east from the Gasherbrum massif; and on the west from the Baltoro, Kabery (Kondus), Sher-pi-gang, Dong Dong, Bilaphond, and Chumik basins, with glacier-passes connecting with the Bilaphond and Kabery, the last first discovered and crossed by our expedition in 1912. The enclosing barriers of the Siachen consist of granite, gneiss, crystal- line schists, slates and shales, sandstones, amorphous and crystalline limestones, and conglomerates, with some igneous intrusions. These rocks alternate with one another at short intervals, and are in places intimately intermingled and interfolded. They are extensively foliated, friable, and easily disintegrated by frost and weathering. Even the granites, largely of the biotite variety, are divided into small sections by joints crossing one another, and intersected by bands of quartz, feldspar, s'chists, and shales, in consequence of which they split up easily into frag? ments. The physical condition of the gneiss and crystalline schists would suggest to the ordinary observer that they were formed largely by metamorphosis of sedimentary deposits. But whether this be the fact, or whether it be that they originated as primary granites and were afterwards metamorphosed by folding, they are brittle, and present in the one case an immatuxe appearance as if incompletely developed, or in the other a decadent one, as if the original structuxe had been overwrought and dis- organized by strain and violence in the upheaval of the great ranges of which they form constituents. This fragile condition of the rocks accounts for the irregular, jagged outlines of the mountains of the region, especially of the granite peaks, many of which are greatly serrated, and for the vast detritus-deposits that load the glaciers and play an important role in the development of their structural features. Owing to the amount of snow covering the mountains and the staining and weathering of the visible rock-surfaces, it is often difficult, even from a short distance, to distinguish the character of the rocks composing a mountain, so that the observer, particularly if he is not a trained geologist, may well be in doubt as to what formation lies before him. The shales and slates, the latter largely of very dark color, are the most easily distinguished. The north-east wall of the Siachen trunk resembles in structure and extent that which, with an unbroken length of 63 kilom. (39 miles), forms the upper portions of the southern Hispar and western Biafo barriers.* Starting at the north-east head, it extends west 4*8 kilom. (3 miles), then turns south-east and continues on 22 kilom. (14 miles) to the Tarim Shehr affluent. Here it turns east and forms the north wall of the Tarim Shehr for 27 kilom. (17 miles) to its sources, making a continuous, unbroken wall 53 kilom. (33 miles) long. The upper 20 kilom. (12 miles) of this wall is, and the remainder appears to be, a part of the main watershed between Turkestan and the Indus, and as such it probably continues on from the head of Tarim Shehr tributary to the Karakoram pass. A second portion continuing around as the south wall of the Tarim Shehr glacier and extending west to the Tarim Shehr promontory there turns south-east and forms the remaining portion of the north-east wall of the trunk to its end, having a length of 53 Klom. (33 miles). Stated in another way, the north-east Siachen wall stretches from the north head of the trunk south-east in a nearly straight line for some 72 kilom. (45 miles), being pierced only by one small and two large affluents. The south-west boundary of the upper half of the trunk can scarcely be called a wall. It consists of numerous mountains of irregular outlines, scattered about in an irregular manner, enclosing vast reservoirs of snow and ice that communicate with the

majba glacier by large secondary glaciers, the whole forming an ice-bound labyrinth that defies description. Still, the mountains and affluents stand in such relation to the main glacier that lines drawn from one headland to another suffice to mark the limits of its bed with sufficient accuracy. From the Peak 36 tributary to the tongue, a fairly continuous wall exists which is pierced by several large affluents. The structure of these walls may be stated in general terms as follows f: The mountains enclosing the Indira Col and the north-east col, at the northern extremity, are composed of slates and shales, light and dark in colour with, possibly, some limestones. Thence down the north-east wall to within about 6 kilom, (4 miles) of the Tarim Shehr opening mostly of light coloured limestones and shales with some conglomerates and at least one igneous intrusion. The limestones are strongly in evidence in the moraines fed by this section. The rocks are soft and the peaks and ridges broken and jagged in outline. From a point shortly north-west of Teram Kangri, the wall and its peaks, including that summit, quite to their tops, forming the north barrier of Tarim Shehr glacier to its end, appear to The same is true of the visible rocks on the south side of Tarim Shehr glacier, though some of the ice-covered peaks at its upper end must contain granite and gneiss, as much debris of this character appears in the moraines of that side. On the extremity of Tarim Shehr promontory, most of which is composed of brown shale, granite crops out over a considerable area. Thence, beginning with Junction mountain, 6353 metres (20,840 feet), rising above the promontory, ascended by us in 1911, down to the great bend, some 25 kilom. (16 miles), the mountains are of dark brown and black slate with occasional sections of lighter colour broken into jagged points and cleft by deep, ragged ravines. The only granite noticed in situ in the whole length of this wall was at Tarim Shehr promontory, From our camps on moraines opposite this wall, the view toward it was most forbidding. The foreground was occupied by the huge black hillock-moraine coming from the Tarim Shehr affluent, the towering hillocks of which, resembling vast heaps of coal piled up at random in a Cyclopean coalyard, shut out from sight the white ice of the glacier beyond, while the background was formed by the succession of black peaks hard in outline and destitute of grace, rendered more desolate by contrast with the snow capping their tops, the whole constituting as sombre and de- pressing a landscape as could well be imagined, far eclipsing the most fantastic conceptions of Boecklin and casting an uncanny shadow over the soul. On the south-west side of the trunk a similar variety of formation occurs, but granite is more and limestone less in evidence. The last three peaks of the King George V. group ending the massive mountain-tongue, interposed between the heads of the Baltoro and Siachen glaciers, which form 11 kilom. (7 miles) of the upper south-west Siachen wall, appear to be mainly composed of granite and gneiss, though on an eastern spur and near its south-east extremity the granite passes over suddenly without discontinuity of outline into black slate. South of this tongue at the entrance of the upper western tributary into the Siachen, the Hawk, a graceful pointed spire of granite, soars from a circle of black slate peaks and ridges to an altitude of 6768 metres (22,200 feet). From this peak downward for 35 kilom. (22 miles) to the great bend, the south-west wall is largely, if not wholly, composed of sedimentary rocks, prominent among which are black slates. Just at the bend, two elevations, the ends of spurs descending from Peak 8, have the appearance of granite.
Key words: Glaciers, Siachen.

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Speculation having been rather freely applied to the identification of these rocks, I beg to offer a few notes upon the subject, the facts regarding which I have described in a paper already published. (a note by the author about the article).
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Gives a summary of the views entertained as to the correlation of the rock-groups of the Hazara area with those of Kashmir.
Key words: Stratigraphy, Hazara, Kashmir.

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This gives information on the geological studies performed during the Karakoram expedition. Further information is not available with the authors.
Key words: Karakoram expedition.

W/149. Wyss, R., Renz, H.H. & Reichel, M., 1940. Geologie des Karakorum. Brill, Leiden.

Wyss took part in the 1925 Netherlands Expedition to the western Karakoram. In this account, he describes various aspects of geology, such as stratigraphy, magmatism, sedimentary deposits, etc.
Key words: Geology, structure, Netherland Karakoram Expedition, western Karakoram.