CONTENTS

ACKNOWLEDGEMENT

The faculty of the Institute of Geology expresses its thanks to Dr. Khairat Muhammad Ibne Rasa, Vice-Chancellor, for his encouragement and a financial grant towards the Expedition. The financial assistance of Dr. M.D. Shami, Chairman, Pakistan Science Foundation, is gratefully acknowledged which made the Expedition a possibility. The local administration of Baltistan has been very co-operative during the field work.

FOREWORD

It gives me pleasure to see the report of the Expedition to Baltistan which was organised by the Institute of Geology, Punjab University. This programme has added a new dimension to the Centenary Celebration of the Punjab University. Looking at the data and details given in the report I feel that the team has done good scientific work. I understand that the area of research is very difficult and more expeditions will have to be organised to complete this programme. Certainly, we should explore all parts of our country to find treasures of natural resources and for development of the area.

I congratulate Professor F.A. Shams on organising the Expedition and leading it successfully.

K.M. IBNE RASA
Vice-Chancellor

REPORT ON

THE PUNJAB UNIVERSITY EXPEDITION TO BALTISTAN, NE PAKISTAN

by

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Abstract: Report is given of geology and petrology of the north-eastern part of the Shigar Valley, Baltistan, including structural and geomorphologic information. An original geological map on 1:12500 scale is presented on the basis of an expedition carried out during the summer, 1982. Significant achievements are briefly stated including economic mineral resources of the area.

The programme was a part of the University Centenary Celebration planned by the Institute. The project will continue for a few years.

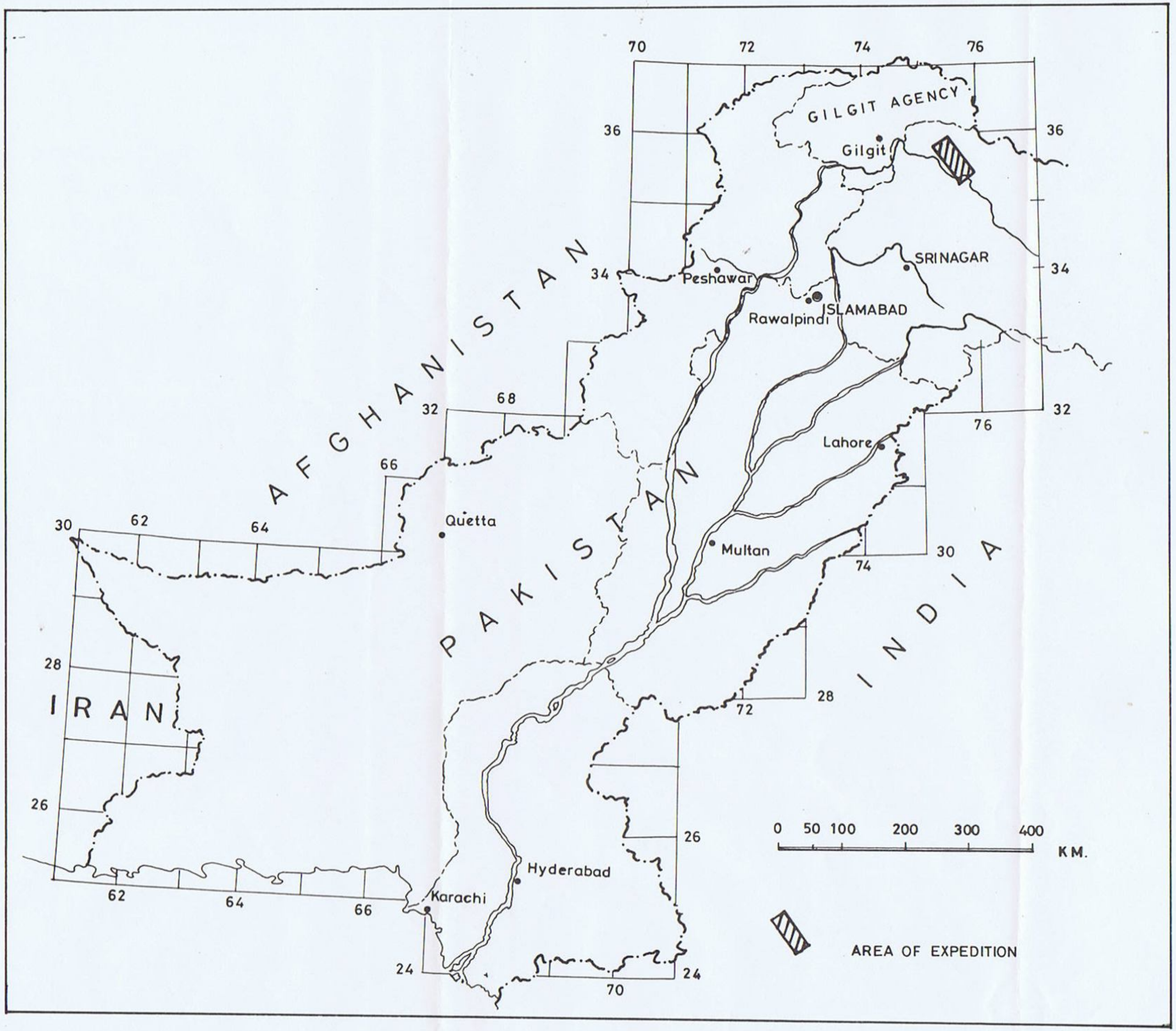


Fig. 1: Location Map of Baltistan District.

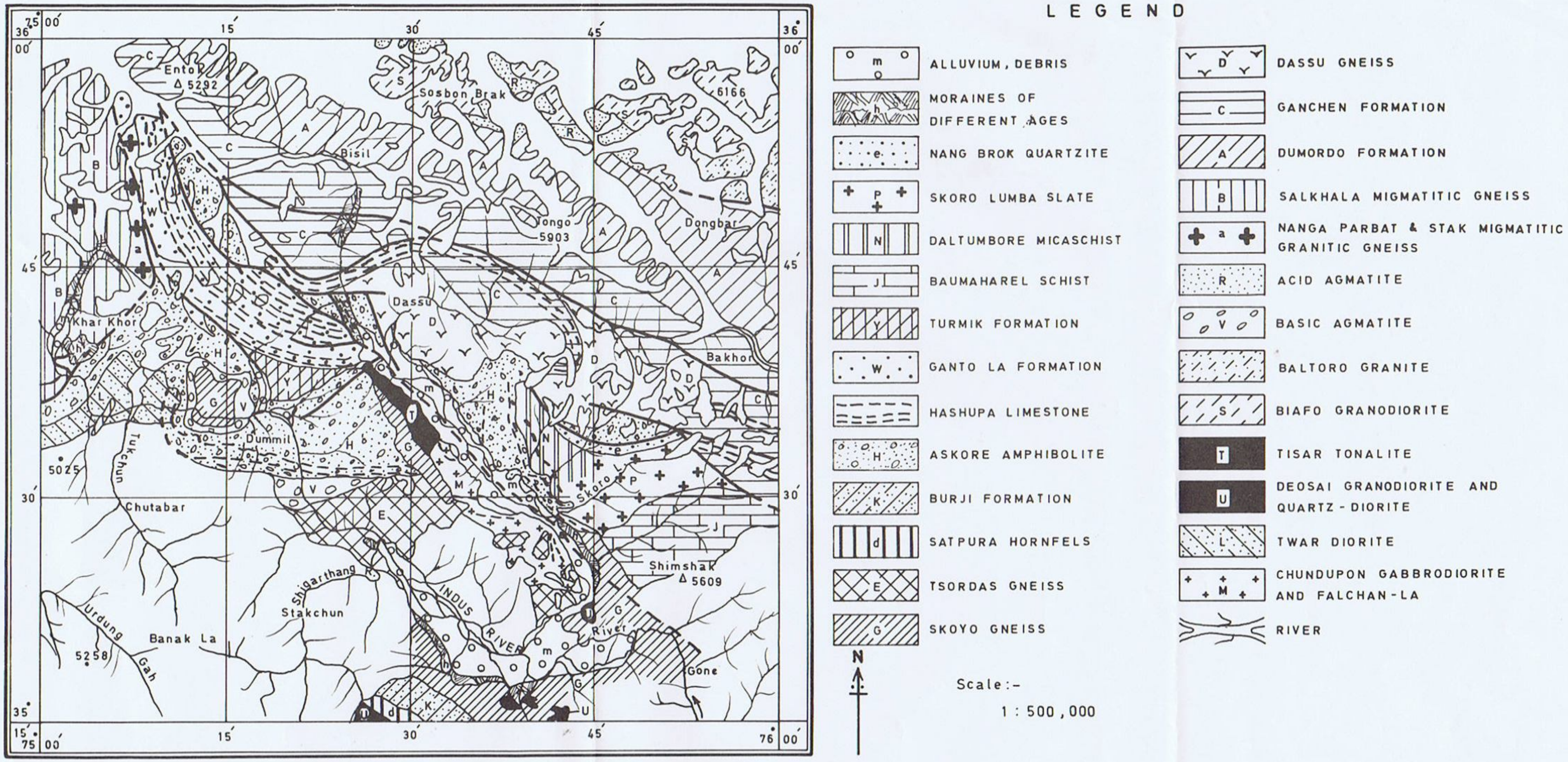


Fig. 2: Part of Desio's (1964) Map of Western Karakorum including Baltistan area.

1. INTRODUCTION

Baltistan is a district of the Federally Administered Northern Areas of Pakistan located in the extreme northeast of the country, with Skardu as its headquarter (Fig.1). As the so-called "Little Tibet", it has been fairly known to explorers and mountaineers due to its offering approach-routes to Baltoro, Biafo and Siachen Glaciers and to the chain of high Karakorum peaks, including the majestic K^2 (8611 m). Among prominent scientists who made early observations were Col. Godwin-Austin, Lydekker, McMahon, Hayden and Wadia but the real scientific breakthrough came with the De Fillipi Expedition (1913-14) and the Desio Expeditions (1929, 1953-54). The Desio Expedition of 1953-54 greatly increased our geological knowledge, described in many volumes of publications. The Geological Tentative Map of Western Karakorum published by Desio (1964) covers areas of various Expeditions and the adjoining territories, with invaluable geological and structural details, Part of Desio's Map covering Baltistan and contiguous areas is shown as Fig.2.

The University of the Punjab, Lahore, has been associated with Karakorum research for quite some time Mr. Javed, a student of the Punjab University, was included in the Desio Expedition of 1953-54: no publication was, however, produced by the University. During the summer of 1955, Professor O.A. Broch, Unesco Advisor and Head of Department of Geology, and F.A. Shams then Research Scholar, carried out field work up to North of Bunji via Kaghan Valley - Babusar Pass - Chilas route. The well known "Chilas Layered Complex" was closely studied about 52 years after the pioneer work of Wadia (1932). Description of dunite unit of the Complex was given by Shams (1956) as a rafractory raw material. During 1960, Dr. P.J. Stephenson, who had participated in the Antartica Expedition as a member of Fuchs' team and had completed 1 year term as a Unesco Advisor at the Punjab University, lead an Expedition to Saltoro and attempted ascent of K[12]. The geological map of Dr. Stephenson was included by Desio (1964) in his map of the NW Karakorum. Punjab University also collaborated with Kyoto University, Japan, in scientific expeditions to Karakorum and Hindu Kush during 1956 and 1957 (Matsushita and Huzita, 1965, 1966).

During the summer of 1968, a party of two M.Sc. Final Year students (Messrs K.A. Butt and S. Mehdi Zaidi) and a small group of teachers (Messers Mehmood, Nawaz and Shams) worked for a total period of 2½ months and produced the first detailed geological map of the area between Babusar and Indus, greatly improving the earlier work (Wadia, 1932). Later, these researches gave rise to important publications. Shams (1975) described petrology of the Complex that established first-ever model for the world's largest anticlinal intrusion of noritic-dioritic rocks in an Island arc. Shams and Shafeeq (1979) described petrochemistry and Zulfiqar and Nawaz (1976) mapped and described area between Babusar Pass and slightly North of Babusar Rest House. Latter authors published a detailed account of the area and established tectonic-lithologic contact between Precambrian Salkhala metasediments and marginal amphibolite zone of the Indus ophiolite belt, later recognised as a continuation of the Upper Indus Suture line after swirling around loop of the Nanga Parbat - Haramosh orogen. Again during 1974, a 10 days reconnaissance field work was carried out in Baltistan by a small team of staff members lead by Shams (1974). In the succeeding years many student training-cum-research projects were organised by staff of the Institute (Messrs. Munir Ghazanfar, Aftab Mahmood Iftikhar Hussain Baloch, Akhtar Ali Saleemi and Drs. Shafeeq, Nawaz and Zulfiqar). Publications/theses/reports produced so far on the Northern Areas by students and staff of the Institute are included in the list of publications of the Institute (Shams and Nazir, 1982, Shams, 1984).

The programme to organise the present Expedition was initiated during 1980 and a circular was issued to Universities and major geoscientific organisations. The circular, Appendix I, also gives organisational framework of the Expedition.

1.1. Membership

Membership of the Expedition was raised from Universities and public-sector geoscientific agencies. A Registration Form (Appendix II) was circulated to all relevant institutions for nominating their experts. As a result, following membership was raised.

1. Punjab University, Institute of Geology

1) Dr. F.A. Shams	-- Expedition Leader Sections B and C
2) Dr. M.A. Latif	-- Section A
3) Dr. Shafeeq Ahmad	-- Section C
4) Dr. M. Nawaz Ch.	-- Section C
5) Mr. Riaz Ahmad Sh.	-- Section B
6) Mr. Akhtar Ali Saleemi	-- Section C
7) Mr. Nazir Ahmad	-- Section B
8) Malik Muhammad Hussain	-- Section D
9) Mr. A.Z. Dean	-- Technical Officer and Section F

2. Punjab University, Department of Zoology

10) Dr. Muhammad Sarwar	-- Section E

3. Punjab University, Department of Botany

11) Dr. Akhlaq Ahmad Bhutta	-- Section E

4. Sind University, Department of Geology

12) Dr. Rais Ahmad	-- Section A
13) Dr. L.B. Bozdar	-- Section C

5. Baluchistan University, Department of Geology

14) Dr. N.A. Durrani	-- Section C
15) Mr. Naeem Ahmad Bajwa	-- Section D

6. A.J.K. University, Department of Geology

16) Iftikhar Ahmad Mir -- Section D

17) Mirza Shahid Beg -- Section B

7. Atomic Energy Minerals Centre, Lahore

18) Dr. K.A. Butt -- Section B and C

8. Soil Survey of Pakistan

19) Mr. Ehsan ul Haq Khan -- Section D

9. Water and Power Development Authority

20) Deputy Director

21) Junior Geologist -- Section D

22) Junior Geologist

10. Geological Survey of Pakistan

23) Deputy Director -- Section B

24) Assistant Director -- Section A

1.2 Funds

A budget estimate of Rs. 1,50,000/- was worked out by consultation, given as Appendix III.

Following funds became immediately available:

1. Punjab University	:	Rs. 10,000/-
2. Pakistan Science Foundation	:	Rs. 20,000/-
Total:		Rs. 30,000/-

Many agencies committed indirectly by allowing T.A./D.A. claims to their nominees and through commitment of their field vehicles alongwith P.O.L. expenses.

1.3 Implementation

A Steering Committee was nominated with following members:

1. Dr. K.M. Ibne Rasa (S.I.) Vice Chancellor, Punjab University, Lahore. — Patron and Chairman Steering Committee

2. Dr. M. Afzal, Patron & Member
Chairman,
University Grants Commission,
Sector H-9, Islamabad

3. Dr. M.D. Shami, Member
Chairman,
Pakistan Science Foundation,
P.O. Box 1121, Q-13, Markaz,
Shalimar-7, Islamabad

4. Mr. Asrarullah, Member
Director General, Geological
Survey of Pakistan, Quetta.

5. Mr. A.A. Malik Member
Chairman,
Pakistan Mineral Development
Corporation, P.I.D.C. House,
Dr. Ziauddin Ahmad Road, Karachi

6. Professor Rais Ahmad Member
Chairman, Department of Geology,
Sind University, Jamshoro, Sind.

7. Dr. N.A. Durrani,
Director, Centre of Excellance Member
in Mineralogy, Baluchistan
University, Quetta.

8. Mr. Baqir Hasan,
Director, Geology and Investigation Member
Sunney View, P&I, WAPDA, Lahore.

9. Mr. M. Aslam Alvi, Member
Director, Atomic Energy
Minerals Centre, Ferozepur Road,
Lahore.

10. Dr. M.K. Bhatti, Member
Director, P.C.S.I.R.,
Ferozepur Road, Lahore.

11. Mr. N.Z. Adhami, Member
Chief Geotechnical Division,
NESPAK, WAPDA House, Lahore.

12. Brig. Ch. Abdul Mujib, Member
Director Education,
Northern Areas, Gilgit

13. Rana M. Sultan, — Member
President, Pakistan Institute of Mining Engineers,
189-Shah Jamal Colony, Lahore.

14. Dr. M. Bashir, — Member
Director General,
Soil Survey of Pakistan,
Multan Road, P.O. Shahnoor Studio,
Lahore.

15. Dr. Amir Muhammad — Member
Chairman, Agricultural Research Council, Federal Ministry of Agriculture, Islamabad.

16. Mr. Abdul Hameed, — Member
Joint Secretary,
Ministry of Petroleum and Natural Resources, Pak Secretariat,
Block 'A', Islamabad.

17. Brig. Kaleem-ur-Rehman Mirza — Member
Managing Director, Gem Stone Corporation of Pakistan,
Jamrud Road, Peshawar.

18. Professor M.N. Romani — Member
Dean, Faculty of Science and Engineering,
Punjab University, Lahore.

19. Professor F.A. Shams, — Convener and Leader of the Expedition.
Director, Institute of Geology,
Punjab University, New Campus,
Lahore.

On 6.6.1981, a meeting of the Steering Committee (Fig.3) was held in the Institute of Geology, Punjab University, under the Chairmanship of Dr. K.M. Ibne Rasa, Vice-Chancellor and Patron of the Expedition. Tentative programme of the Expedition (Appendix IV) and budget estimate were submitted for approval. An exhibition of literature and maps relevant to the Expedition was organized at the occasion.

The proceedings of the meeting are reproduced as Appendix V. The Field Station at Skardu was to be set up by 10-7-1981 and research teams were to arrive by 20-7-1981, working till 20-9-1981.

1.4. Progress

Although the Steering Committee approved the programme yet it recommended that, in view of Ramzan, it should be started in the first week of August, 1981 (see Appendix V). As a result, the whole tempo broke down although geoscientists were ready to work during Ramzan. Many agencies and their nominees shifted to their original programmes and could not be coordinated again to take up their Expedition assignments. Otherwise too, shortening of the Expedition period became deterimental to achievement of various targets of the programme. The Steering Committee meeting on 2-7-1981 recommended to postpone the Expedition till the Summer of 1982.

1982 PROGRAMME

The situation recognised for 1981 was faced also during the Summer of 1982 so that the programme could not be initiated in the month of June, 1982. It was decided, however, that a break-through must be made. Due to limitations of funds and relatively smaller team of scientists, it was decided to concentrate on the Shigar Valley zone due to its unique importance.

Consequently, a mini-Expedition was organised so as to provide a basis for a full-fledged work when conditions would allow atleast 2-months continuous stay in Baltistan. Utilizing the opportunity and meeting the obligation, this programme was made part of the Centenary Celebration (1882-1982) of the Punjab University.

A team was created, composed of:-

<u>Staff of Punjab University</u>

<u>Institute of Geology</u>

1. Professor F.A. Shams
2. Dr. M. Nawaz Ch.

3. Mr. Riaz Ahmad
4. Mr. Akhtar Saleemi
5. Mr. Nazir Ahmad
6. Mr. A.Z. Dean

Department of Zoology

7. Dr. Muhammad Sarwar

Geological Survey of Pakistan

8. Mr. Iqbal Haydri

The Expedition members left Lahore for Skardu on 28-8-1982 The programme was launched to map northern part of the Shigar River Valley up to Dassu, covering a span of about 50 km. A total of 3 weeks were spent in field work, carrying out mapping on the scale of 1:12,500 and making extensive sampling and collection of field data.

The first report of the Expedition is being presented herewith, pending conclusion of detailed work on material and data collected in the field.

3. METHODOLOGY OF RESEARCH

In view of short time at disposal, smaller team of workers and the priorities of objectives of the Expedition, the research programme was so planned as to achieve maximum volume of meaningful results regarding the Baltistan region. Consequently, the attention was concentrated on only northern side of the Shigar Valley. Following programme was followed.

1. Reconnaissance survey was carried out of the Shigar Valley in order to familiarize with its regional geological framework.
2. Field stations were setup at Skardu, Shigar and Dassu for detailed investigations, utilizing nala and stream courses for extensions into interior of the valley.
3. Mapping was carried out after establishing lithologic units and their sub-division wherever meaningful; visual extensions were attempted wherever possible.
4. Sampling stations were established so as to acquire most representative field data and geological specimens.
5. Structural observations were made on regional as well as local scale and relevant data collected.
6. Old and young terraces of the river Indus were combed, alongwith its tributary, the Shigar River, for finding fossils and their fragments, concentrating particularly on vertabrate species.
7. Particular attention was given to economic minerals and information was collected regarding usability of major occurrences, including geothermal energy.

8. Field photography was carried out and sketch drawings were made.

Fig.4 shows the tentative geological map of the Shigar Valley, which constitutes the most important single contribution of the Expedition. It was prepared on the basis of 1:12,500 scale enlargement of Topographic Sheet No.(1:250,000) of the Survey of Pakistan. Fig.5 shows location of sampling stations that yielded a total of about 200 specimens.

For the sake of laboratory work, about 50 specimens were thin sectioned and studied petrographically; in this Report, description is given of 26 (twenty six) most representative specimens. Similarly, chemical analysis were carried out of only the most prominent lithologic units of the area. Radiometric and UV tests were carried out on all the specimens. Spot chemical tests were carried out, including qualitative mineralgraphic and X-Ray Diffraction work.

4. GEOMORPHOLOGY

The mapped area constitutes northern (left) part of the Shigar Valley, stretching between Skardu and Dassu, (Fig.1) and including the prominent elbow-shaped bend SE of the Shigar. The valley itself is wide almost along its entire length with rather gentle slope, although there is steep rise in the NE and the SW directions. Many active glaciers exist on both sides of the valley, such as the Koser Gunge,Hoh Lungma and the Biafo glaciers. The world's second highest mountain, K^2 (8611 m) rises in the NE of the area. A ridge runs parallel to the Shigar valley, rising to 5,826 m and separating it from the Indus valley while another rises up to 6,400 m at Koser Gunge and separates it from the Braldu River Valley in the NE.

Rainfall is very scarce, being about 1.5 cm per annum, while the climate is intensely hot as well as cold. Various geomorphic processes are characterised by degradation weathering, mass wasting and erosion by water, wind and glaciers. Wind action is particularly important in the Skardu area which frequently suffers from dust storms during summer season.

Frost action as well as temperature variation produces rock shattering while desert-type polishing of stones is observed commonly. Chemical weathering is more active above Dassu, giving rise to clay-laden river water.

Talus creep is commonly seen in the form of cones, along the slopes of low inclination such as near Skardu Fort, along Skardu-Shigar and Shigar-Dassu roads, On the other hand, mud flows were noted near Sildi, Alchori and Hashupa.

The Shigar river represents a structurally adjusted course along a major shear zone, called the Shigar line. A number of Ist and 2nd order valleys join from NE and SW that

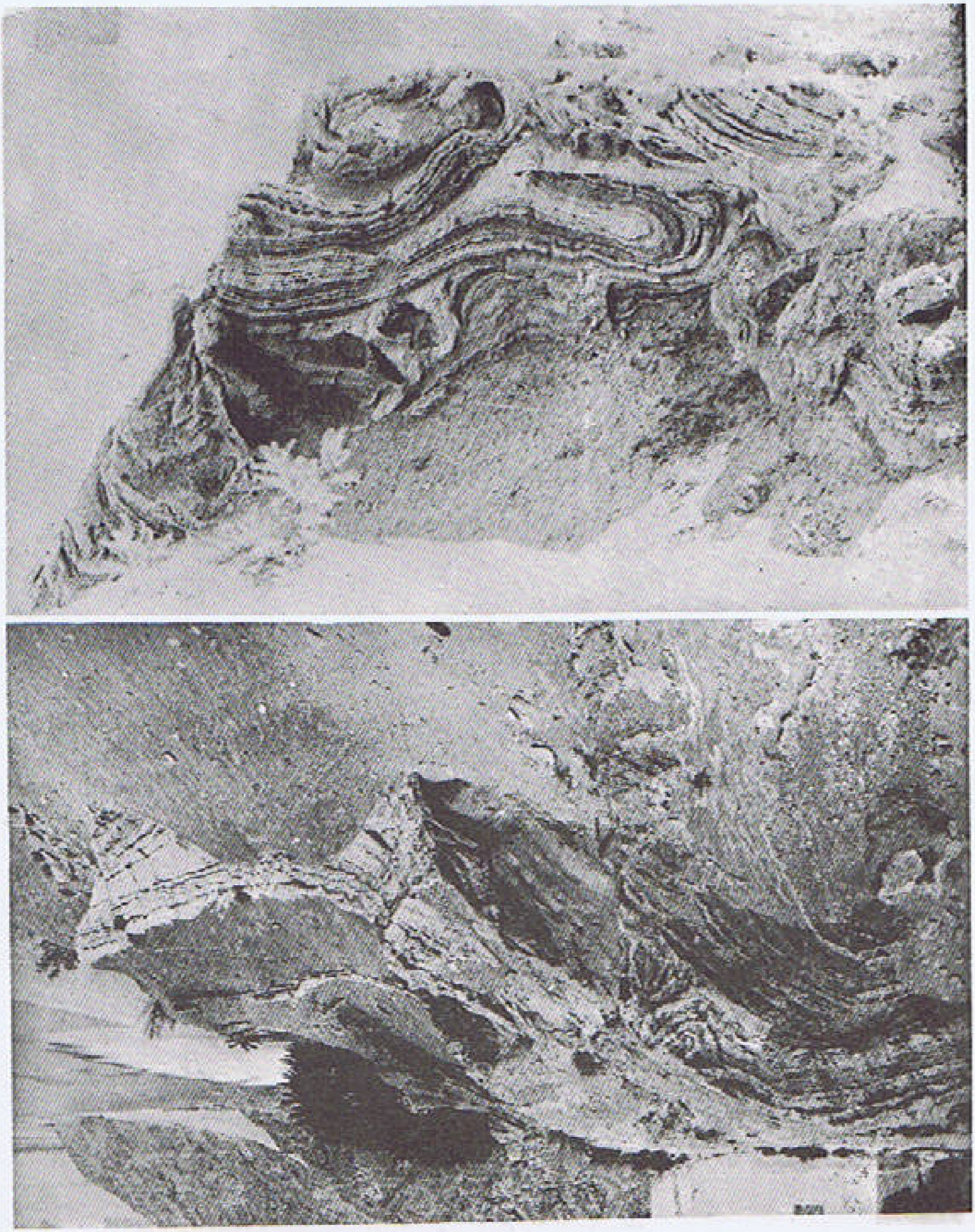


Fig. 4: Folded alluvial of the river Indus.

also appear to be somewhat structurally controlled. Almost all streams are fed by glaciers that exist permanently at higher reaches but extend downwards during winter.

One hot spring was noticed on the Dassu-Askole road issuing out of the Dassu granite gneiss and moderately hot, many more are known to exist.

River terraces are of particular interest, those along the river Indus show folding and faulting (Fig. 6), as if those were affected by recent tectonics related to the Nanga Parbat-Haramosh massif. Otherwise, both cyclic and non-cyclic terraces are present and display deformational effects due to intermittant or continued slow uplift of the area. Mature erosion stages were generally observed.

4.1 Regional Tectonics and Structure

1. Regional Tectonics

The area of reference is part of the Southern Karakorum mountain system, with the River Indus in the South of the Shigar valley marking the N-hading Shigar Fault or the Lower Shyok Fault, with the Upper Shyok Fault running in the North and two joining together near Tisar, whereafter a single fault runs WNW and is called the Hini Fault in Hunza. The Hini Fault is known to join the N-hading Indus Fault NW of Gilgit after the two cross North of the Haramosh spur in a more or less parallel fashion (Fig.7). South of the Shigar Fault in the Baltistan area, outcrops the Deosai batholith extending as Ladakh batholith towards Indian held Kashmir in the East. It is a complex of calc-alkaline plutonic and acid volcanic rocks constituting a fossil island arc that is believed to compare or extend as the Kohistan Island Arc West of the Nanga Parbat-Haramosh orogenic spur (Fig. 8), although lithologies are not satisfactorily Comparable.

The peculiar tectonic feature of double fault system in the Shigar Zone produces not only lithological and structural complications but also constraints on plate tectonic interpretation of this part of the crust. It is customary to call the Transhimalayan region between Indus Fault and the Shigar Fault as the Indus Suture Zone that separates High Himalayas from the Karakorum.

In Baltistan, the Karakorum is represented by high grade (meta) sedimentary Tethyan sequence intruded by Karakorum batholith. The latter is composed predominently of granodioritic to granitic rocks showing a late stage of granitizational adjustment of composition. Desio and Zanettin (1964, 1970) reported 8.6 and 24 m.y. ages for the Karakorum batholith while Casnedi et al. (1978) reported 25-19 m.y. ages from Darkot Pass, NW of Gilgit. Norin (1946) had previously claimed 3 types of granites, aging between pre-Senónian to Tertiay. However, recent dating by Trivedi et al. (1982) showed 235 ± m.y. from Gaik in India. These ages, taking also into account the Lower Triassic age (209-216 m.y., Desio et al. 1964) of granites from Hindu Kush, shows the presence of a late Hercynian intrusive phase of Karakorum batholith. This shows that the batholith had at least 2 phases of emplacement; a Permo-Triassic age of emplacement and a superimposed Miocene-Pliocene remobilized phase. It was during the latter stage that granitization by anatectic liquids was produced.

2. Structure of the Area

Major tectonic feature of the area is the Shigar Fault, already mentioned above, and the prominent bend of the river Indus that may be also strucurally controlled. From Skardu to Dassu, metamorphic rocks show systematic increase in grade up to staurolite and probably sillimanite. South of the village Shigar, a major fold was mapped shown by deformation of the biotite gneiss into an antiform plunging SE and holding intrusions

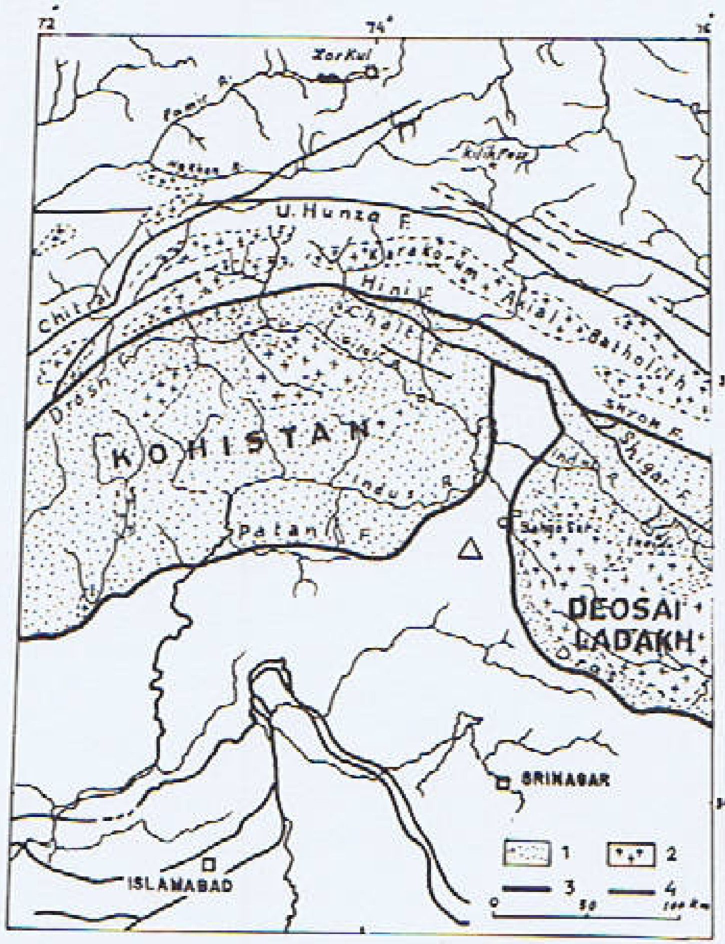


Fig. 5: Fault pattern of the Baltistan area and the environs.

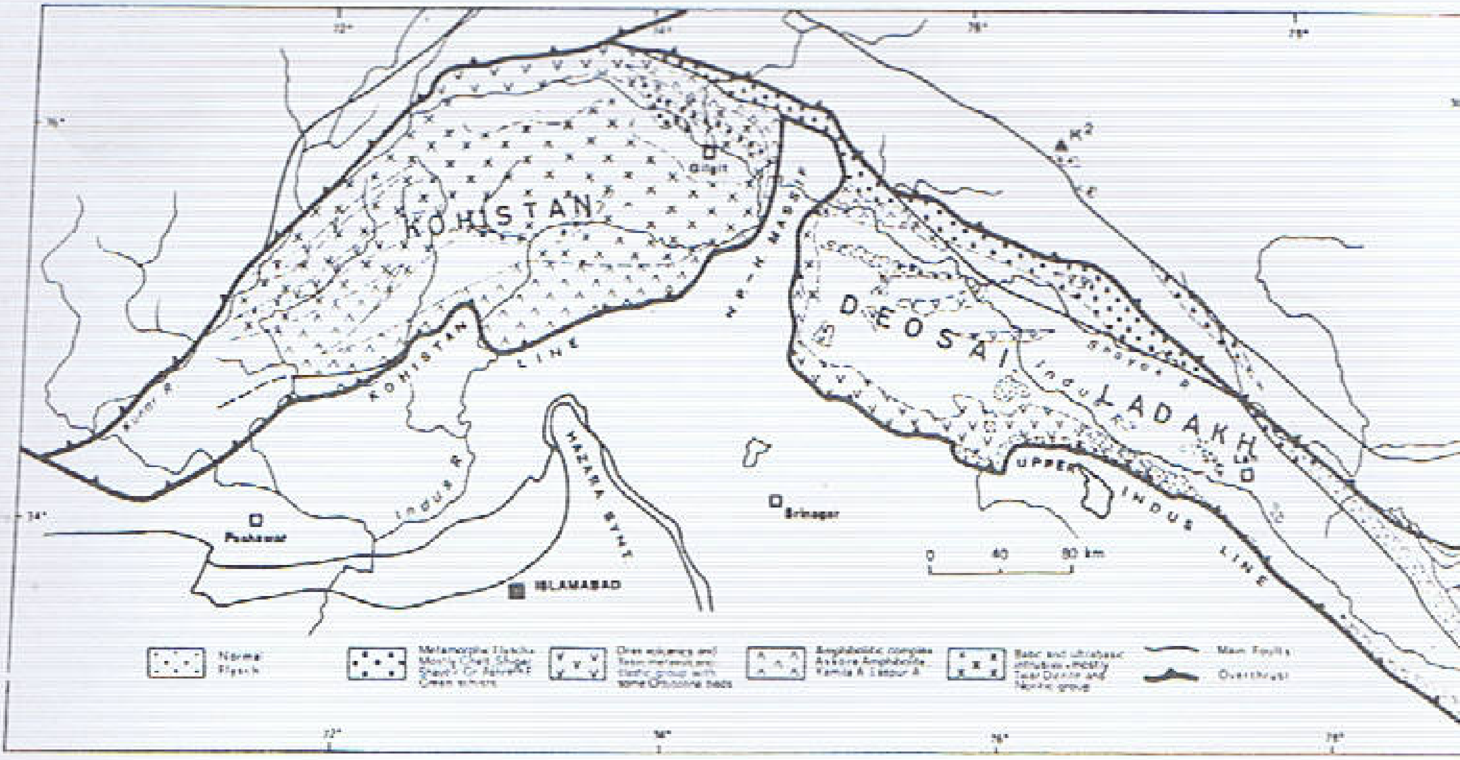
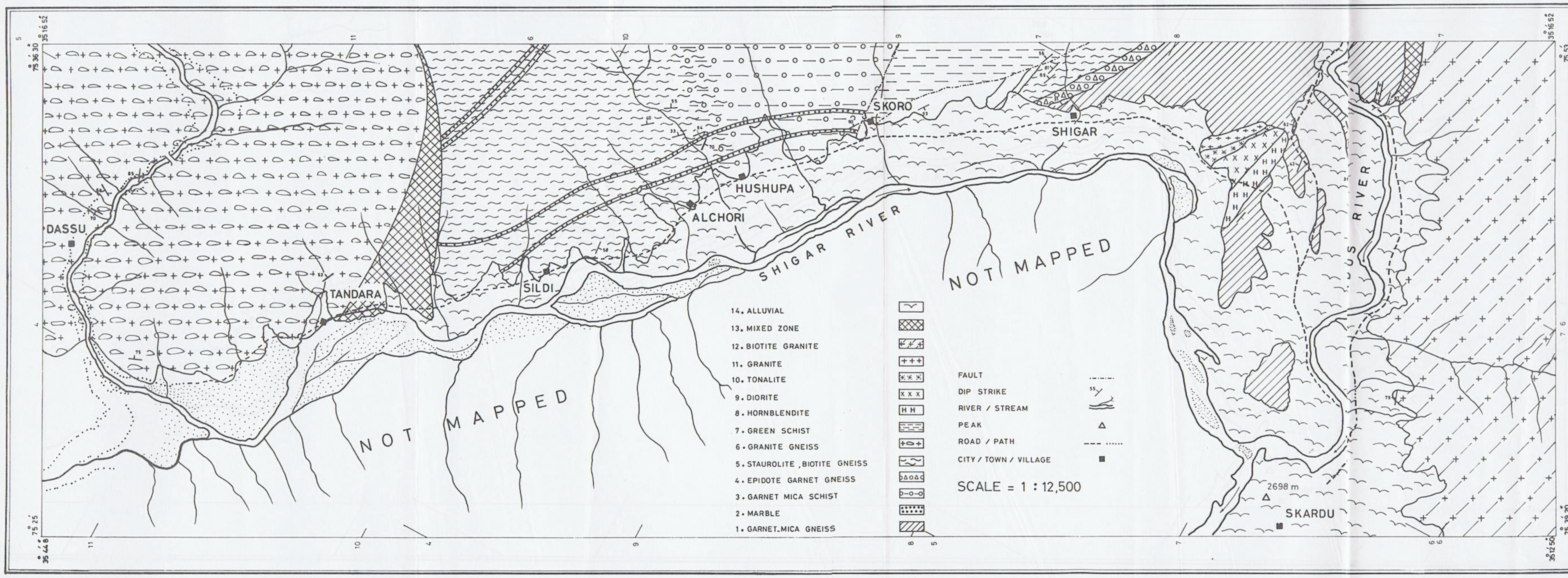


Fig. 6: Deosai-Ladakh and the Kohistan island arc, after Desio (1977).

Fig. 7:

TENTATIVE

GEOLOGICAL MAP OF SKARDU-DASSU AREA, SHIGAR VALLEY, BALTISTAN NORTHERN PAKISTAN



BALTISTAN EXPEDITION (1982), Team Members: Prof. F. A. Shams, A. A. Saleemi, I. H. Haydri (G. S. P.), M. Nawaz Chaudhary, Nazir Ahmad, Riaz A. Sheikh, M. Sarwar (Zoolog Department). Punjab University, Lahore.

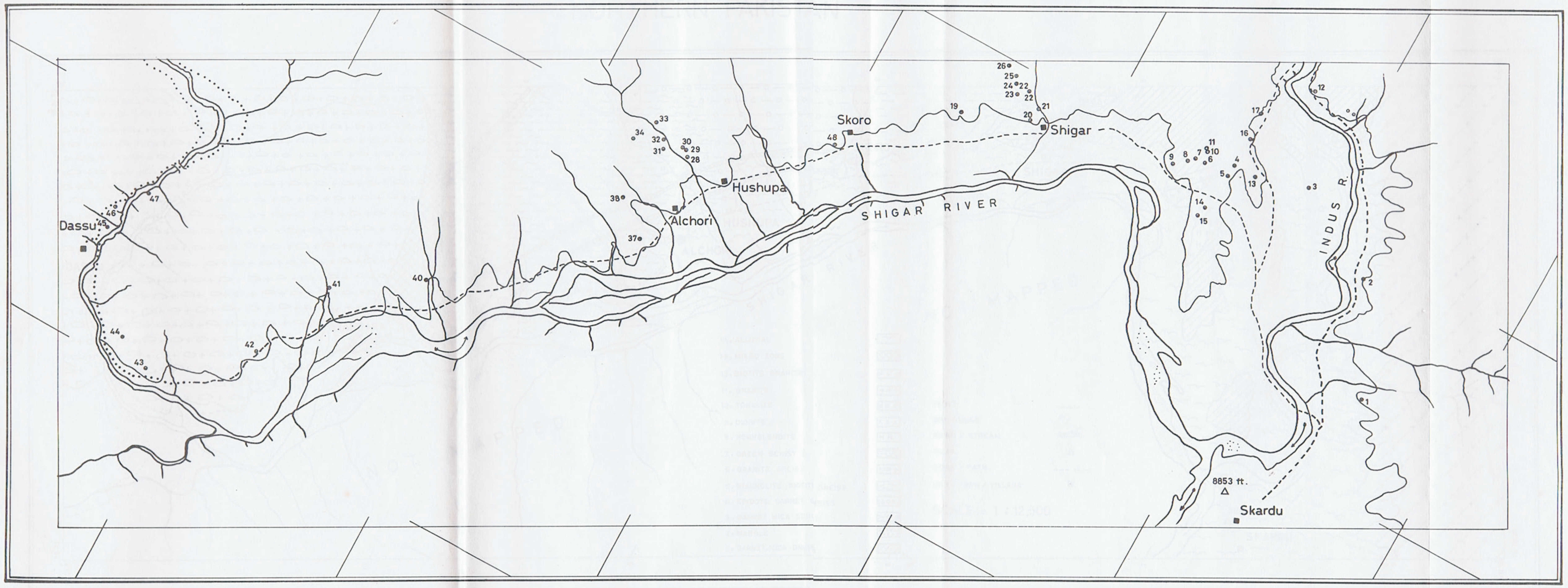


Fig.8 SHOWING LOCATION OF SAMPLING STATION IN SHIGAR VELLEY

of hornblendite, diorite, tonalite and granite as a differentiated series. A massive granite body also intrudes the biotite gneiss, with numerous xenoliths of fine grained blackish calcareous material, some of which shows pre-intrusion folding. Numerous injections of pegmatitic and doleritic composition occur in the vicinity of the granite pluton both parallel to the foliation of the gneiss and to the younger joint planes. In the interior, there is a sudden drop in the metamorphic grade shown by phyllites and talc-carbonate schists that are in contact with greenschists. The latter have extensive quartz veining near Hashupa. This may be the exact location of the Shigar Fault that afterwards runs into course of the river Shigar. NNW of Dassu, the granite gneiss holds a number of complex and zoned pegmatites that contain aquamarine, topaz and rose quartz.

The presence of hot springs, recent tectonics and northward shift of the valley-base shows that the area has been under active influence of the Nanga Parbat-Harmosh orogenic uplift. Seismicity is known from the Shigar zone that hints towards activity of the Shigar Fault although nature of movement is not exactly known. It is planned to carry out geophysical investigations during the next phase of the project.

No blueschists were located although occurrence of serpentinite bodies is known, that feed a small local industry for manufacturing decorative items. On the other hand, blueschists are known from Dras area of Indus Suture Zone (Frank. , that compare with similar occurrence in the tectonic zone of the Swat Himalayas (Shams, 1972, 1980). Therefore, it can be concluded that Shigar Fault may not represent a plate subduction zone as does the Indus (Thrust) Fault. This is also supported by lithological composition of the Deosai batholith that shows its derivation by melting of oceanic crust of the Tethys while the Karakorum batholith shows affinities with continental parental material. Therefore, the latter region may represent a back-arc zone while the Deosai plateau may be taken as a fossil island arc. These conclusions are in line with those arrived at by Nd values of +1.8 and -1.4 from Deosai- Ladakh complex (Allegre and Othman, 1980) from India that shows derivation from oceanic crust. However, detailed work is lacking on the Pakistan side and makes part of our future programme.

5. MAPABLE LITHOLOGIC UNITS

The rock formations were divided as far as possible on the basis of lithology and stratigraphic -tectonic relationship. Ultimately, the units were established in accordance with the scale adopted for mapping. Description of various lithologic units is given below, followed by petrographic and petrochemical presentations.

5.1 Metasediments

The Metasedimentary Sequence is composed predominantly of pelitic rocks while psammatic and calcareous lithologies are subordinate, all rocks are metamorphosed with the grade ranging from garnet to kyanite. The rocks are fine to medium grained and predominantly sub-gneissic. The garnetiferous gneisses are from light grey to dark grey in colour. They weather to greenish rusty brown colours. They are from sub-porphyroblastic to distinct prophyroblastic. Thin quarts veins (up to 5 mm) are cutting the rocks at places.

The Staurolite Mica Gneiss vary from medium to coarse-grained. They are light grey in colour and weather to yellowish grey colour. Thin veins of quartz sporadically cut this rock unit. The rock is distinctly porphyroblastic with porphyroblasts reaching sizes up to 2 cm. Quartz, muscovite, biotite, garnet and staurolite can be readily identified in the hand specimen. Kyanite was located in thin sections only, showing that larger crystals may be present nearby.

The Epidot Garnet Gneiss is hard, compact and slightly to moderately gneissic with over all medium to coarse-grained rock showing black streaks of mica, yellowish green specks, streaks and patches of epidot and whitish spots of quartz and calcite.

Staurolite Garnet Mica Schist is not a distinct unit but is a part of the staurolite mica gneiss, due to abundance of mica minerals. It is medium grained, light grey to greenish in colour while the weathering colour is light rusty. It often contains thin veins of quartz. The rock is porphyroblastic and contains well twinned staurolite crystals. It is composed of abundant mica, quartz, garnet and staurolite.

Kyanite-bearing rock could not be located in field but was identified in thin sections.

Marble occurs interbedded with the meta-pelites. It is medium to coarse grained, hard, compact and massive. It is mainly sugary and granoblastic, However, at places black and white coloured varieties also occur where the marble contains pelitic material or calc-sillicate minerals. Marble weathers into grey to light yellow colour.

5.2 Skardu Biotite Granite

The *Skardu Biotite Granite* is medium to coarse-grained rock. It is white in colour, sub-porphyritic, weathering into yellowish brown to brown and greenish brown colours. The rock contains abundant screens and xenoliths of metasediments. In hand specimen, feldspar, muscovite and biotite are recognizable.

5.3 Dassu Granodiorite Gneiss

This rock is strongly foliated to gneissic, with grey colour, and containing layers rich in biotite. It is porphyroblastic and often shows intricate folding while the weathering colour is greyish rusty brown. In hand specimen, quartz, feldspar, muscovite and biotite can be easily recognised.

5.4 Basic Complex

This complex is composed of hornblendite, meladiorite, diorite, tonalite, granodiorite and granite. It appears to be a composite intrusion.

Hornblendite is a black coloured, coarse grained rock often with pegmatitic bodies in the basal part. Parts of this unit contain pale green epidote. The unit is also cut by amphibole-plagioclase pegmatite veins and patches. This unit grades upward into *meladiorite and diorite.* These are hard, massive, black and white rocks, at places containing fine grained clots of hornblende set in medium to coarse grained rocks. They are hypidiomorphic to subporphyritic rocks, weathering to greenish black to rusty, greenish black colours.

The diorite grades upward into tonalite, granodiorite and granite. Tonalite is medium to coarse grained, subporphyritic to non-porphyritic, grey to white rock with black amphibole crystals. It is massive, hard and well jointed. Granite occurs towards the top; it is white in colour, fine to medium grained, compact and massive rock. It weathers into grey and rusty grey colours.

5.5 Melange Block

The Green Schist is infact an actinolite schist. It is fine grained and dull green in colour, porphyroblastic to sub-porphyroblastic. Actinolite is the predominant mineral. Its weathering colours are light to medium rusty green.

The Talc Carbonate rock is medium to coarse grained dirty white to off white. Carbonate minerals and talc are the main constituents that form irregular patches and intergrowths. The rock is foliated and porphyroblastic. It weathers to rusty light grey to rusty ash grey colours.

5.6 Petrography

Petrographic description is given of selected 26 (twenty six) rock sections, representing Metasediments (6 specimens) Quartzofeldspathic Gneiss (4 specimens) Dassu Granodiorite Gneiss (3 specimens), Skardu Biotite Granite (3 specimens), Diorite Complex (7 specimens) and Melange Block (3 specimens). Routine optical methods were used.

The rocks subjected to chemical analyses were selected out of group included for petrography.

METASEDIMENTS

1. Quartzite (Sample No. NS-60)

The rock is granoblastic but somewhat foliated, with foliation marked by micaceous minerals. It is composed of:-

Quartz (72.0%). It occurs as anhedral grains with irregular boundaries as well as their aggregates. It generally ranges in size from 0.1 to 0.45 mm, strain extinction is notable.

Muscovite (5.0%), It occurs as small elongate and interstitial flakes, generally ranging in size from 0.05 to 0.20 mm.

Biotite (3.0%). Like muscovite, it also occurs as small interstitial flakes. It is deep brown and strongly pleochroic. It ranges in size from 0.05 to 0.15 mm.

Calcite (5.05). It occurs mainly as interstitial grains and as small aggregates. The grains range in size from 0.05 to 0.35 mm.

Albite (4.0%). It occurs as small grains which range in size from 0.15 to 0.45 mm. It is generally altered to clay and sericite.

Orthoclase (6.0%). It occurs closely associated with albite as irregular grains which show minor alteration to clay and sericite.

Chlorite (1.0%). It occurs as tiny light green and slightly pleochroic interstitial flakes, generally ranging in size from 0.06 to 0.15 mm.

Magnetite (1.0%). It occurs as small anhedra which range in size from 0.04 to 0.13 mm.

Limonite/Haematite (1.5%). These occur as tiny grains, specks and amorphous looking aggregates.

Sphene (0.5%). It occurs as dispersed tiny grains.

2. Mylonitised Garnet-Mica Gneiss (Sample No. NS-34)

The rock is mylonised, porphyroblastic and strongly poikiloblastic,with gneissic texture and composed of:-

Quartz (50.0%). It occurs as small grains, from 0.05 to 0.15 mm in size, and their aggregates, also as inclusions in biotite, garnet and chlorite porphyroblasts.

Biotite (15%). It is deep brown in colour and strongly pleochroic to almost straw yellow. It occurs as small flakes from 0.03 to 0.20 mm as well as porphyroblasts with ragged outlines and strongly poikiloblastic. At places it has been replaced by chlorite.

Chlorite (6.0%). It occurs as marginal alteration of biotite as well as porphyroblasts. The poikiloblastic porphyroblasts generally range in size from 0.25 to 1.7 mm.

Garnet (15.0%). It occurs as idioblastic to subidioblastic crystals. It is often poikiloblastic and is almandine variety.

Epidote (6.0%). It occurs as irregularly distributed grains and porphyroblasts, generally ranging in size from 0.05 to 1.3 mm. The smaller grains often occur as aggregates.

Magnetite (3.0%). It occurs as grains ranging in size from 0.05 to 0.40 mm.

Tourmaline (1.0%). It occurs as small idioblastic crystals of schorl from 0.08 to 0.25 mm in size.

Muscovite (4.0%). It occurs as tiny and randomly distributed flakes.

3. Staurolite-Garnet-Mica Gneiss (Sample No. 66)

The rock is gneissic composed of fine micaceous and coarse porphyroblastic layers with two foliation directions marked by mineral orientation. It is composed of:-

Muscovite (52.0%) It is the predominent mineral of the rock occuring as aggregates generally ranging in size from 0.20 to 1.6 mm and making distinct thin layers of intergrown flakes alongwith minor biotite and tourmaline grains.

Biotite (20.0%). It occurs as small flakes as well as porphyroblasts, generally ranging in size from 0.2 to 6.0 mm and strongly pleochroic from straw yellow to reddish brown. The porphyroblasts contain inclusions of muscovite and quartz and occasionally show ragged margins.

Garnet (3.0%). It occurs as dispersed crystals, some altered with irregular margins and enveloped in chlorite mantle, some having remained as tiny relicts. Garnets do not show any effects of rotation.

Chlorite (4.0%). It occurs as alteration products of garnet, staurolite and biotite showing pale green colour.

Staurolite (14.5%). It occurs as golden yellow and pleochroic poikiloblastic porphyroblasts, broken with chlorite and quartz-filled spaces and having quartz, biotite and muscovite inclusions.

Magnetite (3.0%). It occurs as anhedral grains with skeletal shape and ranging in size from 0.05 to 0.20 mm.

Graphite (3.0%). It makes generally dispersed flakes ranging in size from 0.01 to 0.06 mm.

Tourmaline (0.5%). Occurs as tiny grains, pleochroic and oriented along foliation of the rock.

4. *Staurolite - Garnet - Mica Gneiss (Sample No. F)*

The rock is gneissic and porphyroblastic, composed of:-

Muscovite (44.0%). It occurs as flakes and their aggregates, generally ranging in size from 0.05 to 1.0 mm.

Quartz (16.0%). It occurs as small anhedral grains and their irregular aggregates generally ranging in size from 0.07 to 1.2 mm. The bigger grains are poikiloblastic

Orthoclase (8.0%). Occurs as large prisms with inclusions of quartz and tiny muscovite flakes.

Plagioclase (5.0%). It occurs as big porphyroblasts that are strongly poikiloblastic and as a few small grains of size smaller than 0.25 mm. It is of oligoclase composition with inclusions of mica and quartz.

Biotite (5.0%). It occurs as irregular flakes and their aggregates, closely associated with garnet and staurolite and rich in pleochroic haloes. It ranges generally in size from 0.07 to 1.5 mm.

Garnet (5.0 %). It occurs as subidioblastic to irregular grains, ranging in size from 0.10 to 1.1 mm. It is closely associated with biotite and staurolite, shows alteration to chlorite with irregular relicts.

Staurolite (9.5%). It occurs as idioblastic to subidioblastic porphyroblasts, with distinct golden yellow colour and slightly to moderately pleochroism. Its porphyroblasts range in size from 4 to 6 mm and are closely associated with biotite and garnet.

Chlorite (3.0%). It occurs as light green and slightly pleochroic flakes associated with biotite, staurolite and garnet. It ranges in size from 0.2 to 0.75 mm.

Magnetite (3.0%). It occurs as small (0.05 to 0.2 mm) anhedra which show random distribution, also as inclusions in other minerals and making local concentrations.

Kyanite (0.5%). Occurs as a few subhedral grains, showing alteration to muscovite.

Sphene (0.5%). It occurs as small dirty brown grains (from 0.1 to 0.2 mm).

Haematite/Limonite (0.3%). These occur as small grains, specks and colourations.

Zircon (0.2%). It occurs as tiny randomly distributed grains.

5. Staurolite Garnet Quartz Mica Schist (Sample No. NS-67)

The rock is strongly foliated but is massively looking, with garnet porphyroblasts. It is composed of:-

Biotite (38.0%). It occurs as dirty brown interwoven flakes with altered appearance, weak pleochroism and having interwoven muscovite flakes, generally from 1.5 to 4.0 mm in size.

Quartz (40.0%). It occur as tiny anhedral grains, generally dispersed, of more or less similar grain size, up to 0.3 mm, with local aggregates.

Garnet (12.0%) . Occurs as large porphyroblasts, rich with embayed quartz inclusions and somewhat clear margins that hold few biotite flakes. No signs of rotation, up to 1.8 mm in size.

Staurolite (8.0%). Occurs as subhedral prisms with rounded margins, from 1.0 to 1.2 mm in size, and making aggregates with quartz inclusions. Golden yellow pleochroic colour is distinctly seen. Single dispersed crystals are also present.

Magnetite (2.0%). Occurs as single crystals and grains up to 2 mm in size as well as dust that is generally dispersed.

6. *Quartz Mica Schist (Sample No. NS-61)*

It is strongly schistose rock, with wavy foliation and with mica porphyroblasts, weak layered structure due to relatively varying proportions of mica minerals and quartz. It is composed of:-

Muscovite (40.0%). It occurs as generally dispersed flaky mineral, up to 1.5mm in length, locally making concentrations and porphyroblastic aggregates.

Biotite (12.5%). It makes large flakes with ragged and patchy appearance, strongly pleochroic from straw yellow to reddish brown, ranging in size upto 2.5mm . Rare inclusions with colour haloes are present, but common are quartz and muscovite inclusions.

Quartz (46.0%). Occurs as anhedral grains with strain exinction, sutured margins and making local pools and rich layers, its grain size ranges up to 1.0 mm.

Magnetite (1.0%). It occurs as tiny grains, up to 0.1 mm in size, generally dispersed in the rock.

Tourmaline, *monazite* and *apatite* make 0.5% of the rock.

SKARDU BIOTITE GRANITE

1. Granite (Sample No. NS-6)

The rock is hypidiomorphic and porphyritic, composed of:

Microcline perthite (30.0%). It occurs as subhedral to anhedral crystals which range in size from 0.2 to 2.75 mm, commonly with irregular outlines, and containing inclusions of quartz. It shows weak development of perthitic growths of string and bleb type.

Albite (40.0%). It ranges in composition from albite to oligoclase and occurs as subhedral crystals which generally range in size from 0.25 to 5.0 mm, containing inclusions of quartz and mica. The crystals may show zoning. It may show optically-oriented small patches of microcline with antiperthitic relations. It has composition of An_{9-12}.

Quartz (20.0%). It occurs as anhedral grains which range in size from 0.15 to 2.0 mm, besides common inclusions in feldspar minerals.

Biotite (4%). It occurs as dark brown and strongly pleochroic flakes ranging in size from 0.15 to 1.79 mm.

Chlorite (2.0%). It also occurs closely associated with biotite, as its alteration product.

Epidote (1.5%). It occurs as small anhedral grains ranging in size from 0.05 to 0.2 mm, and closely associated with biotite.

Tourmaline (1.5%). It occurs as small subhedral to euhedral grains of schorlite, dark brown and strongly pleochroic.

Muscovite/Sericite (1.0%). These occur as tiny, irregularly distributed flakes that are mostly of secondary nature.

2. Granite (Sample No. NS 7)

The rock is massive granitoid, composed of:-

Microcline Perthite (52.0%). It occurs as subhedral to anhedral crystals, generally ranging in size from 0.7 to 4.5 mm, showing irregular development of bleb and string perthite. Quartz and mica inclusions occur in rare crystals.

Albite (15.0%). It occurs as anhedral to subhedral crystals ranging in size from 0.5 to 3.5 mm, with myrmekitic development at contacts with microcline. Its composition is An_{6-8}.

Quartz (20.0%). It occurs as anhedral crystals which range in size from 0.3 to 4 mm in size.

Biotite (8.0%). It occurs as subhedral brown and strongly pleochroic flakes which range in size from 0.2 to 1.2 mm.

Muscovite (4.5%). It occurs as anhedral flakes which range in size from 0.15 to 2.0 mm

Zircon (0.5%). It occurs as small crystals with random distribution and ranging in size from 0.07 to 0.2 mm.

3. Microgranite Dyke (Sample No. NS-23)

The rock is poorly foliated showing hypidiomorphic porphyritic texture, and is composed of:-

Microcline (50.0). It occurs as anhedral to subhedral and well twinned but rarely perthitic crystals. It generally ranges in size from 0.1 to 1.5 mm. It may contain small inclusions of quartz and mica.

Quartz (26.0%). It occurs as small anhedral grains which range generally in size from 0.1 to 1.2 mm.

Albite (12.0%). It occurs as small subhedral crystals which are well-twinned and range in size from 0.2 to 1.0 mm and have composition of An_{6-9}.

Myrmekite (1.5%). It occurs as small growths at contact between albite and microcline.

Biotite (7.0%). It occurs as dark brown and strongly pleochroic flakes ranging in size from 0.1 to 0.35 mm.

Muscovite (1.5%). It occurs as small randomly distributed flakes.

Tourmaline (1.0%). It occurs as small subhedral to euhedral grains, ranging in size from 0.1 to 0.2 mm.

Calcite (0.5%). It occurs as small randomly distributed grains, ranging in size from 0.05 to 0.15 mm.

Chlorite (0.5%). It occurs as small flakes.

DASSU - GRANODIORITE - GNEISS

1. Biotite Granodiorite Gneiss (Sample No. 78)

The rock shows hypidiomorphic porphyritic to subpoikiolitic texture. It is better classified as a granodiorite paragneiss. It is composed of:-

Plagioclase (50.0%). It is in the oligoclase range, and occurs as subhedral to anhedral crystals; many grains appear as porphyroblastic, having irregular outlines and poikiloblastic and contain inclusions of quartz, biotite and some time of garnet. The plagioclase shows distinct twinning and strong antiperthitic nature of patch and plume type. Vermicular quartz is some time associated. Grains generally range in size from 0.3 to 3.2 mm.

Orthoclase (6.0%). It occurs as anhedral crystals which generally ranges in size from 0.3 to 0.8 mm.

Quartz (25.0%). It occurs as anhedral grains which generally range in size from 0.20 to 2.5 mm. Tiny quartz grains also occur as inclusions in plagioclase and biotite. Quartz may also occur as vermicular growths in feldspar minerals.

Biotite (12.0%). It occurs as subhedral to anhedral flakes, deep brown and strongly pleochroic flakes, ranging in size from 0.08 to 1.65 mm. At places, it containsinclusions of sphene, apatite and albite.

Muscovite (1.0%). It occurs as tiny randomly distributed flakes, ranging in size from 0.05 to 0.18 mm.

Garnet (2.5%). It occurs as anhedral to subhedral grains, rarely euhedral. It appears to be almandine in nature. It generally ranges in size from 0.1 to 0.5 mm.

Sphene (1.5%). It occurs as tiny anhedral to euhedral crystals, rather closely associated with biotite and garnet. It generally ranges in size from 0.08 to 0.15 mm.

Apatite (1.0%). It occurs as randomly distributed grains which range in size from 0.07 to 0.19 mm.

*Chlorite (0.5%).*It occurs as rare flakes of secondary origin.

Magnetite (0.5%). It occurs as tiny and randomly distributed grains ranging in size from 0.05 to 0.10 mm.

2. Biotite Hornblende Granodiorite Gneiss (Sample No. NS 82)

The rock is massive looking with hypidiomorphic porphyritic texture. It is composed of:-

Plagioclase (50.0%). It occurs as oligoclase, making small grains as well as phenocrysts. The general range of size is from 0.20 to 3.0 mm.

Quartz (17.0%). It occurs mostly as anhedral, ranging generally in size from 0.20 to 1.5 mm.

Orthoclase (18.0%). It occurs as anhedral to porphyroblastic crystals with inclusions.

Biotite (12.0%). It occurs as brown and strongly pleochroic flakes which generally range in size from 0.25 to 1.5 mm. The bigger flakes appear poikiolitic with inclusions of sphene, quartz, amphibole and plagioclase.

Hornblende (5.0%). It occurs as strongly poikiolitic porphyroblasts.

Sphene (3.0%) It occurs as anhedral to subhedral crystals ranging in size from 0.03 to 0.30 mm. They are often intimately associated with biotite.

Myrmekite (2.0%). It occurs at contacts between K-feldspar and plagioclase.

Chlorite (1.0%). It occurs as an alteration product of amphibole and biotite.

3. Biotite (Andalusite) Granodiorite Gneiss (Sample No. NS-90)

The rock is strongly gneissic. The foliation planes show folding and flexuring. The rock is porphyroblastic and poikiloblastic, composed of:-

Plagioclase (45.0%). It occurs mainly as porphyroblasts which often show irregular outlines that may be somewhat ragged. These porphyroblasts are fresh and well twinned containing embayed quartz and tablet orthoclase inclusions; these range in size from 1.5 to 3.0 mm. The smaller crystals in the groundmass range from 0.4 to 1.2 mm. The composition of plagioclase is in the oligoclase-andesine range. There is minor alteration to sericite and calcite.

Orthoclase (15.5%). It occurs as anhedral crystals with irregular outlines, ranging in size from 0.4 to 2.5 mm.

Quartz (20.0%). It occurs as anhedral crystals ranging in size from 0.25 to 1.2 mm, with irregular outlines as well as inclusions in the plagioclase porphyroblasts.

Biotite (15.0%). It occurs as individual flakes as well as their aggregates. It generally ranges in size from 0.2 to 1.2 mm. It is strongly pleochroic from neutral pale straw to medium brown.

Muscovite (2.0%). It occurs mainly as a secondary mineral, with flakes ranging in size from 0.1 to 0.3 mm.

Andalusite (1.5%). It occurs as irregular crystals which range in size from 0.1 to 0.3 mm, showing well developed cleavage.

Garnet (1.0%). It occurs as tiny relic grains of reddish colour that range in size from 0.05 to 0.08 mm, some are enclosed by feldspar.

Zircon (traces). It occurs as tiny rounded relics in feldspar.

HORNFELSED GNEISSES

1. Silliminite Biotite Gneiss (H-2)

The rock is gneissic, porphyroblastic and subpoikioblastic, showing hornfels texture and composed of:-

Quartz (48.0%) . It occurs as anhedral grains and their aggregates, also as inclusions in plagioclase and biotite. It generally ranges in size from 0.1 to 0.35.mm.

Biotite (25.0%). It is dark brown and strongly pleochroic, occuring as small flakes (from 0.1 to 0.3 mm) as well as porphyroblasts (up to 1.5 mm), that are often poikiloblastic.

Plagioclase (13.0%) . It occurs as small crystals,ranging in size from 0.1 to 0.25 mm as well as porphyroblasts (up to 1.5mm) which are often polikiloblastic, with drop inclusions of quartz. The composition is in the basic andesine range.

Orthoclase (5%). It occurs as small (0.10 to 0.40 mm)crystals

Silliminite (5.0%). It occurs as acicular crystals and their radiating and sheaf-like aggregates, associated with biotite flakes.

Magnetite (3.0%). It occurs as randomly distributed tiny anhedral grains, generally ranging in size from 0.05 to 0.20mm.

Tourmaline (1.0%). It occurs as small (0.07 to 0.20 mm) but well formed grains of schrolite composition.

2. Garnet Sillimanite Biotite-Gneiss (Sample No. NS. 27)

The rock is porphyroblastic and poik oblastic. It is gneissic although the gneiss structure is somewhat obliterated due to hornfelsing. It is composed of:-

Quartz (48.0%). It occurs as small grains (from 0.08 to 0.35 mm) and as their aggregates, also as inclusions in the porphyroblasts of biotite and plagioclase.

Biotite (20.0%). It is dark brown and strongly pleochroic from light straw yellow to dark brown colour. It occurs as small flakes (from 0.08 to 0.35 mm) as well as poikioblastic porphyroblasts (up to 1.6 mm).

Plagioclase (12.0%). It occurs as small crystals (from 0.13 to 0.20 mm) as well as poikioblastic porphyroblasts (from 0.3 to 1.2 mm), of oligoclase composition.

Sillimanite (6.0%). It occurs as acicular crystals as well as subradial and sheaf like aggregates. Its crystals generally range in size from 0.15 to 0.78 mm.

Orthoclase (6.0%). It occurs as non-perthitic grains, ranging in size from 0.20 to 0.57 mm.

Magnetite (3.5%). It occurs as tiny (0.05 to 0.12 mm) and randomly distributed grains.

Tourmaline (2.5%). It often occurs as idioblastic crystals of schorl, generally ranging in size from 0.08 to 0.20 mm.

Garnet (2.0%). It occurs as a few poikioblastic relics of almandine nature, ranging in size from 0.10 to 0.50 mm.

2. Garnet Sillimanite-Mica-Gneiss (Sample No. AL-6)

The rock is gneissic and porphyroblastic, composed of:-

Quartz (55.0%). It occurs as anhedral grains which at places are elongated parallel to foliation.

Biotite (17.0%). It occurs as elongate and sometimes subidioblastic flakes. It is deep brown in colour and strongly pleochroic. It generally ranges in size from 0.1 to 1.4 mm, occurring both as individual flakes as well as aggregates.

Muscovite (1.6%). It occurs as small flakes parallel to rock foliation. The flakes range generally in size from 0.08 to 0.20 mm.

Sillimanite (8.9%). It occur as tiny grains as well as elongate crystals with cross-fractures. It occurs both as discrete crystals as well as their aggregates, generally ranging in size from 0.1 to 0.4

Zircon (0.5%). It occurs as high relief elongate crystals.

Magnetite (2.5%). It occur as irregular grains and their aggregates. It ranges in size from 0.1 to 0.3 mm.

Garnet (1.0%). It occurs as small crystals which range in size from 0.1 to 0.3 mm.

4. Calc-Silicate Skarn (Sample No. 91)

Coarse-grained, somewhat banded rock, with carbonate minerals somewhat restricted to distinct bands. It is composed of:-

Calcite (28.0%) . As large crystals but with irregular margins and studded with grains of calc-silicate minerals.

Quartz (15.0%) . Occurs as anhedral grains with rounded outlines and highly variable size.

Tremolite (8.0%). It makes elongated prisms with marked cleavage in fresh gtains, but mostly altered, upto 2.5 mm in length.

Wollastonite (8.0%) Makes subhedral to euhedral crystals with well-marked cleavage, occasionally irregularly shaped with size ranging up to 0.5 mm, *Idocrase (6.0%).* Occurs as euhedral crystals with bipyramid faces, showing slight pleochroism, contains inclusions of altered tremolite.

Plagioclase (15.5%). Occurs as large prisms, well twinned and as aggregates of tiny crystals. Composition varies in the labradorite range.

*Epidote (6.5%).*It is present as subhedral grains slightly pleochroic.

Garnet(23.0%). (23.0%) It occurs as colourless grossularite variety, skeletal, anhedral and rounded grains, making chains and aggregates.

DIORITE COMPLEX

2. Hornblendite (Sample No. NS-11)

The rock is medium to coarse grained, hypidiomorphic and porphyritic. It is composed of:-

Hornblende (82.0%). It occurs mainly as subhedral crystals with some anhedral grains as well. It generally ranges in size from 0.30 to 3.0 mm. It is bluish green and strongly pleochroic from light straw yellow to bluish green.

Plagioclase (12.0%). It occurs as subhedral well-twinned crystals which generally range in size from 0.35 to 3.0 mm. It is in the range of labradorite.

Biotite (4.0%). It occurs as medium brown and strongly pleochroic, elongate flakes.

*Magnetite (2.0%).*It occurs as randomly distributed anhedral to subhedral grains.

2. Diorite (Sample No. NS-10)

The rock is hypidiomorphic and porphyritic, composed of:-

Plagioclase (40.0%) It occurs as subhedral well-twinned crystals, ranging in size from 0.3 to 3.5 mm and in composition from An_{36}-An_{40}.

Hornblende (50.0%). It occurs as subhedral crystals, as phenocrysts and as smaller crystals in the groundmass. It ranges in size from 0.2 to 1.5 mm, is fresh and unaltered. It is pleochroic from light green to medium green.

Biotite (1.5%). It occurs as small flakes, ranging in size from 0.08 to 0.25 mm, and randomly distributed.

Apatite (1.0%). It occurs as subhedral to eumorphic crystals ranging in size from 0.07 to 0.25 mm.

Quartz (1.0%). It occurs as small anhedral.

Magnetite (2.5%). It occurs mainly as small grains ranging in size from 0.05 to 0.3 mm, often associated with amphibole. It may be included as well as exsolved by amphibole.

Sphene (1.0%). It occurs as tiny grains, from 0.03 to 0.1mm in size, dispersed in the rocks.

Haematite/Limonite (1.0%). These occur as specks and colorations.

3. Diorite (Sample No. NS-13)

The rock is foliated with hypidiomorphic porphyritic and subpoikilitic texture. It is composed of:-

Hornblende (45.0%). It occurs as small anhedral grains which range in size from 0.1 to 0.35 mm.as well as poikilitic phenocrysts with inclusions of plagioclase. It is medium green and moderately pleochroic, occasionally twinned and with fine schiller texture due to tiny ore rods.

Plagioclase (45.0%) . It occurs mainly as subhedral, well-twinned crystals, of andesine composition. It generally ranges in size from 0.3 to 6.0 mm. The bigger crystals have irregular outline and are poikilitic, with inclusions of small-sized hornblende and quartz. Shadow extinction and broken twin lamellae are often present. At places, it is weakly antiperthitic. Local aggregates of small and somewhat rounded grains is noteworthy.

Epidote (3.5%). It occurs as small anhedral grains ranging in size from 0.15 to 0.35 mm. It is primary as well as secondary after plagioclase, makes local aggregates.

Magnetite (3.0%). It occurs as small anhedral to subhedral and randomly distributed grains, generally ranging in size from 0.08 to 0.30 mm.

Quartz (2.0%) . It occurs as small anhedral grains.

Apatite (0.5%) . It occurs as tiny subhedral to euhedral grains, ranging in size from 0.07 to 0.18 mm.

Muscovite/Sericite (1.0%). These occur as tiny secondary flakes.

4. Diorite (Sample NS-14)

The Rock is porphyritic with hypidiomorphic to poikiolitic texture, and composed:-

Plagioclase (60.0%). It occurs as fresh, well twinned subhedral to anhedral crystals of andesine composition. It is mostly poikiolitic, containing inclusions of amphibole, quartz, epidote and mica, and ranges in size from 0.3 to 5.5 mm. Some crystals show completely irregular outlines.

Hornblende (30.0%). It occurs as bluish green pleochroic and strongly poikiolitic crystals, subhedral to anhedral, and containing inclusions of quartz and plagioclase. It generally ranges in size from 0.1 to 3.0 mm.

Quartz (3.0%). It occurs as randomly distributed grains ranging in size from 0.1 to 0.2 mm.

Epidote (3.0%). It occurs as small anhedral grains which range in size from 0.05 to 2 mm, also occurs as inclusions. Both zoisite and clinozoisite are present. It also occurs as alteration product of plagioclase.

Apatite (1.0%). It occurs as small subhedral to anhedral crystals ranging in size from 0.07 to 2.0 mm.

Muscovite/Sericite (2.5%). These occur as tiny flakes and as aggregates. Sericite is an alteration product of feldspar.

Haematite/Limonite (0.5%). These occur as tiny specks and grains.

5. *Hornblende - Granodiorite (Sample No. NS-15)*

The rock is massive and shows hypidiomorphic and porphyritic texture, composed of:-

Plagioclase (60.0%). It is in the oligoclase range and occurs mainly as subhedral, fresh and well twinned. It generally ranges in size from 0.25 to 2.3 mm. It often shows well developed zoning, the composition of zones ranges from andesine to oligoclase.

Quartz (20.0%). It occurs as anhedral grains which range in size from 0.25 to 3.0 mm.

Hornblende (9.0%). It occurs as anhedral to subhedral crystals ranging in size from 0.2 to 1.4 mm, green in colour and pleochroic.

Biotite (3.0%). It occurs as light brown pleochroic flakes, ranging generally in size from 0.10 to 0.38 mm.

Chlorite (2.0%). It occurs mainly as an alteration product of amphibole.

Epidote (3.0%). It occurs as anhedral grains which range in size from 0.08 to 0.35 mm, closely associated with hornblende aggregates.

Magnetite (3.0%). It occurs as anhedral to subhedral grains, either individually or as aggregates. It generally ranges in size from 0.1 to 0.35 mm.

6. Biotite-Granodiorite (Sample No. NS-17)

The rock is massive, with hypidiomorphic and porphyritic texture, composed of:-

Plagioclase (58.0%). It occurs as subhedral prismatic crystals, fresh, showing well-developed twinned and zoned structure. Average composition is in the oligoclase range but the zones show variation in composition from andesine to oligoclase. It generally ranges in size from 0.5 to 2.7 mm.

Quartz (30.0%). It occurs as anhedral grains which generally range in size from 0.3 to 2.6 mm.

Biotite (8.0%). It occurs as greenish brown and strongly pleochroic flakes, generally ranging in size from 0.15 to 0.55 mm.

Epidote (2.0%). It occurs as discrete grains and aggregates. It is colourless and shows normal interference colours, being a zoisite. It ranges generally in size from 0.08 to 0.22 mm.

Muscovite/Sericite (1.0%). These occur as interstitial flakes that appear secondary in origin. They range in size from 0.07 to 0.15 mm.

Magnetite (1.0%). It occurs as small randomly distributed grains.

7. Biotite-Granodiorite (Sample No. NS-18)

The rock is massive, with hypidiomorphic porphyritic texture, composed of:-

Plagioclase (48.0%). It is in the oligoclase range and generally occurs as subhedral twinned crystals, ranging in size from 0.35 to 2.7 mm. It is fresh and well twinned; holds extension of K-feldspar and drop quartz inclusions.

Quartz (30.0%). It occurs as anhedral grains, generally ranging in size from 0.3 to 3.4 mm and showing strain extinction, irregular fractures and sutured boundaries. Smaller grains are strain free.

Biotite (10.0%). It is greenish brown and pleochroic from light greenish brown to dark greenish brown. It generally ranges in size from 0.15 to 1.7 mm, is patchy with marginal and band chloritization. Ore and tourmaline are associated closely.

Orthoclase (8.0%). It occurs as anhedral crystals, non-perthitic to feebly perthitic. They generally range in size from 0.3 to 2.7 mm. It shows slight alteration to sericite and clay, but is sometime strongly altered.

Myrmekite (1.0%). It occurs as small growths at borders of orthoclase with or without contact with plagioclase.

Apatite (1.0%). It occurs as small, subhedral and randomly distributed grains, ranging in size from 0.12 to 0.23 mm.

Chlorite (1.0%). It generally occurs as tiny flakes associated mostly with biotite or developed from the latter.

Tourmaline (0.4%). It occurs as small (0.15 to 0.25 mm) grains of schorl, distinctly pleochroic.

Magnetite (0.5%). It occurs as small randomly distributed grains.

Zircon (0.1%). Tiny euhedral crystals.

MELANGE BLOCK

1. Talc-Carbonate Rock (Sample No. NS-43)

The rock is foliated. Talc imparts rather prominent but irregular foliation to the rock. It is composed of:-

Carbonate (65.0%). It occurs as subhedral cyrsls and aggregates of magnesite. The crystals are often elongated, parallel to the foliation. It generally ranges in size from 0.15 to 0.70 mm

Talc (30.0%). It occurs as well-developed flakes, often associated together and imparting foliations to the rock.

X Fe^{3+} (3.5%). It occurs as flaky particles, which are undergoing alteration to iron oxides. They range in size from 0.08 to 0.21 mm.

Haematite/Limonite (2.5%). These occur as small grains, stains and specks.

2. Actinolite Schist (Sample No. 39)

It is a green coloured , strongly foliated rock that breaks easily along its foliation planes with marked fracture planes accross it. It is composed of:-

Actinolite (74.5%) Occurs as long acicular prisms generally with pointed ends, up to 4 mm in length, pleochroic from greenish yellow to bluish green colour and showing strong parallelism. Occasionally, tiny prims are randomly oriented.

Quartz (10.5%). It occurs as tiny grains, generally 0.2 mm in size, and as lenticular grains and aggregates along foliation planes. Rare local pools of larger grains are present as well as bands running oblique to rock foliation.

Epidote (8.5%). It occurs as yellow coloured, slightly pleochroic and zoned grains, ranging in size up to 0.2 mm, generally dispersed but as rare porphyroblasts, up to 0.5 mm in size, associated with quartz and having its inclusions.

Albite (5.0%). Occurs as tiny anhedral grains, up to 0.2 mm in size, showing simple twinning.

Magnetite (1.5%). It occurs as generally dispersed anhedral tiny grains and as trains alongwith quartz that makes bands oblique to foliation.

3. Actinolite Porphyroblastic Schist (Sample No. NS 40).

The rock is fine grained, greenish in colour, with tiny porphyroblasts. In thin section, the porphyroblasts show variable angle of orientation to the rock foliation. It is composed of;-

Actinolite (45.5%) Occurs as twinned acicular prisms of variable size in the groundmass and defining foliation of the rock. Greenish yellow to green pleochroism is distinctly seen. In addition, large porphyroblasts are distributed of more than 5 mm in size and oriented obliquelly to the rock foliation, showing simple and polysynthetic participation. Porphyroblasts show patchy colour zoning, occasionally porphyroblasts make local aggregates when biotite is associated.

Quartz (28.5%). Constitutes groundmass mineral of the rock as tiny anhedral grains up to 0.2 mm in size, rarely larger grains are present.

Albite (10.0%). Occurs as tiny anhedral grains, in the groundmass, intergrown with quartz.

Epidote (12.5%). Occurs as subhedral equant grains in the groundmass, up to 0.3 mm in size, locally making aggregate and rarely porphyroblasts of up to 0.6 mm size, zoning and twining is frequently seen in porphyroblasts.

Biotite (2.5%). Occurs as pleochroic flakes generally associated with porphyroblastic actinolite but also in the matrix, pleochroism varies from straw yellow to light brown.

Ore (0.5%). It is present as tiny anhedral grains up to 0.1 m in size.

PETROCHEMISTRY

Although a large number of specimens were collected yet only a few were subjected to chemical analyses in order to define the main chemical constraints. The analytical work was carried out by Dr. Shafeeq Ahmad by wet gavimetric and spectrophotometric methods.

1. Diorite

The rock (NS-10) is a member of the basic complex, with other members being hornblendite, tonalite, granodiorite and granite. The analysed specimen is composed of 40% andesine plagioclase, 50% hornblende, 1.3% biotite, 1.0% quartz, 2.5% magnetite, 1.0% sphene and 1.0% hematite/limonite. The chemical analysis in terms of oxide percentages is given below:-

SiO_2	= 46.41	CaO	= 11.17
TiO_2	= 0.80	Na_2O	= 1.85
Al_2O_3	= 18.15	K_2O	= 0.83
Fe_2O_3	= 0.92	H_2O	= 0.08
FeO	= 9.39	H_2O^+	= 0.26
MnO	= 0.48	Total	= 99.88
MgO	= 9.56		

2. *Metasediments*

Two specimens of schists were analyzed, both were medium to high grade metamorphic rocks that were derived from pelitic sediments.

The specimen (NS-66) is a schist composed of 52.0% muscovite, 20.0% biotite, 3.0% garnet, 4.0% chlorite, 12.5 staurolite 3.0% magnetite, 3.0% graphite, 2.0% quartz and 0.5% tourmaline.

The specimen (N-F) is a paragneiss composed of 44.0% muscovite, 16.0% quartz, 8.0% Orthoclase, 5.0% plagioclase, 5.0% biotite, 5.0% garnet, 9.5% staurolite, 3.0% chlorite, 3.0% magnetite, 0.5% kyanite, 0.5% sphene, 0.3% hematite/limonite and 0.2% zircon.

Chemical analyses of the two specimens in terms of oxide percentages are given below:-

		NS-66	N-F
SiO_2	=	58.14	57.78
TiO_2	=	0.32	0.34
Al_2O	=	21.67	22.71
Fe_2O_3	=	3.25	2.84
FeO	=	4.03	4.24
MnO	=	0.28	0.32
MgO	=	1.44	1.99
CaO	=	1.68	1.21
Na_2O	=	1.06	1.62
K_2O	=	6.82	5.90
H_2O^-	=	0.08	0.07
H_2O^+	=	0.85	0.72
Total	=	99.62	99.67

3. Dassu Granodiorite Gneiss

This is a paragneiss that had undergone granitization and suffered injection of pegmatite bodies that carry gem quality aquamarine, topaz, rosy quartz and a host of other minerals.

The specimen (NS-90) is composed of 45.0% plagioclase, 15.5% orthoclase, 20.0% quartz, 15.0% biotite, 2.0% muscovite, 1.5% andalusite, 1.0% garnet and traces of zircon, apatite and ore grains. Chemical analysis in terms of oxide percentages is given below:-

SiO_2	=	68.26
TiO_2	=	0.30
Al_2O_3	=	15.25
Fe_2O_3	=	0.62
FeO	=	3.77
MnO	=	0.32
MgO	=	1.35
CaO	=	2.82
Na_2O	=	3.85
K_2O	=	3.10
H_2O^-	=	0.08
H_2O^+	=	0.16
Total	=	99.88

4. Skardu Granite

This is a younger granite of anatectic origin that makes distinct intrusion with thermal aureole and swarms of xenoliths of the country rocks.

The specimen (NS-7) is composed of 52.0% microcline perthite, 15.0% albitic plagioclase, 20.0% quartz, 8.0% biotite, 4.5% muscovite and 0.5% zircon and traces of ore grains. The chemical analysis in terms of oxide percentages is given below:-

SiO_2	=	68.83
TiO_2	=	0.22
Al_2O_3	=	15.39
Fe_2O_3	=	1.22
FeO	=	2.74
MnO	=	0.22
MgO	=	1.65
CaO	=	1.56
Na_2O	=	3.25
K_2O	=	4.50
H_2O^-	=	0.04
H_2O^+	=	0.14
Total	=	99.76

5.8 PETROCHEMICAL INTERPRETATION

The chemical data of metasediments, Dassu granodiorite gneiss and the Skardu granite were recasted into C.I.P.W. Norms (Table 1). Fig. 9 shows plotted positions on a Brammell diagram including the variation trend of the Hazara granitic complex (Shams, 1983).

Table 1. C.I.P.W. norms of analysed rocks

Specimen	Skardu granite	Dassu granodiorite gneiss	St. garnet mica schist	St. garnet mica gneiss
Number	NS-7	NS-90	NS-66	F
Q	25.50	23.10	18.18	17.70
or	26.68	18.35	40.03	35.03
ab	27.27	32.48	8.90	13.62
an	7.78	13.90	8.34	6.09
C	2.35	0.41	9.48	11.42
hy	7.40	9.80	8.35	10.34
il	0.36	0.54	0.61	0.63

The metasedimentary nature of the schist and gneiss formations is comparable to those of the Hazara area. On the other hand, Dassu Gneiss plots in the igneous field, indicating mainly magmatic nature of the formation. Whether or not it represents a metamorphosed greywacke or a volcanic material, requires detaild work that will be reported later. Plotted position of Skardu Granite is marvelously located next to the average calc-alkaline granite (Nockolds, 1951). If the plotted position of rocks are recognised as representative, then a trend of evolution is well defined with Skardu granite as a product of anatexis.

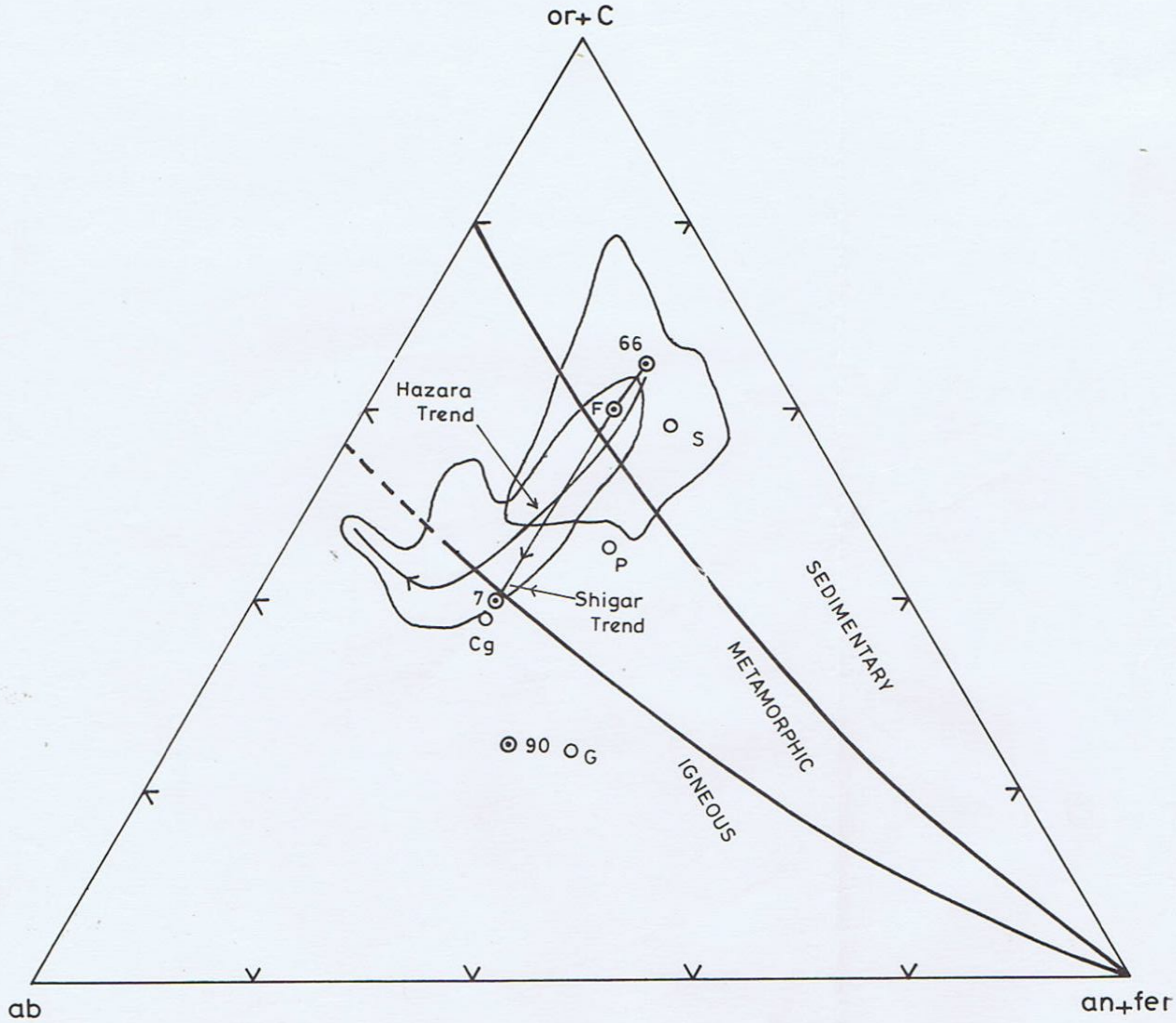


Fig. 9: Brammell diagram showing plots of Baltistan rocks and including Hazara trend (Shams, 1983)

6. PALAEOZOOLOGY

Dr. Muhammad Sarwar

6.1 General

As a member of the "Geological Expedition to the Northern areas, Gilgit and Baltistan", I have been there in the field from 25th of August, 1982 to 7th of September, 1982, I had to return earlier due to University Examinations. During this period I tried to explore the vertebrate-bearing continental deposits, invertebrate bearing deposits, ecological condition of past and present and its relation to the living human population. I found extensive molasse deposits along the Indus River. The major exposures were seen near Sazin, Chilas, Gilgit, Sassi, Skardu and in the Shigar Valley. The area around Skardu appeared to be relatively more promising for the Vertebrate fossils, during the work, it yielded some small vertebrate bony fragments. After a careful examination, these bone fragments turned out to be mammalion and reptilion. Being much fragmentary, these cannot be categorised to a specific or generic level. Their nature, however, indicates that these must have belonged to some advanced memmals of probably the Pleistocene epoch. Similarly, the reptilion bone fragments cannot be labelled as more than "Chelonian Samples". Although, these were very much fragmentary in nature and not worth placing in a Reference Museum, yet very useful for further study.

At many places, the strata of the Old river terraces were folded which indicates how much tectonically active that area is. These Quaternary tectonics must have some bearing upon palaeoecology of that area affecting animal as well as plant life in the near past. A comparison of fossils from the older folded beds and the younger strata can throw some light on the steady morphological changes in animals and plants. These evolutionary changes can then be correlated with extinction of the vertebrates and can help in the conservation of endangered species, such studies will be part of next phase of the Expedition.

6.2 Micropalaeontology

Apart from vertebrates, I also found some microfossils pertaining to the order foraminifera in the clay beds near Skardu. Their distribution can be employed usefully in many ways in future investigations under the Expedition.

6.3 Medical and Ecological

In and around Gilgit-Skardu areas, I found a number of human individuals with endemic goitre. At present, the disease is believed to be due to Iodine deficiency in food and water. This deficiency leads to enlargement of thyroid glands. A detailed study of human population of the area in relation to the prevailing ecological conditions may indicate some other reason as well which could help controlling the disease more effectively.

Due to shortage of time the said areas could not be thoroughly explored.

7. ECONOMIC GEOLOGY

The petrotectonic and geodynamic framework of the Shigar zone is comparable to subduction-related continental collision belts covering an island arc, back-arc and crustal suture; such zones are known to have considerable potential of natural resources (Mitchel et al., 1981). Reconnaissance work in the Shigar zone, combined with previous information, justifies systematic exploration. Metasedimentary formations, acid igneous intrusions and basic complexes indicate abnormal regimes of pressure and temperature, and consequent mobilization of mineral material. Besides, presence of an active fault zone shows probability of abnormal heat flow. Economic geology potential of the area is given below:-

7.1 Serpentine

This beautiful rock, of variable green shades and considerable transluscency in thin plates, makes it a valuable material for preparing decorative items and tea pots, cups etc. It was utilized even before Independence and is being currently exploited under management of the Gem Stone Corporation of Pakistan. Large scale exploitation requires construction of approach road. During present expedition, only float material was collected and further work to find other industrial resources that are commonly associated with such rock bodies will be undertaken during next phase of the project.

7.2 Gem Stones

Aquamarine, the gem variety of beryl, was known before Independence. Occurring in the pegmatites near Dassu, it was continuously mined and marketed. Middlemiss (1919) has given a detailed account of its occurrence and economics of its mining. Presently, it is being mined under the management of Gem Stone Corporation.

Rose Quartz occurs in lumps in the Dassu pegmatites but its utilization is limited due to lean market value, although manufacture of marketable items may increase its demand.

Topaz was identified in colourless varieties but detailed work could not be undertaken in order not to interfere with the work of the Gem Stone Corporation.

Emerald was not located but its occurrence came to be known otherwise. This was very much expected due to presence of rock associations comparable to the Swat occurrences. No work was undertaken by the team itself although, talc-carbonate rock and a melange zone within reach of the acidic igneous lithologies was abundantly present.

Green Tourmaline was another mineral of which detrital grains were noted in the sediments of streams; no effort was made to locate the source. A few specimens were seen from local people.

7.3 Building Stones

Marble:- This white saccharoidal thick-bedded rock is present as part of the metasedimentary formation of the area. It can be used as a building stone but only locally as its transport will be very expensive.

Granite:- This is another rock that can be trimmed into blocks and used as building stone. Most useful will be the Skardu granite which is a massive rock and presence of blackish xenoliths may further enhace its beauty for interior decoration.

7.4 Beryl

Bluish green beryl is found in the Dassu pegmatites as large hexagonal crystals and crystalline masses. This mineral is an important ore of Beryllium and can be taken out even by air transport.

7.5 Copper Ore

Presence of Copper ore was an important discovery made during the Expedition. It occurs as sulphide minerals in a porphyry rock found as large blocks in the eastern side of the valley. Preliminary assay of a specimen showed presence of about 1-1.5% copper. Detailed work could not be undertaken due to other priorities but will make part of next phase of the project.

7.6 Uranium Minerals

Uranium minerals, as uraninite and pitchblende, were found in the river sands near Dassu. No effort was made to locate the source, being outside the scope of project.

7.7 Gold

Gold is known to occur in the Indus river placers since time unknown. Historically, the metal is known to have been exploited out of old terraces, particularly near Oldhing in the East of the area under study. Systematic exploration and development of a cheap technology may make it a very important industry.

7.8 Geothermal Energy

Presence of hot springs along Shigar fault are well known. Systematic work can help to develop this source of energy for household heating and also for cottage industry. It is notable that rapid increase in population of Skardu and environs, trees and forests are gradually coming under increased exploitation which is a serious matter to be reckoned with.

Analytical examination of hot spring water may also prove some source to supply drinking mineral water, even as an industry.

8. RESULTS AND RESEARCH INDICATORS

Although main stress during the first phase of the Expedition was on mapping various lithologic units of the northeastern side of the Shigar Valley yet some important results were obtained, those not only proved the significance of the work but also indicated some directions for future research. Many of the latter will form part of the 2nd phase of the Expedition. These are briefly stated below:

1. The metasediments showed a lithology that is comparable to the Dumordo Formation of Desio (1964) and can be accepted as equivalent of the Wadia's Precambrian Salkhalas. Although these lithologies form part of the southern Karakorum synclinorium of Ebblin (1983) yet also appear comparable to those involved in the Nanga Parbat-Haramosh litho-tectonic evolution (Misch, 1949); This touches the problem of northern limit of Gondwanaland and extension of regime of Cambrian-Precambrian lithologies. Apparently, only one phase of prograde metamorphism was primarily involved while a younger phase of metamorphim was of granitizational-metasomatism involving retrogression causing controlled Facies convergence is very well marked, like those noticed in the case of Nanga Parbat gneisses (Misch, 1949; Shams et al. 1979). Like the latter, this area also presents a wonderful land for detailed study of the interplay of tectonics and granitization process.

2. The Skardu granite is a younger granite of anatectic origin; besides its massive nature and xenolithing character, it has thermal aureole and shows a high temperature-low pressure regime. In a way, it can be taken as a continuation of the granitization phenomena leading to anatexis but the age of emplacement should be much younger. Comparable phenomena, such as granitization of para-gneisses with the introduction of metasomatising fluids etc. may be taken as imprint of somewhat earlier episode. The emplacement of Skardu granite and variety of acid minor bodies, produced

low pressure high temperature environments, evidenced by hornfelsing of metasediments, occurence of andalusite and sillimanite in Dassue gneiss etc. Considering the occurrence of low temperature-high pressure blueschist facies South of the Deosai zone (Virdi et al. 1977), it is tempting to conclude that paired metamorphic belts were produced during the Island arc evolution of the Deosai Zone, related to continental collision and plate subduction phenomena. Similar evidence has been observed in the Ladakh Himalayas with a comparable lithotectonic framework.(Frank 1977) This is an important direction for further research.

3. The Shigar fault is a seismically active tectonic line, with its hot water springs. The Nanga Parbat uplift, even active at present, is evidenced by northwards shift of the Shigar river bed. However, slippage tectonics on the Shigar fault has not been studied vis-a-vis southwards upthrusting of the Karakorum zone. It is considered important to carry out geophysical studies and careful structural-tectonic investigations to find solution to this problem of regional implication.

4. No systematic mineral exploration has been carried out. The plate-tectonic status of the area and the constituent lithologies deserve concentrated efforts. An important conclusion from the occurrence of beryl and topaz bearing pegmatites near Dassu concerns specific levels of pegmatitic mineralization. Comparable occurrences are found in the Nanga Parbat-Haramosh, Mansehra, Swat and Lower Dir areas. This is an important factor in dealing with origin, uplift and mineralization episodes in the Himalayas and related orogenic elements. It gives an important indicator for planning mineral exploration related to acid magmatism in the collisional orogenic belt of the Himalayas. Work in this direction has been taken into hand on the basis of results already obtained, including discovery of copper-bearing porphyry rock.

Appendix - I

The Institute of Geology
Punjab University
Lahore-20

First Circular
10-5-1981

PUNJAB UNIVERSITY GEOLOGICAL EXPEDITION TO BALTISTAN SUMMER, 1981

1. The Northern Areas of Pakistan are very important geologically and hold key to many intricate problems concerning episodes of mountain building, mineralization and related phenomena. However, contrary to Gilgit and Hunza regions, Baltistan has remained somewhat neglected. Our present knowledge is based mostly on a few short-termed foreign expeditions and reconnaissance work carried out by geological and mineral development agencies of the country. As a result of this sketchy information, a number of scientific controversies prevail of rather fundamental nature. The most important controversy concerns tectonic status of the Shigar Fault that runs northwestwards in Baltistan and, cutting NE spur of the Haramosh orogenic protrusion, joins the Chalt Fault in the Hunza area. The Shigar Fault has been accepted as a deep crustal fracture but opinions vary from a tectonic break within a continental plate to a tectonic suture between two lithospheric plates. The latter status was so far given to the Upper Indus Fault that occurs in the South accross the Ladakh-Deosai batholith. There is yet another school of thought that considers both these Faults as tectonic sutures with the intermediate zone marking an independent orogenic belt. All such models have considerably varied implications so that for all purposes only one model will have to be established. This is an important problem for geological researches in the Baltistan area.

2. Considering the nature of deep crustal fractures, such as the Shigar Fault, those can have important mineralogical implications. For instance, the Shigar fracture could have been suitable for invasion of mineralizing solutions from depths while contemporary structural disturbances could have produced situations favourable for receiving and holding the mineral matter. The regional heat and pressure regimes, that normally accompany such crustal phenomena, are expected to have mobilized previously dispersed minerals into useful concentrations as well as reconstituting the pre-existing rocks. No foreign expedition has explored the Baltistan region rigorously from such points of view and for its economic mineral resources.

3. Topographically, Baltistan has rather steep gradient, Shigar valley being the gateway to Karakorum including the K-2. Two major glaciers of the Karakorum range, the Biafo and the Baltoro, are active within Baltistan alongwith many minor glaciers. The Braldu and Basha rivers join near Mango to generate the Shigar river which flows into the mighty Indus near Sakrdu. The valley of the Shigar river is a major alluvial fill alongwith glacial morain and rock debris. Optimum use of water and soil resources of Baltistan is an urgency of geographical environments and needs careful planning. Therefore, besides utilizing opportunity for glacial studies the water and soil resources of the area should also be surveyed in detail. Geochemical reconnaissance can be carried out to delineate various soil-types of the area and the nature of bedrock-population relation. Due to NW-SE linear outcrops of mountain belts in the Northern Areas, results obtained from Baltistan may find useful application elsewhere under similar geological conditions.

4. Baltistan, the socalled "Little Tibet", is the abode of distinct ethnic group with life style of the land of lamas. Besides studying their cultural and social evolution since the recent past, it will be tempting to carry out an archaeological exploration. From geological point of view, however, palaeozoological investigation will be of considerable value to the Expedition. It is now generally accepted that vertabrate fossils occur even accorss the Tibetan plataue. Occurrence of vertabrate fossils in the lower Hunza river valley is known already so that any such discovery in the Baltistan area will mean a regional tie-up of consideration scientific importance.

5. In order to achieve some of the objectives as imperative in the above statements, a suitable part of Baltistan has been selected and following sections of research have been set up under auspices of the Expedition:-

   Section A: Regional Geology, Stratigraphy, Geomorphology.

   Section B: Structural and Tectonic Geology, Geophysics

   Section C: Mineralogy, Petrology, Geochemistry, Economic Mineral Resources.

   Section D: Glaciology, Water and Soil Resources, Engineering Geology.

   Section E: Palaeozoology, Palaeobotany, Medical Geology.

   Section F: Miscellaneous Topics.

6. Baltistan is connected to Rawalpindi by air and to Gilgit (or the Karakorum Highway) by road. In addition, there are roads and paths for approaching various parts of the project Area and many rest houses are available for stay and putting up field camps. Skardu, being the headquarter of Baltistan, will serve as the contact point for logistics and for necessary official liaison. A small field laboratory will be established for quick testing of samples, labelling, packing and related works, with literature required during field work and drawing and drafting facilities.

7. The Expedition team will be raised from national Universities to associate experts of various fields, including some research staff. In addition, a number of scientists from public sector organizations will be also coopted. Some of the leading research and industrial organizations of the country will be asked to collaborate for testing of material collected during the Expedition.

8. Funds are being raised through University Grants Commission, Pakistan Science Foundation, government departments, industries and other agencies. Universities are expected to make their own contribution, particularly when their staff members will be involved. Contributions will also be raised for field equipment, tentage and general logistics.

9. A preliminary Report will be released by Leader of the Expedition within one month from conclusion of the Expedition. The Final Report will be published by the Team within 9-12 months. Even afterwards, the participating scientists may continue their research and make publications based on material and data collected during the Expedition with due acknowledgement to the Expedition programme.

10. Period of the Expedition will be tentatively from 15th to 31st September, 1981 to be finalized by the Steering Committee. Field work programmes of individual scientists and individual teams can however be shorter and may vary according to nature and extent of research. This responsibility will lie with leaders of various teams as tied to specific objectives of the Expedition.

11. The tourist season in Baltistan is from Ist April to 31st October, with following climatic conditions:

Months	Average Temperature Minimum	Average Temperature Maximum	Rain fall	What to wear
i) 16th May to 31st Aug.	13.88°C (57°F)	26.66°C (80°F)	0.60"	Light cloths
ii) Ist Sep. to 15th Oct.	7.22°C (45°F)	23.88°C (75°F)	0.30"	Light woolies

Fresh and Juicy apples, plums, mulbery, apricots, peaches, graphes will be abundantly available during the Expedition period. Beautiful roses, lilies and pansies will make the landscape enchanting with pine and fir trees.

12. A proforma for participants in the Expedition is attached which should be filled and returned for registration by return post.

13. A National Steering Committee for the Expedition has been set up with the membership attached.

(PROF. F.A. SHAMS)
Convener, Steering Committee
and
Leader, Baltistan Expedition.

Appendix - II

THE PUNJAB UNIVERSITY GEOLOGICAL EXPEDITION TO BALTISTAN SUMMER, 1981

(REGISTRATION FORM)

I have read circular announcing the geological expedition to Baltistan, Northern Areas, during the Summer of 1981, and declare that:-

1. I shall be available from ___________ to ____________.

2. I shall contribute to Section(s) __________ (Please enclose your plan of work and specific objectives, alongwith a copy of your biodata).

3. My T.A./D.A. expenses will be/will not be borned by my parent organization.

4. I shall bring my own transport/shall need transport facilities.

5. I shall bring necessary field equipment, such as:-

   1. --------------------
   2. --------------------
   3. --------------------

6. I shall need following items of equipment during my field work

   1. --------------------
   2. --------------------
   3. --------------------

7. I shall make my own arrangements for boarding and lodging/ I shall need such facilities to be arranged for me.

8. I shall like to travel by air/road to Skardu.

9. I shall bring my own transport/shall need transport to Skardu

10. Any special instruction/information (use extra sheets, if necessary)

D E C L A R A T I O N

I declare that I shall report achievements of my research to Leader of the Expedition and shall contribute paper(s) for inclusion in the Expedition Report.

Signature __________

Dated __________ Name and Designation ______

____

(Signature and Seal)
Head of the Organization.

Appendix - III

BREAK UP OF BUDGET ESTIMATE
for
BALTISTAN EXPEDITION, 1981.

1.	T.A./D.A. of scientists (14)	= Rs.	30,000
2.	T.A./D.A. of field staff (8)	= Rs.	10,000
3.	Field Transport, running expenses and Hire Charges.	= Rs.	20,000
4.	Tentage, Field support material including minor items of equipment.	= Rs.	10,000
5.	Foodstuff, medicines and other Field Facilities.	= Rs.	5,000
6.	Guides, Labours.	= Rs.	5,000
7.	Rent of field Laboratory/Office and of Rest Houses.	= Rs.	10,000
8.	Contingencies	= Rs.	5,000
9.	Unforeseen	= Rs.	5,000
10.	Follow-up Laboratory work, (analytical, technical etc.)	= Rs.	30,000
11.	Maps and Reports, preparation and Publication.	= Rs.	20,000
	Total	= Rs.	1,50,000

Appendix - IV

TENTATIVE PROGRAMME FOR THE BALTISTAN EXPEDITION 1981

1.	Meeting of the Steering Committee:	
	Approval of the Programme	6-6-1981
2.	Collection of Logistics, Field Requirements and Registration of participants:	Till.30-6-1981
3.	Meeting of the Steering Committee:	
	Finalization of the Programme	2-7-1981
4.	Establishment of Field Station at Skardu	10-7-1981
5.	Meeting of Team Leaders at Lahore	16-7-1981
6.	Arrival of Research Teams at Skardu	20-7-1981
7.	Field Meeting of Team Leaders at Skardu	25-7-1981
8.	Field Meeting of Team Leaders at Skardu	15-8-1981
9.	Field Meeting of Team Leaders at Skardu	20-9-1981
10.	Farewell Dinner at Skardu	25-9-1981
11.	Teams leave for home	
12.	Meeting of Steering Committee and Team Members	
	Approval of First Expedition Report	1-11-1981
13.	Release of Final Expedition Report	12.1.1982

(PROF. F.A. SHAMS)

Appendix - V

PROCEEDINGS OF A MEETING OF THE STEERING COMMITTEE, BALTISTAN EXPEDITION, HELD ON 6-6-1981 IN THE INSTITUTE OF GEOLOGY, UNIVERSITY OF THE PUNJAB, NEW CAMPUS, LAHORE

1. The members started arriving by 4-30 P.M. and were shown various sections and Laboratories of the Institute.

2. After a group photograph of the Steering Committee at 5.30 P.M., the members were escorted to library of the Institute where there were displays of available literature on the Baltistan area and geological/topographic maps. Each member was given a circular regarding the Expedition, a copy of the proposed budget, a copy of the tentative programme and a list of references to literature about the area.

3. The meeting was started with recitation from the Holy Quran by Dr. Shafeeq Ahmad.

4. Dr. Khairat Muhammad Ibne-Rasa, the Vice-Chancellor, Patron and Chairman of the Steering Committee, addressed the members. He gave a brief account of the history of developments of geological teaching at the Punjab University and highlighted its efforts in initiating pioneer research in many areas of the country and producing geologists with specialized training in major branches of the subject. The Vice-Chancellor also informed that as a result of extended activity of the Department, it was raised to the status of an Institute of Geology in August, 1979. Simultaneously, professional courses were introduced to produce geologists with a stronger background for serving various development projects of the country and the geological agencies. He told the members that in line with its traditions, the Institute is arranging an expedition to Baltistan with a pure national status. He stressed that it will be only in a national expedition that full information of research can become available for development purposes because foreign expeditions do not impart with complete information and therefore a contribution towards national development is not achieved. He also informed the members that during 1962, the Punjab University contributed to K-12 expedition which was led by Dr. P.J. Stephenson who had previously worked on staff of the Institute as an UNESCO expert. Besides, the staff of the Institute has been doing regional mapping and research on Hazara, Swat, Northern area, Azad Kashmir, Baluchistan, Salt Range, Potwar etc. It is benefitting that Institute should serve the national geological sector by organising an expedition to Baltistan,

which area, I understand has been least explored disregarding its importance. He requested the participants to offer their full co-operation to make the Expedition a success.

5. Prof. F.A. Shams, leader of the Expedition, described its aims and objects and reasons for selecting this particular area. He informed the members, that a circular has been already provided to members which contains necessary details. He drew attention of the members to the fact that Baltistan has seen very little geological activity sofar due to bad transport conditions for approaching the area. The results produced so far do not compare will and different interpretations are being given which are rather confusing. With this background, the area selected covers a part of Northern Himalaya, southern part of Karakorum with the Shigar fault having its own controversy. There are other important problems for research as pointed out in the circular.

6. During discussion almost all members participated and exchanged views regarding various problems which are normally concerned with such an Expedition. After detailed discussions, following decisions were arrived at:-

i) The proposal was unanimously supported by all members. However, it was pointed out that the proposed budget appears fairly weak in view of the extent of work involved and the standard of publication to be achieved. It was recommended that all means should be utilized to raise more funds.

ii) In view of the forthcoming Ramzan, the actual field work should be started in the first week of August, 1981.

iii) Arrangements be made for group insurance of the participants.

iv) Arrangements should be made for medical care in the field and a good base-camp and a field laboratory be established at Skardu to provide field facilities and a central point for meetings.

v) The participants from various organizations should be able to draw their T.A./D.A. from their parent organizations and should also carry instruments and field requirements from their own organization as much as they can. The organizations be requested to allow official use of vehicles wherever available.

7. The Vice-Chancellor as Patron of the expedition and Chairman of the Steering Committee should write personal letters to heads of various organizations sothat approval is obtained quickly and organizational contributions may

be created to the maximum.

8. Professor F.A. Shams stressed that members of the Committee should see that established experts are put on the job sothat the research becomes of highest order. Members of the various teams will be drawn and co-ordinated on the basis of nature of particular plans of work. He thanked the participants for their approval of the programme and enthusiastic support to see it a success. The members dispersed after having further discussions on a cup of tea.

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