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CONTENTS

WORKSHOP ON STRATIGRAPHY OF PAKISTAN

(20-21 February, 1983)

WELCOME ADDRESS

By

PROFESSOR F. A. SHAMS
Director

Mr. Asrarullah, Director General, Geological Survey of Pakistan, Mr. Vice-Chancellor, distinguished delegates to the Workshop, respected colleagues of the profession, dear students, ladies and gentlemen.

In connection with Centenary Celebration of the Punjab University, a Seminar was organised on 23rd November, 1982, and many of you were kind to respond to our invitation. During that full-day programme, 18 papers were offered (although not all could be presented) and an Exhibition was organised with the co-operation of many geoscientific agencies of the country. The occasion was utilized to apprise educatonal and professional circles regarding the past, the present and the contemplatable future of the Institute of Geology, as the oldest seat of geological learning in the country. Many stalwarts of the profession, representatives of the Planning Commission and the Federal Ministry of Petroleum and Natural Resources, Heads of many geoscientific organisations of the country and a large number of alumni of the Institute honoured us by their presence and participation in the deliberations of the Seminar.

The Seminar, however, had rather a generalized approach. Infacts, it was actually so planned so that it may stand as a forerunner for the future programmes; the present Workshop is the first in the list. According to title of the Workshop, its aim is to assess the progress made in stratigraphic research in the country and to identify major problems that require our urgent attention.

All of you are well aware that at the time of independence only about 28% of the new country was known geologically. On the other hand, no seat of geological learning came to the share of Pakistan. Thus, formidable challenges were to be faced both for the production of trained manpower and for the exploration and utilization of natural resources. The pioneer efforts of the Punjab University and the Geological Survey of Pakistan are well known. The national awareness of the problem, however, saw rapid establishment of geological institutions at the universities and of a number of federal and provincial level agencies. As a result of activities of all such organisations and of many national and international research teams, the volume of geological knowlege of the country acquired considerable growth.

For worthwhile planning of research, it is always essential to undertake frequently a comprehensive review of the previous work. Such a process not only helps in correlating broadly the progress made in various branches of research but also assists in identifying major problems, that may require further work as well as those having emerged as a result of the previous work. This Workshop aims exactly at such targets, being in the sequence among others, of efforts that culminated into *Memoir 12* and *Geodynamics of*

Pakistan 1979 published by the Geological Survey of Pakistan. *Proceedings of the International Committee on Geodynamics, Group 6*, on Alpine-Himalayan system (1980) published by Peshawar University, and the *Granites of Himalaya, Karakorum and Hindukush* being published by the Punjab University. The proceedings of the recent Seminar and the present Workshop will be published under the Centenary programme.

I take this opportunity to thank Mr. Asrarullah for sparing time out of his very busy schedule and to accept my request to inaugurate the Workshop. My thanks are addressed also to Dr. Khairat Muhammad Ibne Rasa, Vice-Chancellor, for accepting my request to preside over the occasion. It may not be out of context to state that in Dr. Khairat, we at this University, have a person deeply devoted to the development of science. I may mention also the dynamic and inspiring collaboration of Mr. M.W.A. Iqbal, Deputy Director General, Geological Survey of Pakistan, Lahore, of Dr. S.M. Ibrahim Shah, Director, Geological Survey of Pakistan and Secretary Stratigraphy Committee of Pakistan, Quetta, of Mr. Hilal Asghar Raza, Chairman, Hydrocarbon Development Institute of Pakistan, Islamabad, and above all of Dr. Taseer Hussain, a glittering alumni of this Institute and currently Professor Howard University, U.S.A., without co-operation of these gentlemen, the Workshop might not have been realized.

The National Institute of Oceanography, the Oil and Gas Development Corporation, the Atomic Energy Minerals Centre, Lahore, WAPDA, NESPAK, Attock Oil Company, PUNJMIN Universities, S.D.A. and many other agencies have extended their active co-operation.

The Workshop will be spread over 3 to 4 sessions each session covering a major aspect of stratigraphy of Pakistan (see programme) Simultaneously, an Exhibition has been organised where specimens, publications and maps of unique value are displayed.

Ladies and gentlemen, I welcome you all to this Workshop and to the Exhibition.

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COMPARISON BETWEEN LATE MIOCENE MAMMALIAN FAUNAS FROM AFGHANISTAN AND INDO-PAK SUB-CONTINENT: PALEO-BIOGEOGRAPHIC IMPLICATIONS

By

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Abstract : *Localities of Tertiary mammal fossils from Afghanistan have been placed in a biogeochronological sequence and correlation has been attempted with those of Greece, Turkey, Iran and Pakistan. It is concluded that faunas of Afghanistan and Pakistan were distinct about 8 Ma ago although geographically these were less than 300 km apart. Explanation is given of the differences.*

INTRODUCTION

Until 1976, the Tertiary mammals of Afghanistan were known only by scarce fossil remains which had been found in the Bamian (Raufi & Sickenberg, 1973) and Laghman-Lalalabad (Lang & Lavocat, 1968). Since 1976, we have discovered many mammal-bearing fossil localities in several Neogene basins of Afghanistan (Fig. 1) (Heintz *et al.*, 1978a: Heintz *et al.*, 1978b; Sen *et al.*, 1979; Brunet *et al.*, 1980). The main localities have been placed in a local biochronological sequence ranging from Upper Miocene to Midd e Pliocene (Tab 1) and their ages have been discussed (Brunet *et al.*, 1981). Correlation with other Neogene localities of Eurasia have been proposed (Table 2).

The most important fossil locality of Afghanistan is Molayan, in Khordkabul Basin (30 km S-E of Kabul). The one-metre fossiliferous layer belongs to a stratified complex of fresh water deposits. The bones are very well preserved and sometimes still in connection. Up to now, twenty four mammal taxa have been identified, that point to a late Miocene age, more precisely, Turolian.

Molayan is situated 3,000 km east of Maragha (Iran) and 300 im west of the Potwar Plateau; from latter, the well known Siwalik faunas of Pakistan have been recovered. The geographical proximity of Pakistan invites comparison of the Molayan fauna with that of the Pakistan Siwaliks rather than with faunas geographically much more distant. The faunal list which is more suited to meet that requirement has been recovered in the Khaur region from a stratigraphic sequence characterized by a marker sandstone called the

"U sandstone" (Badgley & Behrensmeyer, 1980; Barry *et. al.*, 1982), its age is estimated at about 8 Ma according to paleo-magnetic data (Tauxe, 1979).

The Molayan mammalian fauna differs sharply from that of the "U sandstone" despite their identity in age (around 8 Ma) and their geographical proximity (300 km).

COMPARISON

1. **Hyracoidea** represented by Pliohyrax in Molayan are unknown in Pakistan.

2. **Tubulidenta** and *Creodonta* unknown in Afghanistan are represented in the Potwar Plateau.

3. **Primates**– The differences are of familial level : Cercopithecoids (Mesopitkecus) in Molyan, Hominoids (Ramapithecus, Sivapithecus) in Pakistan.

4. **Insectivora** – Soricidae and Tupaiidae reported in the Potwar are unknown in Molyan; Erinaceidae are present in both countries, but it is impossible for the present to determine the differences or similarities.

5. **Rodentia** – Sciuridae, Gliridae, Ctenodactylidae, Rhizomyidae represented in the Potwar are unknown in Molayan. Gerbillidae and Hystricidae present in Molayan are absent around 8 Ma in Potwar. Among Muridae, the genus Progonomys represented in Pakistan is unknown in Afghanistan; Parapodemus described in Potwar has not been found n Molayan, but has been recovered in Afghanistan from more ancient and more recent localities (Brunet *et al.*, 1981); Karnimata is known in Pakistan as well as in Afghanistan, but the species are distinct and belong to two independent lineages.

6. **Carnivora** – Amphicyonidae, Mustelidae, Viverridae exist in the Potwar but are unkwnon in Afghanistan. Hyaenidae and Felidae are represented in both the regions, but with different genera.

7. **Proboscidea** – Gomphotheriidae and Deinotheriidae are known in Potwar and in Molayan, but with the two fragmentary Afghan remains it is impossible to make a more precise determination.

8. **Perissodactyla** – Chalicotheriidae and Rhinocerotidae are represented by different genus: Chalicotherium and Brachypotherium, Chilotherium, Gaindatherium in Potwar, Ancylotherium and Dicerorhinus in Molayan. In Equids the Molayan Hipparion differs from those described from the Potwar Siwaliks.

9. **Artiodactyla** – Anthracotheriidae and Tragulidae well known in Potwar are totally absent in Afghanistan. Suidae, only one genus IMicro-stonyx) in Molayan, several different genus in Potwar. Giraffidae, the genus Paleotragus in Molayan and large giraffes (cf. Bramatherium) in Potwar. Cervids are unknown in Molayan, but are present in Taghar, a little bit older locality. In the Siwaliks the Cervids appear very late around 2. 9 Ma (Barry *et al.*, 1982). Bovidae, Miotragocerus and Gazella are represented by distinct species in Afghanistan and in Potwar, four Molayan genus (Protoryx, cf. Prostrepsiceros, cf. Graecoryx, Bovidae indet. small species) are unknown in Potwar where the genus Elaschistoceras has been described.

CONCLUSIONS

At the end of this comparison, it appears that, about 8 Ma ago, the faunas in Afghanistan on the one hand, and in Potwar Plateau on the other hand, were distinct, though geographically very near to one another (less than 300 km). From a taxonomic point of view, this is reflected by differences which range from the specific to the ordinal level. It is impossible to be certain that even one species would be common to both faunas.

These differences cannot be explained by a chronological gap between Molayan and the "U sandstone" time interval. As a matter of fact, if one compares the Molayan fauna with those of the Siwaliks from 12.5 to 5.5 Ma (Moonen *et al.*, 1978; Barry *et al.*, 1982), the differences remain to the same degree.

At first the element of explanation can be found in the palaeo-environment. The composition of the Molayan fauna denotes an open environment of grassland to savannah type, with sparsely scattered woodlands. The environment of the "U sandstone" (Badgley & Behrensmeyer, 1980), characterized by a mosaic of vegetation types from forest to woodland to open grassland, implies a climate on the whole warmer and more humid than in Afghanistan. Therefore, certain faunal differences between Molayan and the Potwar Plateau can be explained by differences in palaeoenvironment, for instance: Tragulids and Anthracotheriids in Pakistan, Gerbillids in Molayan, etc. However, the environment cannot account for all the faunal differences. If it did, the existence of open paleoenvironments in both regions should logically have resulted in a greater taxonomic similarity of the bovids, giraffids, equids, etc. Moreover, however, how to explain the presence of the cervids about 8 Ma ago in Afghanistan and only 2.9 Ma in Indo-Pak subcontinent.

In our opinion, in addition to the differences in palaeoenvironment, there had been an obstacle, may be a mountain barrier, which considerably restrained the faunal exchange between Molayan and the Potwar Plateau. This barrier would have been located in the same place as the present day Baluchi Range, that is to say, in line, westwards, with the Indus Tsangpo suture zone (Bassoulet *et al.*, 1980). So, about 8 Ma, this barrier would have perpetuated, in a way, the biogeographical isolation which characterised the Indo-Pak subcontinent before it was united (35-40 Ma) with Eurasia.

Finally, it was classically admitted that the Dhok Pathan fauna of the Indo-Pak subcontinent Siwaliks was similar to that of the Western Asia and European Turolian (Pilbeam *et al.*, 1977; Moonen *et al.*, 1978); our comparison shows, on the contrary, that about 8 Ma ago, these faunas were biogeographically kept apart.

ACKNOWLEDGEMENTS

The authors would especially like to thank Professor D. R. Pilbeam (Harvard University), Professor S. T. Hussain (Howard University) and Dr. S. Ibrahim Shah (Geological Survey of Pakistan) who allowed them to take part in the Potwar field work and for one of them (M.B.) in the "Workshop on the Stratigraphy of Pakistan", held in the Punjab University, Lahore in February 1983.

REFERENCES

Badgley, C & A. K. Vehrensmeyer 1980 Paleoecology of Middle Siwalik sediments and faunas northern Pakistan – Pal. Pal. Pal. 30 : 133-155.

Barry, J. C., E. H. Lindsay, L. L. Jocobs 1982 A biostratigraphic zonation of the Middle and Upper Siwaliks of the Potwar Plateau of northern Pakistan – Pal. Pal. Pal. 37 : 95-130.

Bassoulet, J.P., J. Boulin, M. Colchen, J. Marcoux, G. Mascle & C. Montenat 1980 L'evolution des domaines tethysiens au pourtour du bouclier indien du Carbonifere au Cretace – Mem. B.R.G.M. n^{o} 115 : 180-198.

Brunet M., J. P. Carbonnel, E. Heintz & S. Sen 1980 Premiere decouverte de Vertebres dans les formations continentales de Pul-e Charkhi, bassin de Kabul, Afghanistan. Implications stratigraphiques – Bull. Mus. natn. Hist. nat., Paris 2 (4) n^{o} 3 : 277-285.

Brunet M., E. Heintz & S. Sen 1981 Datations paleontologiques et sequence biochronologique dans le Neogene continental d'Afghanistan – C. R. Acad. Sc., Paris 293-III : 305-308.

Heintz E., M. Brunet & J. P. Carbonnel 1978a Decouverte du premier grand gisement a Mammiferes fossiles d'Afghanistan – C. R. Acad. Sc. Paris 286 D : 945-947.

Heintz E., M. Brunet, L. Ginsburg & J.L. Hartenberger 1978b Recherches paleomammalogiques en Afghanistan. *In* : 6e Reun. Sc. Terre, Orsay : 205.

Lang L. & R. Lavocat 1968 Premiere decouverte d'une faune de vertebres dans le Tertiaire d'Afghanistan et datation de la serie de Bamian – C. R. Acad. Sc. paris 266 D : 79-82.

Moonen, J.J.M., P. Y. Sondaar & S. T. Hussain 1978 A comparison of larter fossil mammals in the stratotypes of te Chinji, Nagri and Dhok Pathan Formations (Punjab, Pakistan) – Palaeontology Proc. Konink. Nederl. Akad. Wetensch. Amsterdam B 81 : 425-436.

Pilbeam, D. R., J. Barry, G. E. Meyer, S.M.I. Shah, M.H.L. Pickford,

W.W. Bishop, H. Thomas & L.L. Jocobs 1977 Geology and palaeontology of Neogene strata of Pakistan – Nature 270 : 684-689.

Raufi, F. & O. Sickenberg 1973 Zur Geologie und Palaontologie der Beckens von Lagman und Jalalabad – Geol. Jb. 3 : 63-99.

Sen S., M. Brunet & E. Heintz 1979 Decouverte de Rongeurs "africains" dans le Pliocene d'Afghanistan (bassin de Sarobi). Implications paleobiogeographiques et stratigraphiques -- Bull. Mus. natn. Hist. nat. Paris, 4e ser., C, 1, n^{o} 1 : 65-75.

Tauxe, L. 1979 A new date for Ramapithecus – Nature 282 : 399-401.

* * * * *

Table 1. Biochronology of the Neogene mammal-bearing fossil localities of Afghanistan.

	m.y.	Continental stages		Afghan fossil localities
LOWER and MIDDLE PLIOCENE	3			Sarobi (Sarobi)
				HADJI RONA (Sarobi)
				? Laghman - Jalalabad
		Ruscinian	U.	? Baminan
				Dawrankhel 14 (Khordkabul)
				DAWRANKHEL 15 (Khordkabul)
			L.	PUL-E CHARKHI (Kabul)
UPPER MIOCENE	5.5			
			U.	Gurgemaydan 5, 6, 7, 8 (Aynak)
				MALANG (Khordkabul)
				Ghazgay 12 & 13 (Khordkabul)
		Turolian	M.	MOLAYAN (Khordkabul)
				GHAZGAY (Khordkabul)
			L.	Ghazgay (Khordkabul)
	9			TAGHAR (Khordkabul)
			U.	SHERULLAH 9 (Khordkabul)
		Vallesian		Sherullah 10 (Khordkabul)

Table 2. Correlations of the main mammal-bearing Neogene localities of Afghanistan with other Eurasian localities.

	m.y.	Continental stages		Main Afghan fossil localities	Correlations
LOWER AND MIDDLE PLIOCENE	3				
			U.	HADJI RONA DAWRANKHEL 15 & 14	
		Ruscinian	M.		CALTA (Turkey)
			L.	PUL-E CHARKHI	MARITSA (Greece)
	5,5				D.P. 13 (Pakistan)
UPPER MIOCENE			U.	MALANG	
	8	Turolian	M.	MOLAYAN	PIKERMI (Greece) U SANDSTONE (Pak.) MIDDLE MARAGHA (Iran)
				GHAZGAY	
			L.	TAGHAR	
	9				
		Vallesian	U.	SHERULLAH 9	YGSP 450 & 311 (Pakistan).

TERTIARY BIOSTRATIGRAPHIC STUDY BASED ON BIVALVE AND GASTROPOD FAUNA

By

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Abstract : *The biostratigraphic study of the Tertiary formations based on bivalve and gastropod fauna includes large faunal collection from different lithofacies representing various basinal provinces and covering a large geographic areas of Sind, Baluchistan, Punjab and NWFP. Fortysix sections representing twenty six major localities were measured.*

The study consists of systematic treatment and description of 313 species including 36 new species, revision and redesignation of previously described faunal distributiio within and outside Pakistan, determination of Index Species, assignment of age and correlation and paleoecology paleoecology.

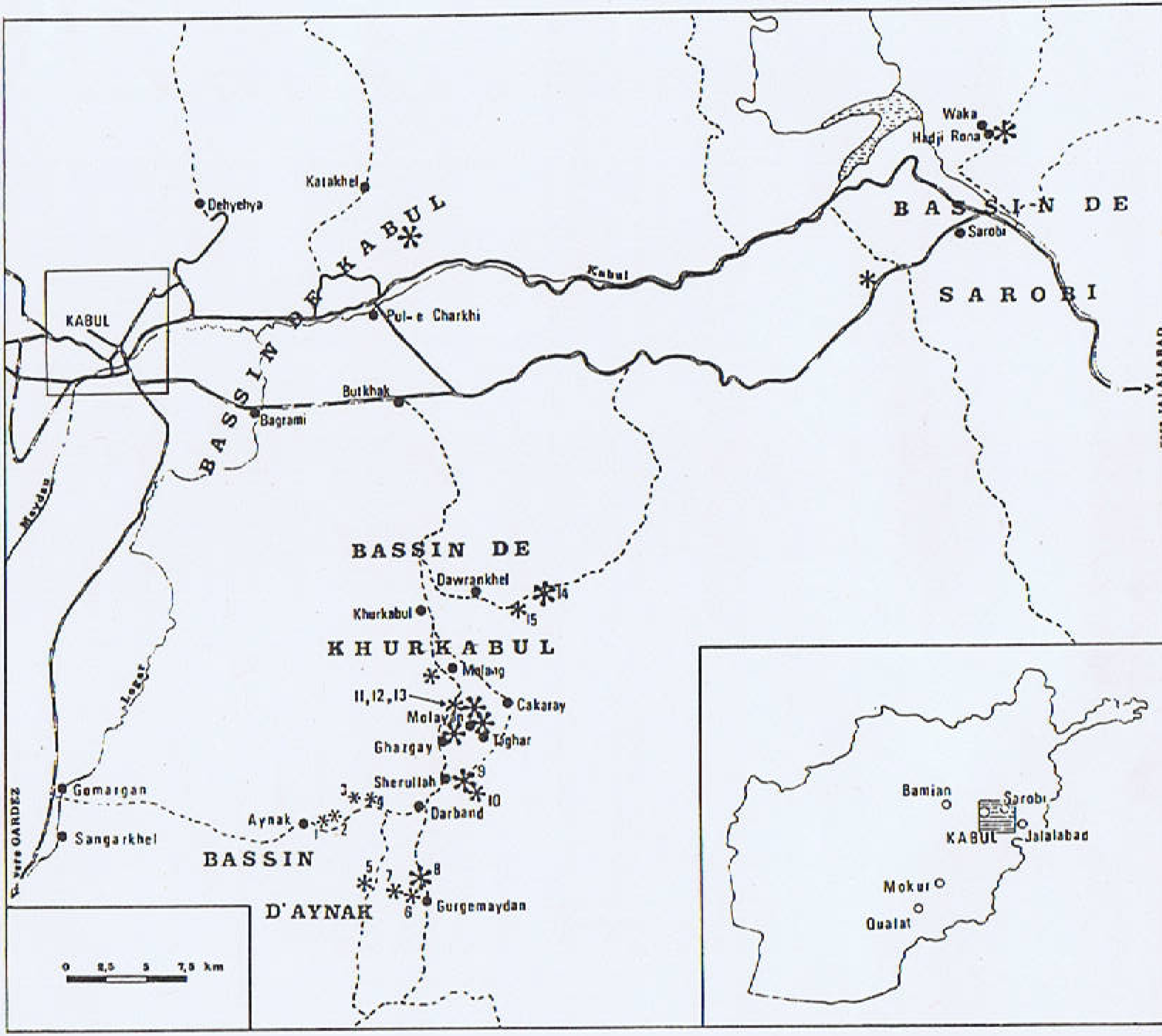
INTRODUCTION

The purpose of this paper is to present a resume on the Tertiary biostratigraphic study undertaken by the writer based on the bivalve and gastropod fauna. The paleontological research on the Tertiary bivalves & gastropods dates back to 1853 and is being continued upto present. The status of the work done in this field has been presented by the writer from time to time (Iqbal, 1972a; 1974, 1981). However, a resume is given for ready reference : —

STATUS OF PALEONTOLOGICAL RESEARCH

(1853 to 1982)

1.	Archiac		
2.	Haimc	1853-54	Area : Sind & Punjab. i) Described 103 new species. ii) Systematic treatment of species. iii) Assignment of age & correlation with Europe. Publications : — 1
3.	Cossmann		
4.	Pissarro	1909, 1927	Area : Sind


BASSIN DE KABUL
BASSIN DE SAROBI
BASSIN DE KHURKABUL
BASSIN D'AYNAK
KABUL
Kabul
Maydan
Logar
vers JALALABAD
vers GARDEZ
Dehyehya
Katakhel
Pul-e Charkhi
Butkhak
Bagrami
Waka
Hadji Rona
Sarobi
Dawrankhel
Khurkabul
Molang
Cakaray
11, 12, 13
Molayan
Ghazgay
Tighar
Sherullah
Darband
Aynak
Gomargan
Sangarkhel
Gurgemaydan
0 2,5 5 7,5 km
Bamian
Sarobi
KABUL
Jalalabad
Mokur
Qualat

			i) Described 85 new species. ii) Systematic treatment Publications : 2
5.	Vredenburgh	1916, 1923, a,b,c,d; 1925; 1927; 1928 a, b.	Area : Sind & Baluchistan i) Described 230 species including 221 new species. ii) Systematic treatment. iii) Revision of previous work. iv) Regional correlation v) Geological history. vi) Comparison with Europe. Publications : — 9
6.	Douvile :	1929	Area : Sind i) Described 35 new species ii) Discussion on previous work iii) Systematic treatment. Publications : — 1
7.	Cox :	1930; 1931	Area : Sind, Baluchistan & NWFP. i) Described 35 new species ii) Correction & redesignation of previously described species. Publications : — 2
8.	Eames :	1950; 1951	Area ; Punjab & NWFP. i) Described 285 forms including 252 new species. ii) Revision iii) Assignment of age. Publications : — 2
9.	Iqbal :	1963; 1969 a,b,c,d; 1972 a,b,c; 1973; 1974; 1979; 1980 a,b,c,d.	Area : Sind, Baluchistan, NWFP & Punjab. i) Bibliographical work : — 1. Tertiary bivalves & gastropods. 2. Geology of northern Pakistan. 3. Geology of southern Pakistan. ii) Stratigraphic nomenclature : — 1. A guide to Stratigraphy of Pakistan. iii) Biostratigraphic studies : — 1. Khadro & Lakhra fms (Paleocene),

Kirthar Province.

2. Hangu Fm & Lockhart Lst. (Paleocene) Salt Range & Kohat Province.
3. Ghazij Fm (L Eocene), Axial Belt & Sulaiman Province.
4. Margala Hill Lst. & Chorgali Fm (L. Eocene), Salt Range & Kalachitta.
5. Kirthar fm. (M. Eocene), Kirthar, Sulaiman & Kohat Provinces.
6. Nari & Gaj fms. (Oligo-Miocene), Kirthar & Sulaiman Provinces.

a. Faunal collection from 46 measured sections representing 26 major localities.

b. Described 313 species including 36 new species.

c. Revision & redesignation of previously described forms.

d. Age determination & regional correlation.

e. Geological history.

f. World-wide comparison of the fauna.

Publications : – 16.

BIOSTRATIGRAPHIC STUDY

The biostratigraphic study of the Tertiary formations based on the bivalve and gastropod fauna, includes a large faunal collection from different lithofacies representing various basinal provinces and covering a large geographic areas of Sind, Baluchistan, Punjab and NWFP (Iqbal, 1963; 1969a, b,c,d; 1971a, b,c; 1973; 1974; 1979; 1980a, b,c,d,; 1981). The fauna have been collected from 46 measured sections representing 26 major localities. The study consists of systematic treatment and description of 313 species including 36 new species; revision and re-designation of the previous described forms; faunal distribution within and outside Pakistan; determination of index fauna; assignment of age and correlation and paleoecology. The brief description of this study is given below : –

PALEOCENE

Formations :

Khadro & Lakhra : Kirthar Province, (Sind)

Hangu & Lockhart Lst. : Salt Range, Kohat (Punjab & NWFP).

Fauna :

1. Bivalves 25, gastropods 68, new species: 5.
2. Index species : Bivalves 19, gastropods 57.
3. Four gastropods known to occur in Hangu Fm (NWFP) were reported for the first time in Lakhra Fm. (Sind).
4. Two bivalves and nine gastropods from Hangu Fm (NWFP) and Lakhra Fm. (Sind) reported first time from Lockhart Lst. (Punjab).
5. One species is common form in Sind, Punjab, Baluchistan and NWFP.
6. One bivalve species is common Paleocene form in Pakistan (Sind) and France.
7. Common occurrance of such species in relatively older and young formations in different basinal provinces indicates their geographical extent chronological distribution.
8. It is also possible that Sind, Punjab, Baluchistan and NWFP areas were connected with each other during Paleocene time.

Age & Correlation :

1. Early Paleocene age of Khadro Fm (Sind), Hangu Fm (Punjab & NWFP) is further confirmed.
2. In Sind, Khadro fm. is conformably overlain by nonmarine, unfossiliferous Bara fm., therefore it is younger to the underlying fm and represents Late Paleocene age.
3. Similarly, the Lockhart Lst (Punjab & NWFP) conformably overlies the Hangu Fm. of Early Paleocene, therefore it represents Late Paleocene age.
4. Khadro fm (Sind) is correlated with Hangu Fm (Punjab & NWFP).
5. Lakhra fm (Sind) is correlated with Lockhart Lst. (Punjab & NWFP).

Paleoecology :

1. The fauna is typically marine, it was laid down on near-shore zone of a shallow warm sea, about 15 to 30 metres deep.
2. Muddy water conditions prevailed in the parts representing Sind & Punjab while partly muddy to clear water conditions prevailed in the part representing NWFP.
3. The parts representing Sind & NWFP, due to fluctuating wave base were subjected to rapid changes in ecological condition.

4. The oceanic connection between Sind, Punjab, Baluchistan & NWFP during Paleocene time is evident.

EOCENE

Formations :

Kirthar fm.	:	Kirthar-Sulaiman-Kohat provinces (Sind, Baluchistan, Punjab and NWFP).
Ghazij fm.	:	Axial Belt-Sulaiman Province (Baluchistan).
Margala Hill Lst & Chor Gali	:	Salt Range-Kalachitta (Punjab).

Fauna :

1. The fauna from Ghazij, Margala Hill lst and Chor Gali of Lower Eocene age consists of 67 bivalves, 51 gastropods including 29 new species.
2. Fauna from Kirthar fm. of Middle Eocene consists of 12 bivalves, 13 gastropods.
3. Index species 47, including 13 for lower Eocene and 34 for Middle Eocene.
4. Nineteen bivalves and four gastropods are regarded as common Eocene forms within Pakistan and other parts of the world.
5. Five species are regarded as common Eocene forms in Sind, Punjab, Baluchistan and NWFP.
6. Common occurrance of such species suggests possible oceanic connection between Sind, Punjab, Baluchistan and NWFP and other parts during Eocene time.

Age & Correlation :

1. Early Eocene age is assigned to Ghazij Fm. (Baluchistan), Margala Hill Lst. and Chor Gali Fm. (Punjab) and Middle Eocene to the Kirthar fm (Sind, Baluchistan & NWFP).
2. Ghazij fm. is correlated with the Laki fm (Sind-Baluchistan), the lower part is correlated with Margala Hill Lst while the upper part with Chore Gali Fm. of Salt Range & Kala Chitta.
3. The Chor Gali Fm. conformably overlies the Margala Hill Lst & Sakesar Lst. and is therefore correlated with the upper parts of Shekhan. Whereas the Margala Hill Lst. is correlated with the lower part of Shekhan Fm. and with Panoba Shale (NWFP).
4. The Kirthar fm. may be correlated in parts with Nisai fm. of Axial Belt & Baluchistan Basin. The lower part is correlative with Kuldana Fm. of Kalachitta & Kohat.

Paleoecology :

1. The fauna of the Ghazij Fm. is typically marine, it was probably laid down on sublittoral to littoral zone of a warm sea about 50 to 60 metres deep under clear water condition but due to fluctuating wave base, the ecological condition rapidly changed into shallower muddy water environment.

2. The Margala Hill Lst. & Chorgali formation contain typically marine fauna laid down probably in littoral to sublittoral zone of a warm sea under clear water condition. In case of Chorgali formation, the fauna suggests rapid changes into shallow muddy water environment.

3. The fauna from Kirthar fm. is essentially marine, the deposition would have taken place under a very shallow sea, not far from the shore and under clear water condition.

OLIGO-MIOCENE

Formation :

Nari Fm. : Kirthar & Sulaiman Provinces (Sind & Punjab).

Gaj. Fm. : kirthar Province (Sind).

Fauna :

1. Bivalves 25, gastropods 54 including 3 new species.

2. Index species for Oligo-Miocene 59 and for Miocene 12.

3. One bivalve species regarded as common form in Sind, Punjab, Baluchistan & NWFP.

4. Eight bivalves and fourteen gastropods are common Oligo-Miocene forms in Pakistan and other parts of the world.

5. Nine species previously known to occur in other parts of the world are reported for the first time from Pakistan.

Age & Correlation :

1. The age of Nari fm is Rupelian to Early Aquitanian (Oligocene to Early Miocene) except in the Gaj River where it represents Rupelian to Chattian (Oligocene) due to absence of the upper most strata.

2. The age of Gaj fm is Late Aquitanian to Burdigalian (Late Early Miocene).

3. Nari fm. correlates with parts of the Khojak formation of Axial Belt and Baluchistan Basin. The Gaj fm. correlates with lower part of Hinglaj fm. of Baluchistan Basin and with Murree Fm. (in parts) of Upper Indus Basin.

Paleoecology :

1. The fauna is typically marine indicating near shore zone of a shllow warm sea, 15 to 30 metres deep. The sediments forming the upper part of Nari are devoid of fossils due to unfavourable environment such as too much of sandy or muddy water. The Gaj fm is throughout fossiliferous indicating favourable conditions for the fauna to thrive.

2. The occurrence of common Oligo-Miocene forms in Pakistan and other parts of the world suggests oceanic connection during Oligo-Miocene time which might have been interrupted later on.

FAUNAL DISTRIBUTION

It is interesting to note that certain bivalve and gastropod forms restricted to Paleocene, Eocene and Oligo-Miocene in Pakistan, also occur in other parts of the world indicating the same restricted geological range. These parts in whcih such common forms occur are : Afghanistan, Russia, China; India, Burma, Indonesia; Africa, Middle East, Iran, Turkey and Europe.

REFERENCES

Archiac, E.J.A.D. & Haime, J., 1853-4, Description des animaux fossils du group Kummuliticue l'Inde, Paris.

Cossmann, M. & Pissarro, G., 1909, The mollusca of Ranikot series. . . . , Pal. Indica, Geol. Surv. India n.s., v. 3, Mem. 1, 83 pages, 8 pls.

1927, The mollusca of Ranikot series. . . ., Pal. Indica, Geol. Surv. India, Geol. Surv. india, n.s.v. 3, Mem. 2, 31 pages, 4 pls.

Cox, L.R. 1930, The fossil fauna of the Samana Range. . . . ., Mem. Geol. Surv. India, Pal. Indica, n.s.v. 15, pt. 8, pp. 129-222, pl. 17-22.

1931, A contribution to the molluscan fauna of Indian Eocene. . . , Trans. Roy. Soc. Edinburgh. . . . ., v. 57, pt. 2, pp. 25-92, 4 pls.

Bouville, H., 1929, Les couches a' Cardits beaumonti. . . . . ., cans le Sind, Pal. Indica, Geol. Surv. India, n.s.v. 10, Mem. 3, pp. 27-73, pls. 5-11.

Eames, F.E., 1950, A contribution to the study of Eocene in W. Pakistan. . . . ., Phil. Trans. Roy. Soc. London, No.627, v. 236, 168 pages, pls. 9-17.

1951 A contribution to the study of Eocene in W. Pakistan. . . . . , Phil. Trans. Roy. Soc. London, No. 631, v. 236, 168 pages, 6 pls.

Iqbal, M.W.A., 1963, Systematic Paleontology of the Ghazij Shale. . . ., Masters Thesis, Univ. California, Los Angeles, USA., 118 pages, 12 plates, 4 figures.

, 1969a Megafauna from the Ghazij fm. . . . . ., Mem. Geol. Surv. Pakistan, Pal. Pakistanica, v. 5, 41 pages, pls. 8-12, figs. 1-4.

, b The Tertiary Pelecypod & Gastropod Fauna from brug, Zindapir, Jhalar & Chharat. . . , Mem. Geol. Surv. Pakistan, Pal. Pakistanica, v. 6, 94 pages, fig. 1, pls. 1-7, maps.2, charts. 2.

, c Bibliography of Tertiary Bivalve and Gastropod Species. . . ., Rec. Geol. Surv. Pakistan, v.18, 63 pages.

, d Cretaceous correlation of Turkey-Iran-Pakistan CENTO Publications, Ankara, Turkey.

, 1972a Pakistan Ke Salasi Rukaz Sipian aur ghoonge, Earth Sci. Sec., 13th Session, Sci. Conf., Scientific soc. Pakistan, March 10-14, 1972, Karachi.

Iqbal, M. W. A., 1972b, The Tertiary Bivalves & Gastropods of Sind, Geonews, Geol. Surv. Pakistan, V.II, no.2, pp. 39-41.

, c, Paleocene Bivalve & Gastropod Fauna from. . . .Sin, Punjab & NWFP, Mem. Geol. Surv. Pakistan, Pal. Pakistanica, v.9, 104 pages, 3 maps, 3 charts, figs., pls. 13-21.

, 1973, Biostratigraphy of the Tiyon fm. . . . . Sind, Pakistan, Rec. Geol. Surv. Pakistan, v. 22, 40, pages, 2 maps, 3 charts, fig. 1, pls. 22-25

, 1974, The Tertiary Bivalves & Gastropods of Baluchistan, Seminar, Department Geol. Sci., Univ. Baluchistan, 4-18 Sept., 1972, Geonews, Geol. Surv. Pakistan, v. IV, April, 1974, pp. 43-47.

, 1977, in Shah, S.M.I., editor Stratigraphy of Pakistan Mem. Geol. Surv. Pakistan, v. 12, 138 pages, 13 figs., 4 tables.

, 1979, (in Ahmad, Z., & Others), Bibliography of the Geology of Northern Pakistan, Rec. Geol. Suurv. Pakistan, v.48, 37 pages.

, 1980a, Oligo-Miocene bivalves & Gastropods from Kirthar province. . . ., Rec. Geol. Surv. Pakistan, v. 51, 59 pages, 3 maps, 5 figs, 3 charts, pls. 27-36.

& Shah, S.M.I., 1980b, A guide to stratigraphy of Pakistan, Rec. Geol. Surv. Pakistan, v. 53, 34 page, 3 figs.

, 1980c (in Ahmad, Z. & Others), Bibliography of the Geology of southern Pakistan, Rec. Geol. Surv. Pakistan, v. 54.

, 1981 Tertiary bivalves & gastropods of Pakistan, Geol. Bull. v:16, Institute Nummals Punjab Univ. Lahore.

Vredenburgh, E., 1916, Flemingostres, an eastern group of U. Cretaceous & Eocene Ostreaidae. . . . ., Rec. Geol. Surv. India, v.67, pp. 196-202, pls. 17-20.

Vredenburgh, E., 1923a, Indian Tertiary Gastropoda, No.4. . . . , Rec. Geol. Surv. India, v.54, pl.3, pp.243-76, pl. 14-16.

, b, Indian Tertiary Gastropoda, No.5. . . . . . . , Rec. Geol. Surv. India, v.55, pt. 1, pp. 52-7, pls. 1-5.

, c, On some fossil forms of Placuna, Rec. Geol. Surv. India v.55, pt.2, pp-119-32, pl. 19.

, 1925 Description of mollusca from Post Eocene Tertiary formations of N.W. India. . . . , Mem. Geol. Surv. India, v.50, pt. 1, 325 pages, 11 pls.

, 1927 A review of Genus Gisortia. . . . ., Pal. Indica, Geol. Surv. India, n.s. v.7, mem.3, 78 pages, 32 pls.

, 1928a, Description of Mollusca from the Post Eocene formations of N.W. India. . . . . . ., Mem. Geol. Surv. India, v.20, pt.2, pp. 351-462, pls. 14-33.

, b, A supplement to the mollusca of the Ranikot Series; Pal. Indica, Geol. Surv. India, n.s.v.10, mem. 4, 75 pages, 9 pls.

* * * * *

DEPOSITION OF PHOSPHATE IN THE HAZARA HIMALAYAS AND THE PRECAMBRIAN GLACIATION

By

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Abstract : *Tanakki Conglomerate in Hazara is located at the base of formation which lies below the phosphate-bearing unit of Cambrian age. Though some diagnostic characteristics of mudflow as well as of aquatic preluvial sediments are evident in some parts of the outcropp but dominant compositional and textural features indicate this unit to be of glacial origin.*

Regional stratigraphic location of Tanakki Congolerate fits well into the global picture when viewed in the context of Late Precambrian glaciation. A broad correlation of Tanakki Conglomerate with Late Precambrian Tillites based on the comparison of dates from other continents and particularly from Tien Shan, China, is proposed.

Considering various views on water cooling effects on the phosphate deposits, it is likely that Late Precambrian glaciation in this region could have contributed, though indirectly, towards deposition of phosphate in Hazara by raising the phosphorous concentration in the sea.

INTRODUCTION

Tanakki Conglomerate in the regional stratigraphic sequence of Hazara Himalayas is located at the base of the formation which lies immediately below the phosphate-bearing unit. It is locally developed and is 20 to 60 ft. thick. It is composed of pale red (5 R 6/2) to greyish red (10 R 4/2), unsorted, subangular to angular pebbles and rare cobbles of slate and phyllite derived from the underlying rocks, all embedded in a silty to sandy matrix. Some conglomeratic beds are strongly compacted and contain lenses of coarse sandstone. The unsorted composition of the Tanakki Conglomerate is attributed to the tillites of glacial origin.

Tillites can be confused easily with "mixtites" that are formed by nonglacial processes such as submarine sliding and mudflows. The distinction between the two rock types becomes rather difficult if tillities had suffered subaqueous mass movement. Thus, some genuine tillites may be misidentified as mudflows and some nonglacial conglomeratic beds as tillites. Nevertheless, characteristics of mixtites favour an origin by mudflow sedimentation in active tectonic environment in contrast to glacial origin.

Road-cut exposure of Tanakki Conglomerate at about 5 miles southwest of Abbottabad near Tanakki village, is a reddish brown heterogeneous mass of different size material composed of silt, mud, pebbles, cobbles and boulders of different rock types. Textural and compositional nature of this outcrop is identical to that of a mudflow rather than of tillite. At an other locality, about 4 miles northeast of Abbottabad, there are two isolated outcrops of Tanakki Conglomerate (See Pl 1 in Bhatti *et al.*, 1972, for location). At the northern outcrop, Tanakki conglomerate is typically hard and compact like a tillite but its lower contact is apparently transitional and grades from silty clay to siltstone.

Krishnan (1953) co-related the Tanakki Conglomerate of Hazara with the Talchir Boulder Bed of the Salt Range (Tobra Formation of Pakistani literature, Shah, 1974) mainly because of their physical resemblance and presence of straited cobbles reflecting a glacial origin.

Gansser (1964, p. 58, 241) had noted the occurrence of striated boulders and tillites from the Balaini Conglomerate in the Kashmir Himalayas, East of Hazara; although, he pointed out that striated boulders can be found in mudflows as well yet he did not question a glacial origin for the Balaini Conglomerate. The Tanakki Conglomerate occupies the same stratigraphic position as the Balaini Conglomerate in the region. Therefore, a glacial origin for the Tanakki Conglomerate was proposed. In view of their common glacial origin, Tanakki Conglomerate and Balaini Conglomerate, were both correlated with the Talchir Boulder Bed of Permain age in the Salt Range and were therefore regarded to be Gondwana components (Wadia, 1957; Surrange, 1966, p. 55). Since the discovery of Cambrian fossils in the Tarnawai Formation (Latif, 1972, p.92), which is higher in the stratigraphic sequence, the Tanakki Conglomerate is believed to represent Late Precambrian glaciation (Latif, 1974, p.1).

The lower contact of the Tanakki Conglomerate is apparently transitional and grades from very low grade metamorphic silty clay to siltstone. At the southern outcrop (Bhatti *et al.*, 1972, pl.1) the lower contact of the Tanakki Conglomerate is faulted. The fault is associated with pseudoconglomerate sediments and does not appear to have effected the younger rocks. Lithologic gradation and structural dislocation suggest that (1) at least lower part of the conglomerate was aquatic, probably a preluvial sediment, and (2) strong tectonic activity might have followed sedimentation of the underlying metasediments of the Hazara Formation. Quite identical inferences have been drawn concerning the Chinese Precambrian tillities of Tien Shan Geosyncline. Bushinskii (1969) described lower part of the tillites to be aquatic in places, whereas a structural dislocation (the Chinning Movement) was noted over the metamorphosed Pre-Sinian sediments in Tien Shan (Chinese Acad. of Geol. Science, 1976, p.7). Comparable aquatic sediments at the base and synchronous tectonic displacement provides reasonable criteria to correlate in time the Tanakki Conglomerate with Late Precambrian tillites of Tien Shan, which has been regarded to be of glacial origin by the Chinese geologists.

In addition to the above, the stratigraphic location of Tanakki Conglomerate fits well into the global picture when viewed in the context of Late Precambrian glaciation.

This global synchroneity of the late Precambrian glaciation assumed by many earlier workers (Harland, 1964; Dunn and others, 1971) has been recently questioned in the light of important data indicating rapid polar shifts (Crawford and Daily, 1971). Deynoux and others (1978) have argued strongly for the diachronism of glaciation. However, additional data and precise dates on the Late Precambrian tillites from Australia and their correlation with the tillites from other continents led Coats and Preiss (1980, p.181) to suggest that, in spite of the variation in absolute dates, an approximate synchronous correlation is possible. Their deduction is based on the indication that same glaciation might have affected very large areas of earth's surface during the Late Proterozoic.

A broad correlation of the Tanakki Conglomerate with the Late Precambrian tillites can be attempted on the basis of dates from other continents and particularly from the Tien Shan, China (Table 1). Therefore it is reasonable to assign the same age of abut 680 m.y. (Sinian) to the Tanakki Conglomerate, similar to the Nantuo tillite of China.

PHOSPHATE OF HAZARA AND THE PRECAMBRIAN GLACIATION

An association of glaciation and phosphogenesis appears to be supported by an apparently close stratigraphic association between tillites and phosphorites. However, this association is more apparent than real, mostly a considerable time interval exists between deposition of the phosphate and the period of glaciation. Notably, this association is consistently seen in the Late Precambrian-Cambrian sections of Tien Shan, China (Bushinskii, 1968), Hazara, Pakistan (Bhatti *et al.*, 1972), Georgina basin, Australia (Cook and McElhinny, 1979) and Volta basin in West Africa (Trompette *et al.*, 1980, p. 64).

Cook and McElhinny (1979) have shown a corresponding temporal relationship between the periods of glaciation and phosphogenesis. This relationship is well pronounced in Late Proterozoic and Phanerozoic, whereas Mesozoic and Cenozoic are almost virtually devoid of glaciation.

It is of interest to mention that a similar correspondance between the periods of phosphogenesis and formation of evaporites is also apparent, although the latter reflects a warm and arid climate contrary to that of glaciation. The difference between these two is that evaporites are syndepositional to phosphorites, whereas tillites are mostly predepositional with an intervening rock unit. Only one exception of a minor occurrence of "Phosphatic tillite" is cited from China by Bushinskii (1969, p.176). This occurrence is of mixtite and its phosphatic content is derived from an earlier deposition. Nevertheless, there does appear to be an empirical relationship between some periods of phosphogenesis and glacial episodes. The cooling of surface waters by glaciation would create an unstable density stratification which invoke the movement of water masses in the ocean. It would indirectly help in developing an upwelling system, which is an essential requisite for the formation of phosphorite. For instance, modern phosphorites are being formed in the areas of oceanic upwellings mainly near equatorial waters and notably away from the polar glacial regions.

The cooling of water is known to increasese the solubility of phosphorous as well (Gardener, 1973). Gulbrandson and Roberson (1973, p.118) give a residence time for phosphorus of 4.9×10^4 years while an average glacial cycle lasts for 10×10^5 years (Cook and McElhinny, 1979, p.324). Hence, a glacial event would enhance concentration and retention of phosphorus for a longer time interval. This would help create a deep oceanic phosphorus depository but cold waters would inhibit its precipitation and deposition as sediments. Burnett (1977, p.813) has shown that Pleistocene phosphorites of Peru and Southern Chile have radiometric ages which correspond with the integlacial periods when the waters were warm. Thus, phosphate deposition did not take place during the glacial periods when the waters were cold.

Purdue and Miser (1916) expressed a contrary view that, at the time when the Permian Phosphoria phosphorite formed, the glacial conditions favoured retention of calcium carbonate in the sea water and permitted calcium phosphate to settle as sediments. Mansfield (1918) also thought that cold water had retarded the action of bacteria that helped in the formation of aragonite oolites which were later phosphatized.

This study is related to Late Precambrian-Cambrian glaciation which poses two major problems. The first is the extent of the glaciation, and the second is the recognition of genuine tillites of glacial origin.

The result of recent paleomagnetic work on rocks associated with Precambrian tillites shows that those were formed near the paleoequator of that time; this contrasts wih the Permo-Carboniferous and Pleistocene glaciations that had occurred near polar regions (Harland, 1964; Piper, 1972).

Paleomagnetic results obtained by McElhinny and others (1974, p.557) indicate that every large polar shifts took places across almost all continents during the Late Precambrian. This led them to conclude that the poles migrated rapidly over different parts of the globe leaving records of glaciation over various continents. They also made an observation that between 700 m.y. and 600 m.y., a polar migration of at least 180^{o} took place with respect to Godwanaland, the Late Precambrian glacial episode. If this is true such an event is likely to have contributed in raising the phosphorous concentation of the Late Precambrian sea in Hazara and could have affected, though indirectly, the deposition of phosphate in this region.

* * * * *

Table 1.--A generalized correlation of Tanakki Conglomerate with Late Precambrian tillites

Hazara Pakistan	Kashmir Himalaya	Volta Basin West Africa	Tien Shan China	Soviet Tien Shan	Georgina Basin Australia
Tanakki	Balaini	Numee	Nantuo	"tillite"	Yardida
Conglomerate	Boulder Bed	Tillite	Tillite	Precambrain	Tillite
Precambrian		630-720 M.Y.	630 M.Y.	Lower Cambrian	670 M.Y.

Sources: Rushton (1973) for Pakistan; Trompette and others (1980) for Africa; Chinese Academy of Science (1976) for Tien Shan, China; Bushinskii (1969) for Soviet Tien Shan; and Coats and Preiss (1980) for Australia.

21b

GEOTHERMAL RESOURCES AND POSSIBILITY OF THEIR DEVELOPMENT IN PAKISTAN

By

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Abstract : *The paper discusses exploitation potential of geothermal sources of energy. Describing various types of sources, comments are made on Pakistan's status in this connection.*

INTRODUCTION

The term "geothermal resources" denotes largely heat energy of the earth. This heat is derived from two sources: one–heat generated by the radioactive decay of minerals of Uranium, Thorium, Potassium etc., and two–heat emanating from the magmatic bodies lodged in the upper part of the mantle or lower part of crust.

Dr. Donald E. White of the U.S. Geological Survey has calculated that 3×10^{26} calories of heat (equivalent to 2000 times the heat potential of coal produce of the earth) is stored in the Earth. This heat is largely diffused throughout the crust and hence is not recoverable economically at present.

Distribution of temperature is not precisely known but some estimates in this regard are available. At a depth of 25-50 km i.e. at the base of continental crust, temperature ranges from 1000°C to 1200°C. However the temperatures existing in magma chambers are of main interest as far as exploitable geothermal energy is concerned.

GEOTHERMAL SYSTEMS

The crustal plate margins are the zones where molten material is either added from the mantle (spreading ridges) or where the crustal material is being dragged underneath the other plate and is being consumed in the mantle (subduction zone). in either case, molten material is generated which surges upward into the crust. These rising bodies of molten material provide necessary heat. The molten material is the so called magma which consists of silicates with gasses and water. Volatiles accumulate in the upper part of the consolidating magma and ascend upward through joints and fissures in the crustal rocks.

If the circulating ground water penetrates deep enough, it will be heated by conduction from magma and by the latent heat of the ascending volatiles, the hot water will moves upward. The water thus serves as a medium to transfer heat energy from deep magmatic source to shallow enough depths where it can be recovered by drilling.

If there is no confining bed over the aquifer, the water gets dissipated. However, if there is an impermeable rock overlying the aquifer, the hot water is stored constituting an exploitable geothermal reservoir.

The dominent types of geothermal systems are water dominated or wet steam geothermal system e.g. Otake-Hatchobaru field of Japan, Weirakei field of New Zealand, Sierro Prieto of Mexico etc., and vapour dominated or dry steam geothermal fields e.g. Geysers of U.S.A., Larderello of Italy and Matsukawa of Japan. The water dominated systems are far moe common than vapour dominated systems.

GEOLOGICAL ENVIRONMENTS OF GEOTHERMAL FIELDS

Types of geothermal fields which are being exploited in the world of present are confined to following geologic environments.

1. Along spreading ridges where new materials is being added to the crust and plates are moving apart, Njama fall geothermal field of Iceland is one such field which is located on the Mid-Atlantic ridge.

2. Another type of field is one which is located above a subduction zone, i.e., where one plate plunges underneath another plate and consequently part of it is consumed in the mantle thus giving rise to molten material. Included in this type of geothermal fields are Otake and Hatchobaro of Japan, and Wairakei of New Zealdnd.

3. Geothermal fields associated with the areas of high heat flow e.g. the mountaineous belt extending from Italy to Caucasus through Turkey.

4. Geothermal field associated with inter-plate melting anomalies. Hawaii islands are an example in which case volcanic activity is taking place within the Pacific Plate. Some geothermal fields are associated with grabens and rift valleys e.g. geothermal fields of Kenya and Ethiopia which owe their origin to Afar Ridge, constitute another geologic environment suitable for the existence of a geothermal field.

5. Geopressurised zones are one kind of unexploited reservoirs of geothermal energy. Main example of this field is Gulf of Mexico where gothermal fluids exist under high pressure with dissolved methane. However, this type of fields are under study and will become exploitable only when technology develops to a level where utilization of geopressurized zones becomes economical.

6. Hot dry rock aquifer is another type of geothermal source that can be developed in future. In this case, heat reaches impermeable rocks, heats them up and is stored. By artificial means permeability is created in the rocks. This is achieved by drilling holes up to hot zone and blasting the hot dry rock. Later water is pumped down, where it gets heated and is eventually recovered. The main experiment in this regard is being carried out in Los Alamos U.S.A. So far this is only a future possiblity.

GEOTHERMAL EXPLORATION AND USES

Geothermal exploration includes determination of probable areas of interest based on geologic environments, surface manifestations, geochemical and radioisotope studies, hydrothermal alteration studies, structural and hydrogeologic studies of a given area, followed by geophysical work and exploratory drill holes. These steps help evaluate quality and quantity of the geothermal resources. This is followed by the development stage which includes drilling of geothermal wells and installation of power plants etc.

The uses of geothermal resources are divided broadly into Electric and Non-Electric types. As implied by the name, electric use includes generation of electricity from water-steam mixture/steam. Steam is fed to inlets of turbine which turns the generator and produces electricity. Non-electric uses are diverse, ranging from fish farming, district heating, green-house effect, bathing to industrial uses.

POSSIBLITY OF GEOTHERMAL RESOURCES IN PAKISTAN

Presence of geothermal resources is dependent upon geologic environments and is indicated by surface manifestations most often. Keeping in view these factors, three broad prospective areas for geothermal resource can be expected in Pakistan.

a) Northern Areas of Pakistan

The main control of likely geothermal activity in this region is the plate boundary between Indo-Pak Plate to the South and Eurasian Plate to the North. Subduction zone caused by undertrusting of Indo-Pak Plate below Eurasian Plate could be the case of geothermal activity as evidenced by thermal springs in Gilgit, Hunza and many other place. Thermal springs also occur in Skardu, and Yasin valleys.

It may be mentioned here that India has developed geothermal energy in Fuga Valley, Northern India. The subduction zone in Fuga Valley continues westward extending into Pakistan, hence it may be said that there is a possibility of finding geothermal resource in northern parts of Pakistan. Moreover, surface manifestations also lend weight to this possibility.

b) South-Western Parts of Pakistan

Another suitable geologic environment for geothermal resource may exist in Chagai, Baluchistan. Koh-i-Sultan an other subsidiary volcanic cones emerged as a result of upsurge of molten material produced by anatactic melting of Arabian Plate after having been thrusted underneath the Eurasian Plate. Geothermal activity in the world is known to be closely linked with volcanicity. It is probable that some geothermal field may be located in and around this volcanic area.

c) Other Areas

The other areas of concentration of geothermal manifestations are Dadu district, Manghopir area of Karachi, some parts of Punjab and Azad Kashmir may also be of interest.

CONCLUSIONS

As discussed above, there is a good possibility of finding geothermal resource in our country. This could help us with our growing energy needs. Since this source of energy is rather a new comer, very little, if at all, attention has been paid to this burgeoning field of energy. A modest programme has been commensed by the Geological Survey of Pakistan to undertake studies in this important field. Geochemical studies of water samples collected from thermal springs in Northern Pakistan were analysed and interpreted during the author's participation in the International Post-Graduate Training Programme held in Pisa, Italy, in 1982. Since report on the said work is under publication, it may be mentioned that results of the study are encouraging.

In view of the preceding discussion, it is imperative that a comprehensive plan may be prepared to explore geothermal resources of the country and systematic study may be undertaken, preferably in collaboration with experts from countries like U.S.A. and Japan where this source is being successfully utilised since long.

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GEOLOGY AND PETROLOGY OF THE SHANGLA BLUESCHIST ZONE, SWAT HIMALAYAS, N.W.F.P., PAKISTAN

By

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Abstract : *Based on detailed mapping of the Shangla zone, Swat, petrographic description is given of various lithologic units. Major and trace element analyses are reported of blueschist rocks alongwith discussion on their petrotectonic importance.*

INTRODUCTION :

The Shangla area is a part of Alpurai subdivision of Swat district, N.W.F.P. and lies between long 70^{O} 34'5" E to 72^{O} 40' 0" E and Lat 35^{O} 50' 30" N to 35^{O} 54' 10" N, covered in the 1 : 50,000 Survey of Pakistan toposheet No. 43 B/9. The area lies on the margin of a regional overthust fault, which is south-western continuation of the Patan fault (Desio, 1977), recently renamed as the Main Mantle Thrust (MMT). It is believed to mark trace of subduction plane of the Indo-pak plate.

For regional geology and structure of the Swat area, we owe fundamentally to the poineer work of Martin *et al.* (1962) which had opened gateway to researches in the Swat Himalayas. According to these workers, lithologies towards South of the MMT are composed of Palaeozoic metasedimentary rocks and their amphibolite horizons, belonging to Lower Swat-Buner Schistose Group. Towards North of the MMT, outcrops complex of the socalled Upper Swat Hornblendic Group which is the southwestern continuation of the Upper Indus Ophiolite Belt (Shams, 1975). Beyond northern limits of the ophiolite belt, another tectonic megashear occurs as a continuation from the Karakorum and therefore called the Main Karakorum Thrust (MKT). In between the two thrusts, the region is recognised as a section of a fossil island arc, as the so called Kohistan Island Arc, or the Kohistan zone (Desio, 1979).

Following regional reconnaissance work of Martin *et al.* (1962), the senior author, besides others, undertook detailed studies of specfic geological phenomena that were operative during the petro-tectonic evolution of the Swat Himalayas. The 1971 field season had brought fruit when blueschist rocks were discovered near Topsin (Shams, 1972), soon followed by another discovery near Shangla in the East (Desio, 1977). Later claims of blueschist occurrences at Babusar (Tahirkheli, 1979) and Dir (Jan, 1982) were not supported by field or laboratory description of the material, if present. Nevertheless, the MMT being a major tectonic suture line of the Himalayas, blueschists could develop anywhere along this petrotectonic belt.

On the other hand discovery of blueschists in the Indian Himalayas came a few years later (Virdi *et al.* 1977). These discoveries not only negated the claim that blueschist rocks do not occur anywhere in the Himalayas (Powell *et al.* 1973) but also provided basis for the application of concepts of plate tectonics (Desio, 1977, Bard *et. al.*, 1979, Windley *et al.*, 1979).

The early publication by Shams (1972) was followed by description of mineralogy (Shams *et al.*, 1980), age data and tectonic importance of blueschist rocks (Desio and Shams, 1981). The present study was carried out during the summer of 1980 and was aimed at petrographic study of the Shangla blueschist area on the basis of mapping on 5" to 1 Mile scale (Fig. 1) and some petrochemical work.

MAPPABLE LITHOLOGIC UNITS OF THE AREA

1. Serpentinites

Serpentinites make an alongated body extending in the NNE-SSW direction breaking into discontinuous smaller outcrops and ending southwards as a sheared mass within phyllites. The rock is massive with recognisable crystals of olivine (5-35%) and pyroxene (3-63%) in a thin groundmass of serpentine minerals. The latter are composed of subparallel and sheaf-like aggregates of antigorite (20-84%) and fibres and veinlets of crysotile (4-17%). Typical mesh texture is visible. Hornblende is present as an alteration product of pyroxene alongwith rare chlorite. Magnesite (1.5-22.5%) occurs as fine-grained aggreates while fibrous talc (6-60%) is ubiquitous. Chromite (-12%) occurs as tiny grains with brown to black thin edges while magnetite and its alteration products, hematite and limonite, are occasionally present. Locally, such as near Bar Kotki, chromite had concentrated into lens-shaped aggregates in serpentinite. Traces of Nickel and Cobalt have been reported from these rocks.

2. Talc-Carbonate Rock and Talc Schist

These rocks, varying from whitish to brownish grey in colour are intimately associated with serpentinites as marginal zones. Talc-carbonate rock makes main outcrop East of Alpuria while talc schists make relatively thin body passing into broken portions of the serpentinite in the central part of the mapped area. Mineral compositions of the two rock types are comparable except for their relative proportions. Major minerals being talc (30-88%), carbonate (24-52%), quartz (8-56%), plagioclase (up to 6%), antigorite (2.5-9%), muscovite and fuchsite, hematite and limonite occur mainly in the talc schist.

Emerald is mined from talc schist in the vicinity of the area.

3. Spilites-Keratophyres

These rocks were located during mapping for the first time, occuring in intimate association with serpentinite bodies in the central and north-western parts of the area. In the NW corner of the mapped area, isolated small bodies and blocks are seen in a melange-type association with phyllite, green schist, serpentinite, talc schist and glaucophane schist, extending towards margional amphibolite zone of the Upper Swat Hornblendic Group in the N and NW, separated by the MMT. With a greenish grey, bluish grey to dark grey colour, the rocks show vesicular structure while effects of albitization are prominently seen in thin sections. Prominent minerals consist of sodic plagioclase (An 8-20, 10-63%) with abdundant mica and epidote inclusions, free epidote (10-46%) making granular aggregates and columner crystals, actionalitic to glaucophanitic amphibole (7-58%) as acicular to prismatic crystals, chlorite (5-49%) as flakes and fine scaly aggregates, subhedral pyroxene crystals (15-40%), carbonate (5-15%), muscovite and biotite flakes (3-40%), secondary serpentine and talc (7-12%) with quartz (3-10%) sphene (5-15%), hematite and magnetite (together 1-3%).

4. Greenschists

These rocks occur mostly in the south-western part of the mapped area, with minor occurrences in the NW. These are fine to medium-grained schistose rocks with light green to dull greyish green colour, composed of quartz (9032%), chlorite (36-88%) plagioclase (7-16%), epidote (5-14%), actinolite (5%), muscovite (2-5%), biotite (tr-2%) and sericite (4-15%). Hematite, pyrite and Fe-Ti ores together make 3-4% of the rocks.

A variety of greenschists is of pelitic origin, showing alternations with blueschists.

5. Blueschists

These rocks occur mostly in the NW part of the mapped area. of Shangla, and make atleast four types of rock associations.

i) **Phyllitic schist association**: It occurs in the southern margin of the blueschist rocks with transitional zones composed of plagicoclase--quartz bands alternating with chlorite-actinolite layers. In the southern extermity, aragonite-calcite make up to 30% of the transitional schists.

ii) **Greenschist association**: In this case, blueschists show alternations with greenschists. The latter are brownish green to greyish green, containing chlorite, epidote and actinolite and locally euhedral pyrite crystals. Porphyroblasts of sodic plagioclase make prominent white spots on the rock.

iii) **Piedmontite schist association**: In this case, the blueschists alternate with purple coloured piedmontite schist, as near Shangla check-post.

iv) **Spilite-Keratophyre association**: This association occurs W and NW of Shangla and W of Shangla police post. The blueschist shows greenish-grey to bluish-grey colour related to volcanic rocks of the area.

6. Phyllitic Schist

The rocks occupy N-S central part of the mapped area, and provide base to the serpentinite and spilite keratophyre intrusions and showing close association with greenschists and blueschists. These are mostly schistose rocks, of light grey to light brown colour and with silky shine on foliation planes. Occasionally, massive looking phyllites are present, such as near Kotkai, these contain considerable graphite. Lithologically, the phyllites vary between argillaceous, calcareous and carbonaceous varieties as is shown by their mineral compositions. No attempt was made to map these sub-types separately both in view of the scale of mapping and also due to their generally gradational relation. The overall mineralogy consists of quartz (30-70%), sideritic carbonate (12-45%), plagioclase (4-32%), muscovite and biotite (together 1-22%), chlorite (3-10%), graphite (5-10%), epidote (3-5%), hornblende (7-10%) sphene (1-4%), and pyrite, hematite and magnetite (together 3-8%). The calcic minerals are found mostly in calcareous varieties of the phyllitic schist unit.

7. MIXED ZONE ROCKS

This unit occupies major part of eastern half of the mapped area and is composed of alternating marbles, amphibolites and garnet mica schists that constitute a metasedimentary formations; various lithotypes could not be represented separately on the scale of the map adopted although are described individually herewith. Field observations show these rocks as progressively higher grade equivalents of the phyllitic schist towards the Choga granitic gneiss sheet in the East.

i) Garnet Mica Schists

The rocks succeed phyllitic schist indicating progressive increase in the metamorphic grade eastwards without significant development of biotite grade rocks.

The primary mineralogy of rocks consists of quartz (55-60%), muscovite (9-12%), straw yellow to yellowish brown biotite (1-3%), graphite (3-5%), magnetite (up to 4%) and traces of sphene. Garnet (8-25%) shows rotational texture, is full of quartz and mica inclusions and is altered to chlorite and ore. It reaches up to 2.5 cm in diameter in schists in the northern part of the area. In the South, rare staurolite (up to 10%) with helicytic quartz inclusions marks higher metamorphic grade.

ii) Amphibolites

This rock makes thick beds alternating with marble. Towards North, garnet is common while it is rare in the South. Mineral composition of the amphibolites consists of hornblende (50-60%), actinolite (up to 5%), quartz (12-16%), plagioclase (10-16%), epidote 2-10%), relic pyroxene (5-10%). Garnet makes up to 12% of the rock and is common to northern parts of the area. Sphene (2-4%), biotite (1-3%) and ore grains (1-3%) are sporadically distributed.

iii) Marble

Alternating with amphibolites and having psamitic to pelitic layers, marbles occur as beds up to many hundred ms thick. Locally, pyrite-rich layers are present. Milk white variety is present at some places, such as near Alpurai. Average mineralogy consists of calcite crystals (90-94%), muscovite flakes (2-4%) and quartz grains (4-6%), although local modal variations have wide range and pyrite may be locally abundant.

DESCRIPTION OF THE BLUESCHIST ZONE

As seen on the Map (Fig. 1) the blueschist body is wedge-shaped, thicker in Mangarkot, Shangla and Topsin areas and thinner towards W. As described already, four groups of rocks are associated in the blueschist zone while the latter can be further divided on the basis of mineral paragenses. Table I gives average mineral composition of various types of blueschist rocks.

Table 1. Average mineral compositons of various types of blueschists

Minerals :	I		II		III	IV	V	VI	
1. Glaucophane	43.5	34.5	25.5	40.5	30.5	25.3	20.2	25.3	56.1
2. plagioclase	10.5	10.3	1.6	1.3	10.7	30.5	10.3	36.4	14.1
3. Quartz	–	3.0	28.4	1.2	53.4	–	–	2.3	1.5
4. Epidote	34.5	25.2	27.0	31.5	3.3	5.7	62.4	15.2	8.2
5. Chlorite	4.5	10.4	8.8	3.2	–	–	2.4	18.3	6.3
6. Actinolite	–	–	–	–	–	–	–	–	–
7. Muscovite	–	7.4	–	13.3	2.1	38.5	2.2	–	10.3
8. Sphene	6.4	4.2	3.4	2.5	–	–	1.5	2.5	3.5
9. Carbonate	–	4.5	4.3	–	–	–	–	–	–
10. Ores	0.6	0.5	0.5	1.1	–	–	–	–	–
11. Pyroxene	–	–	–	2.2	–	–	–	–	–
12. Graphite	–	–	0.5	3.2	–	–	–	–	–

CHEMISTRY OF THE BLUESCHISTS

Table 2 gives whole rock analyses of blueschist rocks from Shangla zone. The recast analyses are plotted in triangle (Fig. 2) with areas of plots of world occurrences from literature. Typical petrochemical nature of the Swat blueschists is supported, showing also the abnormal sodic nature of some of the rocks. The enhanced soda activity in the latter case has been commented upon already (Shams, 1979).

TABLE 2

CHEMICAL ANALYSES OF GLAUCOPHANE SCHISTS AND ITS ASSOCIATED ROCKS ALONG WITH TRACE ELEMENT DATA

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SiO_2	43.20	43.76	48.81	46.37	45.36	46.44	48.14	50.05	50.07	51.28	68.33	65.61	40.83	40.07	38.22
TiO_2	0.92	0.88	0.82	0.96	0.68	0.84	0.92	1.24	0.18	0.20	0.24	0.24	X	X	0.08
Al_2O_3	16.33	18.21	16.26	17.28	18.09	13.01	17.02	19.09	20.32	24.17	16.34	19.73	0.60	0.52	9.93
Fe_2O_3	9.52	5.21	9.26	7.92	8.17	9.36	2.50	3.96	5.25	4.42	2.32	1.37	3.74	5.22	3.10
FeO	6.26	6.70	3.89	6.48	4.46	8.98	7.20	6.34	5.18	3.67	2.52	2.81	5.18	1.15	9.36
MnO	0.32	0.52	0.42	0.34	0.34	0.36	0.24	0.22	0.18	0.18	0.28	0.18	0.18	0.10	0.32
MgO	6.01	8.78	4.66	5.82	6.14	5.82	10.68	8.63	7.64	5.14	1.98	2.50	43.40	36.04	30.96
CaO	10.04	9.67	8.74	8.39	9.97	8.98	4.33	3.03	3.48	1.43	1.69	1.44	1.48	7.75	1.45
Na_2O	2.56	2.28	2.50	2.00	2.48	2.68	4.20	4.20	5.20	2.37	2.40	3.45	1.80	1.12	1.52
K_2O	1.61	1.61	1.40	1.40	1.70	0.12	0.67	0.85	1.60	6.00	1.70	0.60	X	0.07	0.07
P_2O_5	0.18	0.12	0.18	0.16	0.08	0.28	0.10	0.12	0.12	0.16	0.12	0.10	0.08	0.08	0.12
CO_2	0.69	2.13	1.03	0.52	0.44	1.72	0.07	0.08	0.12	0.21	0.44	0.02	0.12	0.21	0.02
Cr_2O_3	X	X	X	X	X	X	X	X	X	X	X	X	0.13	0.10	0.05
H_2O+	1.85	1.71	1.69	1.75	1.61	1.14	3.96	2.38	0.69	0.88	1.02	1.85	2.61	7.27	4.25
Total : :	99.49	99.58	99.68	99.39	99.56	99.53	100.03	100.09	100.03	100.09	99.38	99.90	100.15	99.70	99.45
Cu	75	55	115	120	60	90	110	70	38	115	25	48	48	43	20
Ni	130	95	90	105	105	115	85	90	160	130	75	77	2125	1875	115
Co	70	70	63	95	75	75	55	75	55	50	20	35	125	120	75
Zn	188	100	175	175	125	125	150	100	100	150	75	125	75	62	125

1–16 —— Analyst. Shafeeq Ahmad. (1–5; glaucophane Schists, 6–8; green Schists. 9–10; Volcanics, 11–12; Phyllites 13–15, Serpentinites).

ORIGIN OF THE BLUESCHISTS

The variety of rock association and the diversity of mineral parageneses shows that the blueschist rocks of the area might have originated by more than a single process. Nearness of the subduction zone of the Indo-Pak shield, marked by the Patan Fault or the Main Mantle Thrust, is a notable geotectonic environment. At the same time, occurrence of serpentinite body and of spilite-keratophyre bearing melange zone are important lithologic environments. Parent lithologies are basic igneous, calcareous as well as argillaceous, having essential mineral paragenesis of greenschist facies:

i) Basic igneous : albite-epidote-chlorite-muscovite-glaucophane.

ii) Calcareous : calcite-epidote-chlorite-glaucophane.

iii) Agrillaceous: quartz-albite-muscovite-chlorite-glaucophane.

The low to moderate temperature and high water vapour pressure were responsible for formation of the particular mineralogy. The activity of soda solutions, issuing both from spilitic magma as well as from serpentinized ultramafics were responsible for convergence of petrochemical conditions of diverse lithologies to those produced by simple recrystallization under tectonic transport. Detailed studies are in hand to arrive at specific conclusions regarding relative importance of various processes and their interactions.

No comparable studies are available from any other part of Pakistan, although claims of occurrences of blueschists from Babusar (Tahirkheli, 1979) and from Dir (Jan, 1982) have been made; curiously, those claims even lack minumum field and laboratory description of blueschists, if sampled at all.

Provious studies from Topsin area (Shams, 1972, 1979: Shams *et al*, 1980) have shown that at least one variety of glaucophane schists had developed from doleritic material intrusive into pelitic schists. The latter, like the metasediments of the Shangla zone, belong to the Lower Swat-Buner Schistose Group (Martin *et al.*, 1962) of Paleozonic age. On the other hand, age of the Topsin blueschist has been found to be 85 $\pm$ 1.7 m.y. (Shams, *et al.*, 1980) giving a northwards drifting rate of 10.7 cm/year of the Indo-Pak plate. It may be intersting to know ages of the dolerite intrusion and the spilite-keratophyres of the Shangla zone in order to further refine plate-tectonic evolution of the Swat Himalayas. Whether or not this magmatism is comparable to the Permain Panjal volcanism in Kashmir Himalayas is an important question to check upon. Another question that awaits answer is the role of melange tectonics in view of rather local but elongated outcrop of the blueschists, comformable to the southwards extending shear zone.

REFERENCES

Bard J.P. Maluski, H., Matte, Ph. and Proust, F. 1979 The Kohistan Sequence: crust and mantle of an obducted island arc., Proc. Intern. Commit. Geodynamics, Grp. 6, Mtg. Peshawar, Geol. Bull. Univ. Peshawar, 13, 87-94.

Desio, A. 1974 Geological reconnaissance in the Middle Indus Valley between Chilas and Besham Qila, Pakistan. Bull. Soc.Geol.Ital., 9, 345-368.

Desio, A. 1977 The occurrence of Blueschists between the middle Indus and the Swat Valleys as an evidence of subduction (North Pakistan). Rend. Accad. Naz. Lincei, Roma, 62, 1-9.

Desio, A. 1979 Geologic evolution of the Karakorum in Geodynamics of Pakistan (Farah and DeJong, Ed), Quetta, 111-124.

Desio A. and Shams, F.A. 1980 The age of the blueschists and the Indus-Kohistan Suture Line, NW. Pakistan. Rend Acc. Naz. Lincei, 68, 74-79.

Martin, N.R. Siddiqui, F.A. and King, B. 1962. A geological reconnaissance of the region between the Lower Swat and Indus rivers of Pakistan. Geol. Bull. Punjab Univ., 2,1-15.

Powell, Mct. C. and Conaghan, P.J. 1973 Plate tectonics and the Himalayas, Earth Planet. Sci. Lett., 20, 1-12.

Shams, F.A. 1975 Petrology of the Thak Valley Igneous complex, Gilgit Agency, Northern Pakistan. Proc. Accad Naz. Lincei, Rome, 59, 453-464.

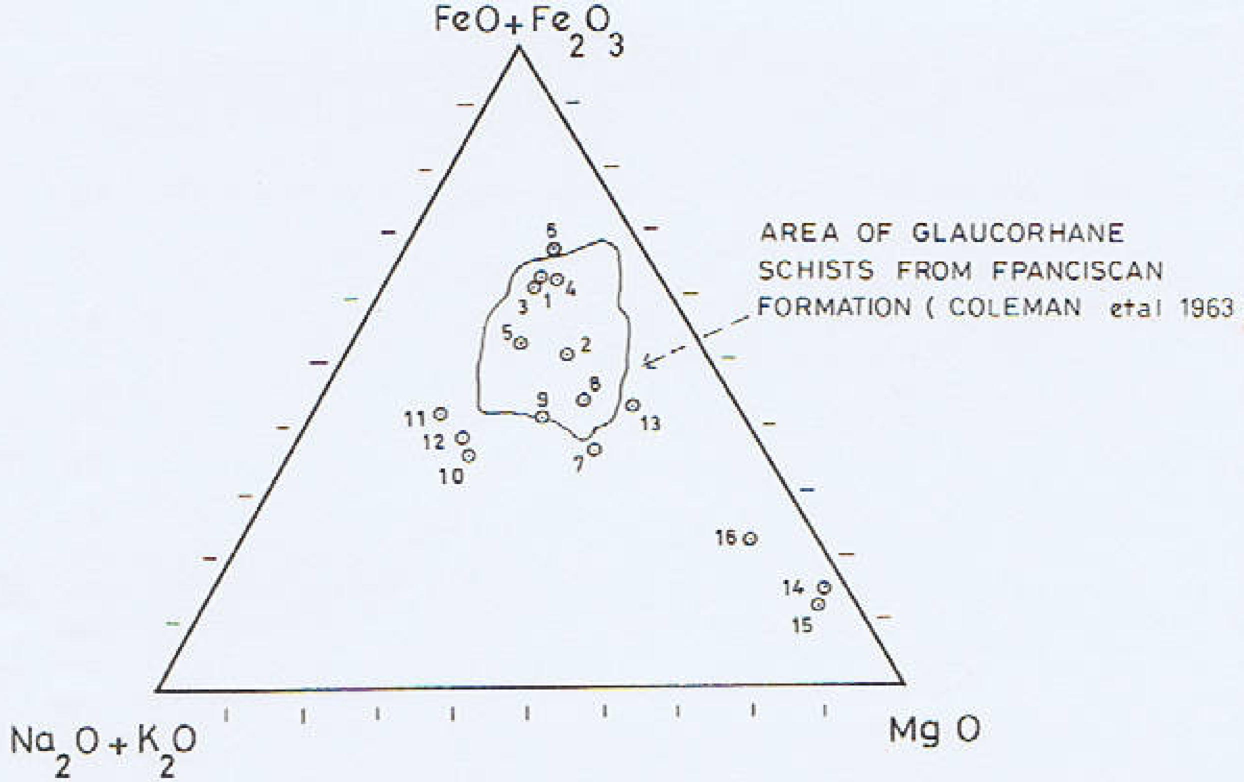
Shams, F.A. 1972 Glaucophane-bearing rocks from near Topsin, Swat First record from Pakistan. Pakistan J. Sci. Res., 24, 343-345.

Shams, F.A. 1979. Origin of the Shangla blueschists, Swat Himalayas, Pakistan. Geol. Bull. Peshawar Univ, 13, 67-70.

Shams, F.A., D.R.C. Kampe, and C.J. Jones, 1980 Mineralogy of the blueschists of Swat Himalayas, Pakistan., Min . Mag., 44.

Tahirkheli, R.A.K. 1979. Geology of Kohistan and adjoining Eurasian and Indo-Pakistan continents, Pakistan., Geol. Bull. Peshawar Univ. 11,1-30.

Virdi, N.S. Thakur, V.C. and Kumar, S. 1977, Blueschist facies metamorphism from the Indus Suture Zone of Ladakh and its significance. Him. Geol., 7. 479-82


FeO+Fe2O3
AREA OF GLAUCORHANE
SCHISTS FROM FPANCISCAN
FORMATION (COLEMAN etal 1963)
Na2O+K2O
Mg O
1
2
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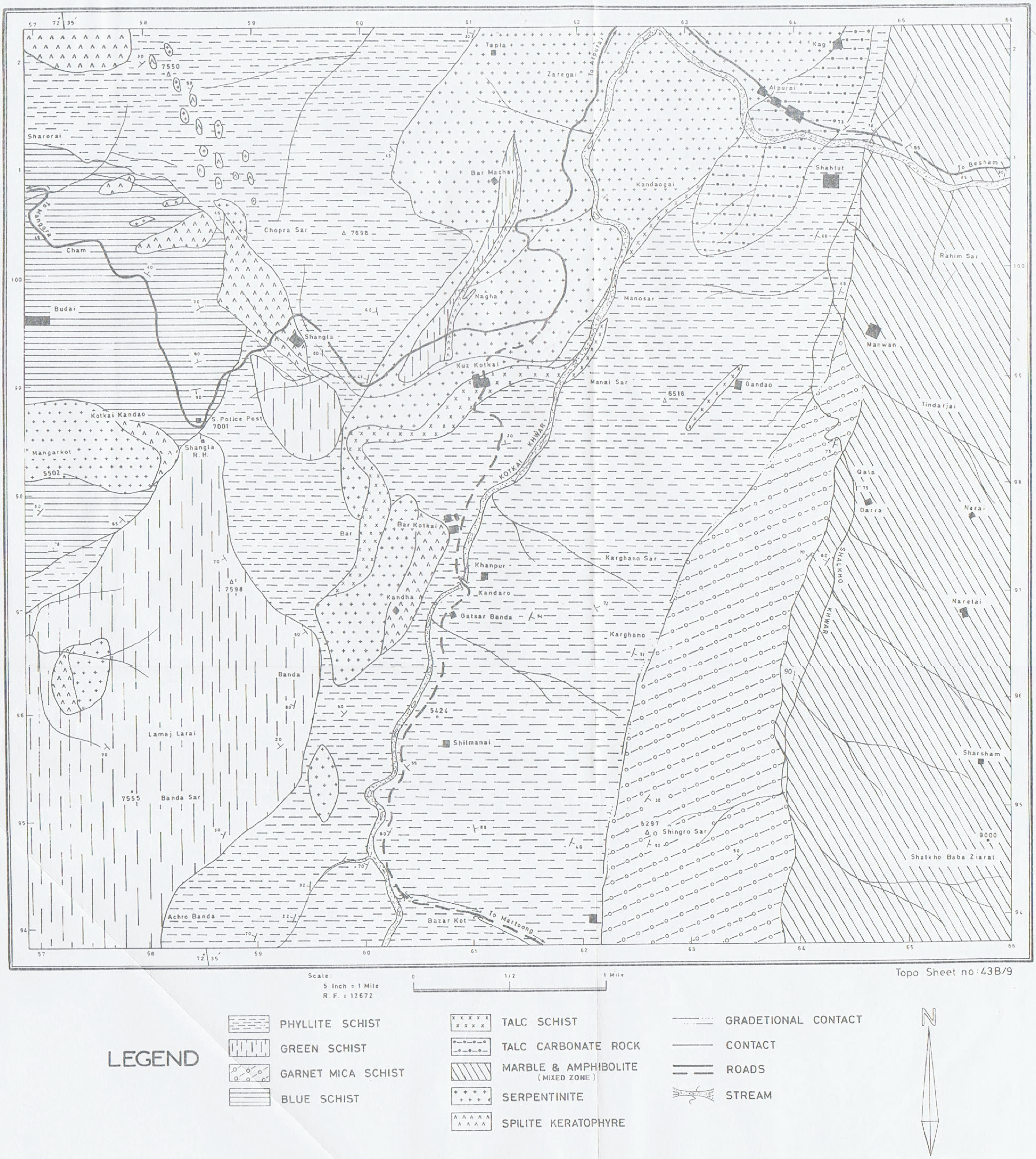

GEOLOGICAL MAP OF THE SHANGLA PAR AREA, DISTRICT SWAT

PAKISTAN

STRATIGRAPHY OF THE SURGHAR RANGE

By

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Abstract : *Sedimentary rocks of marine and non-marine origin ranging in age from Permian to Pliocene constitute most of the stratigraphic sequence in the Surghar Range. The sequence comprises 10 lithostratigraphic units with a commulative thickness of more than 5,000 meters. The lithologies consist predominantly of limestone, shale and sandstone with subordinate marl, dolomite and minor interformational conglomerates.*

Permian-Triassic boundary is marked by a slight lithological break indicating a paraconformity. Cretaceous-Paleocene and Eocene-Miocene sequences are also intervened by unconformities.

INTRODUCTION

Surghar Range is part of Trans-Indus mountains. It is bounded by the river Indus in the East and the Kurram river on the southern side, while it merges into Shinghar Range towards northern and northeastern sides.

The paper is based on field investigations carried out by the author in the Surghar Range regarding its stratigraphy.

PERMIAN

Zaluch Group :--

The Zaluch Group is partially developed in the Surghar Range around Landa Pusha and Narmian Nalas where it is represented by Wargal Formation and Chhidru Formation.

Wargal Formation :

The Wargal Formation is light grey to medium grey with chert nodules randomly occuring in the upper part. It is fine textured and medium to thick bedded.

Base of the formation is not exposed anywhere in the Surghar Range. Its upper contact with the Chhidru Formation is trasitional.

The formation contains abundant brachiopods with sponges, bryozoans, corals, bivalvas, gastropods, nautiloids, commonoids, trilobites and crinoids.

The age of the formation on the basis of fauna is considered to be Late Permian.

Chhidru Formation

The Chhidru Formation is comprised of limestone, sandstone, shale and marl.

The basal part of this formation is soft sandy shale which is pale grey to dark grey and thinly bedded. It is followed by alternating beds of shale and limestone. The top 2 meters thick corresponding to white sandstone unit (Kummel and Teichert, 1965) consists of white to yellowsih, carlcareous sandstone of fine to medium texture and thin medium bedded. It contains angular to subangular quartz grains, cemented in calcitic matrix with little feldspar.

The Chhidru Formation conformably overlies the Wargal Formation. Its upper contact with Mianwali Formation at Landa Pusha Nala indicates a slight lithological break (paraconformity), where the top of Chhidru Formation is marked by a 10 cm thick highly arenaceous grey and slightly yellowish limestone having big lateritic encrustation of rusty brown colour.

The fauna of this formation consists of abundant brachiopods with bivalves, gestropods, corals, bryozoans, crinoids, nautiloids, ammonoids and some conodonts. The fauna indicates Late Permian age for this formation.

TRIASSIC

Mianwali Formation :

The Mianwali Formation is well exposed in the area. It is divisible into Kathwai, Mittiwali and Narmia Members.

Thickness of Mianwali Formation is measured to be 108 meters in the area.

The lower contact of Mianwali Formation with the underlying Chhidru Formation of Permian age is marked by a para-conformity, equivalent in magnitude to atleast one stratigraphic stage.

The upper contact with the overlying Tredian Formation is conformable. It is marked by a coquinoidal or pissolitic limestone beds.

The fauna indicates Early Triassic age for this Formation.

Kathwai Member : The Kathwai Member in Landa Pusha, consists of shale and limestone. The shale is mainly greyish black to dark grey, weathers rusty brown and at places grey, fine to medium grained, very thickly bedded with coal lenticles or layers developed at places, highly fissile and weathered.

The limestone is grey, weathers to yellowish brown, at places prominant brown patches on weathered surface, very fine grained, rather pure, thinly bedded, jointed, rarely fossilferous and oyster-bearing, fossils recrystallised, poorly preserved and are unextractable.

In the adjoining Narmia Nala, this member contains dolomite also. The dolomite unit is 75 cm thick, It is pinkish brown with subhedral to anhedral grains, finely crystalline, calcite recrystalised, cquartz makes up about 5 – 10% of the whole mass, hard and jointed. It is highly fossiliferous. The fossils are recrystallised and dolomitised comprised of mainly brachiopods and shell fragments of other fossile.

Thickness of this member is 2-3 meters in the area. The member contains ammonites alongwith conodonts, fish teeth and a rich palynological assemblage (Kummel and Teichert, 1970).

Mittiwali Member : The Mittiwali Member is comprised of coquinodil limestone at the base followed by a thick sequence of shale, limestone, sandstone and a little dolomite. The coquinodal limestone is grey and medium bedded. The shale is greenish grey, weathers to greenish black or olive green, fine grained, mainly silty, thin to very thin bedded, micaceous, fissile with gypsum developed at places.

The limestone is argillaceous and marly, grey to dark grey, weathers to earthy brown or earthy grey with distinct brownish patches developed all over the weathered surface.

It is fine to medium grained, thin to medium bedded with furruginous thin partings or layers developed along bedding planes. The sandstone is grey to white, brown mineral grains are very commonly distributed among the quartz grains.

Thickness of this member is measured to be almost 100 meters in the area.

The fauna of this member includes ammonoide and little bivalves.

Narmia Member : The lower part of Narmia Member consists of shale, siltstone and sandstone. The shale is greyish black to olive green, weathers to dark grey and olive grey, fine to medium grained, thinly bedded highly folded usually in the form of small folds beautifylly exposed, at places disturbed, fissile, often with thin bed of sandstone or siltstone, which are greyish green, medium grained, thinly bedded micaceous and friable.

The upper most beds of this member comprises pisolitic limestone in Lunda Pusha Nala. The pisolites are rounded, ellipsoidal and elongated with brachiopods and echinodermal spines. This bed is 1.7 meters thick in the said nala.

Thickness of this member is 25 meters in the area.

The member contains brachiopods, ammonoids, nautiloids, echinoid spines and crinoidal remains.

Tredian Formation :

The Tredian Formation is divisible into Landa and Khatkiara Members which are described below :—

Danda Member: The Landa Member consists of sandstone and shale in almost equal proportions. The sandstone is reddish brown, pinkish, fine to medium grained, thin to thick bedded, massive micaceous at places and ripple marked. The shale is greenish black to black, weathers to grey, greyish brown, fine to medium grained, thin bedded, micaceous, sandy and fissile, silty concretions of gram size with the same composition are embedded at places.

Khthkiara Member : The Khathiara Member consits of sandstone and shale. The sandstone is white to greyish white with orange, yellowish and pink specks and mottlings of brown mineral grains, medium grained, medium to thick bedded, massive, cross-bedded, and rarely ripple marked. If predominates in constitution. The shale is dark grey to black, fine to medium grained, thin bedded, micaceous and fissile. At places the shale exhibits beautiful alternating black and white thin laminations and grades to siltstone.

Thickness of the Tredian Formation is 60—65 meters in the area.

The lower and upper contacts of this formation with the underlying Mianwali Formation and the overlying Kingriali Formation, respectively, are conformable.

No fossils are found in this formation except some carbonaceous remains. Scott (in Danilchik and Shah 1967) reported pollen assemblages of Permo-Triassic affinity containing extinct striate disaccate forms, which indicate Middle Triassic age for this formation.

Kingriali Formation :

The Kingriali Formation comprises dolomite, limestone and sandstone with minor shale.

The dolomite is grey to yellowish grey, coarse grained evenly granular, medium to thick bedded, rarely thin bedded, massive, sandy, micaceous at places, highly breciated and jointed.

The limestone is slightly grey with bluish staining on the weathered surface. Its grain size varies, mainly it is fine to medium grained, rarely pure, a few detrital limestone beds occur. Where the limestone is deterital, it comprises recrystallised calcite, dolomite and mica, rarely it is oolitic. One bed of this nature occurs Landa Pusha Nala. Oolites are rounded. At places beds are brecciated. It is thin to medium bedded, fine grained, highly jointed and breaks into rectangular chips, rarely it is fossiliferous.

The sandstone is greyish white with pink grains, indicating its dolomitic nature, medium grained, thin to medium bedded, at places thick bedded and massive, quartz grains contitute a major portion of the whole mass, hard to harmmer, jointed.

The shale is green to dark grey on both the surfaces, at places it is coaly, fine to medium grained, very thin bedded, fissile and rarely silty.

Thickness of this formation is measured to be 108 meters in the area.

The lower contact of this formation with underlying Tredian Formation is conformable as the sedimentation was continuous and only the rocks are dolomitised in this part. The upper contact with the overlying Datta Formation is disconformable.

Fossils are rare and poorly preserved in this formation. Some bivalve crinoidal remains and brachiopods have been reported.

The transitional contact of the formation with the underlying Tredian Formation and disconformable contact with the overlying Datta Formation of Jurrassic age, places the formation doubtfully in the Lata Triassic.

JURASSIC

Datta Formation :

Datta Nala (Lat. 33° 00 N; Long. 71° 10' E), has been designated as the type locality of the Datta Formation. On the basis of his investigation, however, author recommend Bhaje Nala (Lat. 32° 59' N; Long. 71° 15' E) as its type locality.

This formation comprises shale, sandstone, siltstone and mudstone.

The shale is green and maroon, weathering to same colours. It is fine grained and very thinly bedded, at places fissile, loose, partly covered and is soft to feel.

The sandstone is white, light grey, Pinkish and yellowish brown. It is medium to coarse grained, evenly granular and grity, quartz grains stand out in the mass, thin to medium bedded, at places thick bedded and massive, normally hard to harmmer, rarely friable, at places grades laterally to siltstone and mudstone. Jointing is common in this unit. It is rarely slightly calcareous.

The siltstone is white, pink brown, black, violet, greenish grey and maroon. It is fine to medium grained, thin to medium bedded, compact and hard, usually interbedded with mudstone or sandstone.

The mudstone presents combination of violet, maroon, yellow, yellowish brown, orange yellow, deep blue, brownish and greyish colours. Rarely, concentration of ferruginuous matter has given rise to the heaviness of samples. It is fine grained, thin to medium bedded, rarely thick bedded, massive, jointed, blocky and breaks into rectangular or cubic pieces. The formation is generally slope – forming with some escarpments of competent rocks.

Thickness of this formation is measured to be 200 meters in the area.

The lower contact of this formation is disconformable with the underlying Kingriali Formation, whereas the upper contact with the Shinawari Formation is gradational.

No diagnostic fossils have been reported from the formation except for some carbonaceous remains. As the formation underlies the Shinawari Formation, which in its lower part has yielded lower Toarcian ammonites, the age is inferred as Early Jurassic, mainly Pre-Toarcian.

Shinwari Formation :

The Shinawari Formation is comprised of shale marl and limestone. The shale is dark grey, violet, and reddish brown, weathering to same colours, fine grained, thinly bedded and fissile, at places silty. It also contains fossilised wood. The marl is grey to dark grey with reddish brown ferruginous layers or partings at bedding planes. It is fine grained, thin to medium bedded, compact and hard, at places exhibits spheroidal weathering. The limestone is grey to dark grey, weathers to yellowish grey and brown, fine to medium grained, oolitic beds occur 25 meters above the base. The oolitic bed is 35 cms thick. The oolites are rounded and ferruginous. Pebbles of small size and various shapes also occur in this bed. It is thin to medium bedded, rarely platy, hard and jointed. The formation is slope-forming with some escarpments of competent rocks.

Thickness of this formation is measured to be 30 meters, in the area.

The formation has a transitional contact with the underlying Datta Formation and overlying Samana Suk Formation.

The formation contains brachiopods, ammonoids, bivalves, gestropods and crinoids. The fauna indicates Middle Callovian age for this formation.

Samana Suk Formation :

The Samana Suk Formation comprises sandstone, limestone, marl and shale.

The sandstone is a basal unit of this formation. It is whitish grey, medium grained and thick bedded. The limestone is grey, rarely pinkish, medium to coarse grained, medium bedded and platy. A few conglomerate beds are interbedded with limestone. The pebbles range from ½ cm to 1 cm in length. They appear to be of intraformational conglomerate type. The cementing material in these beds is carcareous. At places limestone is sandy and made up of shell fragments. Shells and fossils are highly recrystallised and unextractable. Two oolitic beds in the limestone occur about 91 meters above the base. The oolites are usually rounded, red and black in colour. The marl is grey and thin bedded. The interbedded shale is thin and greenish grey. It is very minor in constitution.

The thickness of this formation is 120 meters in Baroch Nala.

The lower contact of this formation with the underlying Shinawari Formation is gradational. Alternating beds of shales, marl and limestone are found. Limestone beds increase as one proceeds higher up, ultimately to white to greyish white sandstone band which marks the boundary between the two formations. The upper contact with the overlying Chichali Formation is disconformable.

From the uppermost beds, a Middle Callovian fauna have been recorded from the Surghar range (Fatmi, 1968, 1972). It consists of brachiopods, ammonoids, bivalves, gestropods and crinoids.

The fossils indicate Middle Callovian age for this formation in Trans-Indus ranges (in Fatmi, 1973).

CRETACEOUS

Chichali Formation :

The formation is divisible into lower, middle and upper members. The lower member consists of shale and sandstone. The shale is browhish green to green, weathers olive green, lower-most 15 meters covered part is soft, while the upper bedded part is rather harder. It is sandy and glauconitic; rarely phosphatic nodules and abundant belemnites occur. This shale passed upward into sandstone which is called as "green sand" because of its peculiar colour. It is medium grained, medium bedded, soft friable, contains rare molluscan fragements and abundant ammonites.

The middle member consists of sandstone which is greenish grey to rusty brown, fine to medium grained, hard calcareous and fossiliferous. The fauna includes ammonites and abundant belemnites.

The upper member comprises glauconitic sandstone. It is green with black specks, weathers to greenish brown, medium to coarse grained, medium to thick bedded, massive and contains pyritic nodules. The member is mainly unfossiliferous. A few bivalves occur in the upper part.

The formation forms slopes.

Thickness of the formation is measured to be 85 meters at Chichali Pass.

The lower contact of the Chichali Formation with the Samana Suk Formation is disconformable. Its upper contact with Lumshiwal Formation is sharp though it appears to be gradational. The upper most shaly unit of Chichali Formation is glauconitic while lower siltstone, and shale of Lumshiwal sandstone in contact with the Chichali Formation are non-glauconitic and ferruginous.

The formation encloses abundant ammonite fauna, which indicates Late Jurassic to Neocomian age in Trans-Indus ranges for this formation (in Fatmi, 1973).

Lumshiwal Formation ::

The Lumshiwal Formation consists predominantly of sandstone with subordinate interbeds of shale and siltstone.

The sandstone is greyish white with yellow brown and green specks, at places black carbonaceous lenticles developed, medium to coarse grained, quartz grains dominate in constitution. At places, sugary and granular texture developed due to courseness of quartz grains, thin to medium bedded, rarely thick bedded, where coarse grained it is friable, highly jointed and weathered. The shale is highly carbonaceous with coaly appearance, fine grained, very thin bedded and friable. The grit bed occurs at about 55 meters above the base, It is snow white, weathers to bluish white, very friable, quartz grains makes up 80% of the whole mass, grains are mostly angular, size varies, maximum size like that of pea.

The siltstone is greyish brown, black with rusty and brown patches and lamination, Weathers to rusty brown and greyish with ferruginous layer developed at bedding planes, numerous criss-cross pattern, gypsum and nodules of ferruginous matter embedded at an interval of 2-2.5 meters, fine to medium grained, thin to medium bedded and micaceous. In upper most part, siltstone weathers in the form of rounded nodules.

The formation forms steep slopes alternating with escarpments of harder units.

The lower contact of the formation with Chichali Formation is sharp and conformable, because of glauconitic nature of the latter formation, boundries are easily recognizable. Its upper contact with the Hangu Formation is unconformable. It is marked by the occurrence of coal seams, lateritic beds and ferruginous encrustations in Surghar Range.

From the lower-most bed in Makarwal and Baroch nala sections, Grypaea and Hibolithes are recorded.

From Sheikh Badin Hills, some Upper Aptian fossils have been recorded by Spath (1939). In the rest of the Trans-Indus range, the formation is mainly unfossiliferous. An Aptian Albian age is doubtfully assigned in this area. The age of the Lumshiwal Formation is considered to be Cretaceous by Waagen (1880) and Gee (1938).

Danilchik and Shah (1967) remarked that the formation may be of Early Cretaceous age if it is related to the rocks of Late Aptian age in the vicinity of Sheikh Badin, on the other hand it may be of Late Cretaceous age because it conformably underlies and is lithologically graditional with a fossiliferous formtion known to be of Palacene age.

The author is of the view that the formation is Early Cretaceous in age as the part of the formation exposed in Surghar Range is related to the exposures of this formation in Kala Chitta and Hazara, where the upper calcareous top is also developed, which is absent in Surghar Range. Therefore, the formation, if related to Hazara, and Kala Chitta area, seems to be of Early Cretaceous in age on the basis of lithology.

PALEOCENE

Hangu Formation

The Hangu Formation consists of sandstone and shale with occasional limestone beds in the upper part. The carbonaceous strings, veins and thin layers are present throughout the formation and indicate a terrestrial condition at that time. The standstone is grey in colour with yellow (limonitic ?) patches normally medium bedded and medium grained with very common carbonaceous strings and thin veins throughout. The shale is grey to dark grey; at places it is of maroon colour, thinly bedded and slightly silty in upper horizons. About six metres above, a 6 meres thick siltstone bed of dark grey colour occurs. The siltstone is very thinly bedded, argillaceous with calcite veins. It makes a prominent horizon in the section.

The shale horizon in the basal 5 meters is highly carbonaceous, grading into lignite to sub-bituminous coal seams (Pascoe 1959) which is being worked out at different localities in Lumshiwal-Datta nala sections. The coal seams at the outcrops are 30 cm —1 metere in thickness. It is followed by 1.5 meteres thick beds of sandstone which is rather greyish and coarse grained sandstone with carbonaceous stringers. It is succeeded by one meter thick highly carbonaceous grey shale.

The linestone occurs in the upper half of the formation and constitutes 15%. It is dark grey in colour, slightly arenaceous, compact and gives foetid smell from the freshly broken surface. A 2.5 meters thick horizon of interbedded shale and limestone occur about 7 meters below the top, which has yielded well preserved gestropods and bivalves shells.

The Hangu Formation is capped by a 15-30 cms thick bed of calcareous, yellowish sandstone through out the Surghar range. A similar horizon is reported by Pascoe (1959) occuring at the top of the formation in the main Salt Range area.

The formation forms steep slopes intervening between the escarpements formed by the Lockhart limestones.

Thickness of the formation is measured to be 33 meteres in the area.

The formation is highly fossiliferous. In Surghar range Cox (1931) and Iqbal (1972) have recorded number of molluscan species. Davis (1937) identified many species of formanifera.

A preliminary identification made by the authors (in Akhtar and Reza, 1980) has revealed the presence of following formaniferra in the formation. *Cibicides sp., Discorbis sp., Nomeline spp. Alabomine sp., Nanion spp Nonionella spp Gyroidina spp Nalilinexia spp* the larger formanifera are *Rotalia spp Lockhartia spp Opercullina spp Pararotalia spp etc.*

Among the molluscs, the author has identified *Torebellum (Nauryna) Plicatum, crommium sindiensis, crommium sp., globularia brouispira Euspira sp., and Venericordia burgi I.*

On the basis of fossil essemblage, Early Paleocene age is assigned to the formation.

Lockhart Limestone

The Lockhart limestone consists of nodular limestone and subordinate beds of marl with thin impersistant shale beds in the upper part. The limestone is mainly grey, with light brown and yellow weathered surface, medium grained, and commonly medium bedded, provided the low nodularity allows demarcation of the individual beds. The typical weathering colour is due to "decomposition of iron contents" (Pascoe 1959). The nodules are 10-20 cms in length and are commonly eye or wedge shaped with light brown marly or shaly partings-flows around weak places. The intercalated marl is grey in colour with light brown weathering surface, sometimes black and gives foetid smell from the fresh surface. It is very much calcareous in the upper part, where it is thin bedded and rather nodular. Both nodules and interestitial argillaceous matter are richly fossiliferous, commonly formainifers and molluscen shells occur. The interbedded shale is dark bluish grey to dark grey with bituminous contaminations at places. Though pappery and fissile in nature, but forms interbeds up to 10-20 cms in thickness, at an interval of 30 cm—1.70 cms.

The formation is easily recognizable throughout the extent because of its bold topographic expression. Because of its massive nature and genle sloping, incompetent formations above and below, it forms low, straight escarpments and high sky lines.

The thickness of this formation is measured to be 55 meters in Lumshiwal nala.

The lower contact of the Lockhart limestone is sharp and conformable, marked by a change of lithology i.e. from terrestrial to a carlcareous facies. The contact is recoginterbeds of olive grey shale.

The upper contact, though reported to be of transitional nature, is sharp in Lumshiwal area. The Nammal Formation succeeds with a sharp change in lithologies i.e. from brownish black, bitumminuous shale of Patala Formation to bluish grey soft, thin bedded marl of the Nammal Formation.

The main bulk of faunal wealth of Patala Formation consists of microfossils, particularly the foraminiera. Besides, a fair assemblage of gestropods, bevalves corals and bryozoa also occurs in the formation. The preservation of most of the microfossils are fairly better than those of Lockhart Limestone, but none of those exceed more than a 2.5 cm in length in the washed samples of the authors collection.

Haque (1956) and Nicol (1960) identified a number of species of foraminifera.

Among mega-fauna, pelecypoda and gestropods are important but these are mostly of small size. Probably geological conditions for their proper growth were not favourable.

Cox and Pascoe, (1959), identified a number of species of pelecypods and gestropods in this formation from various localities of Salt Range. Author has identified *Turritella Hollandi, T. Ranikoti, T. (Stiracolpius) Horniensis, Mesalia sp., Venericardia hollandi, Carbula Pakistenica* (in Akhtar and Reza 1980).

The fauna indicates late Paleocene to lower Eocene age for this formation.

EOCENE

Chharat Group

The Chharat Group is represented by Nammal Formation and Sakesar Limestone which are described below.

Nammal Formation

The Nammal Formation consists of light grey limestone, marl and greenish grey shale in subordinate quantity. The lower portion consists predominantly of bluish grey marl with the same weathering colour, thinly bedded and at places nodular but of considerably small size. It is associated with occasional thin beds of calcareous claystone and grey, fine grained, slightly arenaceous thick bedded limestone. The marl is commonly interbedded with subordinate thin bedded, grey calcareous shale in the Baroch nala; Danilchik *et at.*, (1967) have termed this part as the "Nammal Marl".

A thin zone of 15 meters follows it, which consists of marl and subordinate interbeds of grey to greenish grey colour weathering light grey, thinly bedded and calcareous shale. Succeedingly, a 30 cms thick bed of dirty white impure gypsum crops out at the base of the Chichali range. Succeeded at the top by 52 meters thick units, principally composed of bluish grey to dark grey limestone, which is yellowish brown in colour, platy in nature and gives feited smell from freshly broken surface. At places, it shows stratigraphic structure and contains very occasional small chert nodules. It is intercalated with thin beds of marl and shale, as is seen in the lower horizon.

The lithological characters preserve a close similitude throughout its extent, though, much compositional variations are observed.

The topographic expression is depicted by slope forming feature of this formation.

The thickness of the formation is measured to be 128 meters in Chichali nala.

The lower contact, though covered in Chichali nala, is graditional in its adjoining areas. The contact zone consists of a thin trasitional part of interbedded greenish grey shale and bluish grey marl. Towares the southern end, in the Lumshiwal nala, the contact is rather sharp with the underlying Patala Formation.

The upper contact is not very sharp but can be easily recognised. The upper limestone beds of the Nammal Formation gradually become thick bedded and contain common chert conceetation. It grades into Sakesar Limestone.

The Nammal Formation is richly fossiliferous, containing mainly the formaniferaand ostracods, and gestropods, lammellibranches and crinoids.

Haque (1956) has described about a hundred species of smaller formanifera from the type locality; most of those being good index fossils.

In the author's collection from the basal part, a general preponderence of *Globigerine, Globorotalia, Pseudogloborotolia* is observed, besides many well preserved *Astaculons, Nodosarians, Spiroloculies* etc. (in Akhtar and Reza 1980).

Cox (1931; in Fatmi 1973) identified in number of species of molluscs.

The author has identified *Cordium inequicon vexum* from his faunal collection.

The age as indicated by the above mentioned fauna is late Palaeocene to Eocene (in Fatmi, 1973).

Sakesar Limestone

The extensively developed Sakesar Limestone maintains a constant lithological character throughout its outcrop in the Surghar Range. It is comprised of light grey foraminieral limestone with subordinate marl particularly in the lower portions. The limestone is grey, weathering to light grey and is medium bedded. It is argillaceous in the lower 24 meters and contains very thin occasional intercalations of 5 or 10 cms thick calcareous shale beds. It is followed by 90 meters of grey, massive, nodular limestone with thin, small eye-shaped chert nodules. The limestone and some of them enlarge to 25 cms in length.

The main part of formation, about 110 meters thick, consists of light grey, massive nodular limestone, crowded with abundant alveolines and nimmulites, with thin insignificant layers of marls. Chert layers and nodules are much more common as compared to the lower half portion. This is commonly of black or deep brown colour but pinkish nodules are also observed. It is part of Sakesar Limestone which forms narrow gorge at about 70 meters upstream in Chichali Nala, known as Chichali pass or locally called as "Darwaza". This narrow small gorge is of only 4 meters in width at one place and normally 80 meters deep. It serve as the main storage tank of the Chichali nala.

A 14 meters zone consisting of greenish white flaggy limestone with interbeds of marls and subordinate shales forms the top of the formation. Though apparently similar to Lockhart Limestone, the latter differs in its more consistant nodular character, absence of chert and its typical yellowish brown weathering colour.

It forms very typical precipitous scarps and cliffs resembling walls of ruined fortress (Krishnan, 1960), and extensive dip slopes all along its exposure from East of Khewra in the Salt Range to the South of Lumshiwal nala in the Surghar Range.

The formation is measured to be 230 meters in Chichali nala.

The lower contact with the Nammal Formation is not very sharp but easily recognizable. The chertless, rather light grey limestone of Nammal Formation becomes slightly nodular, massive and cherty in case of Sakesar Limestone.

The upper contact with the Mitha Khattak Formation of Middle Eocene (Danilchik and Shah, 1967) is marked by an occassional unconformity that is of wide stratigraphic range in the Surghar Range. The basal 9 meters of Mitha Khattak Formation consits of conglomerates, notably containing pebbles of nommulitic limestone (Abid, 1967).

The fauna of this formation includes foraminifera and molluscs which indicates an Early Eocene age for this formation (in Fatmi, 1973).

MIOCENE

Rawalpindi Group

The Rawalpindi Group is represented by Kamlial Formation, which is described below:

Kamlial Formation

The Kamlial Formation comprises sandstone and clay in almost 60 : 40 ratio. The sandstone is purple-grey, medium to coarse grained and medium to thick bedded. It is distinguished by its spheroidal weathering character. The clay is reddish brown.

The formation unconfotmably overlies the Sakesar Limestone and the contact is marked by a basal conglomerate with derived fossils. The formation is conformably overlain by the Chinji Formation of the Siwalik Group. A number of fossil mammals have been recorded from the formation. These fossils indicate Middle to Late Miocene age for the formation.

MIOCENE-PLIOCENE

Siwalik Group

The Siwalik Group is developed in parts of Sirghar Range. This group is divisible into Chinji, Nagri and Dhok Pathan Formations which are described below in ascending order : —

Chinji Formation

The Chinji Formation comprises clay and sandstone in 80 : 20 ratio. The clay is bright red, friable, valley forming; it is associated with claystone at places. The claystone is compact on fresh surface. It breaks into small blocks on hammering. Sandstone is ash grey, medium grained, medium bedded hard, calcareous and forms 2-18 meters thick units.

At places, lenses or beds of intraformational pseudoconglomerate occur which are comprised of pebbles of clay and sandstone. The pebbles are mainly angular to sub-angular and cemented in sandy and calcareous matrix.

Thickness of the formation ranges from 250 to 300 meters in the area.

The lower and upper contact of Chinji Formation are conformable, respectively, with the underlying Kamlial Formation and the overlying Nagri Formation.

Abundant vertebrate fauna have been reported from this formation which indicates Late Miocene (Sarmatian) age for this formation.

Nagri Formation :

The Nagri Formation consists predominantly of sandstone and clay. The sandstone is medium gray, very thick bedded, commonly crossbedded, medium grained, angular to subangular, micaceous, feldspar-rich, marly, silty, and in some beds, clayey. The formation contains a few thin lenticular pebble-conglomerate beds and widely scattered pebbles throughout. The pebbles are rounded and consist of chert, quartzite, milky quartz, granite, diorite, and rarely, rhyolite. The clay is reddish brown.

The thickness of the formation is estimted to be 2000-2200 meters in the area.

The formation contains vertebrate fauna, which indicates early Pliocene age for this formation.

Dhok Pathan Formation

The Dhok Pathan Formation comprises clay and sandstone. The clay is yellowish brown. It alternates with thin beds of siltstone. The sandstone is light-grey, bluish-grey, fine to medium-grained sandstone, containing lenses of conglomerate. The conglomerate consists mostly of pebbles, but also contains cobbles as much as 15 cms in diameter. At the base of this unit, there is greenish-grey to yellowish-green fine to coarse-grained sandstone which is locally cross-bedded. The upper part forms scarps and consists of boulder to pebble conglomerate in a soft sandstone matrix. The pebbles and cobble are oriented with their longer axes parallel to bedding; they represent subrounded fragments of limestone, quartzite, and granite.

The thickness of the formation is almost 700 meters in the area.

The lower contact of this formation is conformable with the underlying Nagri Formation, while the upper contact is not exposed in the area.

On the bases of vertebrate fauna, Middle to late Pliocene age has been assigned to this formation.

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REFERENCES

Akhtar, M. and Raza, S.M.	1984	Stratigraphy of Mesozoic and Early Tertiary rocks of surghar range Mianwali District, Punjab, Pakistan. G.S.P.IR No. 183.
Danilchik, W and Shah, S.M.I.	1967	Stratigraphic nomenclature of formations in the Trans-Indus Mountains, Mianwali District, West Pakistan: project Report, Pakitan Investigations; (IR)PK-33, United States Department of the Interior Geology.
	1976	Stratigraphy and Coal Resources of the Makarwal area Trans-Indus Mountains, Mianwali Distt: Pakistan Project Report, Pakistan Investigation (IR) PK-60, United States Department of the Interior Geological Survey.

Fatmi, A.N. 1973 Lithostratigraphic units of the Kohat Potwar province, Indus Basin, Pakistan, G.S.P. Mem. vol. 10.

Shah, S.M.I. (Editor) 1977 Stratigraphy of Pakistan, G.S.P. Mem. Vol. 12, P.121, map.

Bard, J.P. Maluski, H., Matte, Ph., and Proust, F. 1979. The Kohistan Sequence: crust and mantle of an obducted island arc., Proc. Intern. Commit. Geodynamics, Grp. 6, Mtg. Peshawar, *Geol. Bull. Univ. Peshawar,* 13, 87-94.

Desio, A. 1974 Geological reconnaissance in the Middle Indus Valley between Chilas and Besham Qila, Pakistan. *Boll. Soc. Geol. Ital.*, 9, 345-368.

Desio, A. 1977 The occurrence of blueschists between the middle Indus and the Swat Valleys as an evidence of subduction (North Pakistan). *Rend. Accad. Naz. Lincei,* Roma, 62, 1-9.

Desio, A. 1979 Geologic evolution of the Karakorum in Geodynamics of Pakistan (Farah and DeJong, Ed), Quetta, 111-124.

Desio A. and Shams, F.A. 1980 The age of the blueschists and the Indus-kohistan Suture Line, NW. Pakistan. *Rend Acc. Naz. Lincei,* 68, 74-79.

Martin, N.R, Siddiqui, F.A. and King, B. 1962. A geological reconnaissance of the region between the Lower Swat and Indus rivers of Pakistan. *Geol. Bull. Punjab Univ.*, 2, 1-15.

Powell, Mca. C. and Conaghan, P.J. 1973 Plate tectonics and the Himalayas, *Earth Planet. Sci. Lett.*, 20, 1-12.

Shams, F.A. 1975 Petrology of the Thak Valley igneous complex, Gilgit Agency, Northern Pakistan. *Proc. Accad Naz. Lincei,* Rome, 59, 453-464.

Shams, F.A. 1972 Glaucophane-bearing rocks from near Topsin, Swat-First record from Pakistan. *Pakistan J. Sci. Res.*, 24, 343-345.

Shams, F.A. 1979. Origin of the Shangla blueschists, Swat Himalayas, Pakistan. *Geol. Bull. Peshawar Univ.*, 13, 67-70.

Shams, F.A., D.R.C. Kampe, and C.J. Jones, 1980 Mineralogy of the blueschists of Swat Himalayas, Pakistan., *Min. Mag.*, 44.

Tahirkheli, R.A.K. 1979. Geology of Kohistan and adjoining Eurasian and Indo-Pakistan continents, Pakistan., *Geol. Bull. Peshawar Univ.*, 11, 1-30.

Virdi, N.S. Thakur, V.C. and Kumar, S. 1977, Blueschist facies metamorphism from the Indus Suture Zone of Ladakh and its significance. *Him. Geol.*, 7, 479-82.

THE BURIED SHIELD AROUND JHANG FROM GRAVITY DATA

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Abstract : *Results of semi-detailed graviy and magnetic survey of Ashaba-Bagh area of Jhang district covering about 200 sq. km. (Lat. 31° 02: to 30° 16: N, long. 72° 11: to 72° 28 E) are interpreted in terms of crystalline basement topography. Graphical methods have been utilized to filter out regional gravity gradients. Our interpretation indicates gentle northward rise of the basement. Positive residual anomalies have been interpreted as bulges in the basement.*

INTRODUCTION

Vast alluvial plains of Punjab are underlain by thick sequence of sedimentary formations whose distribution is controlled, to some extent, by the configuration of Precambrian rocks of the Indo-Pak shield. The study of shield configuration can be aided by gravity and magnetic methods. This provides a useful indirect exploration tool by identifying and extrapolating various geological features. Regional gravity surveys by G.S.P. and O.G.D.C. have covered most of the areas falling in the Punjab Province. Results of a semi-detailed gravity and magnetic survey in Ashaba—Bagh area of Jhang district are presented here. The gravity anomalies were analysed by residual and second derivative methods of interpretation. The anomalies are explained mainly in terms of basement configuration. Attempt has been made to formulate some idea of the depth extent and the lateral distribution of sedimentary formations overlying the dense metamorphic basement.

SURVEY AND RESULTS

The area is located in the Survey of Pakistan toposheets Nos. 44 A/4, A/7 and A/8, between Lat. 30° 02' to 31° 16' N and Long. 72° 11' to 72° 28' E. A total of 400 gravity and magnetic observations were made. All the observations were referred to a local base station established at Ashaba Canal rest house, which in turn was connected to the network of gravity stations in Pakistan (Farah & Ali, 1964). Gravity observations have been corrected for instrumental drift, elevation differences and latitudinal changes from the base. The Bouguer anomaly values were reduced to the datum of mean sea level. A uniform Bouguer density of 1.6 g/cm_3 was used for the reductions. The maximum expected error in the final anomaly map for any gravity station is less than ± 0.13 mgal. The error in the magnetic survey was about ± 10 gammas. The corrected data have been plotted on 1:50,000 topo map and have been presented in the form of Bouguer anomaly contour map with 0.5 mgal contour interval

(Fig. 1), and vertical magnetic anomaly map contoured at 10 intervals (Fig. 2).

The magnetic data seems to be less meaningful because the wave lengths of the magnetic anomalies are much shorter than the traverse spacing. The Bouguer gravity map does not show any marked closure. The contours exhibit an East-to-West gradient of about 1.1 mgal/Km in the southern part. In the northern parts, the contours show a swing in the East-West direction and have a maximum northerly gradient of 0.5 mgal/Km.

In order to enhance and sharpen the effect of localized shallow geologic features which are poorly resolved in the Bouguer gravity map, the data have been analysed for residual and second vertical derivative of gravity. The randomly spaced Bouguer gravity data were gridded at a digitization interval of 1.5 Km. Residual gravity values were calculated for every grid station. Griffin's (1940) eight point averaging method was employed for this purpose. Application of the second vertical derivative filter in gravity anomalies may be obvious from an examination of the Bouguer gravity map, other weak anomalies arising from sources that are shallow and limited in depth and lateral extent may be obscured by the presence of stronger gravity effects associated with deeper features of larger dimensions. The second vertical derivative of gravity data enhances these small and weak near-surface anomalies. In addition to enhancing weaker local anomalies, the second vertical derivative can often be used to delineate the contacts of lithologies with contrasting densities. These contacts are reflected by infection points in the Bouguer gravity, which, while difficult to locate on the Bouguer map, are accurately traced by the zero contours of the second vertical derivative map. The exercise yielded useful information about the lateral geological distribution in the area and confirmed the northward thinning out and pinching of the sedimentary cover truncating against the horst block of Sargodha–Shah Kot ridge north of the study area.

The anomalies are considered to correspond to structural units in the basement. These anomalies are interpreted by high frequency anomalies which are believed to be caused by inhomogeneity in the lateral distribution of the overlying sedimentary rocks and varying proportions of alluvial thicknesses of the Flood plains, masking the old system of river valleys and topographic highs. An East-West trending residual high located in the North of Ashaba, has been theoratically analysed. It corresponds to a bulge in the basement, and also leads us to assume that the average density of sedimentary rocks overlying the basement is around 2.5 g/cm^3. Leaving out the huge sequence of evaporites, and considering the assumption to hold good, it is surmised that the possibility of crossing through the sedimentary column at a shallow depth of less than 1000 metres is fairly strong.

The results have shown that such type of surveys can contribute significantly in delineating principal geological elements and their possible distribution. Various gravity anomalies have been explained as the reflection of basement undulations. Lack of geological control has been a major constraint in formulating a comprehensive model.

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REFERENCES

1.	Dobrin, M.B.	1960	Introduction to Geophysical Prospecting. McGraw Hill Book Co. Inc., New York.
2.	Elkin T.A.	1951	The second derivative method of gravity interpretation: *Geophs.* 16, p. 29-50.
3.	Farah, A. & Ali, M.	1964	Gravity bases in West Pakistan. *Rec. Geol. Surv. Pak.* Vol. II, Pt. 2.
4.	Farah, A, Mirza, M.A, Ahmad, M.A. & Butt, M.H.	1977	Gravity Field of the buried shield in the Punjab Plain, Pakistan: *Geol. Soc. of America Bull,* V. 88, 1147-1155.
5.	Kidwai, Z.	1962	Geology of Rechna and Ganj Doaba, West Pakistan, WAPDA & SOIL INV. Div. Bull. 5, p. 12-16.
6.	Mirza, M.A.	1968	Bouguer anomaly map of Jhang-Sargodha-Lyallpur-Sheikhupura Districts (unpublished)
7.	Rahman, A.	1967	A gravity and magnetic study of deep-seated anomaly in the Gujranwala, District, West Pakistan. *Geol. Bull of P.U.,* No. 6, p. 11-23.
8.	Nazirullah, R., Asghar, M. and Ahmad A.	1983	Gravity and Magnetic survey in Jhang-Ashaba-Bagh area, Jhang District, Pakistan. *GSP Information Release* No. 176 pp. 19.

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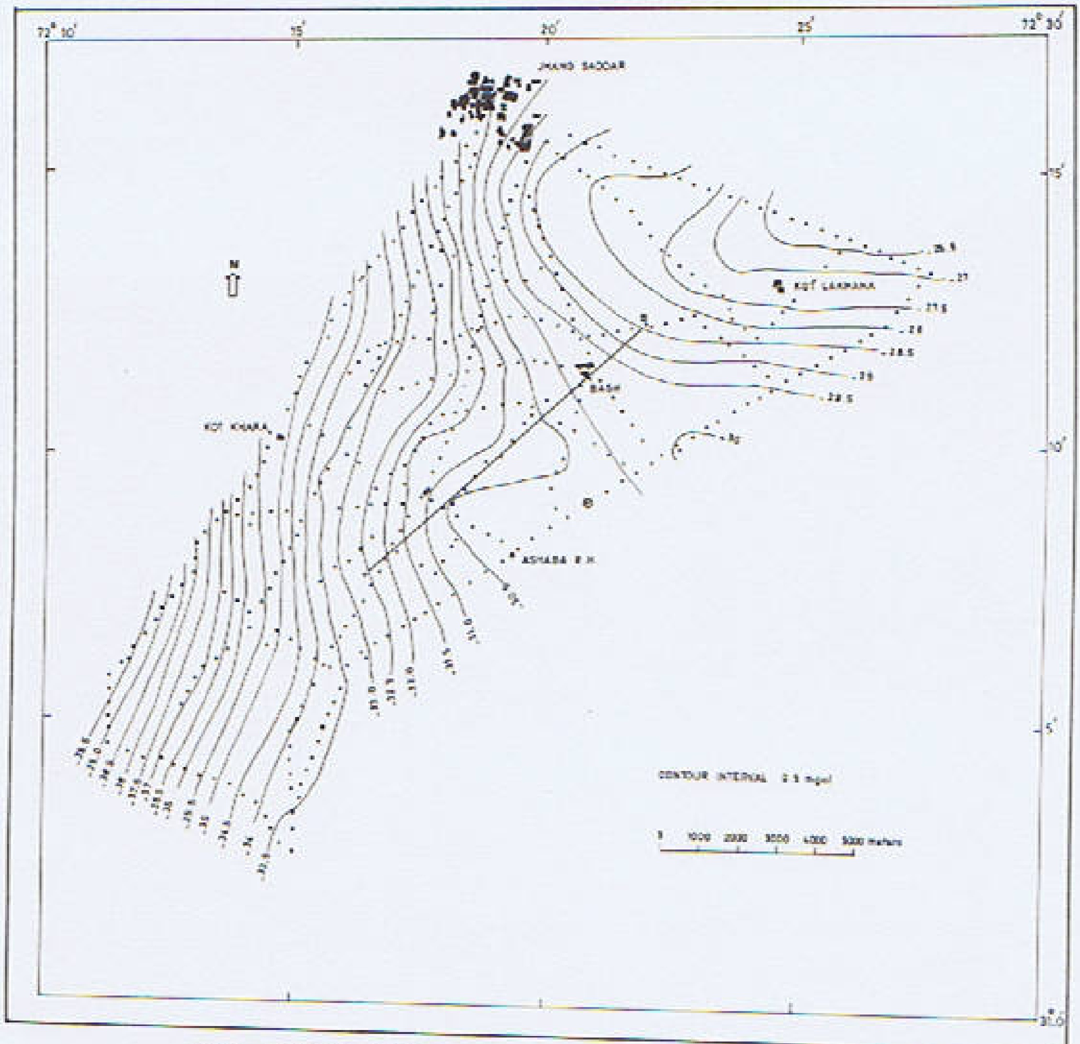

FIG 1 BOUGUER ANOMALY MAP OF JHANG BAGH ASHABA AREA

486

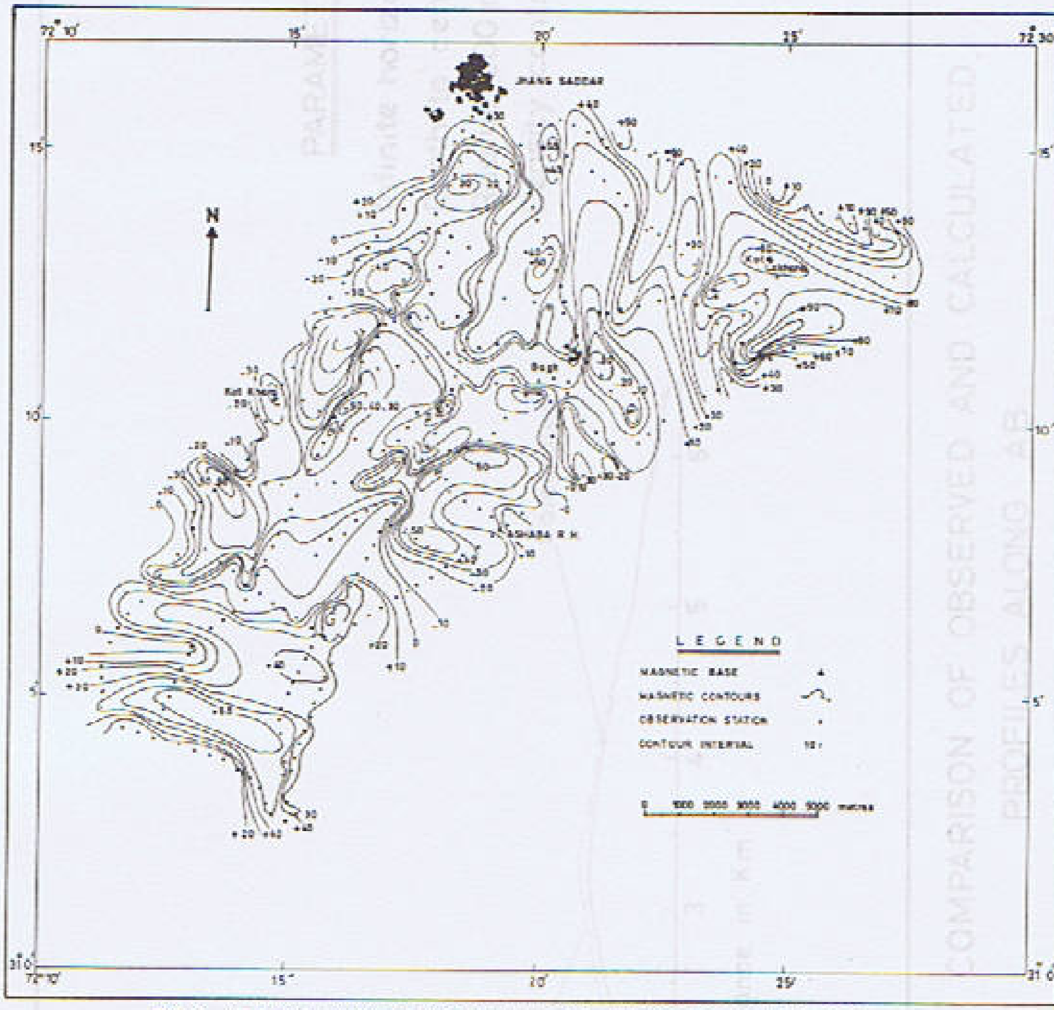

FIG 2 VERTICAL MAGNETIC ANOMALY MAP OF JHANG-BAGH-ASHABA AREA

48c

STRATIGRAPHY OF THE KIRANA HILLS GROUP, DISTRICT SARGODHA, PUNJAB, PAKISTAN

By

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Abstract : *The paper gives necessary details of various litho-units based on a new sub-division of the Kirana Group. Brief description is also given regarding the petrology of various formations alongwith their age and correlation status.*

INTRODUCTION

The few scattered hills of Kirana area (Figs. 1, 2) represent the rocks of Precambrian age exposed in the plains of Punjab. Heron (1913) made a study of these rocks and prepared a reconnaissance map. Dr. S. M. Ibrahim Shah (1961) gave a brief description of stratigraphy of Kirana group. A party of Geological Survey of Pakistan, comprising of the author alongwith M.T. Hassan and M. Hafeez, carried out detailed geological mapping in 1972. In the year 1976-77, an attempt was made to subdivide the Kirana Group on the basis of mapping carried out earlier.

The area is underlain by metasedimentary and igneous rocks. The metasedimentary rock include quartzites and slates with layers of lava, tuffs and volcanic breccia. The lava range in composition from rhyolite to andesite. Many sills and a few dykes of basaltic composition have also intruded the country rock.

On the basis of rocks exposed in Kirana area, the Kirana Group (Shah 1973) has been divided into following five formations (Fig. 3).

TABLE – I

GROUP	FORMATION	DESCRIPTION
	Sharaban Formation	Conglomerate, dull rusty-brown, containing pebbles of quartzite, slate, limestone embeded in calcareous matrix.
	Hadda Formation	Quartzites, dull rusty brown, fine grained, calcareous, typical of shallow marine or deltaic origin; containing minor conglomerate beds, rare lava flows.
	Asianwala Formation	Quartzites, light grey to dirty white, mottled brown, medium to coarse grained, cross bedded, ripple marked, contain minor intercalations of slate.

Taguwali Formation	Phyllite, light grey, minor intercalations of quartzites. Lower part fine grained quartizite, cross bedded. Slates, minor quartzites, with
Hachi Formation	abundant tuff and lava flows.

Three Formations namely Asianwala Formation, Taguwali Formation and Hachi Formation, have been included in Kirana Group.

The other two formations namely—Sharaban Formation and Hadda Formation have not been included in the Kirana Group, because nowhere in the area their direct contact and relationship with Kirana Group could be found. The rocks of these formations are exposed only in an isolated hill called Sharaban. Hadda Formation is thought to be younger than the Kirana Group on the basis of regional trend/structure. The lower contract of Hadda Formation is concealed under alluvium and it is not known what type and thickness of beds are missing.

HACHI FORMATION

Nomenclature and Type Locality

The Hachi Formation is named after the Hachi hill (Toposheet No. 44 A/9), located at grid reference E 854385, north of Railway Station, Sikhanwali. This is a new name assigned to the oldest formation of the Kirana Group. Nowhere in the mapped area its full thickness has been found. Hachi and Shaikh Hills are the type localities.

Rock Character and Distribution

The characteristic lithology of Hachi formation is quartzites, slates, phyllite, tuff and lava flows. All these rock types are present throughout the area wherever this formation is exposed, such as in Buland Hill, Hachi Hill, Shaikh Hill, Bundawali Hill and in Chiniot Hill. The proportion of these rock types vary from hill to hill, and no definite proportion can be established from the new isolated exposures. In Buland Hill, lava and tuff are dominent. In Chiniot area, a small hill located just in the Chiniot Town is entirely composed of lava of rhyolitic composition.

The quartzite are light to medium grey and medium grained arenites, being composed mostly of subrounded to rounded graines of quartz with sericite and clay minerals.

Tuffs and volcanic breccia are present throughout in this formation, while the best exposure of this rock is present in Hachi Hill. The tuffs and volcanic breccia are light grey in colour and are present at different stratigraphic levels interlayed with lava and metasediments. The volcanic breccia is a coarse grained rock with abundant rock fregments and large phenocrysts of feldspar and quartz, set in a fine-matrix. The composition of the rock is rhyolitic. The tuffs are interlayered with quartzites and slates. In general the bedding is not distinct in these beds, but at places clear bedding is present. The rocks are slightly metamorphosed but retain their original texture. The slates interbedded with tuffs seem to have been derived from volcanic ash and other fine volcanic material. The thin section study of 15 rock samples from different beds gave following composition : —

Phenocrysts.......... 15-25% of the rock.
Groundmass.......... 75-88% of the rock.

The groundmass is fine grained and made up of small grains of quartz, microlites of quartz and feldspar and partly devitrified glass. The percentage composition of phenocrysts comes out to be quartz 15-50%, feldspars (mostly perthite) 20-45%, glass and rock fragments 5-10%. The quartz, which occurs both in phenocrysts and groundmass, is angular to subrounded, and has sharp boundaries with the matrix.

The feldspar phenocrysts are mostly represented by perthite and orthoclase. Few grains of magnetite and biotite are also present. The mineralogical composition of tuffs suggest that they have been derived from magma of acidic composition. Lava is interlayered with the metasediments. It is very difficult to study the contact nature. However, it seems to be chilled at the contact. Nowhere, pillow structure has been found in the lava flows. Mostly the lava is of acidic composition and is represented by such rocks as rhyolite, dacite and minor andesite. Lava of rhyolitic composition is present in Chiniot Hill, Hachi Hill, Sheikh Hill and Taguwali Hill. In Hachi Hill, rhyolite is medium grey and the mineralogical composition of the rock comes out to be quartz and feldspar phenocrysts 15% set in fine glassy matrix. The percentage composition of crystallise rock from Hachi Hill comes out to be quartz 25-30%, feldspar (mostly orthoclase) 55% and secondary calcite 15%. A sample of dacite from Shaikh Hill gave the mineralogical composition as; quartz 35-50%, feldspars 45-55% mostly plagioclase of albitic composition, and 2-5% chlorite.

Andesite is present in Hundawali Hill. It is dark gray massive rock. Under microscope, the rock is hollocrystalline fine grained with porphyritic texture. The phenocrysts of feldspars are set in groundmass of oligoclase, orthoclase and quartz. The percentage composition of the rock comes out to be plagioclase of oligoclase composition 45-50%, orthoclase 40-45%, hornblende altered to chlorite 5-7%, with accessory quartz, biotite and ilmenite 7-9%.

Contact Relation and Thickness

The lower contact of the formation is concealed under alluvium in the type locality, and nowhere in the area it could be established. The upper contact with Taguwali Formation is also obscure. But the field relationship suggests that it represents oldest formation of the Kirana area which passed into Taguwali Formation. A thickness of 404 metres has been measured in the type locality.

Age and Correlation

Discountinuity of the Precambrian outcrops of Pakistan and India and highly altered nature of the rocks have rendered the correlation of these outcrops very difficult. No fossil or any trace of organic remains have been found in the Kirana Group during the course of investigation.

Heron (1973) placed these rocks equivalent to Malani rhyolite series of western Rajasthan. Davies *at el.*, (1971, p.244) made age determination of six rock samples, collected from Buland Hill, Kirana area, District Sargodha. The suit as a whole gave an isochron age of 870 + 40 m.y. According to Davies (1971, p.244), this places these rocks in the upper Precambrian, and that the correlation by Heron with Malani Rhyolite series having an isochron age of 745 + 10 m.y. must now be abandoned.

Buland Hill rocks are considered to be representative of Hachi Formation. On the basis of above results, the rocks of Hachi Formation probably lie within the time range of Vindhyan System, which has a base at about 1400 m.y.

TAGUWALI FORMATION

Nomenclature and Type Locality

The name has been assigned after a small place Taguwali (Topo sheet No. 44-A/49), at grid reference E 866423. The type locality and type section of this formation is on southern part of the Kirana Hill, at grid reference and Distribution.

The most characteristic lithology of this formation is phyllite/slate and fine quartzites in the lower part. Phyllite are light silver grey, fine grained, thin bedded to partly bedded at places and showing cross bedding. In the upper part of the formation, phyllite is the dominant rock type with minor slate. The middle part is composed of slate with little shine on the surface. Under microscope, the slate sample gave the mineralogical composition; quartz 60-70%, silt and clay 20-25% and sericite 10-15%. The sericite is somewhat aligned in a direction.

This formatin is quite wide-spread in the area; besides, its type locality in Kirana Hill, it is exposed in Chandar Hill (B 891426) where it is represented by fine grained quartzites; in Mochh Hill (A 912395) about four kilometres south-east of Taguwali, it is mostly represented by fine grained, thin bedded phyllite.

In Chiniot Rabwah area, this formation is represented by fine grained quartzites and thin bedded slates. In Chiniot area, a small hillock of rhyllite is present within this formation.

Contact Relation and Thickness

The upper contact of this formation is with the Asianwala Formation and is gradational. The lower contact with Hachi Formation is nowhere clear and in the type locality it is faulted. The thickness of this formation in the type locality has been measured as (+) 1189 metres.

In Rabwah and Shahkot areas, only small thickness of this formation is exposed.

ASIANWALA FORMATION

Nomenclature and Type Locality

The Asianwala Formation is named after the canal rest house Asianwala (Toposheet No. 44-A/9), located on Sargodha-Faisalabad Road, at about 11 km from Sargodha. This name is new and has been assigned after subdivision of the Kirana Group. Main Kirana Hill is the type locality of this formation, where it is exposed in the northern part of the hill. Type section is along the road, which goes up to top of the Kirana Hill, and is about 4 Killometres from Asianwala rest house (Grid reference G 879490).

Rock Character and Distribution

The characteristic lithology of the formation is quartzite with minor intercalations of slate. The quartzite is generally coarse grained, partly pebbly at places, direct white to light grey mottled brown and thick bedded. It is cross bedded and ripple marked. At places, joints and fractures are filled with brown haematitic material.

The dirty white coarse grained quartzite under-microscope, is coarse grained, composed of well sorted subrounded to rounded grains of quartz 90-95%, with few particle of iron oxide, silt etc. The quartzite is arenite and seems to be formed under shallow water conditions.

The interbedded slates are light grey in colour and occur as thin layers in-between the thick beds of quartzites.

This formation is exposed in Chiniot,

Sangla Hill and Shahkot area. In the Sangla aea, only one isolated hill represents the Precambrian rocks. This exposure is of medium to coarse grained, thick bedded quartzite, which can probably be correlated with the Asianwala Formation. In Shahkot area, this formation is exposed about one Kilometre West of Shahkot town, and represented by light grey, medium bedded and coarse grained quartzites.

Contact Relation and Thickness

In the type locality, the upper contact of this formation is with aluvium. The lower contact is gradational and passes into Taguwali Formation. The thickness measured in the type section at Kirana Hill comes out to be (+) 248 metres.

Age and Correlation

No fossil or any organic remain has been found in this formation. Therefore, it can only be correlated on the basis of its stratigraphic position. It being younger formation of Kirana Group, can be assigned the age around 870 m.y. as Davies (1971 p.240), gave an isochron age of 870+40 m.y. to the older suit of rocks described as Hachi Formation.

HADDA FORMATION

Nomenclature and Type Locality

Hadda Formation is named after the canal rest house Hadda (Toposheet No. 43-4 16), located about 20 Kilometres ESE of Sargodha and about 10 Kilometres NE of Sharaban Hill.

This formation is present in the Sharaban Hill, which is the type locality and the only place where this formation is exposed. This formation is conformably overlain by Sharaban Formation.

Rock Character and Distribution

The main rocks of the Hadda Formation are quartzites, slates, conglomerate and lava flows.

Quartzites dominate the rock types, which are fine grained rusty brown and of marine origin as far as upper part of the formation is concerned. These quartzites are sometimes crosss bedded and show complex contorted layering on the exposed surface due to slumping before consolidation. They are marine or deltaic in origin.

Under microscope, they are fine grained, composed of sub-angular quartz 65-75% set in fine calcareous matrix with iron oxide, calcite and fine clay particles.

Conglomerate occurs in the upper part of the formation interbedded with quartzites ranging to thickness from 1 to 2.5 metres. These congloquartzites, slate, with minor limestone, vein quartz and jasper are set in fine calcareous matrix of rusty brown colour. The pebbles are flattened and are arranged with their long axis parallel to the bedding.

The middle part of the formation is composed of quartzites, light grey to brownish grey, fine grained, thin bedded, some parts phyllitic. Lava flows of green grey colour are present within the quartzite beds. The lower part of the formation is represented by quartzites of light grey colour, which are highly ferruginous at places. Some parts are being mined as hematite ore for use as pigment.

Contact Relation and Thickness

The upper contact with Sharaban Formation is gradational, while the lower contact is concealed under alluvium. The formation is exposed in type locality as isolated hill without any connection with older rocks. In the type locality, thickness of 371.88 metres has been measured.

Age and Correlation

No fossil record has been found in this formation so that estimation of its age and its stratigraphic correlation is difficult. On the basis of regional trend and structure, the isolated exposures of this formation are thought to be lying above rocks of the Kirana Group. This assumption places this formation above the Asianwala Formation.

SHARABAN FORMATION

Nomenclature and Type Locality

The Sharaban Formation is named after the hill called Sharaban (Toposheet Number 44-A/13), located about 17 Kilometres SE of Sargodha. This name is new, and has been assigned after the subdivision of the Kirana Group.

This formation is exposed in the southern end of the Sharaban Hill. The only outcrop of this formation is present in the form of isolated low lying exposure which join with the Sharaban Hill. The upper contact of the formation is with alluvium, and is at least 119 metre thick in the type locality.

Rock Character and Distribution

The characteristic lithology of the formation is conglomerate, with minor stringers of fine grained quartzite. The conglomerate contain flattened and elongated pebbles of quartzites, slates, limestone and few of vein quartz and red Jasper. The beds are 5 to 10 metres thick. The quartzites and slate pebbles are similar to the roacks exposed in the area. The general size of the pebbles is in the range of 1-3 centimetres in diameter that constitute about 80-85% of the pebbles. The rest 10-15 of the pebbles size is in the range of 3 to 10 centimetres. The matrix is rusty brown, fine grained and calcareous in nature. The pebbles are flattened due to stress and are arranged with their long axes parallel to the bedding. The general visual estimate of the percentage of pebbles of various rock types comes out to be quartzite and slates 80-85%.

The limestone pebbles present in the conglomerate are very interesting, as nowhere in the area limestone beds have been found in these Precambrian rocks. The limstone is light grey, fie grained, microcrystalline and can be classified as microcrystalline limestone.

Thin beds of rusty brown quartzite are interclated with the conglomerate. The quartzite is fine grianed and calcareous in nature, and is similar to the matrix present in the conglomerate bed.

The Sharaban Formation is exposed only at one place, in the Sharaban Hill, which is the type locality and nowhere else in the area it has been seen.

Contact Relation and Thickness

The top of this formation is not exposed and the base conformably passes into Hadda Formation. The exposed thickness of the formation is estimated at 118 metres.

Age and Correlation

No fossil or any trace of organic remain has been found in this formation. The exact correlation of this formation or Kirana Group as a whole is very difficult. However, these rocks are regarded as Precambrian and a part of the Indo-Pak Shield.

This formation is the youngest of all on the basis of its stratigraphic position infered from structural set up of the Kirana area.

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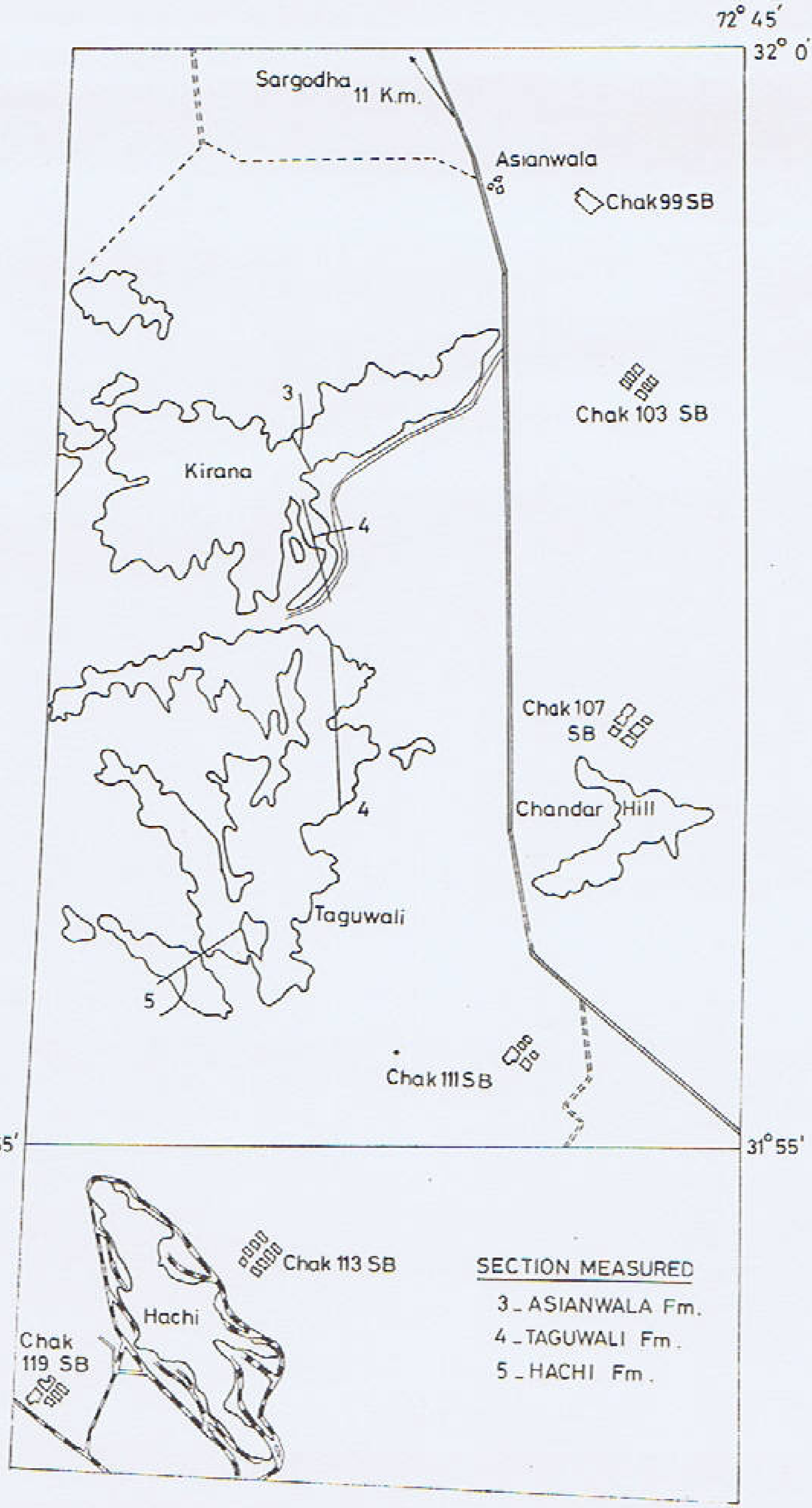
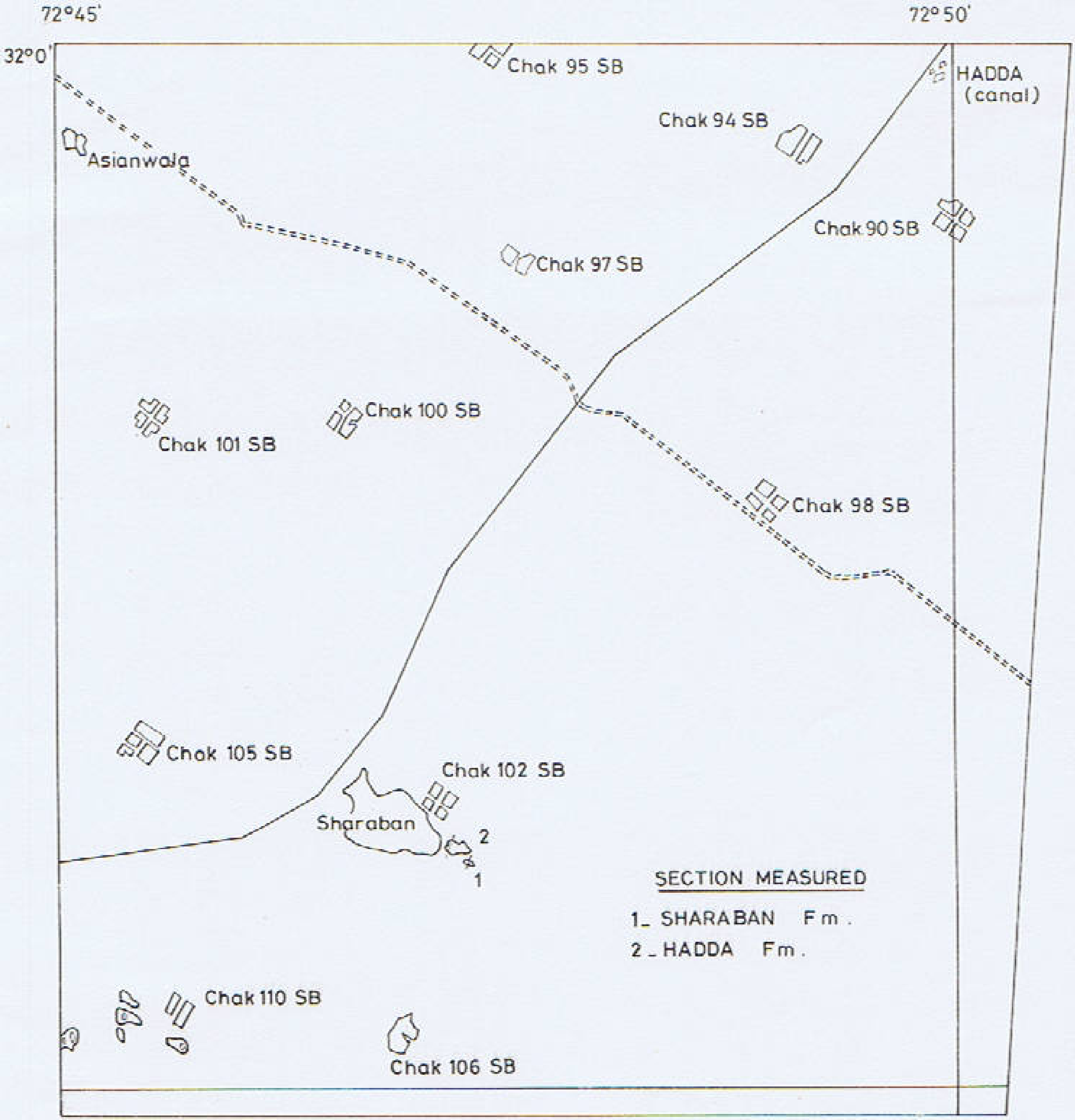
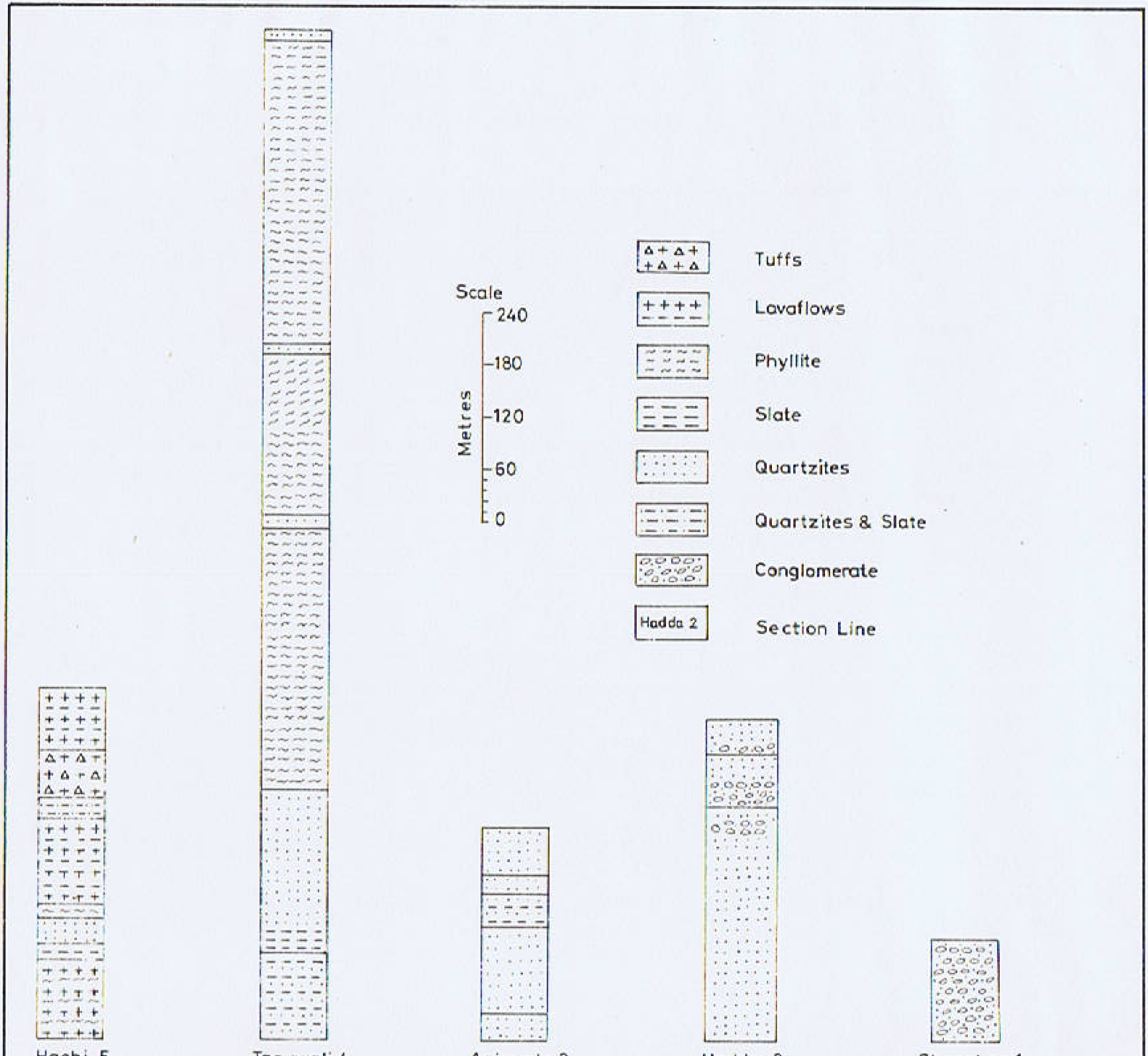

72° 45′
32° 0′
Sargodha 11 K.m.
Asianwala
Chak 99 SB
Chak 103 SB
3
Kirana
4
Chak 107 SB
Chandar Hill
4
Taguwali
5
Chak 111 SB
31° 55′
31° 55′
Chak 113 SB
Hachi
Chak 119 SB
SECTION MEASURED
3 _ ASIANWALA Fm.
4 _ TAGUWALI Fm.
5 _ HACHI Fm.


72°45'
72°50'
32°0'
Chak 95 SB
HADDA
(canal)
Chak 94 SB
Asianwala
Chak 90 SB
Chak 97 SB
Chak 100 SB
Chak 101 SB
Chak 98 SB
Chak 105 SB
Chak 102 SB
Sharaban
2
1
SECTION MEASURED
1_ SHARABAN Fm.
2_ HADDA Fm.
Chak 110 SB
Chak 106 SB

55 C


Scale
240
180
120
60
0
Metres
Tuffs
Lavaflows
Phyllite
Slate
Quartzites
Quartzites & Slate
Conglomerate
Hadda 2
Section Line

STRATIGRAPHY OF KALACHITTA RANGE

By

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Abstract : *Eighteen litho-stratigraphic units of marine and non-marine origin have been studied and described.*

The lithological variation in vertical and lateral extent and the contact relationship have been discussed alongwith various unconformities.

INTRODUCTION

A number of lithostratigraphic sections have been measured, covering all the exposed rock units throughout the Kala-Chitta Range (lat. 33° 0' to 33° 50' N; long. 72° 0' to 72° 50' E).

The rock units described in this paper range in age from Triassic to Recent and mainly consist of sedimentary sequence that are punctuated by important disconformities.

The oldest disconformity in the area is at the close of Triassic period; other disconformities recorded are, at the close of Middle Jurassic, Middle Cretaceous, at the Cretaceous-Paleocene boundary and the Middle Eocene-Oligocene disconformity.

STRATIGRAPHY

The stratigraphy of the area is described.

Triassic

The Triassic system is represented by a variety of rock units varying in lithology from marl and marly limestone to dolomitic limestone and dolomite. These include Mianwali Formation, Chak-Jabbi Limestone and Kingriali Formation.

i) Mianwali Formation : The formation is composed of thinly bedded limestone and marl and marly limestone to dolomitic limestone. The limestone is bluish grey, flaggy and platty. The marl is greenish grey and calcareous. The base of the formation is not exposed.

Only two exposures of the formation are present near Chak-Jabbi rest house, where the formation has a lower faulted contact with Tertiary rocks and the other is near Bagh, where it forms core of a tight anticline.

ii) Chak Jabbi Limestone ; The Chak-Jabbi Limestone is composed of limestone, which is light grey and weathers dark grey, sublithographic and partly dolomitic in the upper part. Yellow patches are also frequently present. It is 22 metres thick near Chak Jabbi Village.

The upper and lower contacts of the formation are gradational.

iii) Kingriali Formation : It is composed of dolomite and dolomitic limestone; its colour varies from brownish grey to pale brown, while the weathering colour is creamish to rusty brown, chopboard weathering is a typical feature. It is medium to thick bedded and jointed. It is 74 metres thick near Chak Jabbi.

The lower contact of the formation is graditional whereas the upper contact is disconformable with overlying Datta Formation.

Jurassic

At the close of Triassic system, the sea regressed and the break in deposition is marked by pisolitic laterite and bauxite disconformably overlying the uneven top surface of Kingriali Formation. The marine conditions prevailed throughout Jurassic period except for a short time at the close of Middle Jurassic and this break is represented by laterite encrustation on top surface of Samana Suk Formation. The overlying Chichali Formation was deposited during Late Jurassic to Early Cretaceous period; as such, there is no lithological discontinuity at the Jurassic-Cretaceous boundary.

i) **Datta Formation :** It is composed of laterite, ferruginous sandstone and clays in the lower part and fireclay in the upper part. However, the lithology is laterally intertounging and interchanging. Towards central and western parts of Kala-Chitta, the laterite and fireclays are well developed, whereas towards East only ferruginous sandstone is present. The thickness of the formation varies from 15 to 30 meters. Its lower contact with Kingriali Formation is unconformable, whereas the upper contact with Shinawari Formation is conformable.

ii) **Shinawari Formation :** This formation is composed of limestone, sandstone and clays. The limestone is brownish grey, hard, cosparitic, while the sandstone is calcareous. The clays are red and are present in the upper part near contact with Samana Suk Formation. The formation is 10-15 meters thick. The lower and upper contacts are conformable.

The fossil bouliceras, some corals and gastropods were found.

iii) **Samana Suk Formation :** This formation consists of a number of lithologies. The major constituent rock being limestone, others are marls, sandstone and clays. The limestone depicts a veriety of microfacies from low energy micritic limestone to high energy intrasparite and oosparite facies. Dolomitic limestone and rare calcareous dolomites are present. Calcareous sandstone and marls are also present. The thickness of formation varies from 120 meters to 225 meters.

The upper contact with Chichali Formation is disconformable whereas lower contact with Shinawari Formation is conformable.

JURASSIC-CRETACEOUS

The deposition of Chichali formation started in late Jurassic and continued up to Early Cretaceous.

i) **Chichali Formation :** The formation consists of glauconitic sandstone, quartzose sandstone and sandy shale. The glauconitic sandstone is medium grained, greenish brown, yellowish brown, weathers to rusty brown, fractured, jointed and fossiliferous. Shale occurs in lower part and is greenish grey in colour. It forms slope with thick vegetation.

The thickness of formation varies from 9 meters to 30 meters. The upper contact with Lumshiwal Formation is gradational, and the lower contact with Samana Suk Formation is disconformable.

CRETACEOUS

The Cretaceous system is composed of part of Chichali Formation, the Lumshiwal Formation, and Kawagarh Formation. The regression of sea occurred twice during Cretaceous period. The first at the close of Early Cretaceous and the second after the deposition of Kawagarh Formation. In southern Kala Chitta, the Kawagarh Formation has not been deposited thus indicating non deposition/erosion from Early Cretaceous to Early Paleocene.

i) **Lumshiwal Formation :** This formation comprises alternation of sandstone, siltstone, shale and limestone. The sandstone is glauconitic which is greenish grey in colour, the weathering colour is brownish green. Shelly limestone inter-beds are also present in the upper part. It forms steep slopes alternating with escarpments of harder rocks.

The thickness of formation varies from 20 meters to 47 meters. The upper contact with Kawagarh Formation is disconformable. In southern Kala Chitta the formation is disconformably overlain by Lockhart Limestone. The lower contact with Chichali Formation is gradational.

ii) **Kawagarh Formation :** This formation consists of alternation of shale, limestone and marl. The shale is greenish grey, splintary and calcareous. The limestone is light grey weathers to greynish brown, thinly bedded to flaggy and argillaceous. Mari is yellowish brown.

The thickness of formation varies from 11 meters to 76 meters.

The formation is well exposed in northern Kala Chitta, but in southern part of Kala Chitta the formation is absent and Lumshiwal Formation is unconformably overlain by Lockhart Limestone.

The upper contact of the formation with the Hangu Formation is disconformable. The lower contact with Lumshiwal Formation is also disconformable.

TERTIARY

At the close of Cretaceous period, the area once again emerged from sea into dry land. The sea transgressed again during Early Paleocene time and deposition of Hangu Formation took place with laterite at its base overlying Kawagarh Formation in Northern Kala Chitta, and Lumshiwal Formation in southern Kala Chitta. This indicates that the southern part of Kala Chitta area remained emerged after the deposition of Lumshiwal Formation and deposition of Kawagarh Formation did not take place in this part.

After Middlé Eocene, the sea regressed and no deposition took place during Late Eocene-Oligocene time. This break is represented by 50 cms to over 1 metre thick boulder bed named as Fatehjang zone, which contains pabbles and boulders of Tertiary limestone, embadded in sandy matrix. During Miocene time, Rawalpindi Group of continental origin was deposited.

PALEOCENE

i) **Hangu Formation :** This formation is composed of ferruginous sandstone, siltstone and shale. The sandstone is reddish green and weathers rusty brown. Laterally, the formation exhibits lenticular nature, and pinches and swells at different places.

The thickness of formation as measured from near East of Surg village is 4 meters.

The upper contact with Lockhart Limestone is conformable whereas the lower contact is disconformable with Kawagarh Formation/Lumshiwal Formation.

ii) **Lockhart Limestone :** The Formation consists of Limestone, marl and rare shale. The limestone is dark grey, weathers whitish to dark grey and brownish grey. It is nodular and massive, micritic to biomicritic in nature, shelly and fossiliferous. Shale and marl are creamish grey in colour. It forms high ridges and cliffs.

The upper contact with Patala Formation and the lower contact with Hangu Formation is conformable.

iii) **Patala Formation :** The formation is composed of light grey to greenish brown marl with interbeds of pale grey limestone and calcareous shale. The interbedded limestone is nodular, and increases in intensity and thickness laterally towards East, where lithological differentiation between Patala Formation and Margala Hill Limestone is difficult. The formation is fossiliferous. It forms gentle slope.

The thickness of Formation as measured from near Chack-Dalla area is 74 meters.

The upper contact with Margala Hill Limestone is transitional whereas the lower contact with Lockhart Limestone is sharp and conformable.

EOCENE

Chharat Group

The Chharat Group comprises following formations : —

1. Margala Hill Limestone
2. Chorgali Formation
3. Kuldana Formation
4. Kohat Formation

i) **Margala Hill Limestone :** The Formation consists of limestone with subordinate marl and shale. The limestone is grey to dark grey in colour and weathers pale grey. It is fine to medium grained, nodular, massive and jointed. The marl is pale grey to brownish grey in colour, while shale is greenish brown in colour. The Formation is fossiliferous and foraminifera are abundant. The formation forms high cliffs and steep slopes.

The thickness of the formation as measured along path towards Burjianwala Laman is 75 meters.

The upper contact with Chorgali Formation and lower contact with Patala Formation is conformable and transitional.

ii) **Chor-Gali Formation:** The formation consist of limestone and shale. The limestone is brownish grey in colour, weathers cream and whitish grey. It is nodular, jointed and fossiliferous. The shale is greenish grey in colour, weather brownish grey, splintary and is more prominent in lower part. Bivalves, gastropods and forminifera are frequently present. The formation generally forms low hills and gentle slopes.

The thickness of the formation as measured East of Jhallar Railway track is 84 meters.

The upper contact with Kuldana Formation and the lower contact with Margala Hill Limestone are conformable.

iii) **Kuldana Formation :** The Formation is composed of vari-coloured shale, marl and argillaceous limestone. The shale is maroon, brown to chocolate brown in colour, weathers chocolate brown with some red gypsiferous horizons. The marl is greyish green and is associated with fibrous gypsum. Gritstone beds embedded in siliceous matrix are also present. Vertebrate fossils have been reported from the Formation. The Formation forms gentle slopes and valleys. The thickness of the formation as measured towards West of Jhallar Railway bridge is 96 meters.

The upper contact with Kohat Formation and lower contact with Chor-Gali Formation are conformable.

iv) **Kohat Formation :** The formation consists of greenish grey, calcareous shale and light grey limestone flooded with nummulities. The thickness of Formation as measured from near South of Kalidilli is 100 meter.

The upper contact with Murree Formation is disconformable wheras the lower contact with Kuldana Formation is conformable.

MIOCENE

Rawalpindi Group

The group as a whole is a body of fresh water clastics and consists of sandstone and shale. The sandstone is dark, purple and grey in colour, alternating with purple and red shale. The group comprises of Murree Formation and Kamlial Formation.

i) **Murree Formation :** The Formation is composed of 1 meter thick zone having pebbles and boulders of Eocene limestone embedded in sandy matrix and is named as Fateh-Jang Member. The Formation is divisible into lower and upper part.

The *upper part* is composed of alternate beds of sandstone and shale. The sandstone is brown buff, coarse grained whereas the shale is red to purple. The *lower part* is distinguished by purple and red sandstone, generally flaggy, pseudo-conglomerate beds occur at places. The shale is splintary purple and red with abundant calcite veins. The thickness of Formation as measured in Jhallar area is 540 meters. The Formation forms low ridges and hilly terrain.

The upper contact with Kamilal Formation is sharp. Taseer *et al.* (1979) have marked a para-conformity at the contact. The lower contact with Kohat Formation is disconformable.

ii) **Kamlial Formation :** The Formation comprises sandstone of purple grey and dark brick red colour, hard and coarse grained. Interbeds of shale and pseudo-conglomerate of yellow and purple colour are present at different intervals. The Formation is distinguished from underlying Murree Formation by its spheriodal weathering. It is characterized by a flood of tourmaline and paucity of epidote. The Formation forms low strike ridges traceable for many km.

The upper contact with Quaternary deposits is unconformable and the lower contact with Murree Formation is sharp.

SUB RECENT AND RECENT DEPOSITS

Nearly horizontally disposed Quaternary terrigionous sediments are present in the northern part of Kala Chitta area. These include unconsolidated deposits of silts sand, gravels and clays. Pinkish to earthly grey deposits of loessic clays have also been noticed in some parts of the area. The bentonite deposits of Dheri Kot and Dheri Chohan occur in these rocks.

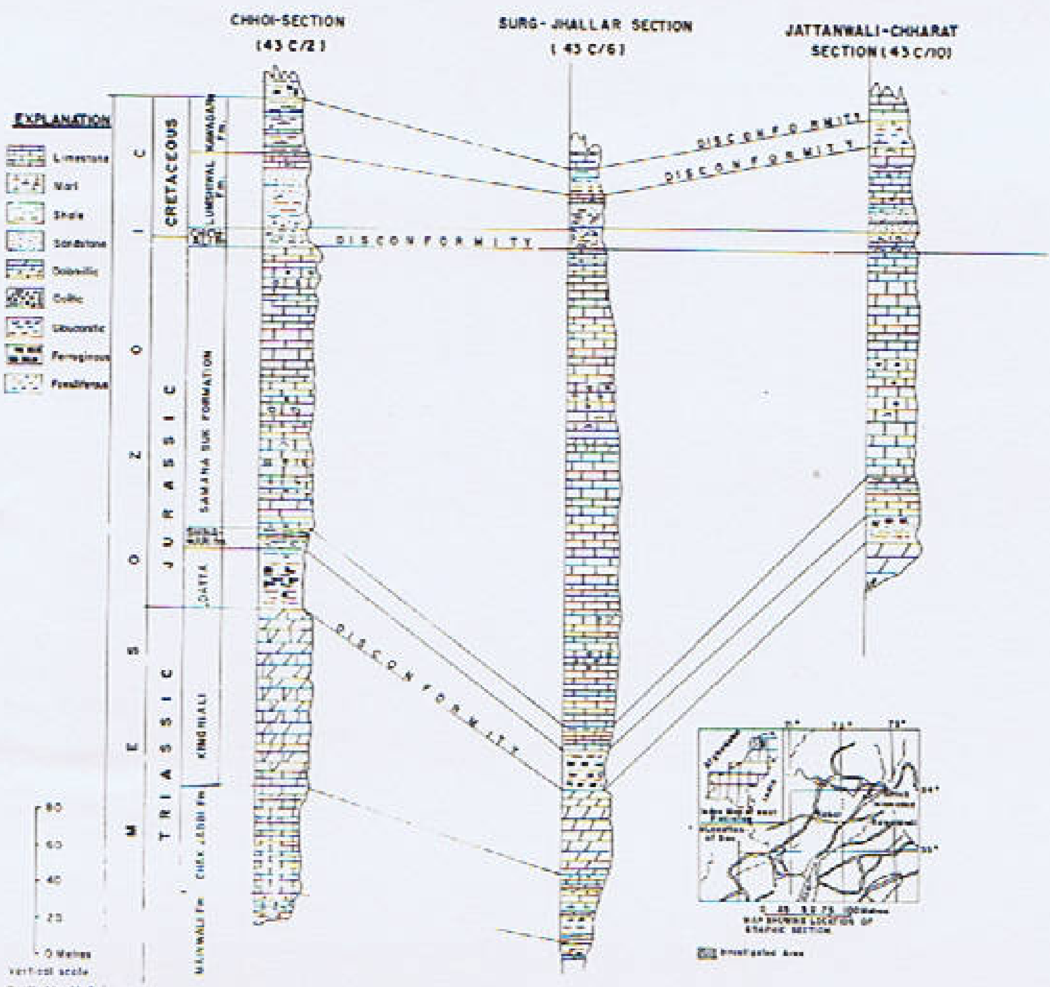
REFERENCES

Fatmi, A.N., 1973, Lithostratigraphic units of Kohat-Potwar Province, Indus Basin, Pakistan, *Geol. Surv. Pak. Mem., 10,* pp.80.

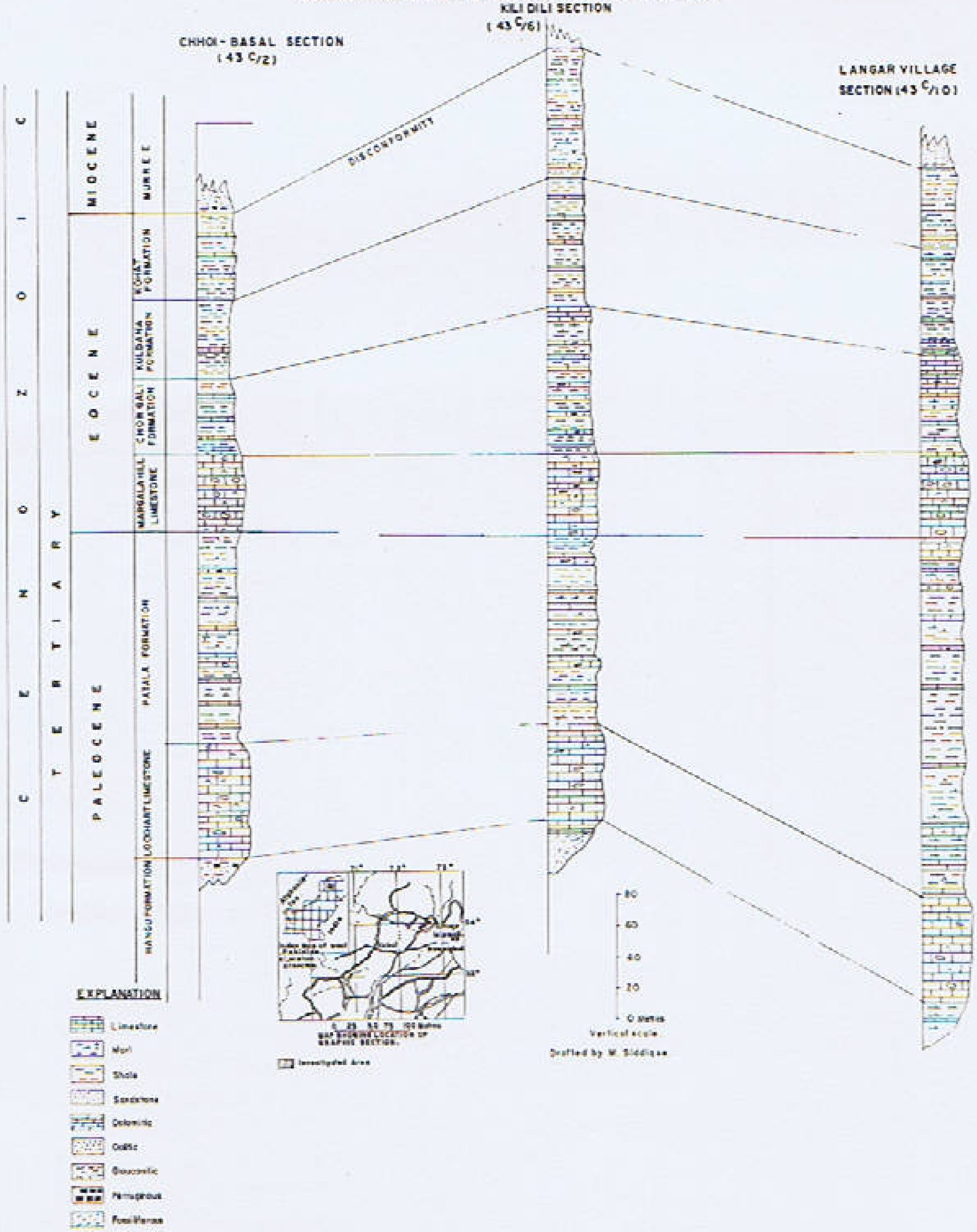
Shah, S.M., 1977, Stratigraphy of Pakistan *Geol. Survy. Pak. Mem., vol. 12, pp.*

Taseer, *etc. al.,* 1979, Neogene stratigraphy and fossil Vertebrates of Daud Khel area, Mianwali Distt. Pakistan. *Geol. Surv. Pak. Mem.* 13, pp. 27.

CORRELATION OF MESOZOIC ROCKS OF KALACHITTA RANGE.



CORRELATION OF CENOZOIC ROCKS OF KALACHITTA RANGE



61 C

AMENDMENT OF THE GENUS GODAVARISPORITES (TIWARI AND MOIZ) AND SOME MIOSPORE SPECIES FROM THE PERMIAN SEDIMENTS OF THE SALT RANGE, PAKISTAN

By

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Abstract : *The present paper deals with the revision of the taxonomic status of one palynomorph genuz viz Godavarisporites (tiwari & Moiz) and three species viz. Granulatisporites spinosus (Kosanke), Ginkogocycadophytus cymbatus (Potonie, and Lelex Balme & Hennelly) and Godavarisporites indicus (Tiwari and Moiz) isolated from the Permian sediments of the Salt Range, Pakistan. Their taxonomic status have been revised in the light of new combinations of morphographic characters. Genus Godavarisporites is thus amended as Godavariretusotriletes and Granulatisporites spinosus, Ginkgocycadophytus cymbatus and Godavarisporites indicus as Acanthotriletes spinosus, Cycadopites cymbatus and Godavarisetusotriletes indicus respectively.*

INTRODUCTION

Genus *Godavarisporites* was instituted by Tiwari and Moiz (1970) from the Lower Gondwana (Permian) Coals of Godavari basin India. *G. indicus* was designated as its type species. A very small population of sporomorphs resembling to *G. indicus* (Tiwari and Moiz) was isolated and thoroughly investigated during the palynological analysis of the rock samples belonging to Dandot and Warchha Formations of the Eastern and Western Salt Range respectively. Two other miospores species comparable to *Ginkgocycadophytus cymbatus* (Potonie and Lele ex Balme and Hennelly) and *Granulatisporites spinosus* (Kosanke) were also isolated and studied. Careful morphographic comparison of the Pakistani sporomorphs with the above mentioned spore taxa revealed that the original authors completely neglected some of the important diagnostic morphographic characters, which should otherwise have been included in the diagnosis of the genus *Godavarisporites* (Tiwari and Moiz) and species *Granulatisporites spinosus* (Kosanke) and *Ginkgocycadophytus cymbatus* (Potonie and Lele ex Balme and Hennelly). Genus *Godavarisporites* and *Granulatisporites spinosus*, and *Ginkgocycadophytus cymbatus* are thus amended in the light of new combinations of morphographic characters.

MATERIALS AND METHODS

Rock samples were crushed to 2mm grain size and treated with commercial Nitric acid for complete oxidation and then with Potassium Hydroxide. After this the residue was washed four times with distilled water by decantation method. Completely neutralized and macerated material was stained with aquas safranine and was mounted in glycerine jelly for microscopic examination.

EXPRESSION OF FREQUENCIES

Relative abundance of various miospore species in the assemblages in which they occured was determined by counting 450-500 specimens in each slide. Relative frequencies of different species are expressed as follows :

Dominent : More than 25%.

Abundent : More than 15% but less than 25%

Common: More than 10% but less than 15%

Frequent: More than 5% but less than 10%

Rare : Less than 5%.

SYSTAMETIC PALYNOLOGY

Anteturma SPORITES H. Potonie 1893.

Turma TRILETES (Reinsch) Dettmann 1963.

Suprasubturma ACAVATITRILETES Dettmenn 1963.

Subturma AZONOTRILETES (Luber) Dettmenn 1963.

Infraturma APICULATI (Bennie and Kidson) Potonie 1956.

Subinfraturma NODATI Dybova and Jachovicz.

Genus GODAVARITEUSOTRILETES (Godavarisporites) (Tiwari and Moiz) Gen. Nov. Plate 23 Fig. 3.

Type species : GODAVARIRETUSOTRILETES INDICUS (Tiwari and Moiz) emend.

AMENDED GENERIC DIAGNOSIS

Amb spherical, anisopolar, "Y" radii and contact area distinct, arms of laesurae upto the entire radial length, bifurcating at tips forming well defined curvaturae. Exine conate, coni with pointed or rounded tips.

GODAVARIRETUSOTRILETES INDICUS (Tiwari and Moiz) Comb. nov. Plate 1 Fig. 1.

1970 *GODAVARISPORITES INDICUS* Tiwari and Moiz P. 96, Pl. 1, Figs. 1-5.

HOLOTYPE :
GODAVARIRETUSOTRILETES INDICUS (Tiwari and Moiz 1970) Comb. nov. Plate 1, Fig. 1-5, P. 96.

DISTRIBUTION :
Dandot Formation Eastern Salt Range: rare, Warchha Formation rare.

DIMENSION :
(5-specimens) Equatorial Diameter 45 (50) 56 u.

AMENDED DIAGNOSIS

Miospore, trilete, amb spherical, polar view, anisopolar, "Y" marking and contact area prominent, represented by dark exinal area in between the trilete marking. Laesurae open, travelling entire radial length, ending sharply towards the peripheral region, bifurcating at tips and forming faintly developed curvaturae, detactable only under oil immersion upon careful L-O analysis. Lips smooth to sinuous. Laesurae 10 μ long, 2 μ wide, exine ornamented with sparasely placed pointed coni, coni uniformly distributed, ± 2 μ in basal diameter 2 μ–2.5 μ high with pointed to rounded tips. Coni exhibiting slight reduction in size within the vicinity of central area.

DISCUSSION

In gross morphology, the present sporo morph is comparable with *Godovarisporites indicus* Tiwari and Moiz (1970) P-96, Pl. 1, Figs. 1-5, differing slightly in size range and sparse distribution of cones on exine. In the figured specimen A, P. 96, Tiwari and Moiz (1970) have shown 27 coni projecting around the equatorial rim, which are not countable in the microphotograph provided (P.1, Fig. 1-5). A faintly discerniable curvaturae perfectae is clearly recognized in Tiwari and Moiz's (1970) specimen, on the basis of which they have compared and differentiated their newly established genus *Godavarisporites* from the Genera *Apiculatispora* (Potonie) *Retusotriletes* (Naumova) Streel (1964) and *Apiculiretusispora* Streel (1964) respectively. Presenting their views Tiwari and Moiz (1970) say (Page 70),

> "*Apiculiretusispora* Streel (1964), although compares closely with the present genus, differs in having bigger size with raised trilete rays, bearing mostly short spines (as seen in the genotype) and prominent arcuate ridges rather than faint rims. All the more, this genus has been reported from the Devonian (Lower Givetian) strata of Belgium, and hence is considered different from *Godavarisporites* gen nov."

The presence of curvaturae is a diagnositc feature of the genus *Godavarisporites* Tiwari (1970), which is also shared by the genera *Retusotriletes* (Naumova) Streel (1964) and *Apiculatiretusispora* Streel (1964) respectively. All the genera accomodating sporomorphs possessing clearly defined or fainly developed curvaturae, normally have prefix "retusi" as a constant feature of their generic epithat, this is not true for the genus *Godavarisporites* Tiwari and Moiz 1970, and due to this reason, the name *Godavarisporites* needs amendment, which is now amended as *Godavriretusotriletes* Tiwari and Moiz, comb nov.

PROBABLE AFFINITES :
Filicinean ?/ Bryophytic ?

SLIDE NO :
11/3.

FILM NO :
11/121082/6.

Genus ACANTHOTRILETES (Naumova) Potonie and Kremp 1954. Type species : *Acanthotriletes ciliatus* (Knox) Potonie and Kremp.

Acanthorriletes (Granulatisporites) spinosus (Kosanke) amend. Plate 1 Fig. 3, 4.

1950 *Granulatisporites spinosus* Kosanke P.22, Pl.3, Fig.

1955 *Anapiculatisporites spinosus* (Kosanke) Potinie and Kremp. P.82, Pl.14, Figs. 252-255.

1957 *Spinositriletes sentus* Dybova and Jachovicz, PP.130, 131, Pl.32, Fig.3.

1967 *Granulatisporites spinosus* Kosanke) Felix and Burbridge P.364, Pl.54, Fig. 10.

HOLOTYPE :
Granulatisporites spinosus (Kosanke) P.22, Pl.3, Fig. 7.

DISTRIBUTION :
Dandot Formation Eastern and Central Salt Range : very rare, Warchha Formation : Common to frequent. Diamensions (69 specimens) Equatorial Diameter 34 (37) 44 μ.

DESCRIPTION

Miospore, trilete, amb rounded to elongated triangular, angles broadly rounded, sides straight to convex, polar view, anisopolar, "Y" radii clearly defined, contact area not detectable laesurae travelling more than 3/4 radius, arms of laesurae 9-15 μ long, ending abruptly towards distal radial region commissure showing lengthwise invaginated groove in the center, guarded by irregular deffuse ± 2 μ thick, low, narrow, sinuous labra, with a tendency of becoming more irregular along the "Y" marking. Exine irregularly scuplttured with spinae, projecting radially all around, spinae bulbus and broad based, sharply pointed, straight to curved, ± 4 μ high and 3 μ high and 3 μ apart bases of spinae rounded to pentagonal in surface facus. Exine ± 2 μ thick distal face more heavily sculptured with curved to straight spines, spines 26-30 around equator.

DISCUSSION

Acanthotriletes faleatus (Knox) Potonie and Kremp 1955 in Smith and Butterworth (1967) with a size range of 29(36) 47 μ, is apparently identical. In contrast to Smith and Butterworth's species, the Pakistani specimen possess spinae which have bulbous bases. It also exhibits great variations as regards the shape of overall amb, which may be triangular, or spherical to sub-spherical in outline, the sides being apparently convex, rather than concave in specimens with triangular outline. *Granulatisporites spinosus* Kosanke (1950) is not justifiable to be treated as granulate, moreover, it is more or less identical to the Pakistani specimen under discussion in gross morphology, including sculptured elements. Kosanke (1950) has stated on P. 22. "The spore coat is characterized by numerous sharp spines which completely cover the distal and all of the proximal side, except an area surrounding the tetrad mark in some specimens. The spines are almost 4 μ long and 1-5 μ wide. The tetrad mark extends nearly to the spore wall and lips are slightly developed."

According to the information provided by Lakhanpal *et al.* (1976), very few specimens of this sort are discribed from India. Only two species of the genus *Acanthotriletes* have been described in detail, and number of species are described without any specific designation. *G. spinosus* is, therefore, emended as *Acanthotriletes spinosus* comb. nov.

PROBABLE AFFINITIES
Filicinean.

SLIDE NO :
$SM_2BB/33$, $SM_2BB/08$, $SM_2BB/9$, $SM_2BB/23$, $SM_2BB/2$.

FILM NO :
16/221082/5, 14/201082/5,
14/201082/8, 14/201082/4,
14/211082/16, 16/221082/11.

Anteturma POLLENITES Potonie 1931.

Turma PLICATES (Naumova) Potonie 1962.

Subturma MONOCOLPATES Iverson and Troels-Smith 1950.

Genus CYCADOPITES Woodhouse ex Wilson and Webster 1946.

Type species : *Cycadopites follicularis* Wilson and Webster 1946.

Cycodopites cymbatus comb. nov.
Plate 1, Fig. 1.

1966 *Ginkgocycadophytus cymbatus* (Potonieand Lele ex Balme and Hennelly Kar, P. 127, Pl. 2, Fig. 39.

HOLOTYPE :
Ginkgocycadophytus cymbatus Balme and Hennelly 1964.

DISTRIBUTION :
Dandot Formation Eastern and Central Salt Range; very rare, Warchha Formation Western Salt Range : rare.

DIMENSIONS :
(10-specimens)
total length : 62(59) 74 μ
total breadth: 38(34) 50 μ

AMENDED DIAGNOSIS

Pollen grain, amb oval, extermites round to pointed, polar view, anisopolar, bilateral, monosulcate, sulcus ± 60 μ long, ± 10 μ apart in the middle, with a maximum width of ± 19 μ at one extermity, gradually tapering while travelling towards the other pole, where it is sometimes completely closed with overlapping margins. Commissure smooth and straight, labra weakly developed, hyaline, not distinguishable from rest of the exine, rarely raised, mostly discontinuous, exine of proximal hemisphere ± 2 μ thick, intrapuncture, relatively thickened along pheriphery, with minute dentations vision only upon careful focusing under oil immersion. Distal hemisphere translucent with relatively less thick and punctuate exine, Puncta ± 2 μ, ± 1 μ apart.

DISCUSSION

Balme (1970) revised the status of the genus *Ginkgocycadophytus* (Samoilovich) and prefered it to be called as *Cycadopites* Wilson and Webster. While presenting his view on P. 412, he says : —

> "Simple monosulcate pollen grains without exinal structure or sculpture have been referred to various from genera, although most recent authors have favoured either *Cycadopites* Wilson and Webster or *Ginkgocycadophytus* Samoilovich. Of these two names *Cycadopites* has clearly priority, and *Ginkgocycadophytus* is invalid unless it can be demonstrated that its type species, *G. caperatus* (Luber), is excluded from *Cycadopites.* From the original description of *G. caperatus* it is probable that at least some specimens assigned to the species were sculptured and samoilovich (1953) certainly used it for spinose forms. It may be appropriate, therefore, to retain *Ginkgocycadophytus* for certain sculptured, simple, monosulcate pollen grains. Jansonius has reviewed the synonymy of *Cycadopites* and defined it in simple terms. His treatment is acceptable except that the genus should be explicity restricted to forms devoid of structure and sculpture."

Ginkgocycadopites cymbatus Balme and Hennelly) Potonie and Lele in Kar (1966) is similar in gross morphology as well as in size range, to the present sporomorphy. In the light of Balme's discussion *Ginkgocycadopites cymbatus* should now be regarded as *Cycadopites cymbatus* (Balme and Hennelly) Potonie and Lele comb. nov.

PROBABLE AFFINITIES
Cyadoginkgops.

SLIDE NO :
$SM_2BB/20$.

FILM NO :
26/311082/9.

ACKNOWLEDGEMENT

Microphotographs were taken on "Forte" films by one of us (Dr. Bhutta) and we are thankful to Mr. Ahmad Ali Khan who made the prints appearing in this paper.

EXPLANATION OF PLATE I.
(All figures magnified X 1000)

1. *Godavariretusotrilete indicus* Tiwari and Moiz) comb nov.

2. *Cycadopites cymbatus* (Potonie and Lele ex Balme and Hennelly) comb. nov.

3. *Acanthotriletes spinosus* (kosanke) comb nov.

REFERENCES

Balme, B.E., 1970. Palynology of Permian and Triassic Strata in the Salt Range and Surghar Range, W. Pakistan. In Stratigraphic Boundry Problems : Permian and Triassic of West Kansas. Geol. Deptt. Sp. Pub. 4. PP. 305-453.

Kar, R.K. 1966. Palynology of the Birren Measures Sequuence from Jharia Coalfield, Bihar-1 symp. Flo & Strat. of Gond. sp. Pub. Birb. Sah. Ist Pabo. 1966. PP. 121-127.

Kosanke, R.M. 1950. Pennsylvanian spores of Illinois and their use in Correlation : Bull. Illinois. State Geol. Survey V. 74, 128PP.

Lakhanpal. R.N., Maheshawari, H.K. and Awasthi, N. 1976. A Catalogue of Indian Fossil Plants PP. 318. Birbal Sahni Insttt. of Palaeobotany, Kucknow. India.

Smith, A.H.V. and Butterworth, M.A. 1967. Misopores in the Coal seams of the Carboniferous of Great Britain. Palaeontological Association London, Special paper in Palaeontology No. 1. PP. 324.

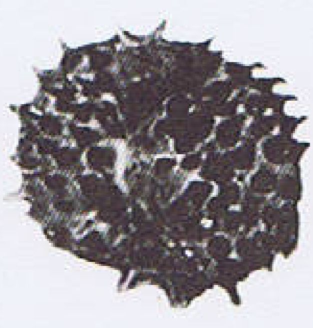
Streel, M. 1964. Une Association de spores du Givetien inferieur de la Vesdre, a goe Belgique). Ann. Soc. Geol. de Belgique 87(7) : 1-29.

Tiwari, R.S., and Moiz, A.A., 1970. Palynological study of Lower Gondwana (Permian) Coals from Godavari Basin, India, 1-on some new miospore genera. Palaeobotanist 19(1) : 95-104 Issued 1971.

PLATE I

1

2



3

4

BIOSTRATIGRAPHIC PROBLEMS OF THE SIWALIKS OF THE POTWAR PLATEAU OF PAKISTAN

By

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Abstract : *Pilgrim's faunal zones of Neogene terrestrial sediments of Potwar are rejected. Instead biostratigraphic interval-zones are proposed, based on extinction of fauna. Four interval-zones, each of 2 m.y. duration, are characterised.*

INTRODUCTION

Middle and late Miocene and younger rocks are widely exposed in Pakistan, particularily along southern margin of the Himalayas in the North and along the western edge of the Indus Basin South to the coast. In places, the rocks are very fossiliferous and have been a rich source of fossil vertebrates for 150 years. Recently, renewed interest in the fossils and particularily in the hominoids has lead to the creation of collaborative research projects between various foreign and host Pakistani institutions. One of these, the Geological Survey of Pakistan-Harvard Joint Project (formerly GSP-Yale Joint Project), has for ten years concentrated mostly, but not exclusively, on the Miocene through Pleistocene sequence on the potwar plateau and adjacent regions, which is one of the most productive fossil collecting areas. Our efforts on the Potwar plateau and elsewhere have been mostly directed towards determining age of the sediments and composition and succession of the faunas, as well as doing paleoenvironmental reconstruction and discovering more fossil material.

The Miocene rocks of Pakistan are exceptional among Neogene terrestrial sequences because they are extremely thick and span a fifteen million year period with few apparent long hiatuses (Johnson *et al.*, 1982). Of fluvial origin and formed as fans and sheets of sediment deposited in troughs bordering the mountains to the North and West (Behrensmeyer and Tauxe, 1982), the Siwalik formations of the Potwar plateau and their correlatives elsewhere formed following the collision of Indo-Pak with Asia and the consequent crustal deformation. Immediately underlying rocks vary in age and character. Most are early or middle Eocene marine limestones and associated clastic sediments and there is thus a major hiatus underlying the terrestrial sequence (Shah, 1977). The age of the onset of fluvial sedimentation on the Potwar plateau is of considerable interest, but the problem has not yet been resolved. In most areas the onset is thought to be of very latest early Miocene age (17–19 MY), but probably varies considerably throughout the Indo-Pak Subcontinent. In Sind (Pakistan) there is an Oligocene and early Miocene marine sequence North of Karachi that appears to pass gradationally into the overlying fluvial beds of the middle Miocene Manchar Formation.

The stratigraphic relationships of the major lithologic units are complex, at least on the Potwar plateau where they have been most intensively studied. Although differentiation of the formations is difficult, because all are composed of lenticular and sheet sandstones combined with silts and clays, individual formations differ in the proportions of sands, silts, and clays; in the geometry of the sandstones and fine-grained deposits; and occasionally in mineralogical content. In addition, parts of some of the formations are laterally equivalent to parts of others and the described series of formations does not form a simple chronological sequence, as were thought by Pilgrim and others (Pilgrim, 1913, 1917; Pilbeam *et al.*, 1979 Barry *et al.*, 1980). A particular goal of our project then has been to modernize and improve the stratigraphic nomenclature applied to these rocks so as to make it a help rather than a hindrance to our geologic and paleontologic research. This has involved re-thinking about the lithostratigraphic, biostratigraphic, and chronostratigraphic nomenclature. The reasons for doing this are themselves complex, but basically follow from the belief that the old nomenclature of Pilgrim and others is unsatisfactory because it is imprecise and because its methodological approach does not lend itself to further refinement.

STRATIGRAPHIC NOMENCLATURE

The lithostratigraphic and biostratigraphic nomenclature of the Neogene terrestrial rocks of Pakistan and India has had a confused history. Stratotypes of six of the commonly recognized mammal-bearing formations are on the Potwar plateau and include from oldest to youngest the Murree, Kamlial, Chinji, Nagri, Dhok Pathan, and Tatrot Formations. The last four, together with the still younger Pinjor Formation and Boulder Conglomerate in India (or their presumed correlatives such as the Soan Formation) constitute the Siwalik Group (Shah, 1977). (Increasingly, however, the term Siwaliks is informally applied to all the Neogene non-marine formations of northern Pakistan and north-western India, and it is used as such in this paper). In the southern and central parts of Pakistan, additional units are recognized. Important ones include the Chitarwata Formation, which near Dera Bugti has what is probably the oldest Neogene mammal fauna in Pakistan, and the Manchar Formation and Dada Conglomerate, which at least near Lake Manchar are approximately of same age as the lower half of the Potwar succession.

Although now considered to be formations (lithostratigraphic units), Pilgrim's units were first conceived of as faunal zones (biostratigraphic units) or, in some cases, as undifferentiated lithostratigraphic-biostratigraphic entities for which there is no currently accepted concept (Pilgrim, 1910, 1913; Hedberg, 1976). Whether taken as lithostratigraphic or biostratigraphic units, they have been treated universally as if they were also chronostratigraphic units as well (Colbert, 1935; Lewis, 1937; Pilbeam *el al.*, 1977). Modern stratigraphic practice, however, demands that these concepts be kept separate and the need for doing so is well illustrated by the problems of Siwalik stratigraphy.

Although the great degree of lithological similarity makes it difficult to distinguish between them yet the stratigraphic units used by Pilgraim and his contemporaries have now been typified as formations (Shah, 1977) and provide a viable lithological framework for at least the rocks of the Potwar plateau. However, the biostratigraphic and ultimately the chronostratigraphic units based on them are seriously flawed and unworkable because of two inherent defects.

The first defect is the result of lack of demonstrable superposition between Pilgrim's six Miocene and Pliocene faunal zones which means that boundaries of the faunal units are imprecise at best or, more typically, totally undefined. As lithological units, Pilgrim 1913 and 1917) was able to demonstrate the superposition of five of this six units (Tatrot, Dhok Pathan, Nagri, Chinji, and Kamlial, but not the Gaj) because he could use lithological correlations over limited area of the Potwar plateau to relate widely separated type areas. The sections in his 1913 paper thus show the same sequences of rock types throughout the Potwar plateau. We know now, however, that there is considerable overlap between some of the Siwalik formations when mapped on a regional scale and, further, there is a three million year long hiatus between Dhok Pathan and Tatrot type sections (Opdyke *et al.*, 1979). Formations, of course, are only lithological bodies and it is legitimate and even expected that they will be laterally equivalent to other formations or separated by long hiatuses. When first formulated, little or no attention was given to the boundaries of the Siwalik faunal zones and it was vaguely presumed that the boundaries of each faunal unit would coincide with the boundaries of the apprent lithologic unit. If the Siwalik biostratigraphic and chronostratigraphic units are to strictly correspond to the lithological units, however, then this means that they must also overlap or have gaps between them. This is acceptable for biostratigraphic units, although I think undesirable, but it is absolutely fatal to the concept of a chronostratigraphic unit. As faunal and temporal units, only the Chinji and Nagri faunal zones are in direct superposition; all the others can only be related by temporally imprecise lithological correlations. Thus only between the Chinji and Nagri faunal zones can a definite boundary be drawn. All other boundaries must remain imprecise or undefined.

The second defect is also a result of confusing stratigraphic concepts. Because some of his type areas had few fossils, Pilgrim unsed fossils from distant regions in order to include enough species to make each faunal zone distinctive. He was therefore forced to assume that his lithological correlations were also chronological correlations. Thus the Kamlial zone is characterized by fossils from the Manchar Formation in Sind, the Nagri by fossils from Haritalyangar in India, and the Dhok Pathan in partly by fossils from near Hasnot. These correlations probably are only broadly correct.

We have no reason to think that Pilgrim's faunal zones are not a series of sequential units, but taken together these two defects make it impossible to either characterize or subdivide them, and thus ultimately they are not useful. In particular, since the units cannot be characterized, they cannot be distinguised from similar units nor recognized outside the type areas. Further, because the superpositional relationships between faunal zones are not demonstrated we cannot define their boundaries nor subdivide them into the smaller units needed for more precise correlations and paleoecological or similar studies. As biostratigraphic or chronostratigraphic units, pilgrim's faunal zones should be discarded.

INTERVAL-ZONES

A series of explicitly biostratigraphic zones that are defined and characterized in reference sections and correlated to a magnetic polarity sequence (Tauxe and Opdyke, 1982; Johnson *et al.*, 1982) provides a more useful biostratigraphic division of the Siwalik faunas. To this end, Lindsay, Jacobs, and myself have proposed four biostratigraphic interval-zones for the middle and upper Siwalk sequences (Barry *et al.*, 1982) (Figure 1). A biostratigraphic interval-zone is the stratigraphic interval between two distinctive biostratigraphic events (Hedberg, 1976) — such as the extinction or appearance of two different taxa — and we chose to use them for three reasons. First they can be precisely defined and precisely located in stratigraphic sections; second they can easily be amended or subdivided; and finally they place emphasis on faunal events as the primary biostratigraphic tool, rather than on vague general comprisons of whole faunas.

Our interval-zones are defined in reference sections, one near Khaur and one near Hasnot. By designating a reference section for each zone, we are able to recognize the stratigraphic horizons of each unit's boundaries and then relate the boundaries to other biostratigraphic and chronostratigraphic events. Because the zones are based on faunal events, however, the exact horizons of the boundaries are subject to change as more fossils are discovered. We have tried, however, to use only common taxa and we believe that the stratigraphic horizons of the chosen biostratigraphic events have been exactly determined in the Siwalik sequence. Designating reference sections also places the boundaries of each biostratigraphic zone in a lithostratigraphic unit, but it should be noted by the reader that the lithostratigraphic units do not set limits on the interval-zones and the correlations between the two reference sections are based solely on the magnetostratigraphy (Tauxe and Opdyke, 1982; Johnson *et al.,* 1982) and not the lithostratigraphy or the biostratigraphy.

These biostratigraphic interval-zones are not chronostratigraphic units, although they may eventually be shown to be isochronous units and thus might be incorporated into a chronostratigraphic zonation. Such a zonation, however, would use biostratigraphic events as only one of several types of occurrences. Other occurrences would certainly include magnetostratigraphic and perhaps geochemical events. Any chronostratigraphic nomenclature should be kept separate from that of both the litho and biostratigraphic schemes.

Details can be found in the primary source (Barry *et al.,* 1982), but currently four biostratigraphic interval-zones are recognised in the middle and upper Siwaliks, that is in rocks between 10 and 1.5 million years old. The four zones are bounded by five successive events; the appearances of 1) *Hipparion s.* l., 2) *selenoportax lydekkeri,* 3) *Hexaprotodon sivalensis,* and 4) *Elephas planifrons*; and the extinction of 5) *Hipparion* s.l. These are all common and easily recognized taxa, even for the non-specialist.

The. four zones and their lower and upper boundaries are: 1) *Hipparion* s.l. Interval-zone: appearance of *Hipparion* s.l. and *Selenoportax lydekkeriu* 2) *Selenoportax lydekkeri* interval-zone: appearance of *Selenoportax Lydekkeri* and *Haxaprotodon sivalensisc* 3) *Hexaprotodon sivalensis* interval-zone: appearance of *Hexaprotodon sivalensis* and *Elphas planifrons*; 4) *Elephas planifrons* Interval-zone; appearance of *Elphas planifrons* and extinction of *Hipparion* s.l. The current estimates for the ages of the boundries in the reference sections are shown in Figure 1. In addition we have attempted to determine the characteristic mammals of each zone and provide secondary paleontological criteria for recognizing each zone and its boundaries.

This work, of course, is not yet complete. The biostratigraphic zonation needs to be extended into rocks less than 1.5 million years old and, most importantly, into the recks older than 10 million years. We currently are working on faunas from the Chinji and Kamlial Formations of the Potwar plateau, which we anticipate will carry the zonation back to more than 16 MY. Important faunas are also known from the Manchar Formation and from Dera Bugti and if these can be magnetostratigraphically correlated to the Potwar sequence, then the possibility exists to carry the zonation event further.

Study and re-analysis of the fossil mammals is an on-going project and as result become available it should be possible to subdivide the current zones and those we anticipate characterizing in the immediate future. As now defined, each of our zones is of about two million years duration in the reference sections. For chronostratigraphic purposes this is rather crude. A future goal might than be to try to develop a chronostratigraphic scheme, based on both magnetostratigraphy and biostratigraphy, that would allow correlations accurate to within 100,000 years.

REFERENCES

Barry, J.C., A.K. Behrensmeyer, and M. Monaghan. 1980. A geologic and biostratigraphic framework for Miocene sedimentsnear Khaur Village, Northern Pakistan. *Postilla.* 1983 : 1–19.

Barry, J.C., E.H. Lindsay and L.L. Jacobs. 1982. A biostratigraphic zonation of the middle and upper Siwaliks of the Potwar Plateau of Northern Pàkistan. *Palaeogeography, Palaeoclimatology, Palaeoecology.* 37 : 95–130.

Behrensmeyer, A.K. and L. Tauxe. 1982. Isochronous fluvial systems in Micene deposits of Northern Pakistan. *Sedimentology.* 29 : 331--352.

Colbert, E.H. 1935. Siwalik mammals in the American Museum of Natural History. *Transactions of the American Philosophical Society. 26 :1–401.*

Hedberg, H.D. (Editor), 1976. International Stratigraphic Guide. Wiley, New York, 200 pp.

Johnson, N.M., N.D. Opdyke, G.D. Johnson, E.H. Lindsay, and R.A.K. Tahirkheli. 1982. Magnetic polarity stratigraphy and ages of Siwalik group rocks of the potwar plateau, Pakistan. *Palaeogeography, Palaeoclimatology, Palaeoecology.* 37 : 17–42.

Lewis, G.E. 1937. A new Siwalik correlation (India). *American Journal of Science.* 33 : 191 204.

Opdyke, N.D., E. Lindsay, G.D. Johnson, N. Johnson, R..A.K. Tahirkheli, and M.A. Mirza. 1979. Magnetic polarity stratigraphy and vertebrate paleontology of the Upper Siwalik subgroup of northern Pakistan. *Palaeogeography, Palaeoclimatology, Palaeoecology.* 27 : 1--34.

Pilbeam, D., J. Barry, G.E. Meyer, S.M.I. Shah, M.H.L. Pickford, W.W. Bishop, H. Thomas, and L.L. Jacobs. 1977. Geology and palaeontology of Neogene strata of Pakistan. *Nature.* 270 : 684–689.

Pilbeam, D.R., A.K. Behrensmeyer, J.C. Barry, and S.M.I. Shah. 1979. Miocene sediments and faunas of Pakistan. *Postilla.* 179 : 1–45.

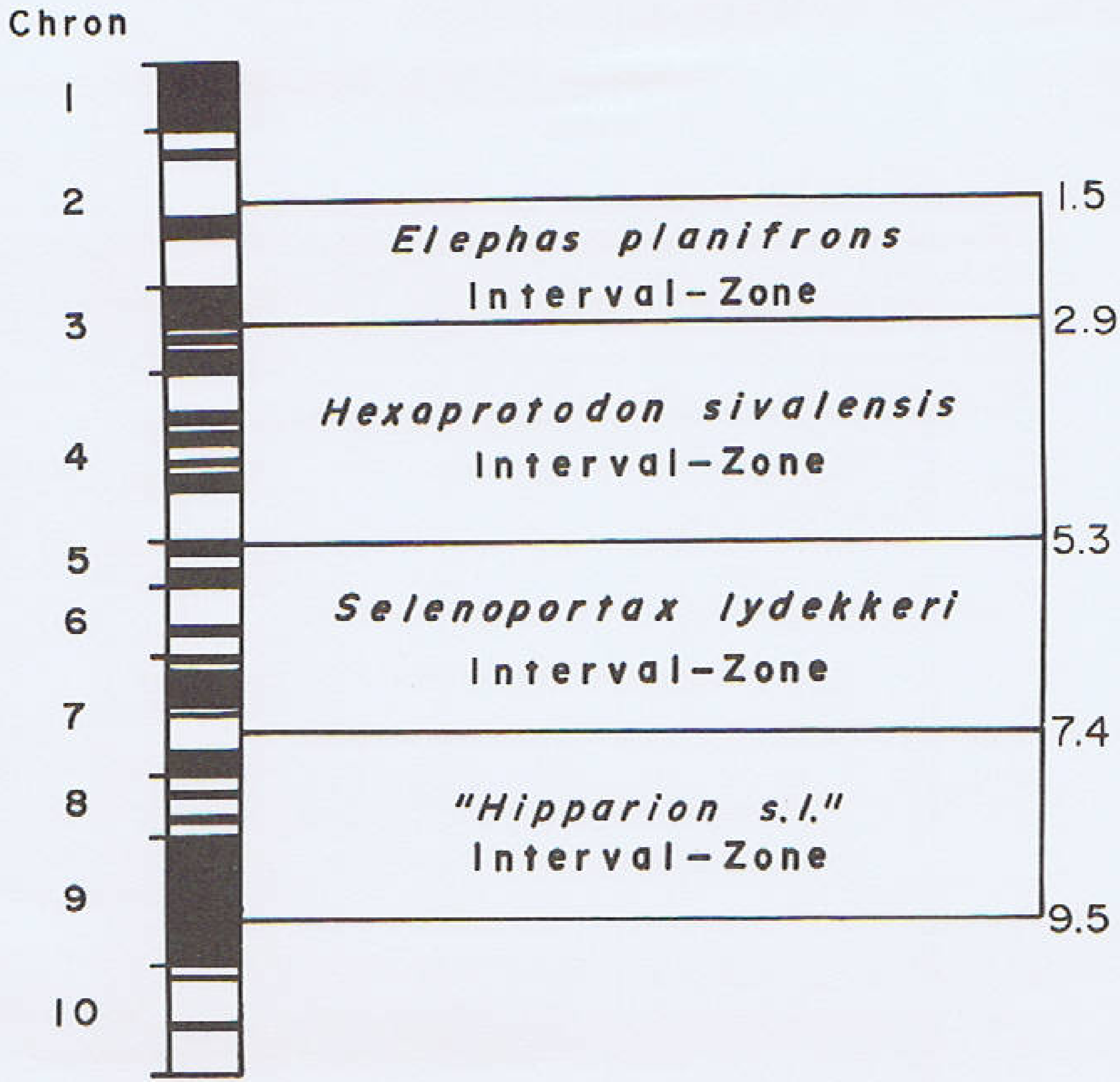
Pilgrim, G.E. 1910. Preliminary note on a revised classification of the Tertiary freshwater deposits of India. *Records Geological Survey of India.* 40 : 185–205.

Pilgrim, G.E. 1913. The correlation of the Siwaliks with mammal horizons of Europe. *Records Geological Survey of India.* 43 : 264–326.

Pilgrim, G.E. 1917. Preliminary note on some recent mammal collections from the basal beds of the Siwaliks. *Records Geological Survey of India.* 48 : 98–101.

Shah, S.M.I. (Editor). 1977. Stratigraphy of Pakistan. *Memoirs Geological Survey of Pakistan.* 12 : 1–138.

Tauxe, L. and N.D. Opdyke. 1982. A time framework based on magnetostratigraphy for the Siwalik sediments of the Khaur area, Northern Pakistan. *Palaeogeography, Palaeoclimatology, Palaeoecology.* 37 : 43–61.


Chron
1
2
3
4
5
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7
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Elephas planifrons
Interval-Zone
Hexaprotodon sivalensis
Interval-Zone
Selenoportax lydekkeri
Interval-Zone
"Hipparion s.l."
Interval-Zone
1.5
2.9
5.3
7.4
9.5

STRATIGRAPHIC SYNTHESIS AND ITS IMPLICATION ON THE GEOLOGY OF PETROLEUM IN MAKRAN

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Abstract : *Makran is a convergent plate margin, where convergence is still on-going. This has resulted in a complex structural development of stratigraphic and sedimentologic units of the main sedimentary sequences in the area.*

The stratigraphic synthesis carried out by the Hydrocarbon Development Institute of Pakistan (HDIP) in Makran has lead to differenciate several facies and to recognise a number of basinal elements. Such interpretation made in the light of plate tectonic considerations has also made it possible to compare Makran with analogues elsewhere in the world.

In view of the presence of a number of favourable factors for the presence of hydrocarbon accumulations in the region, it is felt that the principal reason for failure in locating oil and gas in Makran has been the lack of exploratory drilling.

INTRODUCTION

The Makran region, West of Chaman -- Ornach – Nal faults system, is a part of continental margin where the Arabian plate is being subducted below the Eurasian plate (Fig. 1). It is the widest and the best exposed fore -- arc terrain in the world and offers magnificiant opportunities to study tectonic and sedimentological evaluation of a mature accretionary complex.

HDIP's studies in the Baluchistan Basin in the light of plate tectonic considerations have revealed the existence of following basinal elements on-shore (Fig. 2) :—

1) Chagai Arc
2) Dalbandin Inter-arc Basin
3) Raskoh Arc
4) Mashkhel Kharan fore-arc Basin
5) Panjgur Accretionary Prism
6) Coastal accretionary Fore-arc Basin (also extending offshore more than 10 km).

Axis of tectonism and sedimentation has been progressively shifting southwards. Some 100 km offshore, convergence is still active. Other accretionary forearc basins (slope basins) may be present between the shore line and the active convergence margin.

STRATIGRAPHIC SYNTHESIS

The underthrusting of the Arabian plate under the Eurasian plate marked a fundamental change in the sedimentation pattern in Makran characterised by almost complete absence of carbonates and deposition of thick sandstone and shale units, which form the principal outcrops of the region.

The northern and central Makran fold belts comprise piling up of slope and accretionary sediments on the southern flank of forearc basin formed at consuming plate boundary where abyssal sediments and turbidites covering the subducting plate were being thrusted up to form steep folds and imbricate wedges. With accretion of more sediments, the older parts of the accretionary wedge probably were subjected to further compression culminating in their severe deformation and uplift above sea level. The prograding shelf/slope sequence represented by Miocene-Pleistocene sediments is postulated to be deposited in an accretionary forearc basin and is characterised due to its contrasting tectonics, lithologic characters and depositional environments as compared with the underlying sediments.

Accordingly, Makran sedimentary sequence (Middle Eocene to Pleistocene) has been subdivided into 5 stratigraphic units (Fig. 3) :—

1. Early Miocene rocks deposited in an oceanic basin and consisting of abyssal muds (Hoshab/Siahan shales) and turbidites (Panjgur formation).
2. Late Miocene sediments of accretionary forearc basin deposited in a shallow marine environment (Parkini formation).
3. Late Miocene-Pliocene cyclic sediments East and West of Pasni anticlinorium (Hinglaj formation/Talar).
4. Pliocene-Pleistocene neritic, massive and monotonous sequence of calcareous mudstones (Chatti formation).
5. Early to late Pleistocene marine shoreline deposits (Ormara and Jiwani formations).

SEDIMENTOLOGY

1. Panjgur Formation

Panjgur rocks constitute the lowest structural level seen, forming in the south linear ridges above thrust planes. The Panjgur formation is a turbiditic sandstone-dominated unit, chiefly comprising packets up to several tens of metres thick of a cyclic decimeter-to meter scale greenish turbiditic sandstones and associated shales. Predominantly "distal facies", interrupted by sporadic "megaturbidite" units are also found. In addition, previously undescribed conglomerates occur in the Panjgur strata (e.g. South of Pidarak and in the Gokh Prush Band) and contain a suite of ophiolitic and volcanic pebbles which cannot be matched with rocks currently exposed in the hinterland.

Most Panjgur sandstones seem to have originated on an abyssal plain environment with majority of sediment fed from the East (? the ancestral Indus), but with important subsidiary input from the North, i.e. Makran hinterland itself. In some cases anomalous interabasinal derivation, i.e. from the South quadrant, indicates that not all the turbiditic sections are basin-floor accumulations deriving from the ancestral Gulf of Oman; some may be lower-slope basin-fill sequences.

2. Parkini Formation

It comprises a monotonous sequence of mud and sandstone "rib" beds. However, a detailed study shows that there are interesting variations. Locally thin conglomorates occur, containing the same complement of exotic clastics as the Panjgur rudites. The thin-bedded sandstones which locally comprise up to 10% of the section didplay fairly common turbiditic characters in lower levels of the Parkini. But at higher levels, there are more indications of shallower water deposition. Among these, we have found coquina conglomerates over wide areas. This is supported by the apparent restriction of deep-water facies at lower levels in the Parkini. It appear that the Parkini records a shallowing (uplift) history. That being the case, the Parkini probably best merits interpretation as a lower slope blanket-accumulation. This is supported by the discovery of soft-sediment slump structures.

3. Talar Formation

Interbedded sandstones and shales of the Talar formation which sit concordantly on Parkini shales, reach a thickness of up to 5 km on the N. limb of the Kulanch syncline (Figs. 2 & 3). The sedimentological investigations indicated that they are deposits of a storm-dominated shelf sea. They are notably cyclic, being organised in 20-50 m sequences of shale to fine sandstone or sandy shale to coarser sandstone, these are classifiable between two end member types: "proximal" (? inner shelf) and "distal" (? outer shelf). Facies changes are spectacular, notably across the strike between successions on the North limb of the Kulanch syncline. The Talar-type facies pass along strike into Parkini-type facies in the Ghulamani-Bent area. The characteristic cyclicity is interrupted by coarse sand packets up to 20 m thick containing upper-flow regime structures and abundant mud rip-up layers. These are interpreted as "rare event" (tempestite) bodies and are tracable for many (? 10) km along South limb of the Kulanch syncline. Perhaps, most exciting discovery in the Talar formation concerns local coarse rudite members in the North limb of the Kulanch syncline. These are probably coastal conglomerate deposits, and testify to a markedly different coastal profile in Miocene time. Like Panjgur and Parkini rudites, they contain an interesting exotic pebble suite. In close association with conglomerates in one of the section, is a previously undescribed red mudstone which we strongly suspect is a subaerial deposit.

HYDROCARBON POTENTIAL

Rapid sedimentation associated with subduction favours rapid burial of organic meterial prior to exidation during deposition of turbidites in deep trenches formed by underthrusting. Thomson (1976) has shown that thrust faulting may bury the sediments to depths and subsequently uplift them. Such a process implies consolidation of sediment pile at depth, uplift and subsequent slumping of sediments from high on the slope to the lower slope and trench. Accordingly, the patch of tectonic transport may result in generation and expulsion of oil and gas.

It may be pointed out that petroleum has been encountered in various analogues of the Makran region. The occurrence of hydrocarbons in these analogues are in the residual and/or composite basins of broad ridged forearc (Mentawai trough), a terrestrial upland ridged forearc (Talar basin) and a shelved forearc basin (Honshu). The reservoir facies of these occurrences are marine, near-shore, deltaic, turbidite and reef. Traps are normal fault blocks, thrut faulted folds and stratigraphic.

TRAPS

There is no lack of closed structures of considerable size and shape, which can be located in the onshore and offshore areas of Makran Source Rocks.

SOURCE ROCKS

The turbidites contain considerable organic matter, which as per theory explained by Thomson (1976, could be treated as source rocks. The abyssal Hoshab/Siahan shales could also be regarded as potential source rocks.

The Parkini mudstone facies appear to

be the most potential source rock in the coastal area, for samples from different localities at different stratigraphic levels have been analysed. It appears that the upper horizons of the formation are relatively rich in organic matter than the basal part. It contain fine amorphous, brown to black loptinitic/humic organic matter having OM type from II to III with maturity ranging from Ro 1 to 1.6 %. The source rock studies carried out in Garr Koh Well No. 1 indicated good source rock on the basis of organic contents and hydrocarbon extracts (Quadri, 1980).

GEOTHERMAL MATURATION

Organic maturation of suitable source rocks and optimum generation of hydrocarbons from them are determined by various factors of which temperature, age of the sediments and quantity of the organic contents are believed to be the most important influencing factors. The geothermal gradient for Makran as determined from well-logs is approximately 2°C/100m which is compatible with the convergent plate margins having relatively cool oceanic crust resulting in downward deflection of isotherms in the subducted plate. Active thermal generation of small quantities of light hydrocarbons has, however, been reported from depths of only 250m in the Aleutian Trench even though geothermal gradients in the vicinity of trenches are typical below average (Dow, 1977).

Geothermal gradients of the well drilled in the area as calculated from electric well-logs are as follows :—

1. Kech band 2.4°C/100 m
2. Garr Koh 1 2.6°C/100 m
2. Jal Pari 1 A 1.4°C/100 m

Although well data is scarce, it can be seen that Makran is a relatively cool region. Adopting Gill's model of geothermal source rock maturation (Gill, 1978), it is expected that optimum depths for generation of oil and gas in Makran would be from 3,500 m to 5,500 m. The tectonics, however, may alter these depths drastically due to over-thrusting and underthrusting.

RESERVOIR ROCKS

The sedimentological evolution and gross geometry of various horizons in the stratigraphic sequence of Makran region indicate presence of a variety of reservoir rocks of varying characters and origin.

Reefoid limestone of Eocene age could be classified as fairly good reservoir in the deeper horizons around Central Axis.

The principal outcrops in North and central Makran are severely tectonized turbidites of Panjgur formation containing fine to occasionally very coarse grained sandstones. They were considered to be the best potential reservoir rocks in these areas by previous explorers. The high percentage of well sorted sandstone in the Talar-Hinglaj formations indicates major prospective reservoir in the coastal and offshore areas of Makran.

CONCLUSION

Based on stratigraphic synthesis of Makran region, it has been shown that environments suitable for accumulation of source rock exist in the area. The source rock geochemistry, undertaken by HDIP in collaboration with Imperial College of Science and Technology, indicates that the Parkini formation is fairly good source rock having gas and oil-prone organic contents.

The Talar formation is considered to have the best prospects of hydrocarbon accumulation. Here, following requisites of trapping are found :—

i. Simple warping, rather than tight folding

ii. Pronounced regional facies changes in sandstone bodies.

iii. Sufficient thickness (locally more than 5km) to foster organic maturation in underlying rocks.

iv. Presence of shales (potential source rocks) lower in the section.

The Panjgur sandstones, though they are more porous than the Talar sandstones and comprise sandstone bodies of equal dimensions to Talar bodies, are a less attractive prospect due to their greater deformation. However, prospect of Punjgur reservoir can not be discounted because deformation studied in the South of the area could prove to be of the thin-skinned variety, occuring above a shallow decollement below which the geology could be simpler.

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REFERENCES

Ahmed, S.S., 1969, Tertiary geology of part of South Makran, Baluchistan, West Pakistan, AAPG Bulletin, Vol. 53, No. 7 pp. 1480-1499.

Dickinson, W.R., 1976, Plate tectonic evolution of sedimentary basin in Plate Tectonics and Hydrocarbon Accumulation, APPG Source Note Series 1, 62, p.

Farhoudi G. and Karig, D.E., 1977, Makran of Iran and Pakistan as an active arc system Geology Vol. 5 pp. 664-688.

Gill W.D., 1978, Petroleum Source rocks and origin of oil and gas in Iran, Pakistan and North Sea; Bill. Iranian Petrol. Inst. Tehran, no. 69.

Hunting Survey Corp., 1960. Reconnaissance of Geology of Part of West Pakistan Toronto, 550p.

Jacob, J. H. and Quittmeyer, R.L., 1979, The Makran region of Pakistan and Iran; Trench-Arc system with active plate subduction; Geodynamics of Pakistan. Geological Survey of Pakistan Quetta, pp. 305-317.

Quadri, N.V., 1980, Petroleum prospects of Pakistan and oil oriented exploration guidelines; Petroleum Institute of Pakistan Symposium March, 1980 12 p.

Raza, H.A., 1979 Geothermal gradients in Pakistan; Punjab University Geological Bulletin, Institute Number, Lahore,

Raza, H.A., and Alam. S., 1983, Pakistan's Makran region merits extension oil hunt, Oil & Gas Journal, July, 18, 1983 pp. 170-174.

Raza, H.A., and Leggett J.K., Alam, Kinghorn R.R.F. and Rehman M. 1983, Petroleum Geology of Makran, 8th PIP Symposium, Islamabad.

Leggett, J.K. and Platt, J.P., 1983, Makran Project Report on Ist June, unpublished report in files of HDIP.

Seely, D.R., and Dickinson, W.R., 1977, Structure and stratigraphy of forearc region in Geology of Continental Margins, AAPGS Course Note Series 5 pp. 1-9.

Thomoson, T.L., 1976, Plate tectonics in Oil and Gas Exploration of Continental Margins, AAPG Bulletin, Vol. 60 00. 1463-1501.

Whire, R., 1977, Seismic bright sports in the Gulf of Oman; Earth and Planetary Science letters, 37, pp. 29-37.

Yarborough, H., 1976, Hydrocarbon accumulation, in Plate tectonic and Hydrocarbon Accumulation, AAPG Course Note Series a, 35 p.

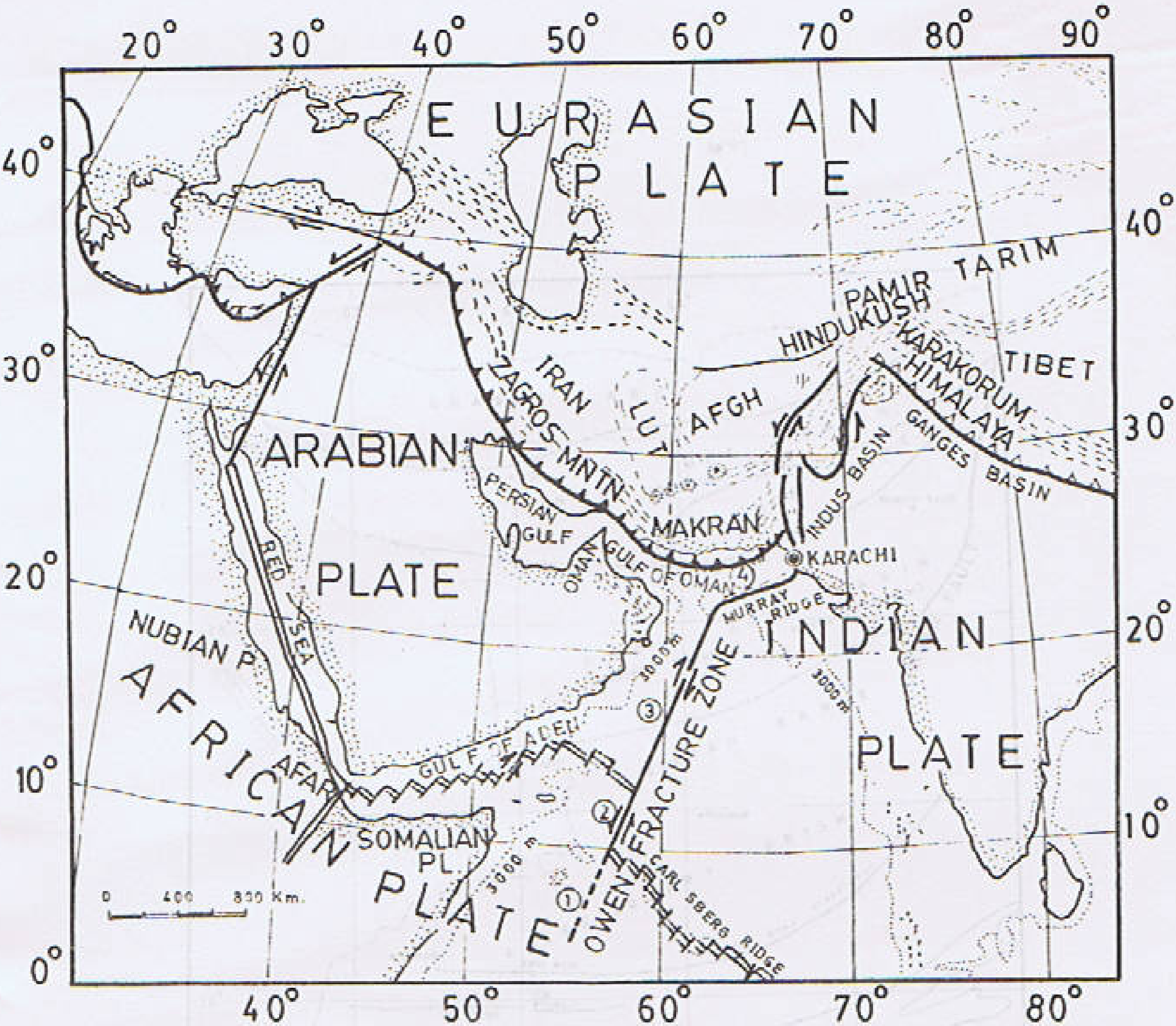

FIG. 1 REGIONAL TECTONIC SETTING SHOWING THE LOCATION OF MAKRAN (AFTER JACOB & QUITTMEYER, 1979)

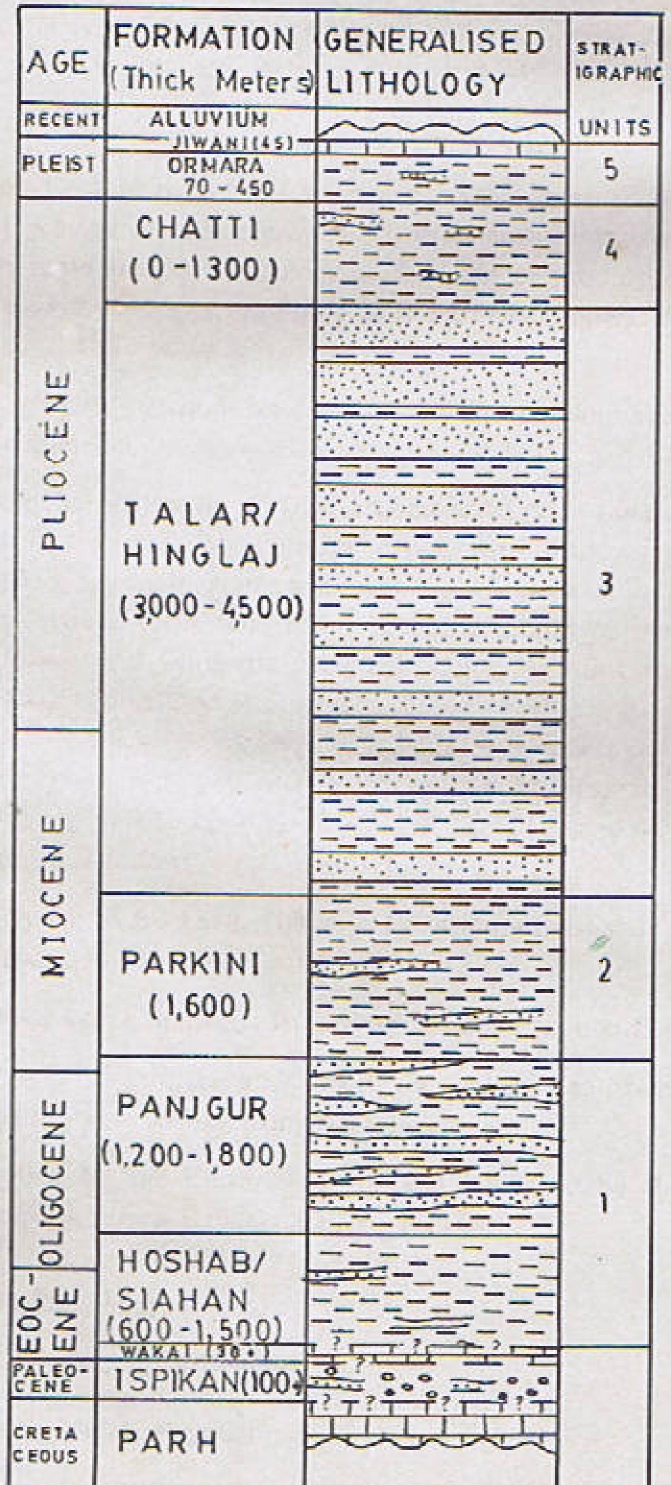

FIG.3 GENERALISED STRATIGRAPHY OF MAKRAN AREA