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CONTENTS

STRATIGRAPHY AND MICROPALAEONTOLOGY OF THE GALIS GROUP OF HAZARA, PAKISTAN.

BY

M. A. LATIF

Department of Geology University of the Punjab, Lahore

Abstract : *The Galis Group is composed of 6 distinct mapable units recognised as formations. The grey limestone considered as Eocene by Middlemiss* (1896, P. 39) *in fact is of Upper Cretaceous age and has been separated as Kawagarh Formation at the top of the Hothla Group. The contact between Hothla and Galis groups is marked by a break in deposition followed by laterite/limonite/haematite/and coal/bituminous shales. The group contains 75 species of Foraminiferida and genera of Ostracoda, recorded and described from Hazara for the first time. The Group ranges in age from Lower Palaeocene to basal Middle Eocene. The south eastern parts of the area indicate relatively shallower conditions of deposition. During the deposition of the Galis Group, intermittent phases of transgression and regression are recorded with a tendency towards a complete withdrawl of marine conditions upwards in the succession.*

INTRODUCTION

The article deals with Lower Paleogene rocks mainly of Hazara and partly of the Rawalpindi districts of Pakistan. Hazara is one of the northern mountain districts of Pakistan, situated to the north of Rawalpindi and Campbellpur districts and bounded on the north by the Indus River between 73° 00′ and 73° 30′ E and 33° 43′ and 34° 20′ N (Fig. 1). The area was mapped during the period 1959-67 by Latif, 1970. 20 rock samples were collected from the sequence under study for micropalaeontological investigations. The sample locations are given in detailed descriptive micropalaeontology. A list of microfossils recorded from the Galis Group was briefly given in a note, Latif, 1970. The purpose of this article is to elaborate the geology of the Galis Group and give systematic descriptions and distribution of microfossils.

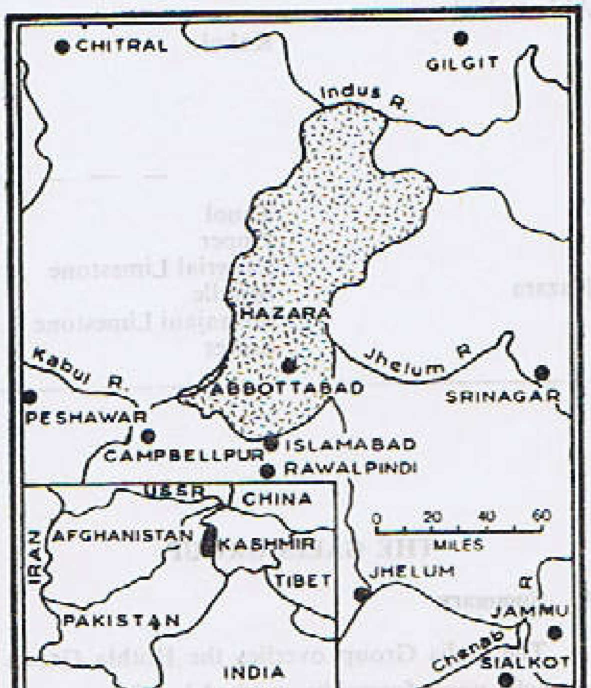

Fig. 1. Location of the Area.

STRATIGRAPHIC SUCCESSION IN HAZARA

Group	Formation	Member	Age	
Havelian			Pleistocene to Recent.	
		unconformity		
Rawalpindi	Murree		Miocene	Lower
		unconformity		
	Kuldana		Eocene	Lower/ Middle
	Chorgali		Eocene	Lower
Galis	Margala Hill Limestone		Eocene	Lower
	Patala		Paleocene	Upper
	Lockhart Limestone		Paleocene	Lower to Upper
	Hangu		Paleocene	Lower
		unconformity		
	Kawagarh		Cretaceous	Upper
Hothla	Lumshiwal		Cretaceous	Lower
	Chichali		Jurassic	Upper
		unconformity		
	Samana Suk		Jurassic	Middle/Upper
Thandiani	Shinawari		Jurassic	Lower
	Datta			
		unconformity		
		Hazira	Cambrian	
	Tarnwai	Galdanian		
		unconformity		
	Sirban		Cambrian	Lower
Abbottabad	Kakul	Mirpur		
		Mahmdagali		
		Sangargali		
		Tanakki		
		unconformity		
	Tanol		Eo-Cambrian	
	Upper			
	Langrial Limestone			
Hazara	Middle			
	Miranjani Limestone			
	Lower			

THE GALIS GROUP

A. Summary

The Galis Group overlies the Hothla Group of rocks unconformably, marked by the presence of laterite/limonite/carbonaceous shales etc. The Group is divided into six formations, based on lithology. The sediments are of marine origin, showing a tendency to shallow upward in the succession. The Group ranges from Lower/Middle Paleocene to basal Middle Eocene.

B. Synonomy

1872 Nummulitic Formation Waagen & Wynne Mem. G.S.I. 9. p. 13.

1896 Nummulitic Series and Kuldana Series Middlemiss Mem. G.S.I. 26. pp. 36-43.

C. Introduction :

The stratigraphic unit to which the name Galis is herein applied, has been the subject of investigations by earlier workers. The unit was first recognised by Waagen & Wyne in 1872 as the Nummulitic Formation. It was described by Middlemiss in 1896 under the name Nummulitic Series (pp. 38-42). His Nummulitic Series included the grey limestone at the base which has now been clearly identified as being of Cretaceous age (Latif 1962), and of a distinctly different lithology, relatively more colosely related to the preceding Hothla Group than to the succeeding one. Other workers, however, just referred to the unit's earlier definitions and descriptions, without any significant alteration.

D. Derivation of the Group name :

The rocks under discussion have been recognised as a group for the following reasons :

1. They show clear marker horizons at the base and the top of the Group, marked by laterite and conglomerate respectively, both due to a break in deposition.

2. The constituent formations show a gradational passage within the Group.

3. The constituent formations are mappable units.

4. The names like Nummulitic Formation and Nummulitic Series do not fulfil the requirements of the stratigraphic nomencalture, which require the use of a geographic term for a unit. Moreover, there is a major rearrangement of the formations. The grey limestone at the base of the Nummulitic Series has been separated as the upper part of the underlying Hothla Group ; and the overlying Kuldana Formation so far excluded from the Nummulitic Series, has been included as the uppermost unit of this Group.

5. (*a*) The Group is very well represented in the Galis area on the Murree–Abbottabad Road, between Kuldana and Bagnotar via Daryagali, Barian, Swargali, Khairagali, Changlagali, Kuzagali, Dungagali and Nathiagali etc. and as such the galis area is suggested as a type area for the whole Group.

The definition of the Group is based on the definition of its constituent formations.

E. Subdivisions of the Galis Group

The term Galis Group, is applied by the present survey to the complete succession of rocks between the Hothla and the Rawalpindi groups, marked by unconformities at the base and the top. Thus it differs from the Nummulitic Series of Middlemiss (1896), in that it excludes the Grey Limestone below and includes the Kuldana Series above (pp. 39—40 and 42-43 respectively). The following subdivisions are recognised :

6. Kuldana Formation ±200 feet Lower to Middle Eocone

5. Chorgali Formation ±150 feet Lower Eocene

4. Margala Hill Limestone ±350 feet Lower Eocene.

3. Patala Formation ±600 Upper Paleocene to Lower Eocene.

2. Lockhart Limestone 900 ±feet Lower Middle to Upper Paleocene.

1. Hangu Formation ±100 feet Lower Paleocene.

Comparison of the Un't Names with those of previous workers

Verchere 1866—67	Waagen & Wynne 1872—74	Middlemiss 1896	Marks & Mohammad Ali 1961—62	Gardezi & Ghazanfar 1965	Latif 1970-77
	Murree series	Murree beds			HAVELIAN GROUP RAWALPINDI GROUP *Murree Format.on*
Nummulitic Limestone	Kuldana beds *Nummulitic Formation*	Kuldana series *Nummulatic Series* (Shales, marls, Limestone, Coal & Variegated Sst.)			GALIS GROUP Kuldana Formation Chorgali Formation Margala Hill Limestone Patala Formation Lockhart Limestone Hangu Formation
Jurass'c	Thin badded Limestone Giumal Sst. Spiti Shale	Grey Limestone Giumal Sst. Spiti Shale			HOTHLA GROUP Kawagarh Formation Lumshiwal Formation Chichali Form tion
Carboniferous Limestone	*Triassic Series*	*Triassic Series*	*Triassic System* Upper Fmn.	Maira Fmn.	THANDIANI GROUP Samana Suk Formation Shinawari Formation
	Below the Trias			*Abbottabad Gp.* Hazira Fmn.	Datta Formation *Tarnwai Formation* Hazira Member Galdanian Member
Volcanic	3rd division	Volcanic etc. Infra-Trias Series	Lower Fmn. Abbottabad Formation	Haematite Fmn. Abbottabad Formation	ABBOTTABAD GROUP Sirban Formation
	Upper Div. Lower Div.	Upper Lst. Lower Sst. & Shale	Upper Fmn. Lower Fmn.		Kakul Formation Mirpur Member Mahmdagali Member
		Tanakki Conglomerate	Lower Formation		Sangargali Member Tanakki Member
	Tanol series Attock Slates	Tanol Slate series	Tanol Fmn. Hazara Slate Formation		*Tanol Formation* HAZARA GROUP Upper Formation Langrial Limestone Middle Formation Miranjani Limestone Lower Formation

F. Lithology

The Group overlies the Hothla Group unconformably, the contact being marked by laterite, which is followed by grey nodular limestones and khaki, buff to greenish grey shales with Foraminiferida of very small size. These are followed by grey nodular to massive limestones, marly limestones and marls containing larger Foraminiforida up to 5 mm. in size. The top of the Group is marked by marl, shale, clay, sandstone and gypsum bands, dominantly of reddish colours.

G. Lateral Distribution

The Group is represented as far south as Saidpur, and as far north as near Galdanian, the two exposures being 39 miles apart approximately. It is represented in the regions of Thandiani, Kakul, Sirban, and Bagnotar, of the Slate Zone and all the regions of the Nummulitic Zone. It is not represented in the Tarnwai, Abbottabad and Havelian regions of the Slate Zone, and is completely missing from the the Crystalline-Metamorphic and Upper Tertiary Zones.

HANGU FORMATION

A. Synonomy

1872 Nummulitic Formation Waagen & Wynne Mem. G.S.I. 9, 13.

1896 Nummulitic Series Middlemiss Mem. G.S.I. 26, p. 41.

1970 Mari Limestone Latif Jb. Geol. B.A. Send. 15 pp. 15—16. (Basal laterite and bituminous shales).

B. Introduction

The rocks are, for the first time, being recognised as a separate unit. These have earlier been described as part of Nummulitic Formation by Waagen and Wynne (1872), Nummulitic Series by Middlemiss (1894) and Mari Limestone by Latif (1970). (laterite, limonite, haemitite, coal, bituminous shale and sandstone.)

C. Lithology

The unit is generally composed of laterite/limonite/haematite and coal/carbonaceous shale/sandstone. Laterite is dominant and is persistent in most of the area unless replaced by limonite or haematite. It is often pisolitic but occasionally massive. The pisoliths are usually ½ centimetre in size but sometimes about a centimetre in diameter. They are generally formed around calcite nuclei and occasionally around sand grains. The rock occurs in various shades of brown, though fresh surfaces show mixed shades of light grey, chalky grey and yellow, dominated by a reddish tinge. The greyish greenish and yellowish pisoliths visibly stand out on exposed surfaces. On the whole the rock is not very much indurated and crumbles easily sometimes to a powdery texture, which factor is also partially due to the variation in size of the pisoliths. The rock is relatively less resistant compared to the underlying and overlying formations.

There is a significant change in the composition of the unit towards northwest, in which direction it becomes limonitic and haematitic. The river Karral Haro and Haro together flowing north east—south west from Dungagali to Bokan, mark the dividing line between laterite and limonite in the south east and haematite to the north west with the exception of exposures north of the Kalabagh Fault. Though the laterite is generally pisolitic and the haematite generally oolitic, the limonite may or may not be so. The maximum thickness of the unit has been recorded as 115 feet near Mandeha Banni, where pisolitic laterite is exposed. Limonite is well exposed near Danna Nuralan, being about 85 feet thick. This is followed upwards by inferior quality coal or carbonaceous shales of a maximum thickness of 17 feet on the ridge south east of Jaswal. In general the coal band is either very thin or represented by bituminous shales, or absent altogether.

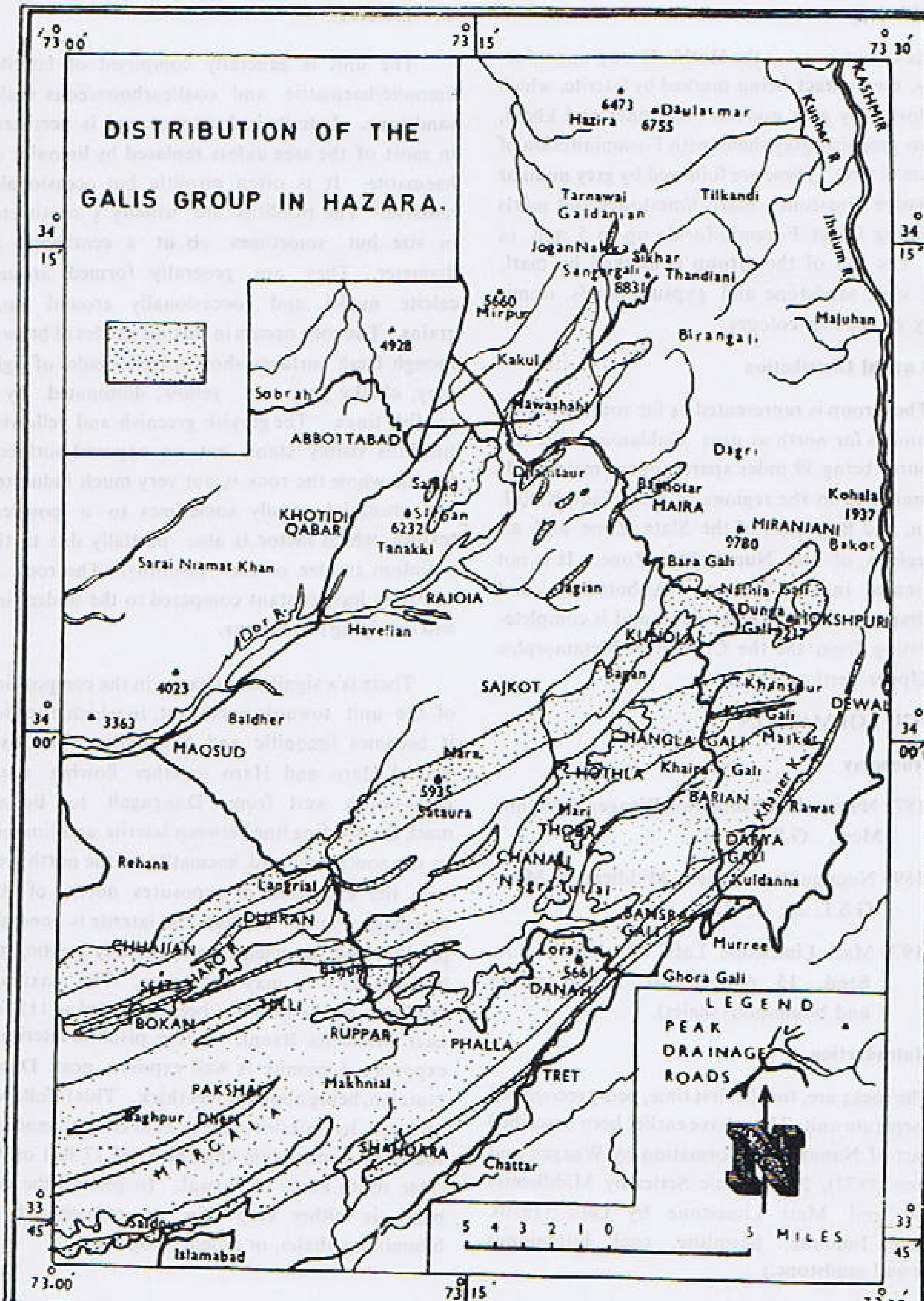
DISTRIBUTION OF THE
GALIS GROUP IN HAZARA.
LEGEND
PEAK
DRAINAGE
ROADS
5 4 3 2 1 0 5 MILES
KASHMIR
Kunhar R.
Jhelum R.
Hazira
Daulatmar
Tarnawai
Galdanian
Tilkandi
Sikhar
Sangargali
Thandiani
Mirpur
Majuhan
Birangali
Kakul
Sobrah
Nawashahr
ABBOTTABAD
Dagri
Bagnotar
MAIRA
Kohala
KHOTIDI QABAR
Tanakki
MIRANJANI
Bakot
Sarai Niamat Khan
Bara Gali
Jigian
Nathia Gali
Dunga Gali
RAJOIA
Havelian
Dor R.
KUNDLA
SAJKOT
Baran
Khanspur
DEWAL
Baldher
HAQSUD
Satura
Rehana
Khaira Gali
BARIAN
Rawat
Mari
THOBA
DARYA GALI
CHANAL
Kuldanna
Langrial
DUBRAN
CHHAJIAN
Murree
Ghora Gali
Lora
DANAH
BOKAN
RUPPAR
PHALLA
TRET
PAKSHAL
Makhnial
Baghpur
SHAHDARA
Chattar
Saidpur
Islamabad
73 00
73 15
73 30
34 15
34 00
33 45

Fig. 2.

The unit is absent further north westwards and is represented by thin sandstone bands of pale to brown colour. The various types of rocks are represented in the following localities :

1.	Laterite	Mari
2.	Limonite	Bandi
3.	Haematite	Dubran
4.	Coal/carbonaceous shale	Changlagali
5.	Sandstone	Kathwal

D. Lateral distribution

The rocks are distributed almost all over southern Hazara where contact between Hothla and Galis groups is exposed.

E. Fauna and Age.

No fassils have been found in this formation. However on the basis of Lower to Middle Paleocene age of the overlying Lockhart Limestone and Early Paleocene age of identical rocks in Kohat Potwar province, the Formation is considered to be of Lower Paleocene age.

F. Lateral variations

The Formation shows considerable variation in a south east—north westerly direction in the Nummulitic Zone. The laterite near Changlagali and Sohaba in the south east, is replaced by limonite near Kundla and Bandi, and by oolitic haematite near Nathiagali and Dubran in the northwest. The overlying coal bands near Malkot in the south east are replaced by carbonaceous shales near Changlagali and by shales near Kuzagali in the north west.

2. LOCKHART LIMESTONE

A. Synonomy

1872 Nummulitic Formation Waagen & Wynne Mem. G.S.I. 9 p. 13.

1896 Nummulitic Series (3. Well bedded massive Nummulitic Limestone) Middlemiss Mem. G.S.I. 26, p. 41.

1970 Mari Limestone Latif Jb. Geol. B.A. Sond. 15, pp. 15-16

B. Introduction

The Lockhart Limestone has been included previously in the Nummulitic Formation of Waagen & Wynne (1872) and Middlemiss (1896, p. 41) described it as well bedded Nummulite bearing grey limestone belonging to the Nummulitic Series. The Grey Limestones have been separated as the uppermost formation of the underlying Hothla Group. Limestone is the predominant component of the Formation.

C. Distribution of the Lockhart Limestone

The Mari limestone exposures are distributed in two distinctly separate areas :

(*a*) The minor one of these occupies the centre of the Slate Zone, distributed in approximately a six miles radius arround Harnow and occpying the regions of Kakul, Bagnotar and Sirban and missing from the regions of Tarnwai, Thandiani, Abbottabad and Havelian.

(*b*) The major one occurs beyond the southern limits of the Slate Zone, occupying roughly the northern part of the Nummulitic Zone with some exposures in the south eastern parts of the map, and distributed in most of the regions except Lora and Barian.

D. Lithology

There is a rturn of marine conditions during the deposition of Lockhart Limestone. It is mainly a calcareous, nodular limestone with a subordinate development of shale in the lower and upper parts. The thin shale bands at the base, developed near Kuzagali, represent the gradual deepening of the marine basin. This is followed by nodular limestones of blusih to light grey colour, as seen on weathered surfaces. When freshly broken, it is, however, generally dark grey and gives a foetid smell. There is a marked decrease of nodules towards the middle, followed by nodular habit once again towards its contact with the overlying shale formation. Calcite veins are common, particularly in the middle part, but they are seldom continuous. The weathered surfaces show clusters, of tiny specks of less than I mm. diameter, marking the appearance of visible Foraminiferida, but not necessarily identifiable with the naked eye. Solution weathering, though not as prominent as in the Kawagarh Formation is present. Honeycomb weathering is also seen in some areas. Near Mari area, the thickness is about 900 feet.

The nodular habit of the limestone, appears to be of structural rather than a sedimentational origin. It is believed that due to the compressional forces, responsible for the folding of these rocks, two sets of shear planes, at right angles to each other, were developed in the thin limestone bands, which are intercalated with shales and marls. These shaley marls subsequently flowed into the fissures resulting from these shear planes, and gave rise to the nodular habit, which closely resembles boudinage structures. This origin is supported by the fact that the nodules are more frequent where shales and marls are interbedded with limestone.

E. Fauna and age :

The following fossils have been recorded.

Macrofossils

Callamophillia indicc, *Litheracea nodulosa*, *Strombus* sp., *Pleurotomaria* Defrance, *Mytilus* Linne, *Spondylus* sp., *Echinolampus* sp., *Bryophiles* sp., *Venericardia* Lamarck Cretaceous—Recent.

Microfossils

Globorotalia uncinata, *Globigerina* aff. *linaperta*, *Globigerina tri-ngul-ris*, *Globigerina troiloculinoides*, *Globigerina velcscoensis*, *Bigenerina* sp., *Textularia*, sp., *Textul ri1 smithvillensis*, *Dorothia oxycona*, *Pyrgo luph-ri*, *Triloculina trigonulo*, *Millioid* sp. *Pseudogloborotalia I h irabadensis*, *Pseudogloborotalia ranikotensis*, *Cibicidina walli*, *Pleuorstomella rimosa*, *Pleurostom-lla gre: tvalleyensis*, *Chilostomella ovoidi?*, *Charltonina madrugaensis Rotalia perovalis*, *Rotalia trochidiformis*, *Lockhartia conditi*, *Lockhartia conica*, *Lockh rtia h imei*, *Daviesina khatiyahi*, *Kathina delseol?*, *Miscell.nea miscella*, *Eoannularia eocenica*, *Linderina* sp. *Actinosiphon punjabensis* *Bairdia McCoy*, *Brachycythere Alexander* and *Nephrokirkos Howe*.

On the basis of the above fauna, the formation is believed to be of Lower ?/Middle to Upper Paleocene age (see details of micropalaeontology at the end of this chapter).

F. Lateral variations of the Lockhart Limestone

The main limestone part of the Formation is seen to contain more argillaceous bands in the south east tnan in the north west. Another important variation is the thickening of the Formation north westwards from about 200 feet near Changlagali, to about 900 feet near Mari.

3. PATALA FORMATION

A. Synonomy

1872 Nummulitic Formation Waagen & Wynne Mem.G.S.I.9 p.13.

1896 Nummulitic Series (4. Shales, Marls) Middlemiss Mem G.S.I. pp. 38-41, 42.

1970 Kuzagali Shale Latif Jb. Geol.. B.A. Sond. 15, p. 16.

B. Introduction

Waagen and Wynne, 1872, recognised it as part of their Nummulitic Formation. Middlemiss, 1896, recognised it as the uppermost part of the Nummulitic Series. With the separation of the lower Grey Limestones as a part of the underlying Group, inclusion of the Kuldana Beds as the uppermost formation of the Galis Group, and the identification of three more formations, Hangu Formation, the Margala Hill Limestone and Chorgali Formation, the position of the Patala Shale in its Group is significantly altered from that of uppermost of previous workers to lower to middle from the point of view of thickness, the number of identified units, and range of the Group. Shale is the predominant component of the unit though thin limestone and marly band intercalations are frequent towards the base and the top of the Formation.

C. Distribution of the Patala Formation :

The Formation is identified as far north as Maira in the Slate Zone, and as far south as Suniari Sandhuri in the Nummulitic zone, being represented in practically all the regions of the Nummulitic zone. The Formation is represented in the Slate zone in the regions of Kakul, Bagnotar and Sirban, but is absent from the Tarnwai, Thandiani and Havelian regions. The presence of the Formation is generally related to the presence of the Lockhart Limestone. The Formation in certain cases serves as a tectonically weak zone resulting in disturbed contacts, particularly towards the top.

D. Lithology

On the whole, it is a shale formation, although marly and limestone intercalations are also common, particularly towards the base and the top. The shales vary in colour from khaki to pale grey, greenish grey to occasionally dark grey. They are generally permeable and as such do not produce mud in the rainy season like other shale formations. These are much cleaved and have a tendency to splinter rather than split. The Formation differs from the Spiti Shale in the absence of (a) black colour, (b) micaceous and arenaceous content, and (c) limonitic concretions and the presence of marls and limestone bands. The Hazara Group of rocks on the other hand, are relatively arenaceous, slightly metamorphosed, with a habit of splitting into plates and are without any visible fossils. The shale bands within Margala Hill Limestone though sometimes of khaki colour, are generally slightly brownish or dull grey with marly intercalations full of Foraminiferida of much larger size. The khaki coloured shales of the Kuldana Formation are generally associated with purple and grey coloured gypseous shales.

The thickness of the Formation at Kuzagali is about 600 feet.

E. Fauna and age

The following fossils have been recorded :

Macrofossils :

Plesiolampus elongata Nautilus cf. *blanfordi, Meretrix* sp. *Crassatella* sp. *Phacoides vredenburgi, Venericardia* cf. *semi-inflata, Cyclolampus vredenburgi, Trigonia* sp. *Cardium* sp., and *Montlivaltia* sp.

Microfossils :

Globorotalia elongata, Globigerina primitiva, Globigerina saldadoensis, Triloculina trigonula, Lenticulina fictus, Cibicorbis nammalensis, Cibicorbis sp, *Cibicidina walli, Cibidides* cf. *lobalatus, Cibicides reinholdi, Cibicides* aff. *reinholdi, Rotalia trochidiformis, Thalmannita crookshanki, Miscellanea prehaimei, Miscellanea miscella* and *Operculina salsa.*

On the basis of the above faunal assemblage, the Formation is of Upper Paleocene age (see details of micoplaeontology at the end of this chapter).

F. Lateral variations

The Formation shows a thickening from 200 feet in the Margala region to over 600 feet in the Kuzagali region. The limestone bands are frequent in the upper parts near Kuzagali.

4. MARGALA HILL LIMESTONE

A. Synonomy

1872 Nummulitic Formation Waggen & Wynne Mem G.S.I. 9. p. 13.

1896 Nummulitic Series (4, Conctetionary and nodular limestone) Middlemiss Mem. G.S.I. 26)pp. 38 & 41—42.

B. Introduction

The Margala Hill Limestone was newly proposed, by Latif 1964, unit of the Galis Group. Earlier, Waagen & Wynne (1872) included it as part of their Nummulitic Formation, and Middlemiss (1896) as 4th unit, shales, marls, concretionary and nodular limestone of his Nummulitic Series. The lower shales and marls having been separated as Patala Formation the upper part of Middlemiss's Unit 4 consisting of concretionary and nodular limestone, has been recognised here as a formation.

C. Derivation of the name and type locality

The proposed name is derived from the Margala Hills, situated north of Islamabad and north west of the Rawalpindi—Murree Road. It is approached by a jeepable road from Chattar, near the 19th milestone of the Rawalpindi-Murree highway, passing through the Margala Hills across the strike of rocks for first 10 miles and later along the strike occupying the ridge tops above Islamabad, ending just above Saidpur. The section near Shahdara is suggested as a type locality. The rocks had not been previously named and were included at the top of the Nummulitic Series and below the Kuldana Formation by Middlemiss (1896).

D. Lithology

The Formation shows a gradational passage with the underlying, Patala Shale. It is essentially a limestone in its type locality in the Margala Hills, with insignificant intercalations of marls and/or shales. It is dark grey on freshly broken surfaces, and grey to pale grey on weathered surfaces. The weathered surfaces sometimes show concentration of Foraminiferida, which range from 2 mm to 7mm in size. The limestone is generally nodular, the nodules varying in length from one foot to about 3.5 feet and up to one foot in breadth. Calcite veins are frequent, particularly when the limestone is massive. In the upper parts, pyrite specks have also been noticed. There is a gradual change of material from Patala Shale to these limestones and, as such, the relatively resistant limestones stand up as cliffs and occasionally forming dip slopes, as seen near Patala, Dungagali, Nathiagali and Lora.

The thickness of Formation at the type locality is about 350 feet.

E. Distribution of the Margala Hill Limestone

The exposures of the Formation have been traced as far north as Nawanshahr and as far south as Ratta Hotar. Most of the exposures are found in the southern part of the Nummulitic Zone, occupying more than one third of the zone area. The type locality, with other principal sections, is situated in the above Zone. The Formation is however, also represented, though quite insignificantly, in the Slate Zone, in Sirban region, and a little northeast in Kakul and also eastwards in Bagnotar region.

F. Fauna and age

The following fossils have been recorded : (see Plates 22 and 23).

Microfossils

Rotalia trochidiformis, Lockhartia conditi, Lockhartia hunti, Lockhartia tipperi, Assilina laminosa, Assilina subspinosa, Nummulites atacicus, Nummulites globulus, Nummulites mamilla, Fasciolites delicatissima, Fasciolites elliptica and *Fasciolites elliptica var. floscaulina.*

On the basis of the above faunal assemblage the Formation is considered to be Lower Eocene (see detailed micropalaeontology at the end of this chapter).

4. CHORGALI FORMATION

A. Synonomy

1896 Nummulitic Series Middlemiss Mem G.S.I. pp. 38 & 41-42.

1970 Lora Formation Latif pp. Jb. Geol B.A. Sond. 15 pp. 16-17.

B. Distribution of the Chorgali Formation.

The formation is represented as far north as Nathiagali near the Government House, and as far south as Nurpur. It is well developed in the Lora valley, on the Ghora Gali—Maksud road between Kotli and Phallgali, Other exposures of the Lora Formation are found near Bansragali, Daryagali and Mangial. It is generally found in the Nummulitic zone in the southern regions but is absent from the Slate Zone.

C. Lithology

The Margala Hill Limestone passes upwards, with a gradual change of material, into the Chorgali Formation which is generally composed of limestones, marly limestones, argillacous limestones, marls and subrodinate shales. The limestones are rarely massive, and generally show a flaggy habit usually under four inches in thickness. The flaggy habit is probably due to the increasing marly intercalations. The limestones weather into creamy light yellow and light grey colours and their freshly broken surfaces are light grey, giving a deceptive resemblance to the Kawagarh Formation. However the presence of larger Foraminiferidia helps in its identification in the field. Occasionally these limestones weather to a chalky appearance. The marls are generally in very light shades of khaki and grey. There is a significant increase in the argillaceous content upwards, which may range from argillaceous limestones to calcareous mudstones, generally medium hard, light to medium grey in colour and visibly devoid of any fossils. Because of the less competent nature of the Formation the rocks are occasionally found to be intensely folded, sheared and brecciated.

D. Fauna and age :

The following fossils have been recorded from the Formation.

Microfossils

Globorotalia reissi, *Globorotalia wilcoxensis*, *Globanomalina ovalis*, *Globigerina prolata*, *Globigerina yeguaensis*, *Glandulina laevigata*, *Discorbis*, *calyptra*, *Gyroidina globosa*, *Rotalia crooskhankiana*, *Rotalia eocena*, *Rotalia trochidiformis*, *Lockhartia conditi*, *Lockhartia hunti*, *Lockhartia tipperi*, *Assilina daviesi*, *Assilina* aff. *laminosa*, *Assilina subdaviesi*, *Assilina subspinosa*, *Assilina globulus*, *Assilina mamilla*, *Bairdia McCoy*. *Pontocyprella lyutimova*, *Parakrithe Brady*, *Henryhowela Puri*, *Quadracythere hornibrookella*, *Quadracythere hornibrook*, *Xestoleberis Sars* and *Cytherella Jones*.

On the basis of the above fauna the Formation is considered to be of Lower Eocene age (see detailed micropalaeontology at the end of this chapter).

5. KULDANA FORMATION

A. Synonomy

1874 Kuldana Beds Wynne Rec. G.S.I. 10, p. 68

1896 Kuldana Series Middlemiss Mem. G.S.I. 26 pp. 42-43.

B. Introduction

The Kuldana Formation was first described and named as "Kuldana Beds" by A. B. Wynne (1874 p. 68) after its occurrence near Kuldana. It was later described by Middlemiss (1896, p. 42-43) as "Kuldana Series".

C. Derivation of the name and type locality

The Kuldana Beds of Wynne (1874) was formalised as Kuldana Formation, by Latif 1964.

D. Distribution of the Kuldana Formation.

The Formation is represented as far north as Kalabagh Cantt., and as far south as Islamabad. It has not been reported outside the Nummulitic Zone. In the Nummulitic Zone itself, it is generally found in the southern half with a tendency to appear associated with the upper formations of the Galis Group. It has however, been seen in contact with the overlying Murree Formation and also faulted against older formations of the Galis Group. The Formation is also very well exposed on the Murree-Abbottabad road near Daryagali, on the Murree Rawalpindi road near Bansragali and Tret, and the Chhattar-Saidpur road near Mangial and Shahdara.

E. Lithology

The Formation consists of crimson, brown, purple, chocolate, green, grey and khaki shales gradually interbedded with khaki to pale grey marls and marly limestone bands and lenses. The clays are occasionally gypsiferous as seen near Bansragali. Impure gypsum is quite well developed near Kalabagh Cantonment. The Formation is generally calcareous at the base and arenaceous towards the top. Its thickness in the type area is about 200 feet.

F. Fauna and age

The following fossils have been rocorded.

Macrofossils

Venericardia elliptica, *Venericardia beaumonti*, *Lucina* sp.

Microfossils

Assilina exponens, *Assilina granulosa*, *Nummulites* sp.

On the basis of the above fossils a Lower to basal Middle Eocene age is suggested for the Kuldana Formation (see detailed micropalaeontology at the end of this chapter).

G. ENVIRONMENTS OF DEPOSITION OF THE GALIS GROUP

Deposition of the Hothla Group was followed by a regression of the sea, exposing these deposits to the various agents of weathering and erosion. The basal beds of the Galis Group in the Nummulitic Zone show the presence of laterite, bituminous shales and coal in the south east ; limonite, sandy shales, oolitic haematite and shales further northwest, suggesting deltaic to near shore conditions of deposition. Sediments of a similar nature occur in the Slate Zone, laterite/carbonaceous shale and coal in the northwest near Dor River and oolitic haematite near Bagnotar in the southeast, thereby showing that the south eastern and north western parts of the area were either exposed or had deltaic conditions, with depth variation in a north east—south westerly direction. The close proximity of identical deposits may be due to the thrust fault separating the Nummulitic Zone from the Slate Zone. The above direction of land and sea seems to have continued during the deposition of the Galis Group with variations only due to the transgressional and regressional phases.

The deposition of Lockhart Limestone took place after a transgression of the sea, which not only covered the whole of the area but also parts beyond in the south and west. The thickening of the Formation northwestwards, further confirms this point of view. During the deposition of Patala Shale there seems to have been a considerable regression of the sea resulting in the deposition of shales, thickening in a northwesterly direction in the Nummulitic Zone. The overlying Margala Hill Limestone and Chorgali Formation were mainly deposited after another transgression of the sea. The Chorgali Formation shows shallowing up of conditions upwards in the succession, which led to intermittent phases of regression and transgression represented by the Kuldana Formation, varied coloured shales, gypseous beds and Foraminiferal calcareous bands. After the Kuldana period probably, the sea finally receded.

There is no record of any deposits younger than Kuldana (Lower to Middle Eocene) and older than the Murree Formation (Lower Miocene) in the area and it is not possible to say with certainty whether deposition in the area continued after the Kuldanas. If it did, it might have been of a very shallow to continental nature, keeping in view the shallowing trend of the sea during the Galis Group. Since the overlying unconformity is more pronounced in the south and southeast, it is possible that the youngest strata, equivalent to Kohat Formation, if they exist, should occur north and northwest of the area under study.

H. DISCUSSION AND CORRELATION OF THE GALIS GROUP.

The end of the Hothla Group is marked by a regression of the sea, as has also been recognised at the Cretaceous-Paleocene boundary in many other parts of the world. This is marked by the presence at the base of these rocks, by pisolitic laterite, limonite, oolitic haematite, sandstones, sandy shales, carbonceous shales and coal, varying in thickness from under 10 feet to 120 feet. Rocks of identical litholotic characters and at almost a similar geological horizon have been recognised in neighbouring areas. In the Salt Range, these are represented by Dhak Pass beds which consist of sandstones, sandy shales, carbonaceous shales with occasional thin limestone bands. A ferruginous pisolite which serves as a marker horizon, occurs at their base. The pisolitic bed varies in thickness from 5 to 100 feet, and has been considered possibly to represent the old land surface on which the Tertiary rocks were deposited (Lex. Strat. Interna. Vol. 3 Fasci. 8, pp. 65-66). In the Kala Chitta, Potwar and Salt Range "carbonaceous, friable, fossiliferous shale with greenish brown pisolitic to oolitic clayey to sandy ferruginous matrix" at the base, has been recorded at this horizon and named as Dhak Pass Beds. A bed of white quartizitic sandstone and fossiliferous shales varying from 250 to 300 feet in thickness has been identified at this horizon from Kohat and named as the Hangu Formation.

This, in Hazara, is followed by 400 to over 800 feet of grey nodular limestones showing tiny specks on weathered surfaces, representing Foraminiferida. In the Salt Range these are represented by the Lockhart Limestone showing a similar lithology and varying from 50 to 500 feet in thickness. A grey to medium grey ; thickbedded to massive and brecciated limestone, known as the Lockhart Limestone is recognised in Kohat. It's basal beds are flaggy, shaly and sandy and the Formation is about 200 feet thick. The ferruginous pisolite above the Kawagarh Formation in the Kala Chitta area is succeeded by Lockhart Limestone/Hill Limestone and seems identical with that in Hazara.

With a gradual passage, the Lockhart Limestone is succeeded by Patala Shale, khaki coloured splintery shales ranging from 200 to 600 feet in thickness. These are followed by Margala Hill Limestone, 300 to 700 feet of grey nodular to massive limestones displaying on their weathered surfaces, clusters of Foraminiferida, ranging from 2 mm. to 7mm. in diameter. The nodule size is much larger, 2½ feet, as compared to less than a foot in the Mari Limestone. In Salt Range these are represented by Patala Shale, 100 to 250 feet, Nammal Formation, 100 to 200 feet and probably by the lower part of the Sakesar Limestone. The equivalent Kohat succession includes the Panoba Shale of about 350 feet in thickness and probably the lower part of the Shekhan Limestone which is composed of nodular limestone containing lower Eocene Foraminiferida. In Kalachitta and northern Potwar these are represented by parts of the Hill Limestone.

This is followed in Hazara, by a gradual regres-

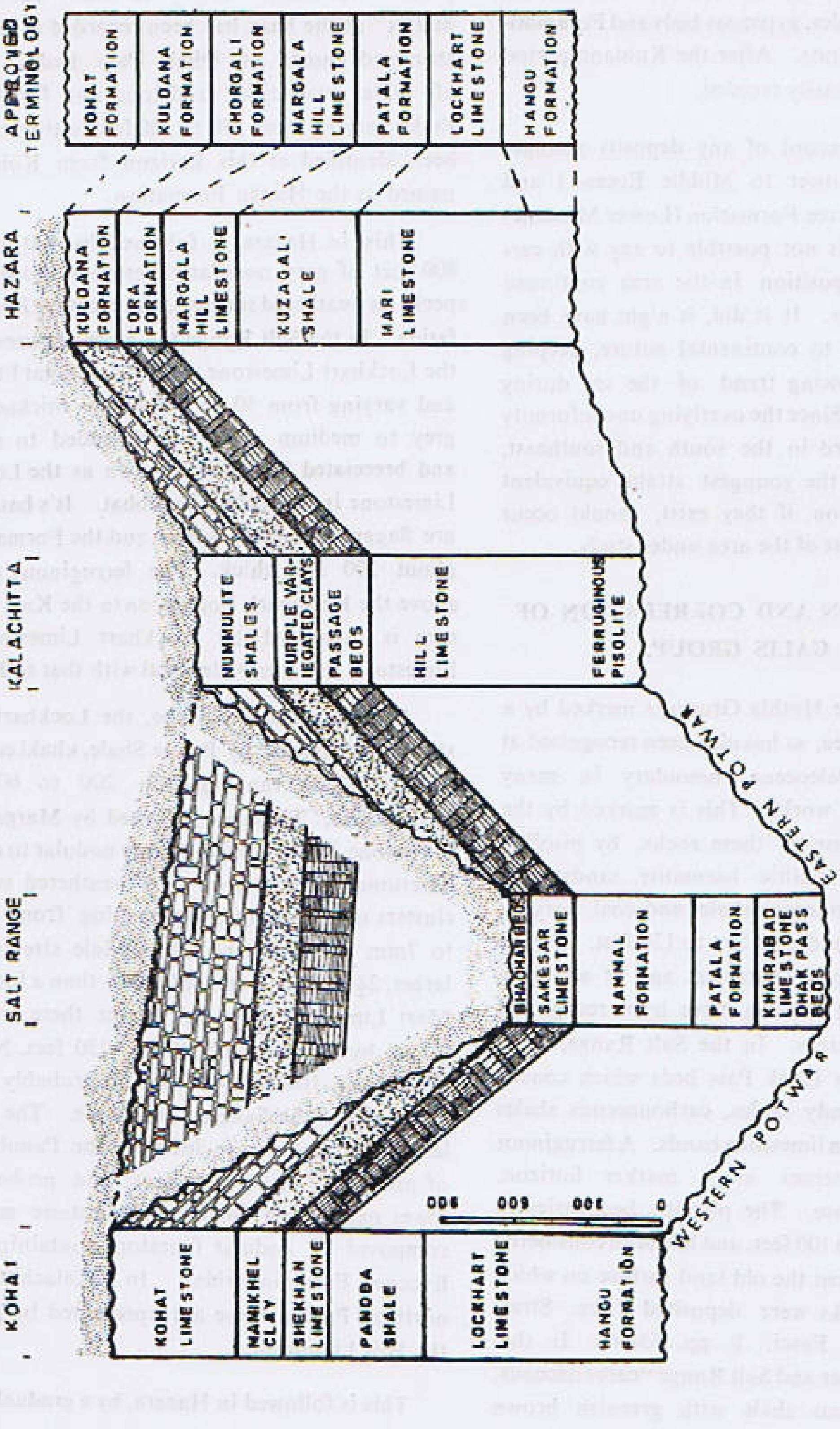

Fig. 3. Regional correlation of Galis Group.

sion of the sea, in which 100 to 200 feet of marls and marly thin bedded limestones of grey colour, weathering in shades of pale grey, are deposited and named as Chorgali Formation. Gee and Evans (1937) identified and named, the green shales and thin limestones, 50 to 80 feet thick, which overlie the Sakesar Limestone in the eastern part of the Salt Range as Bhadrar Beds. Davies (1937) considers them to be of Laki age, on the basis of fossils like *Orbitolites complanatus*, *Assilina* cf. *pustulosa* etc. which assemblage is identical to that from the Chorgali Formation of Hazara. Gill (1953) studied the facies and faunal variations from the Bhadrar Beds of the Salt Range; this however, could not be studied in detail in Hazara. An identical fossil assemblage has been recorded from the top beds of the "Shekhan Limestone" of Kohat, which part has been propsed to be separated as "Jatta Formation". Rocks of the same lithologic characters and similar faunal assemblage have been recognised from the Kala Chitta and northern Potwar and named as "Chragali Formation".

The regressive phase continued further upwards in Hazara during which red shales, gypsiferous beds and calcareous conglomerate of thickness varying from 200 to 700 feet were deposited and named as Kuldana Beds by Wynne (1874). On the basis of physical characters Wynne 1874) considered them homotaxial to the Subathu beds of Simla Himalayas. The quick variation in the petrological and physical characters led Middlemiss (1896) to think of these as a passage between the underlying Nummulitic limestones and shales, and the overlying Murree sandstones and shales This statement may, however, be contradicted by the fact that the microfossils in the upper beds show some affinities with the Middle Eocene fauna of the lower part of Kohat Limestone and the general geological setting of the formation in relation to surrounding areas.

In Kohat, identical rocks are named as "Mamikhel Clay" overlain by Kohat Limestone of Middle Eocene age. In Kala Chitta and northern Potwar the Mamikhel Clay is again said to have been recognised, followed by Kohat Limestone with the upper parts missing. This partial representation of Kohat Limestone in the Kala Chitta and northern Potwar, and a probable very thin representation of the lower parts of this limestone in Hazara, points to the presence of an angular unconformity below the Murree Formation. This idea is further confirmed by the complete absence of Kuldana/Mamikhel Clay and Kohat Limestone, further south in Salt Range and southern Potwar regions where the Murree Formation rests directly over the Bhadrar Beds.

K. MICROPALAEONTOLOGY OF THE GALIS GROUP

The Galis Group is composed of 6 distinct formations :

(*a*) Hangu Formation (*b*) The Lockhart Limestone ; (*c*) Patala Formation ; (*d*) Margala Hill Limestone ; (*e*) Chorgali Formation and (*f*) Kuldana Formation. The microfaunal study of these formations is based on 20 rock samples. 8 of the Lockhart Limestone from Changlagali ; 5 of Patala Formation from Kuzagali ; 3 of Margala Hill Limestone from Shahadra ; 2 of Chorgali Formation from Phallagali and 2 of Kuldana Formation from Bansragali. They reveal the presence of 75 species of Foraminiferida and 10 genera of Ostracoda recorded from Hazara for the first time. Though the preservation of the materials is not very satisfactory, it was found possible to compare them with the microfaunal assemblages described from Pakistan, Qatar, Gulf Coast U.S.A. and Trinidad.

Sample number 6 to 8 from the Lockhart Limestone contain *Kathina delseota*, *Daviesina khatiyahi*, *Lockhartia conica* and *Actinosiphon punjabensis*. All these have been found restricted to the Upper Lower Paleocene to Middle Paleocene, the former 3 in Qatar and the later in the Salt Range of Pakistan. The base of the Galis Group therefore seems to be Lower (?)/Middle Paleocene.

The Middle/Upper Paleocene boundary is placed between samples 11 and 12 both from the Lockhart Limestone. *Globigertina triloculinoides*, *Pseudogloborotalia khairabadensis* and *Pseudogloborotalia ranikotensis* found in sample number 11 are known to occur in Middle Paleocene of Pakistan and elsewhere.

Globorotalia elongata, *Miscellanea miscella* and *Operculina salsa* which range up to the top of Paleocene help to place the Paleocene/Lower Eocene boundary between sample number 18 and 19 from the Patala Formation and Margala Hill Limestone repsectively.

The Lower and Middle Eocene are separated on the first appearance of the Middle Eocene *Assilina exponens* in sample number 25 from the Kuldana Formation. The species is supposed to appear above the Lower Eocene, thereby settling the upper boundary of the Galis Group, as basal Middle Eocene.

The Galis Group is therefore considered to range from Lower/Middle Paleocene to basal Middle Eocene.

Systematic Descriptions.

Family: GLOBOROTALIIDAE Cushman 1927

Genus : *Globorotalia* Cushman, 1927.

Globorotalia elongata Glaessner

Plate No I, Fig. No. 1-3.

1937 *Globoratalia pseudoscitula* var. *elongata* Glaessner. Stud. Micropal. Pub. Lab. Pal. Moscow Univ. Vol. 1, pt. 1, p. 33. Figs. 3d-f.

1957 *Globorotalia elongata* Glaessner. U.S. Nat. Mus. Bull. 215, p. 77, pl. 20, Figs. 11-13.

1964 Latif, Geol. Bull. Panj. Univ. No. 4, pp. 33-34, pl. 1, Figs. 3a-c.

Dimensions of the figured hypotype :

Length	0.37 mm.
Breadth	0.31 mm.
Thickness	0.15 mm.

Sample No. 18.

Formation : Patala Formation.

Locality : Kuzagali

Geological range : Upper Paleocene

Distribution elsewhere :

Trinidad—Upper Paleocene

Rakhi Nala, Pakistan—Upper Paleocene.

Remarks : The species identified after that described and illustrated by Bolli, 1957.

Globorotalia reissi— Leoblich & Tappan

Plate No. I Fig. No. 4-6.

1957 *Globorotalia reissi* Loeblich & Tappan. U.S. Nat Mus. Bull. 215, p. 195. pl. 50, Figs. 3a-c.

1964 *Globorotalia* sp. 4, Latif, Geol. Bull. Panj. Univ. No. 4., p. 51, pl. 4, Figs. 4a-c.

Dimensions of the figured hypotype:

Length	0.38 mm.
Breadth	0.36 mm.
Thickness	0.18 mm.

Sample No. 24 :

Formation : Chorgali Formation

Locality : Phallagali

Geological range : Lower Eocene

Distribution elsewhere :

Gulf Coast, U.S.A.—Lower Eocene

Rakhi Nala, Pakistan Lower Eocene

Remarks : The species is identified after that described and illustrated by Loeblich & Tappan. 1957.

Globorotalia uncinata Bolli.

Plate No. I Fig. 7-9.

1957 *Globoratalia* uncinata Bolli. U.S. Nat. Mus. Bull. 215. p. 74, pl. 17, Figs. 13-15.

Dimensions of the figured hypotype :

Length	0.45 mm.
Breadth	0.34 mm.
Thickness	0.20 mm.

Sample No 10.

Formation : Lockhart Limestone

Locality : Changlagali

Geological range : Middle Paleocene

Distribution elsewhere :

Trinidad—Middle Paleocene

Remarks : The species is identified after that described and illustrated by Bolli, 1957.

Globorotalia wilcoxensis Cushman and Ponton

Plate No : I Fig. No. 10-12.

1932 *Globorotalia wilcoxensis* Cushman & Ponton. Contr. Cush. Lab. Foram. Res. Vol. 8, pt. 3, p. 71, pl. 9, Figs. 10a-c.

1957 Bolli, U.S. Nat. Mus. Bull. 215, p. 79. pl. Figs. 7-9.

Dimensions of the figured hypotype :

Length	0.33 mm.
Breadth	0.26 mm.
Thickness	0.21 mm.

Sample No :23.

Formation : Chorgali Formation.

Locality : Phallagali

Geological range : Lower Eocene

Distribution elswewhere ;

Trinidad—Lower Focene

Remarks : The species is identified after that described and illustrated by Bolli, 1957.

Family : HANTKENINIDAE (Cushman) 1927.

Genus : *Globanomalina* Haque, 1956.

Globanomalina ovalis Haque

Plate No. 1 Fig. No. 13—15.

1956 *Globanomalina ovalis* Haque. Mem. G.S.P. Pal. Pak. Vol. 1, p. 148, pl. 14, fig. 3a-c.

Dimensions of the figured hypotype :

Length	0.34 mm.
Breadth	0.26 mm.
Thickness	0.14. mm.

Sample No. 23.

Formation : Chorgali Formation

Locality : Phallagali

Geological range : Lower Eocene

Distribution elsewhere :

Salt Range, Pakistan—Lower Eocene (Laki)

Remarks : The species is identified after that described and illustrated by Haque, 1956.

Family : GLOBIGERINIDAE Carpenter, Parker & Jones, 1862 *Globigerina* aff. *linaperta* Finley

Plate No. 2 Fig. No. 1-3.

1939 *Globigerina linaperta* Finley. Trans. Proc. Roy. Soc. New Zeal. Vol. 69, p. 125, pl. 13, Figs. 54-57.

1957 Bolli, U.S. Nat. Mus. Bull. 215, p. 70, pl. 15, Fig. 15-17.

1964 Latif, Geol. Bull. Panj. Univ. No. 4, p. 60, pl. 6, Figs. 3a—c.

Dimensions of the figured hypotype :

Length	0.32 mm.
Breadth	0.24 mm.
Thickness	0.19 mm.

Sample No. 13.

Formation : Lockhart Limestone

Locality : Changlagali

Geological range : Upper Paleocene

Distribution elsewhere :

Trinidad—Upper Paleocene—Lower Eocene

Rakhi Nala Pakistan—Lower Eocene

Remarks : The species is identified after that described and illustrated by Bolli, 1957.

Globigerina aff. *primitiva* Finley

Plate No 2 Fig. No. 4-6.

1947 *Globigerina primitiva* Finley. New Zeal. Journ. Sci. Tech. Vol. 28 No. 5, p. 291 pl. 8, Figs. 129-134.

1957 Bolli, U.S. Nat. Mus. Bull. 215, p. 71, pl. 15, Figs. 6—8.

Dimensions of the figured hypotype :

Length	0.38 mm.
Breadth	0.30 mm.
Thickness	0.27 mm.

Sample No. 18.

Formation : Patala Formation

Locality : Kuzagali

Geological range : Upper Paleocene

Distribution elsewhere :

Trinidad—Upper Paleocene—Lower Eocene

Remarks : The species is identified after that described and identified by Bolli, 1957.

Globigerina prolata Bolli

Plate No. 2 Fig. No. 7-9.

1957 *Globigerina prolata* Bolli, U.S. Nat. Mus. Bull. 215, p. 72, pl. 15, Figs. 24—26.

1964 *Globigerina prolata* Bolli Geol. Bull. Panj. Univ. No. 4 pp. 61-64, pl. 6, Figs. 4a—c.

Dimensions of the figured hypotype :

Length	0.30 mm.
Breadth	0.24 mm.
Thickness	0.16 mm.

Sample No :23.

Formation : Chorgali Formation

Locality : Phallagali

Geological range : Middle Paleocene to Lower Eocene (Middle part)

Distribution elsewhere :—

Rakhi-Nala, Pakistan—Paleocene

Trinidad—Lower Eocene

Remarks : Bolli separated *Globigerina prolata* from *Globorotalia pseudobulloids* on the apertural position, trochoid or flat nature of spiral side and lower Eocene and Middle Paleocene horizons, respectively, of the two species. In the species described and illustrated above the characters of both species are to be found, the interiomarginal umbilical position of the aperture as in *Globigerina proeata* and flat nature of spiral side as in *Globorotalia pseduobulloids*. The species occurs in the Lower Eocene as does the former, though its presence is suspected in Middle Paleocene. In Rakhi Nala Pakistan, *Globigerina prolata* has been recorded from the Upper Paleocene.

Globigerina soldadoensis Bronnimann

Plate No. 2 Fig. No. 10-12.

1952 *Globigerina soldadoensis* Bronnimann. Bull. Amer. Pal. Vol. 34, pp. 9—11, Figs. 1—9.

1957 *Globigerina soldadoensis* Bronnimann, Bolli, U.S. Nat. Mus. Bull. 215, p. 71, pl. 16, Figs. 7—9.

1964 Latif, Geol. Bull. Panj. Univ. No. 4, p. 70 pl. 8, Figs. 1a-c.

Dimensions of the figured hypotype

Length	0.45 mm.
Breadth	0.40 mm.
Thickness	0.26 mm.

Formation : Patala Formation

Locality : Kuzagali

Geological range : Upper Paleocene

Distribution elsewhere :

Trinidad—Upper Paleocene—Lower Eocene

Rakhi Nala—Upper Paleocene—Lower Eocene Pakistan.

Remarks : The species is identified after that described and illustrated by Bolli, 1957.

Globigerina triangularis White

Plate No. 3 Fig. No. 1—3.

1928 *Globigerina trianglaris* White, Journ. Pal. Vol. 2, No. 3, pp. 195-96, pl. 28, Figs. 1a-b.

1957 *Globigerina triangularis* White, U.S. Nat. Mus. Bull. 215, p. 71 pl. 15, Figs. 12-14.

Dimensions of the figured hypotype :

Length	0.48 mm.
Breadth	0.41 mm.
Thickness	0.33 mm.

Sample No. 9.

Formation : Lockhart Limestone

Locality : Changlagali

Geological range : Middle Paleocene

Distribution elsewhere :

Trinidad—Middle Paleocene—Lower Eocene

Remarks : The species is identified after that figured and described by Bolli, 1957.

Globigerina triloculinoides Plummer

Plate No. 3 Fig. No. 4-6.

1926 *Globigerina triloculinoides* Plummer. Univ. Texas. Bull. 2644, pp. 134-35 pl. 8, Figs. 10a-c.

1957 U.S. Nat Mus. Bull. 215, p. 70, pl. 15, Figs. 18—20.

1964 Latif, Geol. Bull Panj. Univ. No. 4, pp. 59—60, Pl. 6, Figs. la-c.

Dimensions of the figured hypotype :

Length	0.34 mm.
Breadth	0.24 mm.
Thickness	0.19 mm.

Sample No. 11

Formation : Lockhart Limestone

Locality : Changlagali

Geological range : Middle Paleocene

Distribution elsewhere :

Trinidad—Middle Paleocene

Rakhi Nala, Pakistan—Middle Paleocene—Lower Eocene

Remarks : The species is identified after that figured and described by Bolli, 1957.

Globigerina velascoensis Cushman

Plate No. 3 Figs. No. 7—9.

1925 *Globigerina velascoensis* Cushman, Contr. Cush. Lab. Foram. Res. Vol. 1 pp. 18—22. Pl. 3.

1966 El-Naggar, Z.R. Bull. Brit. Mus. Nat. Hist. Supp. 2, pp. 183-185, pl. 16, Figs. 3a—d.

Dimensions of the figured hypotype :

Length	0.36 mm.
Breadth	0.30 mm.
Thickness	0.26 mm.

Sample No. 10.

Formation : Lockhart Limestone

Locality : Changlagali

Geological range : Middle Paleocene

Distribution elsewhere :

U.S.A.	Cretaceous
Guatemala	Paleocene
Austria	Paleocene
Egypt	Upper Paleocene (basal part)

Remarks : The species is identified after that described and illustrated by El-Naggar, 1966.

Globigerina yeguaensis Wienzierl & Applin

Plate No. 3 Figs. No. 10—12.

1929 *Globigerina yeguaensis* Wienzierl & Applin. Journ. Pal. Vol. 3, No. 4, p. 408, pl. 43, Figs. *1a—b*.

1957 Bolli U.S. Nat. Mus. Bull. 215, p. 163, pl. 34, figs. 14a-c.

1964 Latif, Geol. Bull. Panj. Univ. No. 4 p. 71, pl. 8, figs. 2a-c.

Dimensions of the figured hypotype :

Length	0.31 mm.
Breadth	0.25 mm.
Thickness	0.20 mm.

Sample No. 23.

Formation : Chorgali Formation.

Locality : Phallagali

Geological range : Lower Eocene

Distribtion elsewehere :

Trinidad—Base of Middle Eocene to Upper Eocene.

Rakhi Nala, Pakistan—Middle Eocene.

Remarks : The species is identified after that described and illustrated by Bolli, 1957.

Family : TEXTULARIIDAE EHRENBERG, 1938.

GENUS : *Textularia* Defrenace is De Blainville, 1824.

Textulara smithvillensis Cushman & Ellisor

Plate No. 4 Figs. No. 1-2.

1933 *Textularia smithvillensis* Cushman & Ellisor. Contr. Cush. Lab. Foram. Tes. Vol. 9 p. 95 pl. 10, Fig. 11.

1961 Kaasschieter, J.P.H. Inst. Roy. Sci. Nat. Belg., 31, p. 142 pl. 1 fig. 19.

Dimensions of the figured hypotype :

Length 0.52 mm.

Breadth 0.28 mm.

Thickness 0.18.mm.

Sample No : 9.

Formation : Lockhart Limestone

Locality : Changlagali

Gleoogical range : Middle Paleocene.

Distribution elsewhere :

Belgium—Eocene.

Remarks : The species is identified after that described and illustrated by Kaasschieter, 1961.

Textularia Sp.

Plate No. 10 Fig. No. 2.

Dimensions of the figured hypotype:

Length 0.78 mm.

Breadth 0.60 mm.

Sample No. 6.

Formation : Lockhart Limestone

Locality : Changlagali

Geological range : Middle Paleocene

Distrubution elsewhere :

Penn.—Recent.

Remarks : The specimen is from thin section.

Genus : *Bigenerina* d'Orbigny, 1826.

Bigenerina sp.

Plate No. 10 Fig. No. 1.

Dimensions of the figured hypotype :

Length 1.60 mm.

Breadth 0.59 mm.

Sample No. 6.

Formation : Lockhart Limestone

Locality : Changlagali

Geological range : Middle Paleocene

Distribution elsewhere :

Jurassic to Recent

Remaks : The specimen is from thin section.

Family : ATAXOPHARAGMIIDAE Schwager, 1877.

Genus : *Dorothia* Plummer, 1931

Dorothia oxycona (Rueuss)

Plate No. 4 Fig. No. 3-4.

1860 *Gaudryina oxycona* Reuss, K. Akad, Wiss. Wien, Math. Naturw. sitzher. Bd. 40, p. 229, pl. 12, Fig. 3.

1964 *Dorothia oxycona* (Reuss), Moore, R.C. Treat. pt. c., Vol. 1, p. 275, figs. 184 (5a-c).

Dimensions of the figured hypotype :

Length	0.46 mm.
Breadth	0.30 mm.
Thickness	0.30 mm.

Sample No. 10.

Formation : Lockhart Limestone

Locality : Changlagali

Geological range : Middle to Upper Paleocene

Distribution elsewhere :

Germany—Upper Cretaceous—Eocene.

Remarks : The species is identified after that illustrated by Moore, 1964 and described by Ellis & Messina.

Family : MILLIOLIDAE EHRENBERG, 1839.

Genus : *Pyrgo* Defrance, 1824.

Pyrgo lupheri Rau

Plate No. 4 Fig. No. 4-7.

1948 *Pyrgo lupheri* Rau. Journ. Pal. Tuls. Vol. 22, p. 160, pl. 28. figs. 8-9.

Dimensions of the figured hypotype :

Length	0.45 mm.
Breadth	0.34 mm.
Thickness	0.30 mm.

Sample No. 11.

Formation : Lockhart Limestone

Locality : Changlagali

Geological range : Middle Paleocene

Distribution elsewhere :

U.S.A.- Upper Eocene to Middle Oligocene

Remarks : The species is identified after that described and illustrated by Rau, 1948.

Genus : *Triloculina* d'Orbigny 1826

Triloculina trigonula (Lamarck)

Plate No. 4 Fig. No. 8.

1804 *Milliola trigonula* Lamarck. Mus. Nat. Hist. Ann : S. pl. 17, p. 351, pl. 17, Fig. 4.

1826 *Trilloculina trigonula* d'Orbigny A : Ann. Sci. Nat. 7, p. 299, No. 1, pl. 16, Figs. 4-9.

1956 Haque, Mem G.S. P. Pal. Pak, Vol. 1, pp. 57-59, pl. 26. Figs. 10a-c.

Dimensions of the figured hypotype :

Length	0.78 mm.
Breadth	0.52 mm.
Thickness	0.20 mm.

Sample No. 16.

Formation : Patala Formation

Locality : Kuzagali

Geological range : Paleocene

Distribution elsewhere :

France—Eocene

Salt Range Pakistan—Upper Paleocene (Patala Shale)

Remarks : The species is identified after that described and illustrated by Haque, 1956.

Family : NODOSARIIDAE EHRENBERG, 1838

Genus : *Lenticulina* Lamarck, 1804

Lenticulina fictus (Israelsky)

Plate No. 4 Fig. No. 10—12.

1955 *Rabulus fictus* Israelsky, U.S.G.S. Prof. Pap. No. 240, B. p. 53, pl. 15, Figs. 37-38.

Length	0.34 mm.
Breadth	0.30 mm.
Thickness	0.21 mm.

Sample No : 18.

Formation : Patala Formation

Locality : Kuzagali

Geological range : Upper Paleocene

Distribution elsewhere :

U.S.A.—Upper Paleocene or Lower Eocene

Remarks : The species is identified after that described and illustrated by Israelsky 1955.

Family : GLANDULINIDAE REUSS, 1860

Genus : *Glandulina* d'Orbigny in de la Sagra, 1839.

Gluandulina laevigata (d'Orbigny)

Plate No 4 Fig. No. 12.

1826 *Nodosaria* (*Glandulina*) *laevigata* d'Orbigny Ann. Sci. Nat. Paris, Ser. 1, 7, p. 252, pl. 10, Figs. 1-3.

1956 *Glandulina laevigata* (d'Orbigny) Haque, Mem. G.S. P. Pal. Pak. Vol. 1, pp. 103-105, pl. 11, Fig. 15.

Dimensions of the figured hypotype :

Length	0.30 mm.
Breadth	0.20 mm.
Thickness	0.20 mm.

Sample No : 23.

Formation : Chorgali Formation

Locality : Phallagali

Geological range : Lower Eocene

Distribution elsewhere :

Salt Range Pakistan—Lower Eocene

Remarks : The species is identified after that described and illustrated by Haque, 1956.

Family : DISCORBIDAE EHRENBERG, 1838

Genus : *Discorbis* Lamarck, 1804.

Discorbis calyptra Shifflet.

Plate No. 4 Fig. No. 14-61

1948 *Disorbis calyptra* Shifflet, Maryland, Dept, Geol. Mines & Water Resources, Bull. Balt. Md. No. 3, p. 65, pl. 3, Fig. 20ab.

Dimensions of the figured hypotype :

Length	0.37 mm.
Breadth	0.27 mm.
Thickness	0.16 mm.

Sample No : 23.

Formation : Chorgali Formation

Locality : Phallagali

Geological range : Lower Eocene

Distribution elsewhere :

Virginia. U.S.A.—Lower Eocene.

Remarks : The species is identified after that described and illustrated by Shifflet, 1948.

Family : EPONIDIDAE HOFKER, 1951

Genus : *Pseudogloborotalia* Haque, 1956

Pseudogloborotalia khairabadensis Haque.

Plate No. 4 Fig. 1—3.

1956 *Pseudogloborotalia khairabadensis* Haque Mem. G.S.P. Pal. Pak. Vol. 1, p. 188, pl. 14, Fig. 7.

Dimensions of the figured hypotype :

Length	0.80 mm.
Breadth	0.61 mm.
Thickness	0.41 mm.

Sample No. 11.

Formation : Lockhart Limestone

Locality : Changlagali

Gelological range : Middle Paleocene

Distribution elsewhere :

Salt Range Pakistan — Middle Paleocene (Middle of the Khairabad Limestone)

Remarks : The species is identified after that described and illustrated by Haque, 1956.

Pseudogloborotalia ranikotensis Haque.

Plate No. 5. Fig. No. 4-6.

1956 *Pseudogloborotalia ranikotensis* Haque, Mem. G.S.P. Pal. Pak. Vol. 1 pl. 19, Fig. 17.

Dimensions of the figured hypotype :

Length	0.80 mm.
Breadth	0.66 mm.
Thickness	0.24 mm.

Sample No : 11.

Formation : Lockhart Limestone

Locality : Changlalgali

Geological range : Middle Paleocene

Distribution elsewhere :

Salt Range Pakistan—Middle Paleocene Middle of Khairabad Limestone)

Remarks : The species is identified after that described and illustrated by Haque, 1956.

Cibicorbis nammalensis (Haque)

Plate No. 5 Fig. No. 7-8.

1956 *Sakhiella nammalensis* Haque Mem. G.S. P. Pal. Pak. Vol. 1, p. 156, pl. 10, Fig. 1a-c.

1964 *Cibicorbis nammalensis* (Haque). Moore, Treat, pt. C, Vol. 2, pp. 678-680, Fig. 544/3.

Dimensions of the figured hypotype :

Length	0.50 mm.
Breadth	0.32 mm.
Thickness	0.20 mm.

Sample No :18.

Formation : Patala Formation

Locality : Kuzagali

Geological range : Paleocene

Distribution elsewhere :

Salt Range Pakistan—Paleocene

Remarks : The species is identified after that described and illustrated by Haque, 1964.

Cibicorbis sp.

Plate No. 5 Fig. No. 10-12.

Dimensions of the figured hypotype :

Length	0.63 mm.
Breadth	0.41 mm.
Thickness	0.21 mm.

Sample No. 18.

Formation : Patala Formation

Locality : Kuzagali

Geological range : Upper Paleocene

Remarks : The species differs from *C. nammalensis* in an elongated test and fewer number of chambers in the last whorl.

Family : CIBICIDIDAE CUSHMAN, 1927

Genus : *Cibicidina* Bandy, 1949

Plate No. 6 Fig. No. 1-3.

1949 *Cibicidina walli* Bandy. Bull. Amer. Pal. Vol. 32, No. 131, p. 95 pl. 15, Fig. 5.

1964 Moore R.C. Treat. Vol. 2, pt. C. p. 686, Fig. 552 (4).

Dimensions of the figured hypotype :

Length	0.46 mm.
Breadth	0.36 mm.
Thickness	0.13 mm.

Sample No : 18.

Formation : Patala Formation

Locality : Kuzagali

Geological range: Middle to Upper Paleocene

Distritubtion elsewhere :

U.S.A.—Eocene

Remarks : The species is identified after that described and illustrated by Moore, 1964.

GENUS : *Cibicides de Montfort*, 1808

Cibicides cf. *lobalatus* (Walker & Jacobs)

Plate No. 6 Fig. No. 4-6.

1798 *Nautilus lobalatus* Walker & Jacob. Dillon Keating. Ed. 2. London, p. 642, pl. 14, Fig. 36.

1939 *Cibicides lobalatus* (Walker & Jacob) Cushman. U.S. G.S.P. 181, p. 52, pl. 22, Fig. 4-6.

1956 Haque, Mem. G.S.P. Pal. Pak. Vol. 1, pp. 208-209, pl. 16, Fig. 6.

Dimensions of the figured hypotype :

Length	0.60 mm.
Breadth	0.48 mm.
Thickness	0.16 mm.

Sample No : 18.

Formation : Patala Formation

Locality : Kuzagali

Geological range : Upper Paleocene

Distribution elsewhere :

Salt Range Pakistan—Paleocene (Khairabad Limestone)

Remarks : The species is identified after that described and illustrated by Haque, 1956.

Cibicides reinholdi ten Dam

Plate No. 6. Fig. No. 7-9.

1944 *Cibicides reinholdi* ten Dam. Nath. Geol. Sticht. Meded. Harlem. Ser. C. Vol. 5, No. 3, Pl. 135, pl. 5, Fig. 6. Dimensions of the figured hypotype :

Length	0.40 mm.
Breadth	0.30 mm.
Thickness	0.20 mm.

Sample No. 17.

Formation : Patala Formation

Locality : Kuzagali

Geological range : Upper Paleocene

Distribution elsewhere :

Netherlands—Paleocene

Remarks : The species is identified after that described and illustrated by ten Dam, 1944.

Cibicides aff. *reinholdi* ten Dam

Plate No. 6 Fig. No. 10—12.

Dimensions of the figured hypotype :

Length	0.41 mm.
Breadth	0.30 mm.
Thickness	0.17 mm.

Sample No : 17.

Formation : Patala Formation

Locality : Kuzagali

Geological range : Upper Paleocene

Remarks : The species differs from *C. reinholdi* in its more elongated test and a relatively lesser elevation of final chambers.

Family : PLEUROSTOMELLIDAE Reuss, 1960

Genus : *Pleurostomella* Reuss, 1860

Pleurostomella rimosa Cushman and Bermudez

Plate No. 7, Fig. No. 1.

1937 *Pleurostomella rimosa* Cushman & Bermudez, Contr. Cush. Lab. Foram. Res. Vol. 13, pt. 1, pl. 17, pl. 1, Figs. 62-63.

Dimensions of the figured hypotype :

Length	0.36 mm.
Breadth	0.15 mm.
Thickness	0.15 mm.

Sample No : 10

Formation : Lockhart Limestone

Locality : Changlagali

Geological range : Middle Paleocene

Distribution elsewhere :

Cuba—Eocene

Remarks : The species is identified after that described and illustrated by Cushman and Bermudez, 1937.

Pleurostomella greatvalleynsis Trujillo

Plate No. 7, Fig. No 3-4.

1960 *Pleurostomella greatvalleyensis* Trujillo, Journ. Pal. Vol. 34, No. 2, p. 345, pl. 50 Figs. 6a-b.

Dimensions of the figured hypotype

Length	0.50 mm.
Breadth	0.21 mm.
Thickness	0.21 mm.

Sample No. 10

Formation : Lockhart Limestone

Locality : Changlagali

Geological range : Middle Paleocene

Distribution elsewhere :

California U.S.A. Upper Cretaceous.

Remarks : The species is identified after that described and illustrated by Trujillo, 1960.

Family : NONIONIDAE SCHULTZE, 1854

Genus : *Chilostomella* Reuss in Czjzek, 1849

Chilostomella ovoidea Reuss

Plate No. 7 Fig. No. 5-6.

1850 *Chilostomella ovoidea* Reuss, K. Akad. Wiss, Wien Math. Nat. Cl. Denkschr, Bd. 1 p. 380, pl. 48, Fig. 12a-c.

1964 Moore, Treat, pt. C. Vol. 2, pp. 742-743, Fig. 611/1

Dimensions of the figured hypotype :

Length	0.40 mm.
Breadth	0.30 mm.
Thickness	0.30 mm.

Sample No. 13.

Formation : Lockhart Limestone

Locality Changlagali

Geological range : Upper Paleocene

Distribution elsewhere :

Austria—Miocene

Remarks : The species is identified after that illustrated by Moore, 1964.

Family : ALABAMINIDAE HOFKER, 1951

Genus : *Gyroidina* d'Orbigny. 1826.

Gyroidina globosa (Hagenow)

Plate No. 7, Fig. No. 7-9.

1842 *Nonionina globosa*. Hagenow, Nelles, Jahb. f. Min. Geog. Geol. pp. 568-575, pl. 9.

1931 *Gyroidina globosa* (v.Hagenow) Cushman, Journ. Pal. p. 310, pl. 35, Figs. 19a-c.

1946 *Gyroidina globosa* (Hagenow) Cushman & Renz ;. Cush. Lab. Foram. Res. Spec. Publ. No. 18, p. 44, pl. 7, Fig. 15.

1956 Haque, Mem. G.S.P. Pal. Pak. Vol. 1, p. 152, pl. 17, Fig. 6.

Dimensions of the figured hypotype :

Length	0.50 mm.
Breadth	0.42 mm.
Thickness	0.24 mm.

Sample No : 23.

Formation : Chorgali Formation

Locality : Phallagali

Geological range : Lower Eocene

Distribution elsewhere :

Salt Range Pakistan—Lower Eocene (Nammal Limestone and Shales)

Trinidad—Paleocene.

Remarks : The species is identified after that described and illustrated by Haque, 1956.

Family : OSANGULARIIDAE, LOEBLICH AND TAPPAN, 1964.

GENUS : *Charltonina* Bermudez, 1952.

Charltonina madrugaensis (Cushman & Bermudez)

Plate No. 7, Fig. No. 10-12.

1948 *Pseudoparrella madrugaensis* Cushman & Bermudez, Cush. Lab. Foram. Res. Vol. 24 pt. 3, p. 73, pl. 11-12.

1952 *Charltonina madrugaensis* (Cushman & Bermudez) Bermudez, Venez. Minist. Minas & Hidrocorb. Bull. Geol. Vol. 2, No. 4 p. 69.

1964 Moore, R.L Treat. Vol. 2, pt. C, p. 752, Fig. 615/5.

Dimensions of the figured hypotype :

Length	0.36 mm.
Breadth	0.32 mm.
Thickness	0.23. mm.

Sample No : 13.

Formation : Lockhart Limestone

Locality : Changlagali

Geological range : Upper Paleocene

Distribution elsewhere :

Cuba—Paleocene

Remarks : The species is identified after that illustrated by Moore, 1964.

Family : ROTALIIDAE Ehrenberg, 1839

Gunus : *Rotalia* Lamarck, 1804.

Rotalia Crookshankiana Jacob & Sastri

Plate No 8 Fig. No 1-3.

1950 *Rotalia Crookshankiana* Jaccob & Sastri, Sci. & Cult. Cal. Vol. 16, No. 2, pp. 80-81, Figs. 4a-c.

Dimensions of the figured hypotype :

Length	0.76 mm.
Breadth	0.63 mm.
Thickness	0.35 mm.

Sample No 23.

Formation : Chorgali Formation

Locality : Phallagali

Geological range : Lower Eocene

Distribution elsewhere :

Rajputana India—Lower Eocene (Laki)

Remarks : The species is identified after that described and illustrated by Jaccob and Sastri, 1950.

Rotalia eocaena Gumbel

Plate No. 8 Fig. No. 4-6.

1868 *Rotalia eocaena* Gumbel, K. Bayer, Akad. Wiss. Munchen. Math. Physik, Cl. Adh. Bd. 10, Alct. 2, p. 650, pl. 2, Figs. 87 a-b.

Dimensions of the figured hypotype :

Length	0.40 mm.
Breadth	0.34 mm.
Thickness	0.22 mm.

Sample No : 23.

Formation : Chorgali Formation

Locality : Phallagali

Geological range : Lower Eocene

Distribution elsewhere :

Germany—Lower Eocene

Remarks : The species is identified after that described and illustrated by Ellis and Messina.

Rotalia perovalis (Terquen)

Plate No. 8 Fig. No. 7-8.

1882 *Rotalia perovalis* Terquem, Soc. Geol. France, Mem. Ser. 3, Vol. 2, No. 3, p. 70, Fig. 5.

1959 *Rotalia perovalis* (Terquem) Le Calvera & Haque Mem G.S.P. Pal. Pak. Vol. 2, pt. 1, pl 20, pl. 2, Figs. 10-12.

Dimensions of the figured hypotype :

Length	0.70 mm.
Breadth	0.70 mm.
Thickness	0.30 mm.

Sample No : 13.

Formation : Lockhart Limestone

Locality Changlagali

Geological range : Upper Paleocene

Distribution elsewhere :

France—Eocene

Hyderabad—Base of Lower Eocene Pakistan

Remarks : The species is identified after that described and illustrated by Haque, 1956.

Rotalia trochidiformis (d'Archiac and Haime)

Plate No. 8 Fig. No. 9.

1854 *Rotalia newboldi* d'Archiac & Haime. Deser. An. foss. Gr. Num. Inde. p. 347, pl. 26, Figs. 17a-c.

1937 *Lockhartia newboldi* (d'Archiac & Haime) Davies, Mem. G.S.I. Pal. Ind. Vol. 24, Mem. 1 pp. 46-47.

1954 *Rotalia trochidiformis* (Lamarck) Smout, Brit. Mus. Nat. History. pp. 43-45, pl. 1, Figs. 1a-b.

Dimensions of the figured hypotype :

Diameter	0.80 mm.
Thickness	0.52 mm.

Sample No : 8.

Formation : Lockhart Limestone

Locality : Changlagali

Geological range : Middle Paleocene—Lower Eocene

Distribution elsewhere :

Kohat Pakistan—Lower to Upper Ranikot

Salt Range Pakistan—Paleocene—Lower Eocene

Somaliland—Lower—Middle ? Eocene

Qatar—Upper Paleocene—Lower Eocene

Remarks : The species is identified after that described and illustrated by Smout, 1954.

Genus : *Thalmannita* Bermudez, 1952.

Thalmannita crookshanki (Haque)

Plate No. 7, Fig. No. 13-15.

1956 *Ornatomlaina crookshanki* Haque, Mem. G.S.P. Pal. Pak. Vol. 1, pp. 198-199, pl. 18, figs. 10a-b.

1964 Moore, R.L. Treat, Vol. C, p. 621.

Dimensions of the figured hypotype :

Length	0.60 mm.
Breadth	0.52 mm.
Thickness	0.40 mm.

Sample No. : 17.

Formation : Patala Shale

Locality : Kuzagali

Geological range : Upper Paleocene

Distribution elsewhere :

Salt Range Pakistan—Paleocene (Khairabad Limestone and Patala Shales)

Remarks : The species is identified after that described and illustrated by Haque, 1956.

Thalmannita sp.

Plate No. 7, Fig. No. 16-18.

Dimensions of the figured hypotype :

Length	0.80 mm.
Breadth	0.60 mm.
Thickness	0.50 mm.

Sample No. 17.

Formation : Patala Shale

Locality : Kuzagali

Geological range : Upper Paleocene

Remarks : The number of chambers is the same as in *Thalmannita geei* (Haque) but differs in having an elongated test, a very wide open aperture and possibly in the surface ornamentation.

Genus : *Lockhartia* Davies, 1932.

Lockhartia conditi (Nuttal)

Plate No. 9, Fig. No. 4.

1962a *Dictyoconoides conditi* Nuttal, Geol, Mag. Lond Vol. 63, p. 119, pl. 11, Figs. 7, 8.

1932 *Lockhartia conditi* (Nuttal) Davies, Trans. Roy. Soc. Edin. Vol. 57, p. 408, pl. 2, Figs. 7, pl. 4, Fig. 7.

1937 Davies & Pinfold, Mem. G.S.I. Pal. Ind. Vol. 24, Mem. 1, pp. 47-48, pl. 5, Fig. 24.

1954 Smout, Brit, Mus. Nat. Hist. pp. 55-56, pl. 5, Figs. 16-19

Dimensions of the figured hypotype :

Diameter	0.13 mm.
Thickness	0.80 mm.

Sample No. 22.

Formation : Chorgali Formation

Locality : Phallagali

Geological range : Paleocene to Lower Eocene

Distribution elsewhere :

Sind Pakistan—Upper Ranikot

Salt Range Pakistan—Paleocene—Lower Eocene

Qatar—Paleocene

Remarks : The species is identified after that described and illustrated by Smout, 1954.

Lockhartia conica Smout.

Plate No. 9, Fig. No. 3.

1954 *Lockhartiaconica* Smout. Brit. Mus. Nat. Hist. p. 53, pl. 4, Fig. 2.

Dimensions of the figured hypotype :

Diameter	1.60 mm.
Thickness	1.22 mm.

Sample No : 6.

Formation : Lockhart Limestone

Locality : Changlagali

Geological range : Lower ?/Middle Paleocene

Distribution elsewhere :

Qatar—Middle Paleocene

Remarks : The species is identified after that described and illustrated by Smout, 1954.

Lockhatria haimei (Davies)

Plate No. 9, Fig. No. 1.

1927 *Dictyoconoides haimei* Davies. A.J.G.S. Vol. 83, pp. 280-281 pl. 21, Figs. 13-15.

1930b *Lockhartia haimei* (Davies) Davies. Mem. G.S.I. Pal. Ind. Vol. 15, pp. 75-76.

1954 Smout A.H. Brit. Mus. Nat Hist. pp. 49-50, pl. 2, Figs. 1-14.

Dimensions of the figured hypotype :

Length	1.18 mm.
Breadth	1.08 mm.
Thickness	0.52 mm.

Sample No : 11.

Formation : Lockhart Limestone

Locality : Changlagali

Geological range : Middle to Upper Paleocene

Distribution elsewhere :

Thal, Pakistan—Paleocene (Ranikot)

Northern Somaliland—Paleocene

Qatar—Paleocene (Middle & Upper)

Remarks : The species is identified after that described and illustrated by Smout, 1954.

Lockhartia hunti. Ovey var. pustulosa Smout.

Plate No. 9, Fig. No. 2.

1954 *Lockhartia hunti*. Ovey var. Pustulosa Smout, pp. 54-55, pl. 4, Fig. 9.

Dimensions of the figured hypotype :

Diameter	1.00 mm.
Thickness	0.60 mm.

Sample No. 22.

Formation : Chorgali Formation

Locality : Phallagali

Geological range : Lower Eocene

Distribution elsewhere :

Qatar—Lower Eocene

Remarks : The species identified after that described and illustrated by Smout, 1954.

Lockhartia tipperi (Davies)

Plate No. 9, Fig. No. 5.

1926 *Conulites tipperi* Davies. Rec. G.S.I. Vol. 59, pp. 247- 248, pl. 18, Fig. 8.

1931 *Dictyoconoides tipperi* (Davies) Nuttal & Brighton, Geol. Mag. Lond. Vol. 68, pp. 56-57, pl. 3, Figs. 14-17.

1932 *Lockhartia tipperi* (Davies), Davies, Trans. Roy Soc. Edin. Vol. 57, p. 407.

1937 Davies & Pinfold, Mem. G.S.I. Pal. Ind. Vol. 24, Mem. 1, pp. 48-49. pl. 7, Fig. 17.

1954 Smout, Brit. Mus. Nat. Hist. p. 55, pl. 4, Fig. 12.

Dimensions of the figured hypotype :

Diameter	2.50 mm.
Thickness	1.90 mm.

Sample No. 22.

Formation : Chorgali Formation

Locality : Phallagali

Geological range : Lower Eocene

Distribution elsewhere :

Somaliland—Lower Eocene

Salt Range Pakistan—Paleocene—Lower Eocene

Kohat & Kalachitta. Pakistan—Upper Ranikot

Sind Pakistan—Lower Eocene

Qatar—Lower Eocene.

Remarks : The species is identified after that described and illustrated by Smout, 1954.

Lockhartia aff. prehaimei Smout

1954 *Lockhartia prehaimei* Smout. Brit. Mus. Nat. Hist. p. 51 pl. 2 Figs. 21-22.

Dimensions of the figured hypotype :

Length	1.06 mm.
Breadth	0.86 mm.
Thickness	0.61 mm.

Sample No : 15.

Formation : Patala Formation

Locality : Kuzagali

Geological range : Middle—Upper Paleocene

Distribution elsewhere :

Qatar—Lower Paleocene

Remarks : The species is identified after that described and illustrated by Smout, 1954.

Genus : *Daviesina* Smout, 1954.

Daviesina khatiyahi Smout.

Plate No 10. Fig. No. 5.

1954 *Daviesina khatiyahi* Smout, Brit. Mus. Nat. Hist. pp. 67-68, pl. 12, Figs. 9-10.

Dimensions of the figured hypotype :

Length	3.00 mm.
Thickness	0.80 mm.

Sample No : 8.

Formation : Lockhart Limestone

Locality : Changlagali

Geological range : Middle Paleocene

Distribution elsewhere :

Qatar—Middle Paleocene

Remarks : The species is identified after that described and illustrated by Smout, 1954.

Genus : *Kathina* Smout, 1954.

Kathina delseota Smout,

Plate No. 10 Fig. No. 4.

1954 *Kathina delseota* Smout, Brit. Mus. Nat. Hist. pp. 61-62. pl. 7, Figs. 6-8.

Dimensions of the figured hypotype :

Diameter	0.62 mm.
Thickness	0.37 mm.

Sample No : 7.

Formation : Lockhart Limestone

Locality : Changlagali

Geological range : Lower ?—Middle Paleocene

Distribution elsewhere :

Qatar—Middle Paleocene

Remarks : The species identified after that and illustrated by Smout, 1954.

Genus : *Assilina* d' Orbigny, 1826.

Assilina deviesi de Cizancourt

Plate No. 11 Fig. No. 9.

1938 *Assilina deviesi* de Cizancourt, Mem. Soc. Geol. France, n.s. 17, fasc. 1. mem. 39, pl. 3, Fig. 24.

1953 Gill Journ. Pal. Vol. 27, No. 6, pp. 837-838, pl. 89, Figs. 7, 11, 13.

Dimensions of the figured hypotype :

Length 9.00 mm.

Thickness 1.20 mm.

Sample No. 22.

Formation : Chorgali. Formation

Locality : Phallagali

Geological range : Lower Eocene

Distribution elsewhere :

Salt Range } Lower Eocene
Kohat } Pakistan ...
Kalachitta } ...

Remarks : The species is identified after that described and illustrated by Gill, 1953.

Assilina daviesi var. nammalensis Gill

Plate No. 11 and 8/26, Figs. No. 8 and 1 respectively.

1953 *Assilina daviesi var. nammalensis*, Gill. Journ. Pal. Vol. 27, No. 6, pp. 838-839, pl. 91, Figs. 5-6.

Dimensions of the figured hypotype :

Length 2.55 mm.

Thickness 0.50 mm.

Sample No. 23.

Formation : Chorgali Formation

Locality : Phallagali

Geological range : Lower Eocene

Distribution elsewhere :

Kohat & Ptowar—Lower Eocene

Remarks : The species is identified after that described and identified by Gill, 1953.

Assilina exponens (Sowerby)

Plate No 12 Fig. No. 1-3.

1840 *Nummulites exponens* Sowerby. Geol. Soc. Lond. Trans. Ser. 2. Vol. 5, p. 719, pl. 61, Fig. 14.

1861 *Assilina exponens* (Sowerby) Carter, Ann. Mag. Nat. Hist. Ser. 3, Vol. 8, p. 373, 376, pl. 15, Figs. 6a-d.

1927 Nuttal. Rec. G.S. I. Vol. 59, pp. 142-143, pl. 5, Figs. 5 & 6.

Dimensions of the figured hypotype :

Length 2.60 mm.

Breadth 2.50 mm.

Thickness 2.50 mm.

Sample No 25.

Formation : Kuldana Formation

Locality : Bansragali

Geological range : Middle Eocene

Distribution elsewhere :

S. France—Middle Eocene

West Pakistan—Middle Eocene

Remarks : The species is identified after that described and illustrated by Nuttall, 1927.

Assilina granulosa (d' Archiac)

Plate No. 11, Figs. No. 1.

1847 *Nummulina granulosa* d'Archiac, Bull. Soc. Geol. France Vol. 4, p. 1010.

1906 *Assilina granulosa* (d'Archiac) Douville, Mem. Carte. Geol. det. France. pp. 72-75, pl. 4, Figs. 15-17.

1937 Davies, Mem. G.S.I. Pal. Ind. Vol. 24, Mem.

1, pp. 29-31, pl. 4, Fig. 9.

Dimensions of the figured hypotype :

Diameter 5.8 mm.

Thickness 0.80 mm.

Sample No. 24.

Formation : Kuldana Formation

Locality : Bansragali,

Geological range : Lower and Base of Middle Eocene

Distribution elsewhere :

Kohat Pakistan—Lower Eocene

Salt Range—Lower Eocene

Remarks : The species is identified after that described and illustrated by Davies, 1937.

Assilina laminosa Gill

Plate No. 11, Fig. No. 5.

1953 *Assilina laminosa* Gill. Cush. Found. Foram. Res, Contr. Vol. 4, pt. 2, p. 83, pl. 13, Fig. 15.

Dimensions of the figured hypotype :

Length 2.25 mm.

Breadth 1.20 mm.

Sample No. 19.

Formation : Margala Hill Limestone

Loaclity : Margala Hill

Geological range : Lower Eocene

Distribution elsewhrere :

Jaba Salt Range Pakistan — Lower Eocene (Lower Laki, Nammal Formation)

Remarks : The species is identified after that described and illustrated by Gill 1953.

Assilina aff. *laminosa*

Dimensions of the figured hypotype :

Diameter 1.68 mm.

Thickness 1.05 mm

Sample No :22.

Format on : Chorgali Formation

Locality : Phallagali

Geological range : Lower Eocene

Assilina subdaviesi Gill

Plate No 11 & 8/26, Figs. No. 7 & 2 respectively.

1953 *Assilina subd..viesi* Gill, Journ. Pal. Vol. 27, pp. 838-839. pl. 91, Figs. 5-6.

Dimensions of the figured hypotype :

Diameter 2.38 mm.

Thickness 0.45 mm.

Sample No. 23.

Formation : Chorgali Formation

Loacality : Phallagali,

Geologicali range : Lower Eocene

Distribution elsewhere :

Salt Range Pakistan — Lower Eocene

Remarks : The species is identified after that described and illustrated by Gill, 1953.

Assilina subspinosa Davies & Pinfold

Plate No. 11, Fig. No. 3.

1937 *Assilina subspinosa* Davies & Pinfold, Mem. G.S.I. Pal. Ind. Vol. 24, Mem. 1, pp. 33-34, Pl. 4, Fig. 25.

Dimensions of the figured hypotype :

Diameter	2.80 mm.
Thickness	0.70 mm.

Sample No. 20.

Formation : Margala Hill Limestone

Locality : Margala Hill.

Geological range : Lower Eocene

Distribution elsewhere :

Salt Range Pakistan—Upper Paleocene—Lower Eocene

Remarks : The species is identified after that described and illustrated by Davies and Pinfold, 1937.

Assilina spinosa Davies & Pinfold

Plate No. 11, Fig. No. 2.

1937 *Assilina spinosa* Davies & Pinfold. Mem. G.S.I. Pal. Ind. Vol. 24, Mem. 1, pp. 31-33, pl. 4, Fig. 11.

Dimensions of the figured hypotype :

Length	4.80 mm.
Thickness	1.20 mm.

Sample No. 24.

Formation : Kuldana Formation

Locality : Bansragali

Geological range : Lower Eocene (Upper)

Distribution elsewhere :

Salt Range Pakistan—Upper Eocene (Middle & Upper)

Remarks : The species is identified after that described and illustrated by Davies and Pinfold, 1937.

Genus : *Miscellanea* Pfender, 1935.

Miscellanea miscella (d'Archiac & Haime)

Plate No. 13, Fig. No. 1-4.

1854 *Nummulities miscella* d'Archiac & Haime, Nummulitique de l'Inde. Paris, p. 345, pl. 35, Fig. 4.

1935 *Miscellanea miscella* (d'Archiac & Haime) Pfender. Bull. Soc. Geol. Fr. Vol. 4, pp. 231-235, Figs. 1-4, pl. 11, Figs. 6-7, pl. 13, Figs. 2-4.

1937 Davies & Pinfold. G.S.I. Pal. Ind. Vol. 24, Mem. 1, pp. 42-43 Fig. 1(A), pl. 6, Figs. 4, 6-9-10, 17-18.

1954 Smout., Brit. Mus. Nat. His. pp. 72-73.

Dimensions of the figured hypotype :

Length	1.76 mm.
Breadth	1.70 mm.
Thickness	0.56 mm.

Sample No : 17.

Formation : Patala Shale

Locality : Kuzagali

Geological range: Middle & Upper Eocene

Distribution elsewhere :

Europe—Paleocene

Salt Range Pakistan—Lower to Upper Paleocene

Qatar—Upper Paleocene

Remarks : The species is identified after that described and illustrated by Smout, 1954.

Genus : *Nummulites* Lamarck, 1801

Nummulties atacicus Leymerie.

Plate No .14, Fig. No. 2.

1846 *Nummulites atacicus* Leymerie, Mem. Soc. Geol. France. Vol. 1, pp. 358-359, pl. 13, Figs. 13a-c.

1937 Davies & Pinfold, Mem. G.S.I. Pal. Ind. Vol. 24, Mem. 1, pp. 24-25, pl. 3, Figs. 8.

Dimensions of the figured hypotype :

Length	2.30 mm.
Breadth	1.35 mm.

Sample No :19.

Formation : Margala Hill Limestone

Locality : Margala Hill.

Geological range : Lower Eocene

Distribution elsewhere :

Salt Range Pakistan—Lower Eocene

Remarks : The species is identified after that described and illustrated by Davies and Pinfold. 1937.

Nummulties leoninensis Hanzawa

Plate No. 14 Fig. No. 1.

1947 *Nummulites boninensis* Hanzawa, Journ, Pal. Vol. 21. p. 256, pl. 39, Figs. 3-5.

Dimensions of the figured hypotype :

Diameter	2.20 mm.
Thickness	1.15 mm.

Sample No. 24 .

Formation : Kuldana Formation

Locality : Bansragali

Geological range : Lower Eocene

Distribution elsewhere :

Japan—Lower Eocene

Remarks : The species is identified after that described and illustrated by Hanzawa, 1947.

Nummulites globulus Leymerie

Plate No .14 Fig. No. 5-7 & 8-9.

1846 *Nummulites globulus* Leymerie. Mem. Soc. Geol. Fr. Vol. 1, p. 359, pl. 13, Figs. 14a-d.

1937 Davies & Pinfold. Mem. G.S.I. Pal. Ind. Vol. 24, Mem. 1, p. 22. pl. 3, Fig. 3.

1954 Smout, Brit. Mus. Nat. Hist. pp. 79-80, pl. 15, Figs. 5-6.

Dimensions of the figured hypotype :

Length	1.10 mm.
Breadth	1.00 mm.
Thickness	0.60 mm.

Sample No. 23 and 20.

Formation : Chorgali Formation & Margala Hill Limestone respectively.

Locality : Phallagali

Geological range : Lower Eocene

Distribution elsewhere :

Salt Range Pakistan—Upper Paleocene

Egypt—Lower Eocene

Qatar—Lower Eocene

Remarks : The species identified after that described and illustrated by Smout, 1954.

Nummulites cf. *mamilla* (Fitchel & Moll)

Plate No. 14, Fig. No. 3.

1789 *N utilus mamilla* F tchel & Moll. Testacea Microscopicla, pp. 53-54, pl. 6, Figs. 6a-d.

1924 *Nummulite, mamilla* (Fitchel & Moll) Douville. C.R. Acad. Sci. Paris. Vol. 178, pp. 38-39.

1937 Davies & Pinfold, Mem. G.S.I. Pal. Ind. Vol. 24, Mem. 1, pp. 22-24.

1953 Gill, Journ. Pal. Vol. 27. No. 6, p. 837, pl. 88, Fig. 7.

Dimensions of the figured hypotype :

Diameter	1.40 mm.
Thickness	0.90 mm.

Sample No. 22.

Formation : Chorgali Formation

Locality : Phallagali

Geological range : Lower Eocene

Distribution elsewhere : Salt Range, Sind and Baluchistan } Pakistan—Lower Eocene

Remarks : The species is identified after that described and illustrated by Gill, 1953.

Nummulites sp.

Plate No. 14, Fig No. 10.

Dimensions of the figured hypotype :

Diameter	5.60 mm.
Thickness	2.60 mm.

Sample No. 24.

Formation : Kuldana Formation

Locality : Bansragali

Geological range : Eocene

Genus : *Operculina* d'Orbigny, 1826.

Operculina salsa Davies.

Plate No 14, Fig No. 11-15.

1937 *Operculina salsa* Davies. Mem. G.S.I. Pal. Ind. Vol. 24, Mem. 1. p. 37, pl. 5, Figs. 1, 3, 7, 10 & 15.

Dimensions of the figured hypotype :

Length	1.34 mm.
Breadth	0.80 mm.
Thickness	0.40 mm.

Sample No. 17.

Formation : Patala Formation

Locality : Kuzagali

Geological range : Upper Paleocene

Distribution elsewhere :

Salt Range Pakistan—Upper Paleocene (Patala Shale)

Remarks : The species is identified after that described and illustrated by Davies, 1937.

Family : PLANORBULINIDAE SCHWAGER, 1827.

Genus : *Eoannularia* Cole & Bermudez, 1944.

Plate No. 15, Fig No. 1-2.

1944 *Eo nnul ria eocenica* Cole & Bermudez. Bull. Amer. Pal. Vol. 28, No. 113, p. 12, Figs. 11-12.

Dimensions of the figured hypotype :

Length 1.25 mm.

Thickness 0.20 mm.

Sample No : 8

Formation : Lockhart Limestone

Locality : Changlagali

Geological range : Middle Paleocene

Distribution elsewhere :

Somaliland—Middle Eocene

Remarks : The species is identified after that described and illustrated by Cole and Bermudez, 1944.

Genus : *Linderina* Schlumberger, 1893.

Linderina sp.

Plate No. 15, Fig. No.3.

Dimensions of the figured hypotype :

Length 0.85 mm.

Thickness 0.25 mm.

Sample No. 6.

Formation : Lockhart Limestone

Locality : Changlagali

Geological Range : Lower/Middle Paleocene

Remarks : The specimen is similar to *L. brugesi* Schlumberger, except that the umbonal thickening and lamination are less pronounced. *L. brugesi* occurs in the Upper Eocene

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Family : ORBITOIDIDAE. Schwager, 1876.

Genus : *Orbitoides*, d'Orbigny in Lyell. 1848.

Actinosiphon punjabensis (Davies)

Plate No. 15, Fig. No. 4.

1937 *Lepidocyclina* (Polylepidina) *punjabensis* Davies Mem. G.S.I. Pal. Ind. Vol. 24, Mem. 1, pp. 53-55, pl. 7, Figs. 5, 6, 16.

1964 *Actinosiphon punjabensis* (Davies) Moore, Treat.

Dimensions of the figured hypotype :

Length 2.40 mm.

Thickness 0.49 mm.

Sample No. 8

Formation : Lockhart Limestone

Locality : Changlagali

Geological range : Middle Paleocene

Distribution elsewhere :

Salt Range Pakistan—Lower and Middle Paleocene

Remarks : The species is identified after that illustrated by Moore, 1964.

Family : DISCOCYCLINIDAE GALLOWAY 1928.

Genus : *Discocyclina* Gumbel, 1870

Discocylina ranikotensis Davies.

Plate No. 15, Fig. No. 6.

1927 *Discocyclina ranikotensis* Davies, Quart, Journ. Geol. Soc. Lond. Vol. 83, pp. 281-282, text, Fig. 4, pl. 22.

1937 Davies, Mem. G.S.I. Pal. Ind. Vol. 24, Mem. 1, pl. 55.

Dimensions of the figured hypotype :

Length	4.85 mm.
Thickness	0.40 mm.

Sample No. 8.

Formation : Lockhart Limestone

Locality : Changlagali

Geological range : Middle Paleocene

Distribution elsewhere :

Salt Range Pakistan—Middle-Upper Paleocene

Thal & Sind Pakistan—Upper Paleocene (Upper Ranikot)

Remarks : The species is identified after that described and illustrated by Davies, 1937.

Discocyclina seunesi Douville

Plate No. 15, Fig. No. 5.

1922 *Discocyclina seunesi* Douville, Soc. Geol. France. Bull. Ser. 4, tome 22, p. 64.

1958 Neumann, Soc. Geol. France, Mem. Vol. 37, No. 3, p. 1, pl. 23.

1967 Ellis & Messina, Cat. Ind. Foram. Am. Mus. Nat. Hist. Vol. 3, Figs. 28-29.

Dimensions of the figured hypotype :

Length	3.80 mm.
Thickness	0.42 mm.

Sample No. : 8

Formation : Lockhart Limestone

Locality : Changlagali

Geological range : Middle Paleocene

Distribution elsewhere :

France—Paleocene

Remarks : The species is identified after that described and illustrated by Ellis and Messina, 1967.

Genus : *Psnedophragmina* Douville, 1923

Pseudophragmina (*Athecocyclina*) *stephensoni* (Vaughan)

Plate No. 15, Fig. No. 8-9.

1929 *Athecocyclina stephensoni* Vaughan, U.S.Nat Mus. Proc. Vol. 76, No. 2800, pp. 1-8, pol. 6, Figs. 1-4.

1959 *Psuedophragmina* (*Athecocyclina*) *stephensoni* (Vaughan) Bull. Amer. Pal. Vol. 39, No. 182, pp. 386-387, pl. 32. Figs. 1-4.

Dimensions of the figured hypotype :

Length	2.35 mm.
Thickness	0.30 mm.

Sample No. 7

Formation : Lockhart Limestone

Locality : Changlagali

Geological range : Middle Paleocene

Distribution elsewhere

U.S.A.—Paleocene—Eocene

Trinidad Paleocene—Eocene

Remarks : The species is identified after that described and illustrated by Moore, 1964.

Family : ALVEOLINIDAE EHRENBERG, 1839.

Genus : *Fasciolites* Parkinson, 1811

Fasciolites delicatissima (Smout)

Plate No. 16 Fig. No. 3.

1954 *Alveolina delicctissima* Smout. Brit. Mus. Nat. Hist. pp. 83-84, pl. 14, Fig. 13.

Dimensions of the figured hypotype :

Length 1.50 mm.

Thickness 0.35 mm.

Sample No. 21.

Formation : Margala Hill Limestone

Locality : Margala Hills.

Geological range : Lower Eocene

Distribution elsewhere :

Qatar-Middle Eocene

Remarks : The species is identified after that described and illustrated by Smout, 1954.

Fasciolites elliptica (Sowerby) var. flosculina. Silvestri

Plate No. 16 Fig. No. 4.

1837 *Fasciolites elliptica* Sowerby Geol. Soc. Lond. Trans. Ser. 2, Vol. 5, p. 329, pl. 24, Fig. 17.

1861 *Alveolina elliptica* (Sowerby) Carter, Ann. Mag. Nat. Hist. Ser. 3, 8, p. 350.

1939 *Alveolina (Fasciolites) subpyrenaica* Leymerie var. *flosculina* Silvestri. Palaeontogr. Hal. Pisa. Vol. 32, p. 30, pl. 1, Figs. 4-5.

1940 *Alveolina elliptica* (Sowerby) var. Nuttalli, Davies. Q.J.G.S. Vol. 96, pt. 2, pp. 219-220, pl. 12, Figs. 1-4.

1954 *Alveolina elliptica* (Sowerby) var. *flosculina* Silvestri. Smout, Brit. Mus. Nat. Hist. pp. 82-83, pl. 14, Figs. 8-12.

Dimensions of the figured hypotype :

Length

Breadth

Thickness

Sample No. 21.

Formation : Margala Hill Limestone

Locality : Margala Hill

Geological range : Lower Eocene

Distribution elsewhere :

Qatar—Middle Eocene

Remarks : The species is identified after that described and illustrated by Smout, 1954.

ACKNOWLEDGEMENTS

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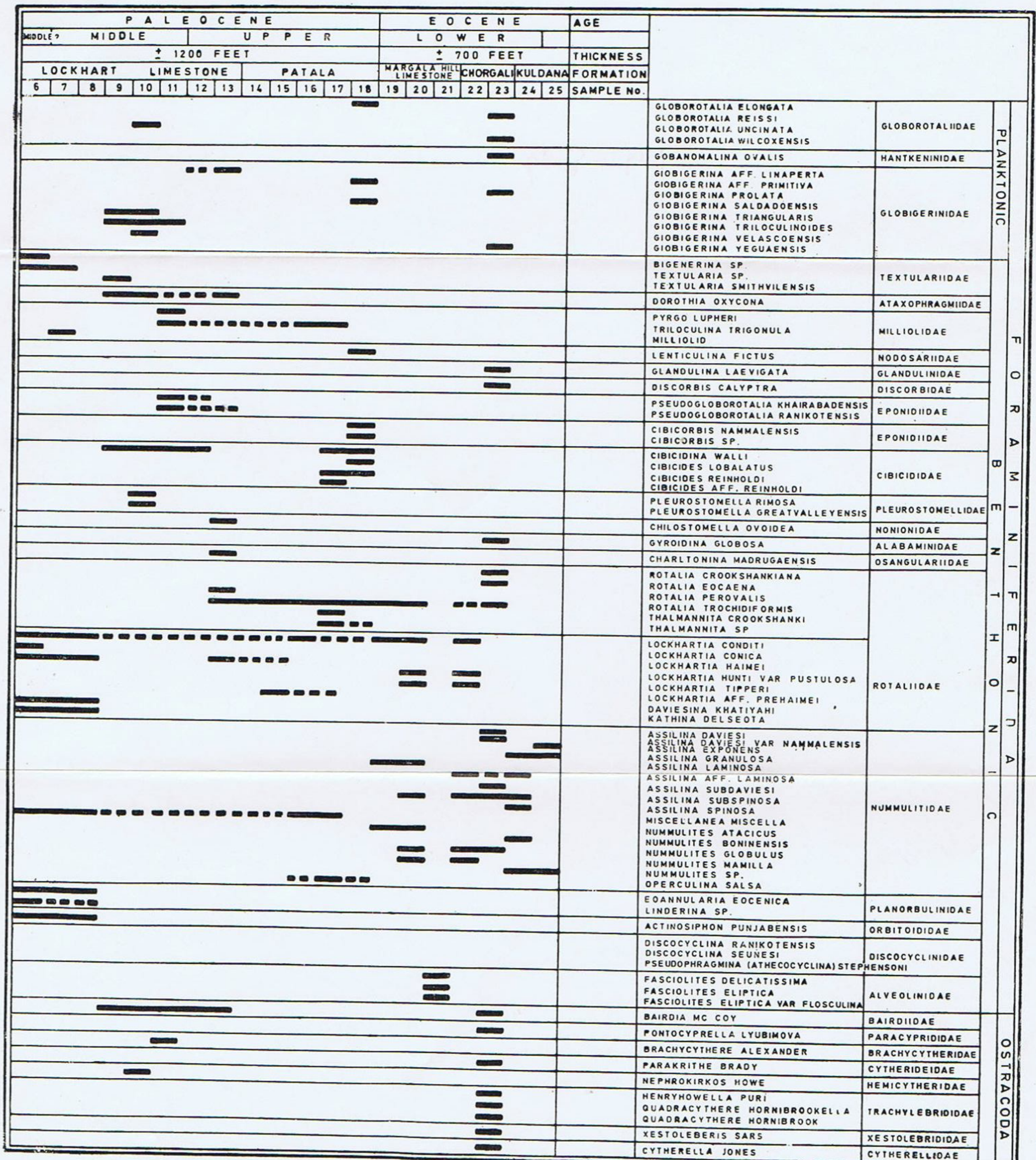

Fig. Microfeuna from Galis Group of South East Hazara, Pakistan.

Plate I (All figures × 80)

1—3 *Globorotalia elongata* Glaessner 1, Spiral view; 2, Umbilical view ; Side view. From sample No. 18, Patala Formation

4—6 *Globoratalia reissi* Leoblich & Tappan 4, Spiral view; 5, Umbilical view ; 6, Side view. From sample No. 23, Chorgali Formation.

7—9 *Globorotalia uncinata* Bolli 7, Spiral view ; 8, Umbilical view ; 9, Side view. From Sample No. 10, Lockhart Limestone

10—12 *Globorotalia wilcoxensis* Cushman 10, Spiral view ; 11, Umbilical view ; 15, Side view. From sample No 23, Chorgali Formation.

13—15 *Globanomalina ovalis* Haque 13, Spiral view ; 14, Umbilical view ; 15, Side view. From sample No. 23, Chorgali Formation.

Plate 2 (All figures × 80)

1—3 *Globigerina* aff. *linaperta* Finlay 1, Spiral view ; 2, Umbilical view ; 3, Side view. From sample No. 13 Lockhart Limestone.

4—6 *Globigerina primitiva* Finlay 4, Spiral view ; 5, Umbilical view ; 6, Side view. From sample No. 18, Patala Formation.

7—9 *Globigerina* aff. *prolata* Bolli 7, Spiral view ; 8, Umbilical view ; 9, Side view. From sample No. 23, Chorgali Formation.

10—12 *Globigerina soldadoensis* Bronnimann 10, Spiral view ; 11, Umbilical view ; 12, Side view. From sample No. 18, Patala Formation.

Plate 3 (All figures × 80)

1—3 *Globigerina triangularis* White 1, Spiral view ; 2, Umbilical view ; 3, Side view. From Sample No. 9, Lockhart Limestone.

4—6 *Globigerina triloculinoides* Plummer 4, Spiral view; 5, Umbilical view; 6 Side view. From sample No. 11, Lockhart Limestone.

7—9 *Globigerina velascoensis* Cushman 7, Spiral view; 8, Umbilical view ; 9, Side view. From sample No. 10, Lockhart Limestone.

10—12 *Globigerina yeguaensis* Wienzierl 10, Spiral view; 11, Umbilical view ; 12, Side view. From sample No 23, Chorgali Formation.

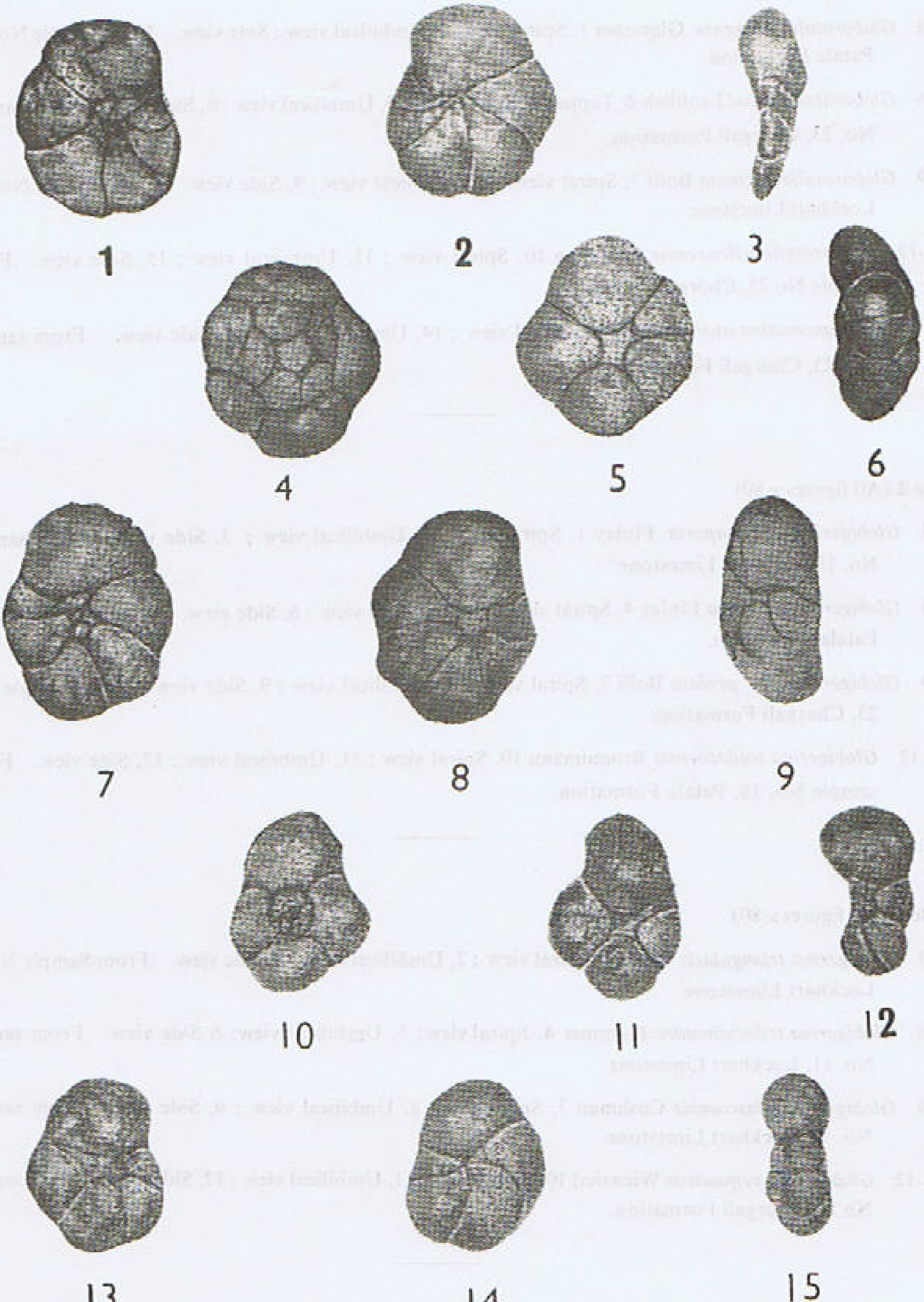

PLATE 1 × 80

PLATE 2 × 80

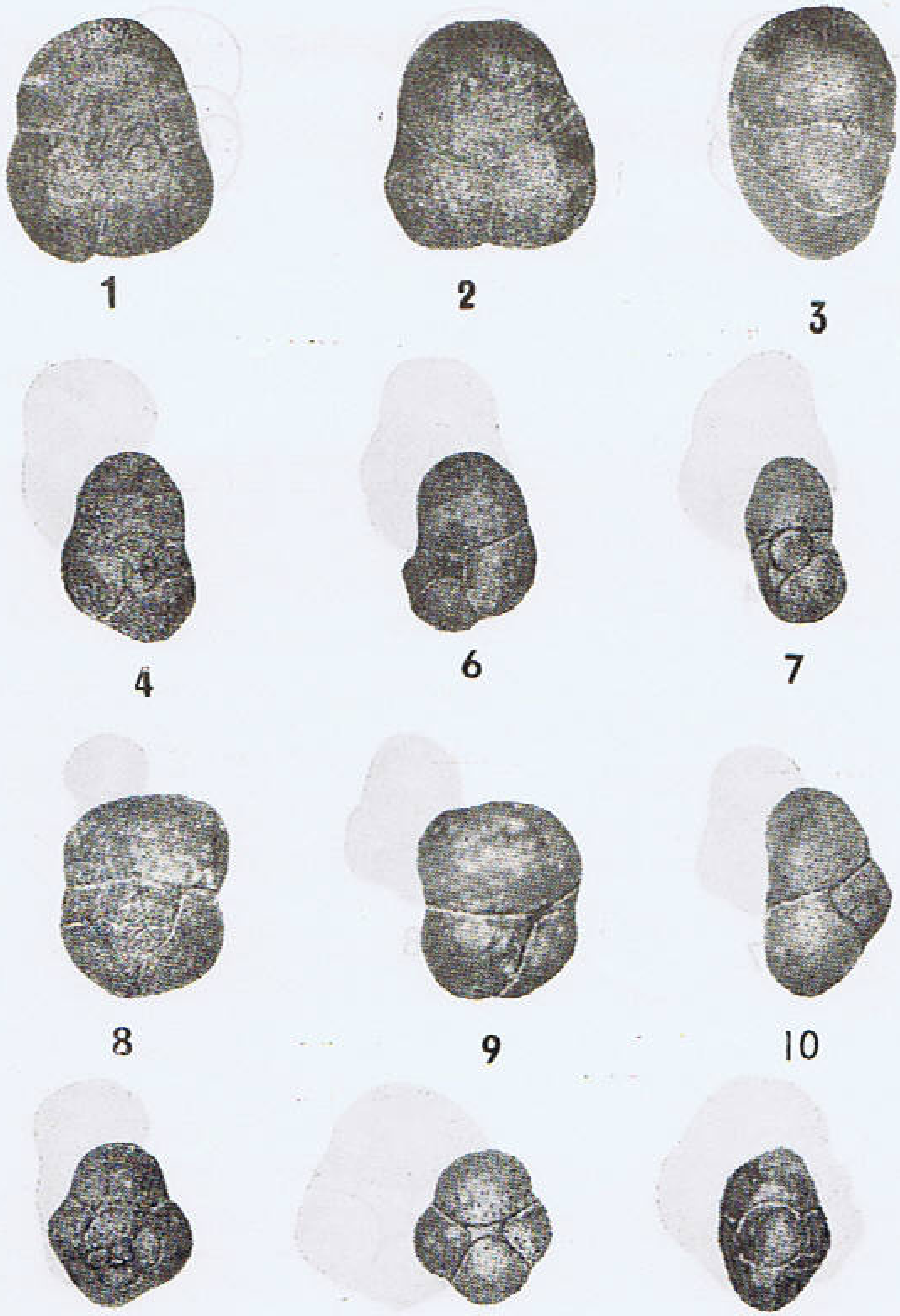

PLATE 3 ×80

Plates 4 (All figures × 80)

1—2 *Textularia smithvillensis* Cushman & Ellisor 1, Side view ; 2, Apertual view. From sample No 9, Lockhart Limestone.

3—4 *Dorothia oxycona* (Reuss) 3, Side view ; 4, Apertural view. From sample No. 10, Lockhart Limestone.

5—7 *Pyrgo lupheri* Rau 5—6 Side view; 7, Apertural view. Form sample No. 11, Lockhart Limestone.

8—9 *Triloculina trigonula* (Lamarck) 8, Side view. From sample No. 16 Patala Formation.

10—11 *Lenticulina fictus* (Israelsky) 10, Side view; 11, Apertural view Form sample No 18, Patala Formation

12—13 *Glandulina laevigata* (d' Orbigny) 12, Side view; 13, Apertural view. Form Sample No. 23, Chorgali Formation.

14—16 *Discorbis calyptra* Shifflet 14, Spiral view ; 15, Umbilical view, 16, Side view. From sample No. 23, Chorgali Formation.

Plate 5 (All figures × 80)

1—3 *Pseudogloborotalia khairabadensis* Haque 1, Spiral view : 2, Umbilical view ; 3, Side view. From sample No. 11, Lockhart Limestone.

4—6 *Pseudogloborotalia ranikotensis* Haque 4, Spiral view ; 5, Umbilical view ; 6, Side view. From sample No. 11, Lockhart Limestone.

7—9 *Cibicorbis nammalensis* (Haque) 7, Spiral view; 8, Umbilical view; 9, Side view. From sample No. 18, Patala Formation

10—12 *Cibicorbis* sp. 10, Spiral view ; 11, Umbilical veiw ; 12, Side veiw From sample No. 18, Patala Formation.

Plate 6 (All figures × 80)

1—3 *Cibicidina walli* Bandy 1, Spiral view ; 2, Umbilical view ; 3, Side view. From sample No 18, Patala Formation.

4—6 *Cibicides lobalatus* (Walker & Jacob) 4, Spiral view ; 5, Umbilical view ; 6, Side view. From sample No 18, Patala Formation.

7—9 *Cibicides reinholdi* Tendam 7, Spiral view; 8, Umbilical view; 9, Side view. From sample No. 17, Patala Formation.

10—12 *Cibicides aff. reinholdi* ten Dam 10, Spiral view; 11, Umbilical view; 12, Side view. From sample No. 17, Patala Formation.

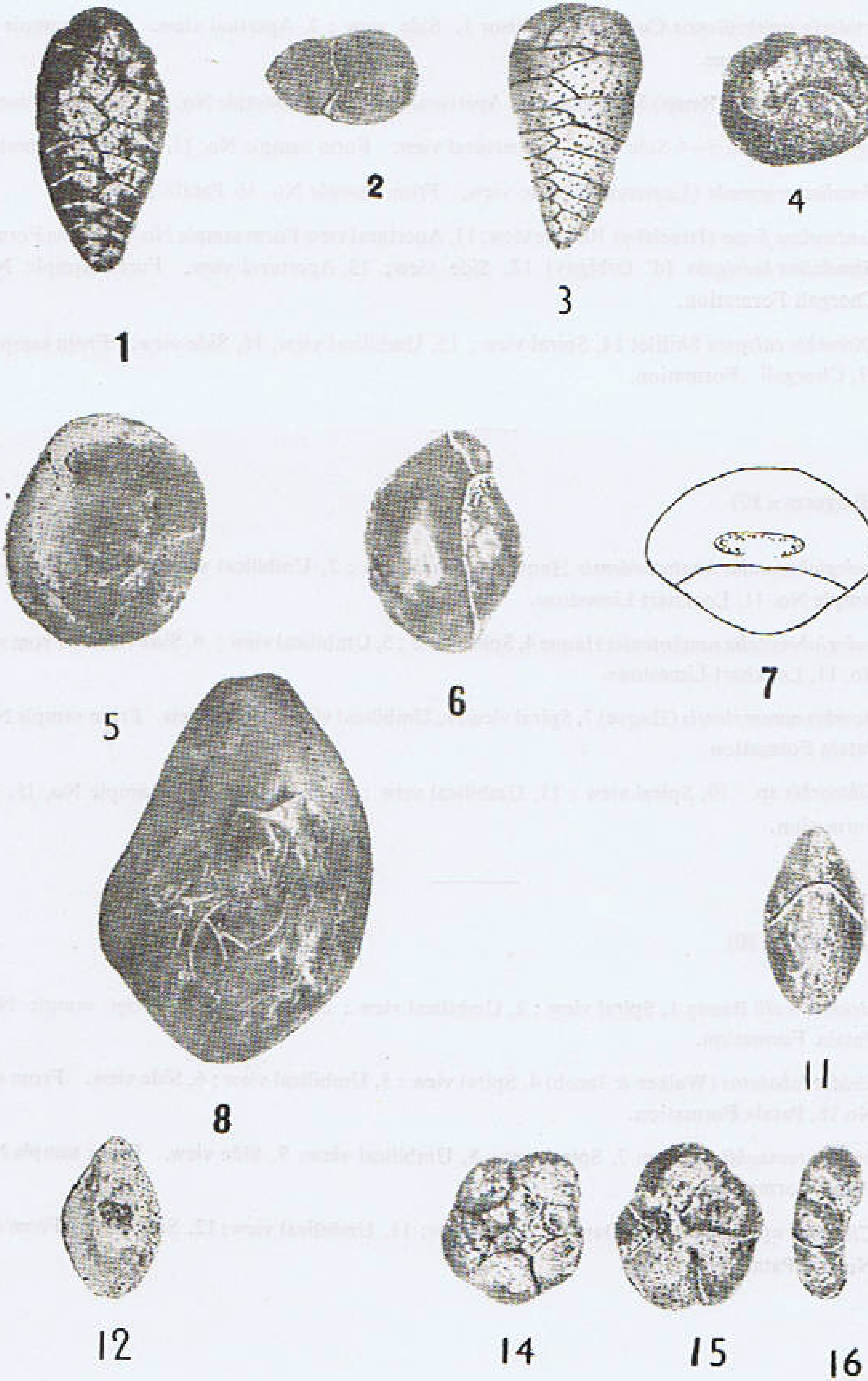

PLATE 4 ×80

PLATE 5 ×80

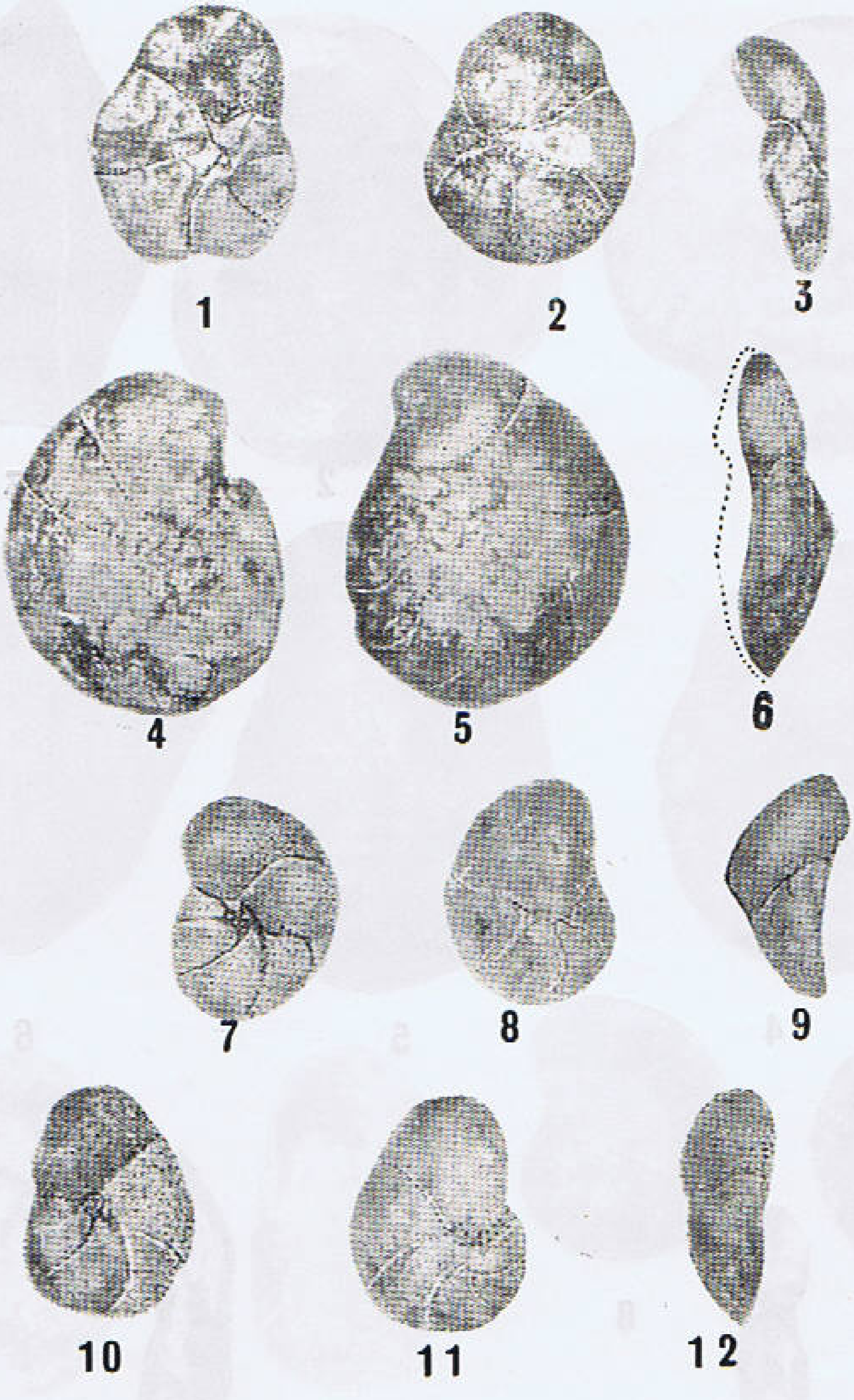

PLATE 6 ×80

Plate 7 (All figures × 80)

1 *Pleurostomella rimosa* Cushman & Bermudez From sample No. 10, Lockhart Limestone.

3—4 *Pleurostomella greatvalleyensis* Trujillo 3, Side view ; 4, Apertural view. From sample No. 10, Lockhart Limestone.

5—6 *Chilostomella ovoidea* Reuss 5, Side view ; 6, Apertural view. From sample No. 13, Lockhart Limestone.

7—9 *Gyroidina globosa* (Hagenow) 7, Spiral view; 8, Umbilical view; 9, Side view. From sample No. 13, Chorgali Formation.

10—12 *Charltonina madrugaensis* (Cushman & Bermudez) 10, Spirl view; 11, Umbilical view ; 12, Side view. From sample No. 13, *Lockhart* Limestone.

13—15 *Thalmannita* aff. *crookshanki* (Haque) 13, Spiral view ; 14, Umbilical view ; 15, Side view. From Sample No. 17, Patala Shale

16—18 *Thalmannita* sp. 16—17, Side views ; 18, Apertural view. From sample No. 17,

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Plate 8 (All figures × 80)

1—3 *Rotalia crookshankiana.* Jacob & Sastri 1, Spiral view, 2, Umbilical view ; 3, Side view. From sample No. 23, Chorgali Formation.

4—5 *Rotalia eocaena* Gumbel 4, Spiral view; 5, Umbilical view; 6, Side view. From sample No. 23, Chorgali Formation.

7—8 *Rotalia perovalis* Terquem. From sample No. 13, Lockhart Limestone.

9— *Rotalia trochidiformis* (d Archiac & Haime) 9 Axial section. From sample No. 13, Lockhart Limestone and 23, Chorgali Formation.

Plate (All figures × 50)

1— *Lockhartia haimei* (Davies) Axial section—From sample No. 6, Lockhart Limestone.

2— *Lockhartia hunti* Ovey var. *pustulosa* Smout. Axial section—From sample No, 22, Chorgali Formation.

3— *Lockhartia conica* Smout Axial section—From sample No. 3, Lockhart Limestone.

4— *Lockhartia conditi* (Nuttall) Axial section—From sample No. 22, Chorgali Formation

5— *Lockhartia tipperi* (Davies) Axial section—From sample No. 22, Chorgali Formation.

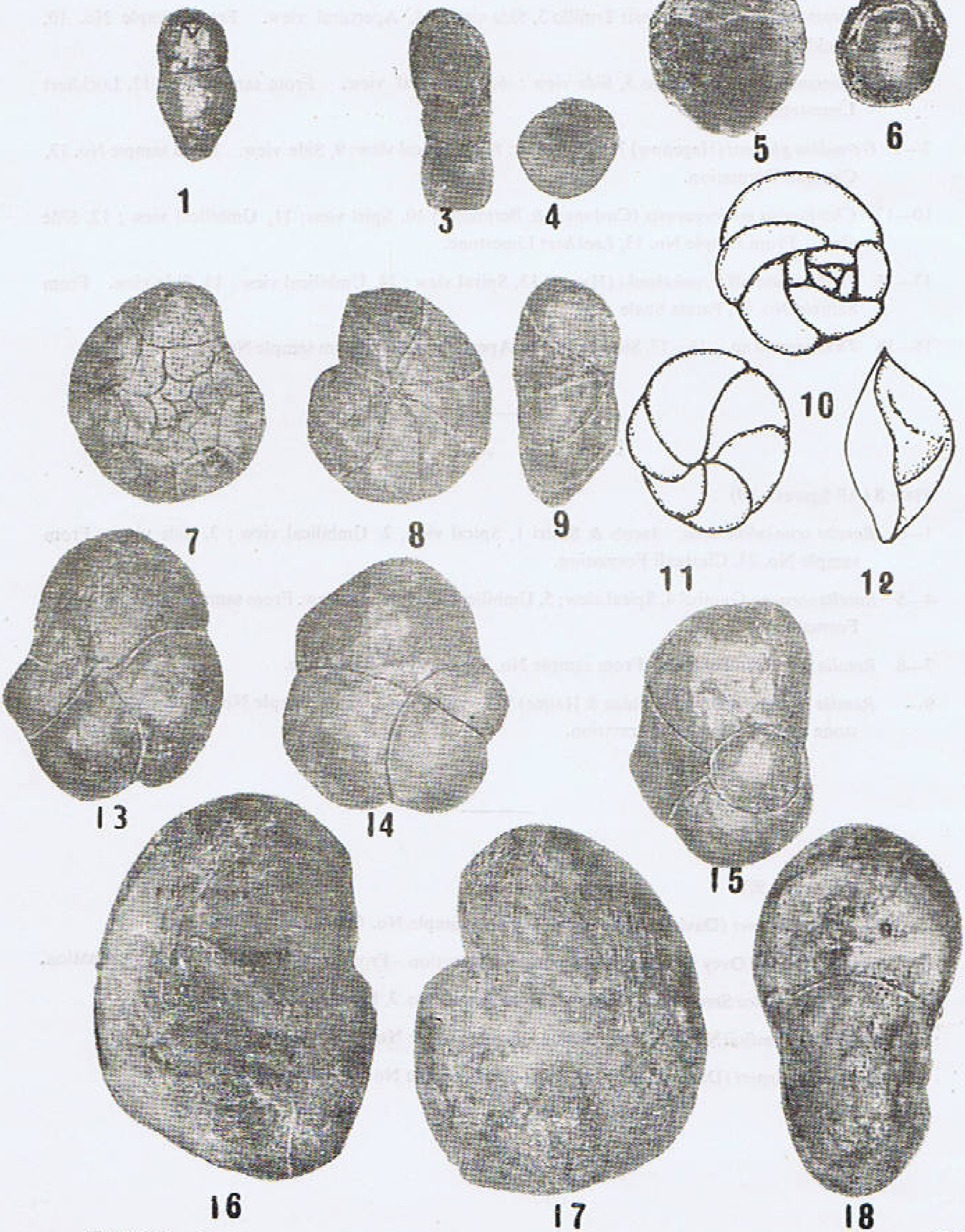

PLATE 7 × 80

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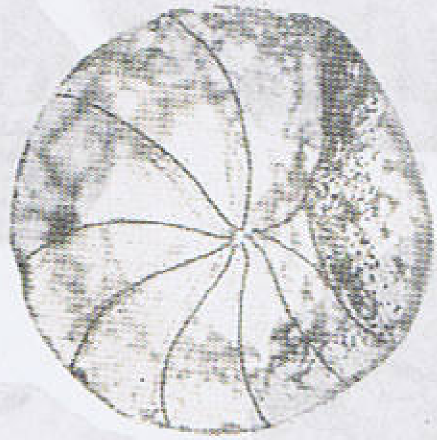

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× 80

PLATE 8

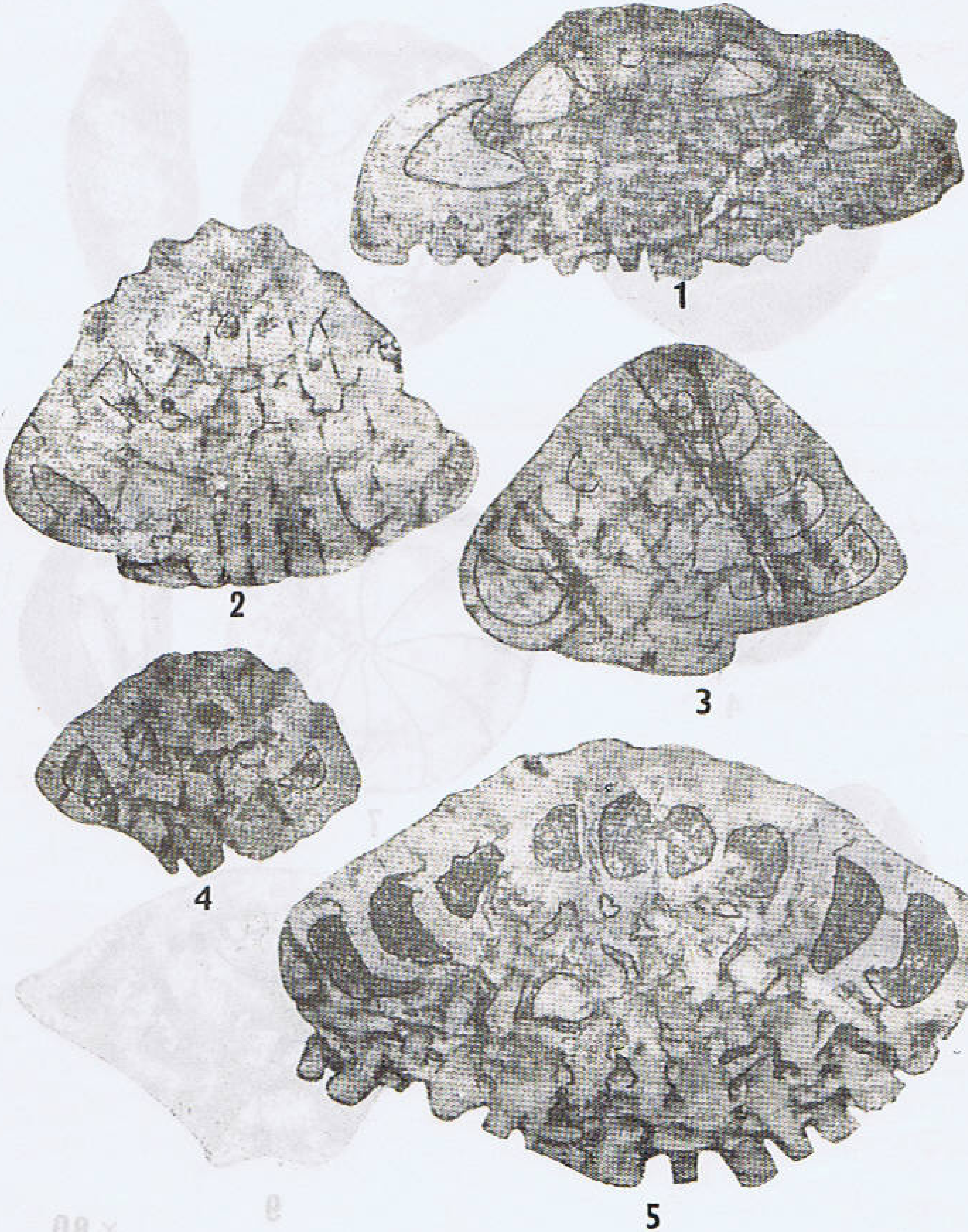

PLATE 9 X 50

Plate 10 (All figures × 50)

1— *Bigenerina* sp. Thin section from sample No. 6, Lockhart Limestone.

2— *Textularia* sp. Thin section from sample No. 6, Lockhart Limestone.

3— *Milliolid* gen. Indet. Thin section from sample No. 6. Lockhart Limestone.

4— *Kathina delseota* Smout. Thin section from sample No. 7, Lockhart Limestone.

5—6 *Daviesina khatiyahi* Smout. Thin section from sample No. 8, & 6, respectively, Lockhart Limestone.

Plate 11 (All figures × 20)

1— *Assilina granulosa* (d'Archiac) Axial section from sample No. 24, Kuldana Formation.

2— *Assilina spinosa* Davies & Pinfold Axial section from sample No. 24, Kuldana Formation.

3—4 *Assilina subspinosa* Davies & Pinfold Axial section from sample No. 20, Margala Hill Limestone.

5—6 *Assilina laminosa* Gill Axial sections from sample No. 19, Margala Hill Limestone and 22, Chorgali Formation, respectively.

7— *Assilina subdaviesi* Gill From sample No. 23, Chorgali Formation.

8— *Assilina daviesi de* Cizancourt var. *nammalensis* Gill Axial section from No. 22, Chorgali Formation.

9— *Assilina daviesi* de Cizancourt Axial section from sample No. 22, Chorgali Formation.

Plate 12 (All figures × 5)

1—3 *Assilina exponens* (Sowerby) 1, Side view; 2, Equitorial section ; 3, Axial section. From sample No. 25, Kuldana Formation.

Plate 13 (All figures × 50)

1—4 *Miscellanea miscella* (d' Archiac & Haime) 1, Side view from sample No. 17 ; Patala Formation 2, 3 and 4, Axial section from sample Nos. 7, 8 and 6 respectively Lockhart Limestone.

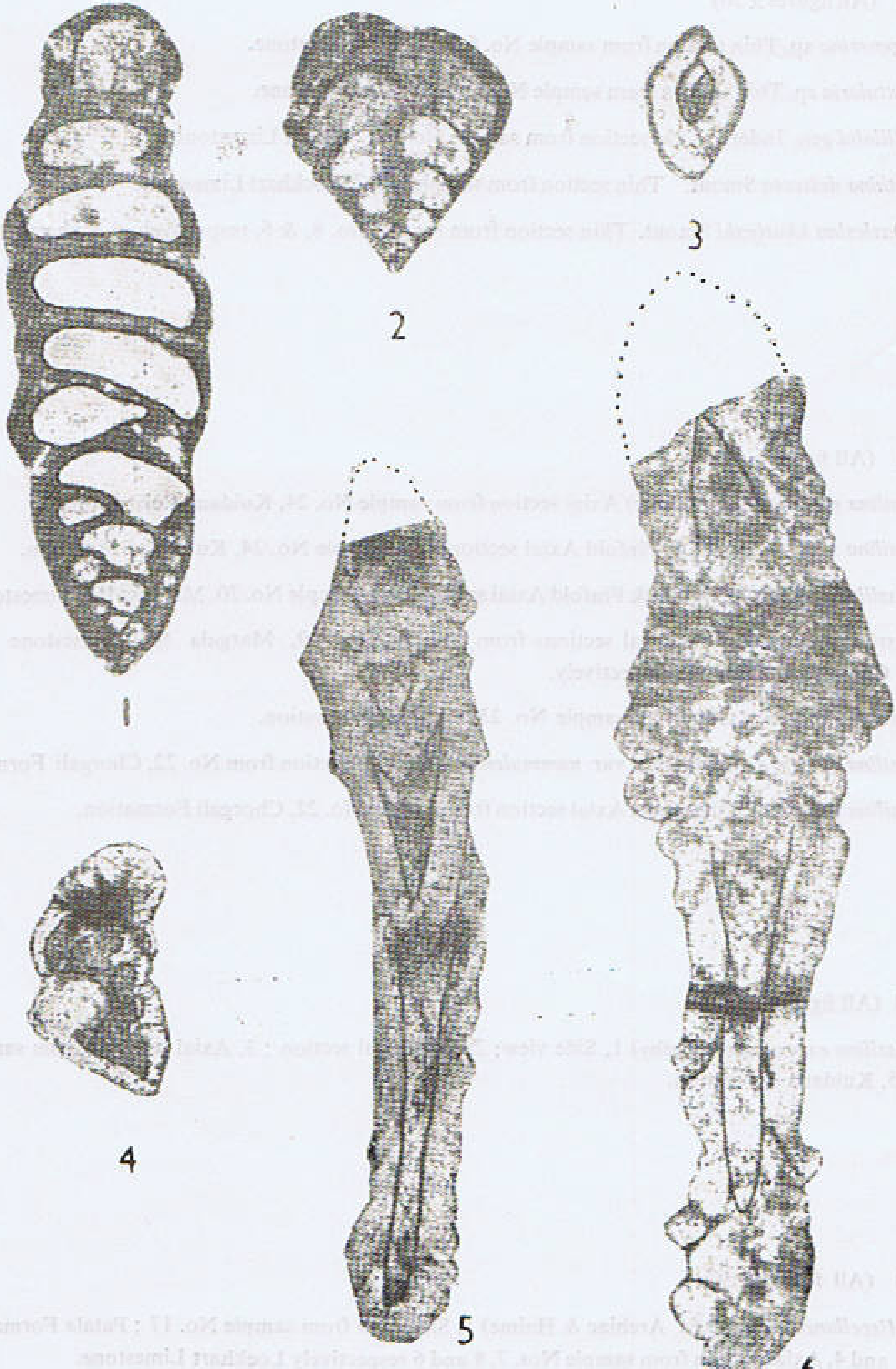

PLATE 10 × 50

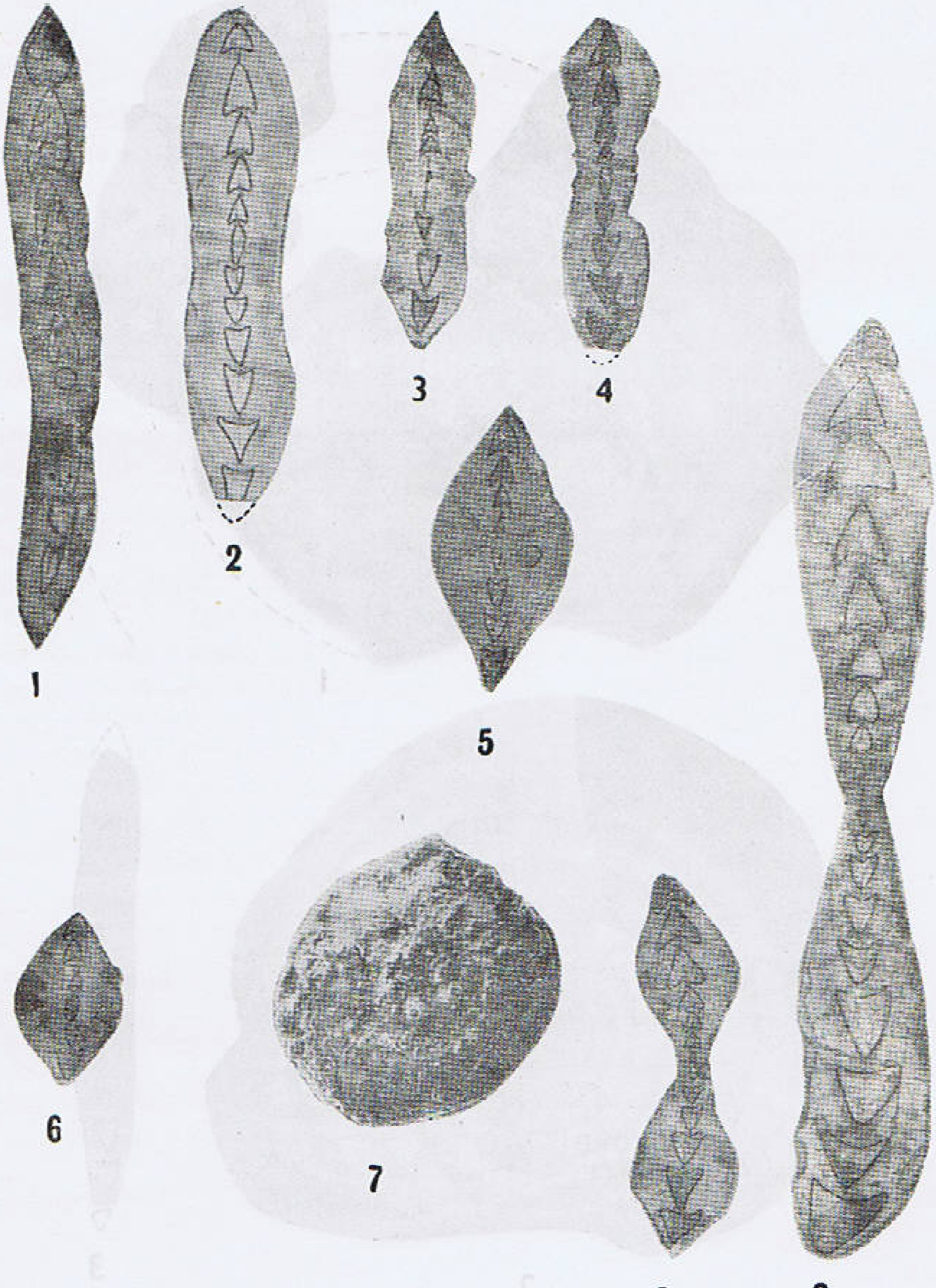

PLATE 11 ×20

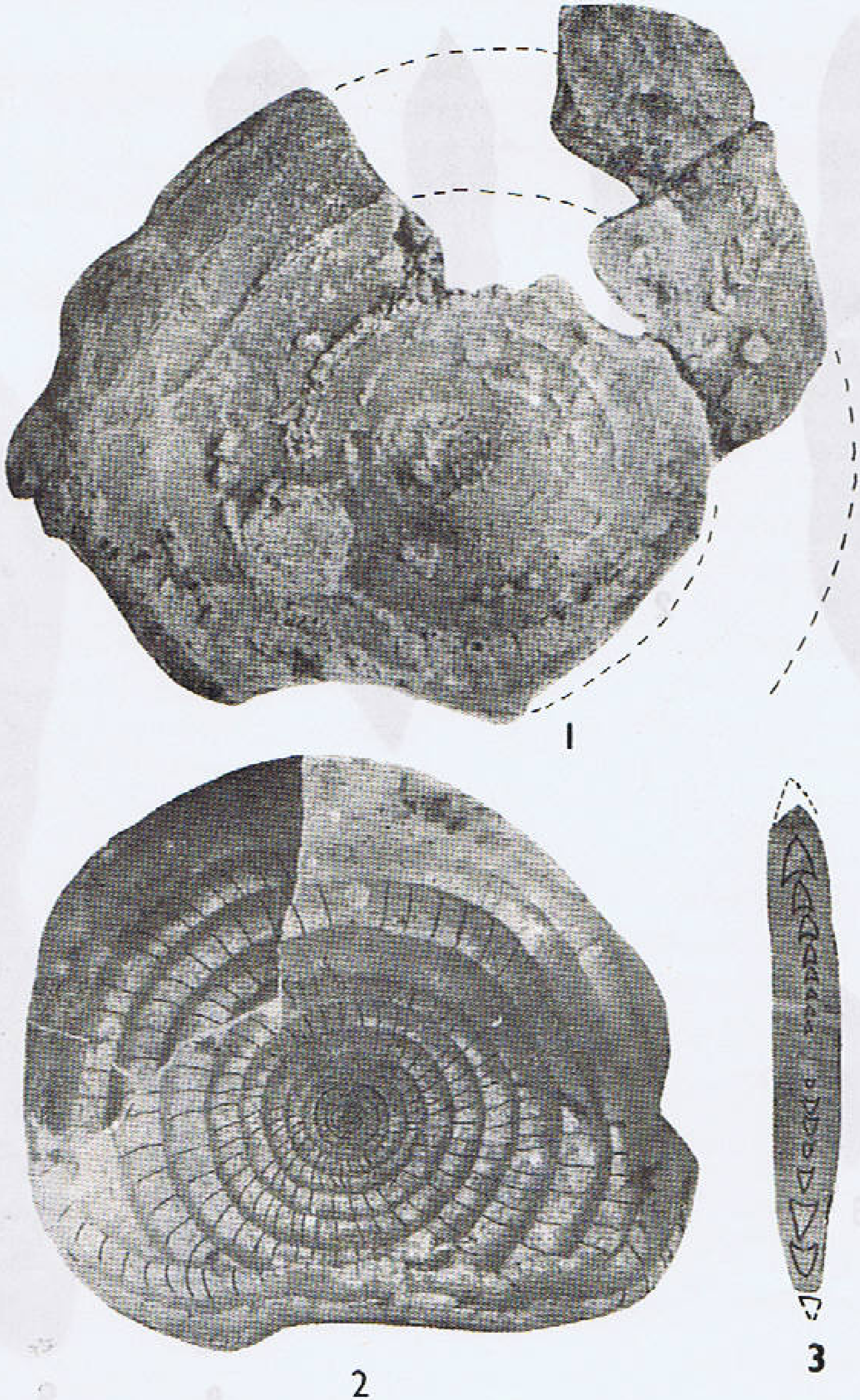

PLATE 12 X 5

PLATE 13 × 50

Plate 14 (All figures × 20)

1— *Nummulites boninesis* Hanzawa Axial section from sample No. 24, Kuldana Formation.

2— *Nummulites atacicus* Leymerie Axial section from sample No. 19, Margala Hill Limestone.

3— *Nummulites* cf. *mamilla* (Fichtel and Moll) Axial section from sample No. 22, Chorgali Formation.

4— *Nummulites kelatensis* Axial section from sample No. 2 Margala Hill Limestone.

5—9 *Nummulites globulus* Leymeri 5 and 6 Side views; 7 Apertural view; from sample 23, Chorgali Formation: 8 and 9 axial sections from sample 20, Margala Hill Limestone.

10— *Nummulites sp.* Axial section from sample No. 24, Kuldana Formation.

11—15 *Operculina salsa* Davies 11 and 12 Side view; 13, Apertural view; 14, Equitorial section and 15, Axial section from sample No. 17, Patala Formation.

Plate 15 (All figures × 30)

1—2 *Eoannularia* aff. *eocenica* (Cole & Bermudez) Thin sections from sample No. 6 and 8, Lockhart Limestone.

3 *Linderina sp.* Thin section from sample No. 6, Lockhart Limestone.

4— *Aktinosiphon punjabensis* (Davies) from sample No. 8. Lockhart Limestone.

5—6 *Discocyclina seunesi* Douville Form sample No. 8 and 6 Lockhart Limestone.

7— *Discocyclina ranikotensis* Davies From sample No. 8, Lockhart Limestone.

8—9 *Pseudophragmina* (*Athecocycline*) *stephensoni* (Vaughan) From sample No. 7, Lockhart Limestone.

Plate 16 (All figures × 10)

1— *Assilina daviesi* de Cizancorut Equitorial section from sample No. 23, Chorgali Formation.

2— *Assilina subdaviesi* Gill Equitorial section from sample No. 23, Chorgali Formation.

3— *Fasciolites* aff. *delicatissima* (Smout) From sample No. 21, Margala Hill Limestone.

4—6 *Fasciolites elliptica* Sowerby From sample No. 21 Margala Hill Limestone.

7—8 *Fasciolites elliptica* var. flosculina From sample No. 21, Margala Hill Limestone.

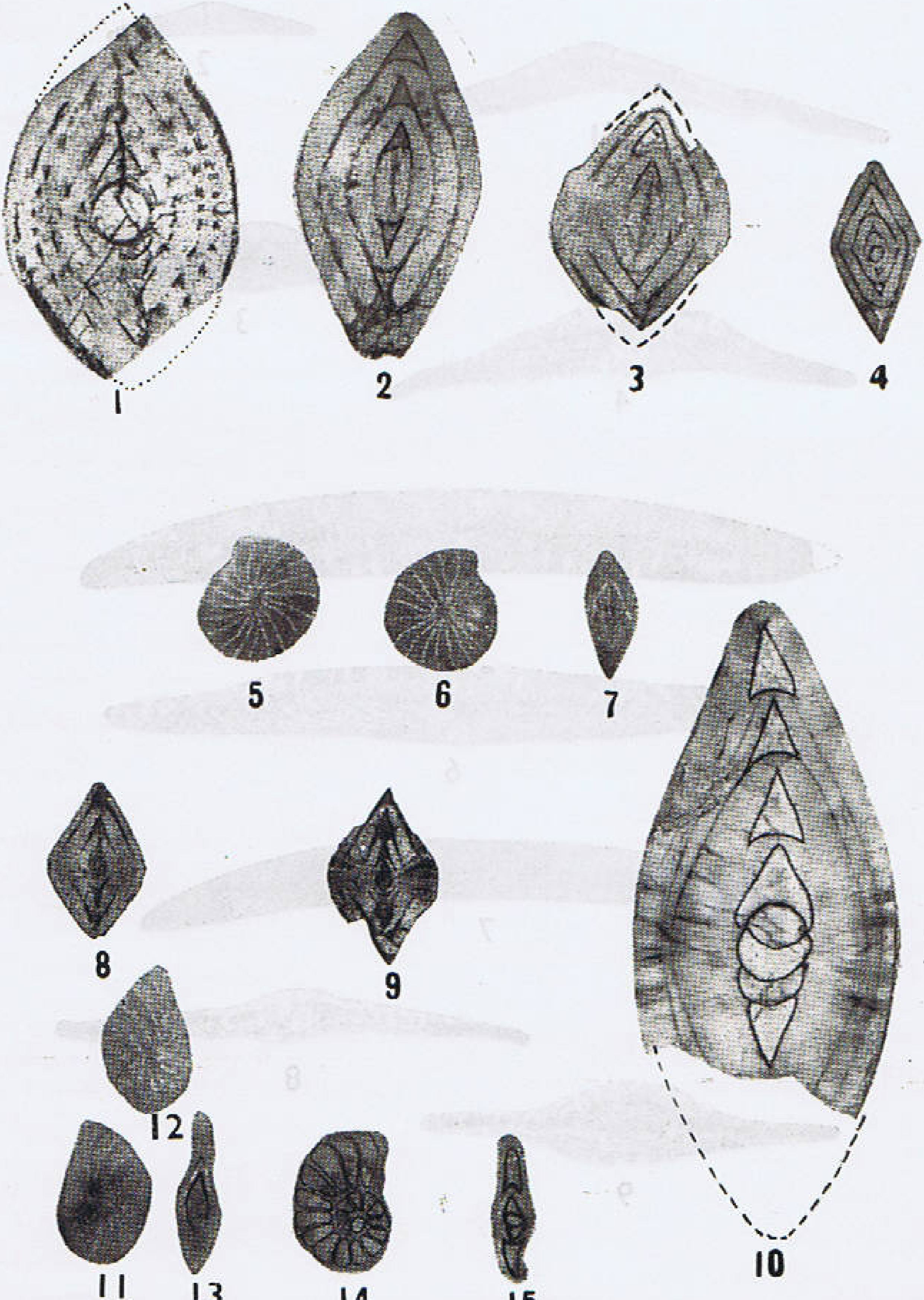

PLATE 14 ×20

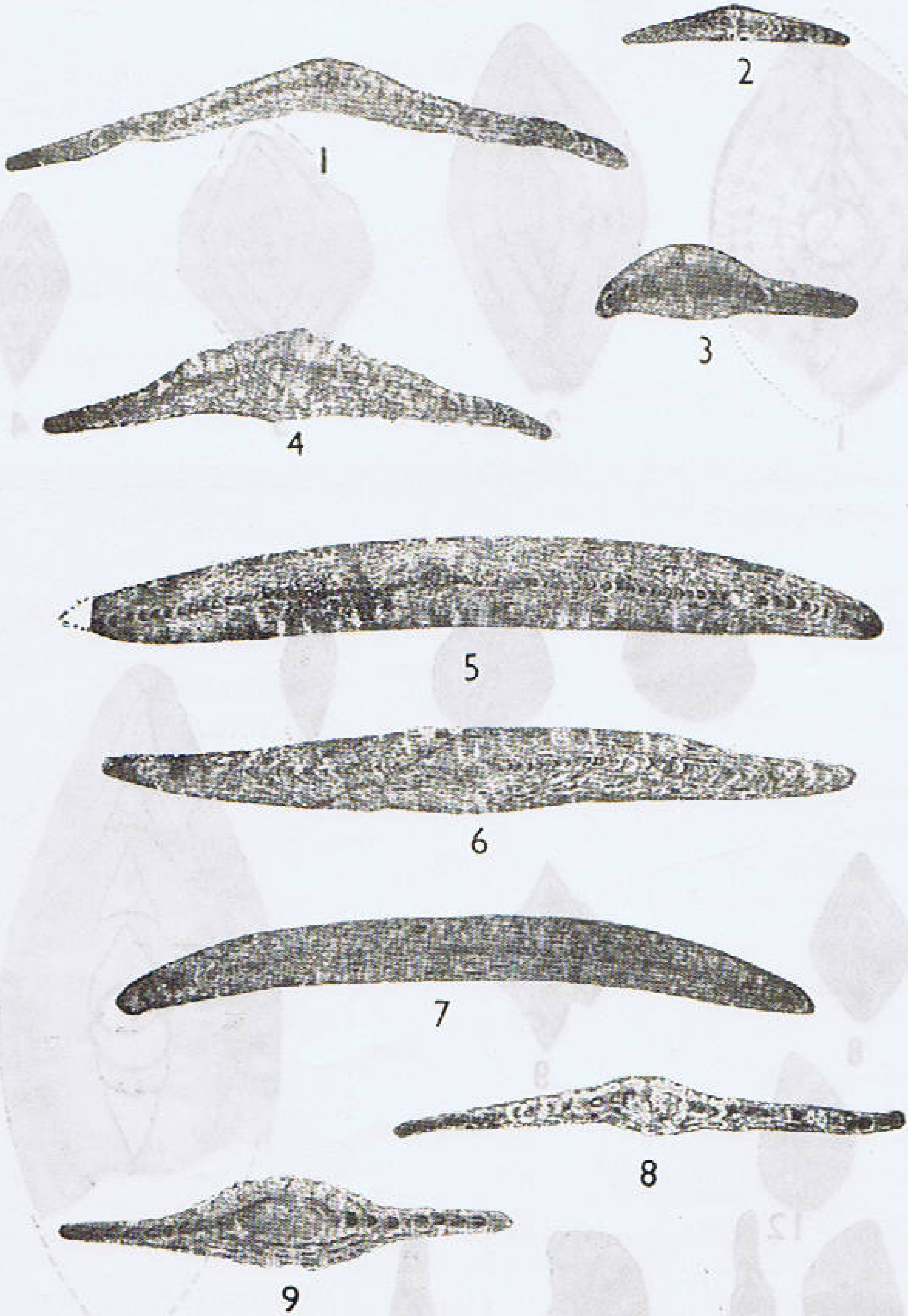

PLATE 15 x30

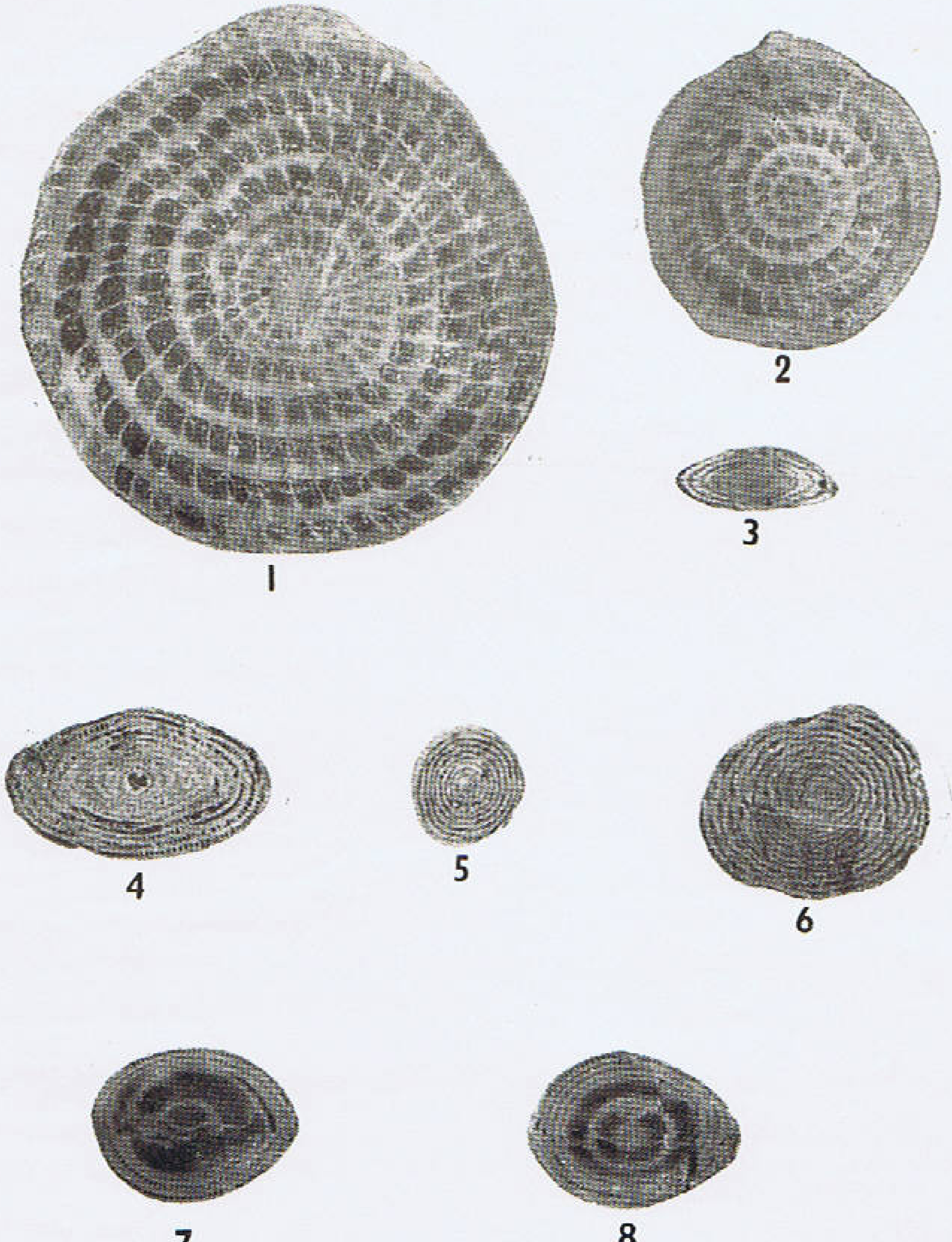

PLATE 16 ×10

THE GEOCHEMISTRY AND PETROGENESIS OF ALBITITES FROM MANSEHRA AND BATGRAM AREA, HAZARA DISTRICT, PAKISTAN

MOHAMMAD ASHRAF*

Glass & Ceramic Division, PCSIR Laboratories, Lahore

M. NAWAZ CHAUDHRY,

Department of Geology, University of the Punjab, Lahore

Abstract : *Albitites are present in the granites and associated metamorphic rocks of the Mansehra and Batgram area. They have been classified as syenitic albitites of three distinct types: (i) pegmatitic albitites, (ii) medium-grained albitites and (iii) fine-grained albitites, the two former being associated with the granites and the latter with the metamorphic rocks. The albitites occur as streaks, stringers and 1—10m wide and 5—70m long bodies. They occur either independently or as composite bodies and are associated with albite-aplites and albite-(microcline) aplites. The shape of these bodies is tabular to lensoid, showing usually sharp contact relationships with the granite and metamorphics. Mineralogically these rocks are usually formed of albite with subordinate quartz, muscovite, rutile, sphene, chlorite, and apatite; zircon, tourmaline and magnetite may also be present. Chemically they contain* SiO_2 66-67%, Al_2O_3 19-21%, Na_2O 9-11%, K_2O 0.2-0.7%. *The origin of these rocks is evaluated in the light of recent experimental work in the granitic system at* 4 *to* 10 Kbs *and it has been suggested that at a water vapour pressure* 10 *Kbs the granitic system shifts towards albite, thereby forming albititic solutions whose deposition and crystallization took place in fissures of the host rocks with gradual cooling of the system.*

INTRODUCTION

The albitites are a part of the acid minor bodies (including aplites, pegmatites, albitized bodies and quartz veins) on which detailed geochemical and petrogenetic studies have been carried out recently by Ashraf (1974). The acid minor bodies were emplaced in the granites and the associated metasediments of the Mansehra and Batgram area (Fig. 1). The area studied lies between longitude 72° 56′ to 73° 23′ E and latitude 34° 15′ to 34° 45′ N′.

The area is composed of semi-pelitic to psammitic schists and quartzites which are intruded by a plutonic complex of granitic rocks of varying types and of different ages. The granitic rocks have been grouped together into the Hazara granitic complex (Shams, 1967). Shams has subdivided the Hazara granitic complex into Susalgali granite gneiss, Mansehra granite, andalusite granite-(potassic granites) and Hakle tourmaline granite-(a sodic granite, youngest of these granites). The first author has added two more types namely Chailsar microgranite (a more sodic variety than Hakle tourmaline granite) and Suthangali granite (also a potassic variety).

Structurally the area constitutes hard crystalline core of a major syntaxial loop of the north-west Himalayas (Wadia, 1931). The general strike of this structure swings in an arcuate fashion (Shams, 1969). The famous Balakot re-entrant is in the east, and the Indus re-entrant lies in the

*Present address : Engineers Combine Ltd. 19-C III Gulberg 3, Lahore.

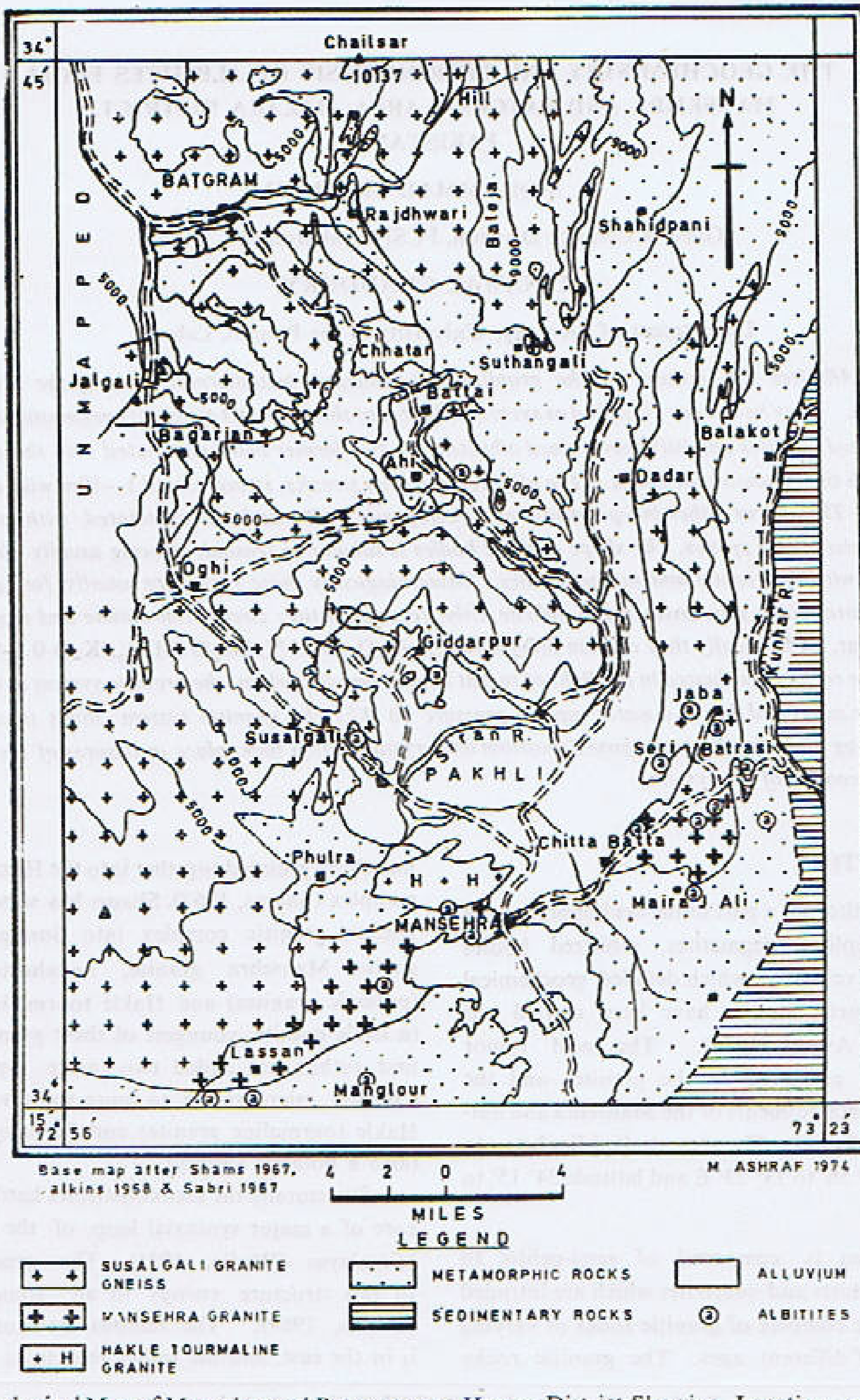

Fig. 1 Geological Map of Mansehra and Batgram area, Hazara District Showing Location and Distributions of the Albitites.

west. In the entire area, the strata dip inwards at different inclinations becoming less and less steeply inclined towards the north.

Topographic relief is moderate and ranges from 525 metres at Pakhli Plain to about 4047 metres above sea level at Chail Sar. Slope angles at most places are 35° to 45°.

THE ALBITITES.

Albitites have been variously described by different authors in the literature available on albitites, it can be clearly seen that albite rich rocks covering a wide range from syenitic to granitic compositions have been called albitites. There is no standard classification of the albitites. This can clearly be seen from the following :

Hatch and Wells (1949) describe albitites as nearly monomineralic rocks with albite as the sole essential component. According to them it is an extreme example of sodic leucosyenite. The feldspar according to them should be either albite or albitic-antiperthite.

In the case of Donets Basin albitites of Gladyshevskaya et al. (1966), the rocks under the microscope appeared to be holocrystalline and composed cheifly of albite with subordinate quartz, carbonate, chlorite, apatite, zircon and epidote. The rock on the basis of analytical results was classed by them as a syenite. Turner (1896) described soda syenite rocks from California. The very same rocks were later on called albitites by Leonardos and Fyfe (1967). On the basis of their mineralogy the rocks were further divided into hornblende-albitites, aegirine-albitites, quartz-epidote-albitites, and quartz-muscovite-albitites. The above authors, therefore, have described the rocks as albitites which fall in the syenite range. Others have described as albitites those rocks which fall in the range of granites. In the case of Urtu Gtszogor off shoot, according to Boguslavskiy et al. (1965), what they call albitites are composed of albite (25 to 55%), microcline (10 to 30%) and quartz (30 to 50%). Goldin (1965) classified albitite rocks consisting of albite (10 to 60%), quartz (10 to 60%), hastingsite (1 to 3%), magnetite (1 to 40%), and sphalerite (6 to 14). According to Shimron (1975) albitites of Sinai are almost pure monomineralic rocks. We propose to define albitite as a holocrystalline rocks falling in the syenitic and granitic fields and consisting essentially of albite, making more than 90% of the total feldspars.

Since albitites cover a considerable range of composition therefore, it is proposed to classify the albitites as follows :

(*i*) *Syenitic albitites* : Those rocks which have quartz less than 10% and albite making up more than 90% of the total feldspars. If some other particular minerals assume importance then a suitable prefix should be added such as hornblende-syenitic albitite, corundum-syenitic albitite etc.

(*ii*) *Granitic albitites* : Those albitites which contain quartz between 10 and 20% and albite makes more than 90% of the total feldspars. Suitable prefix sholuld be added i.e. muscovite-granitic albitites, chlorite-granitic albitites etc.

In the case of those rocks which have albite but contain quartz more than 20% may be called albite-quartz aplites/pegmatites.

In view of the above classification the major albitites of the Mansehra-Batgram area fall in the syenitic albitite type while a few of them are granitic albitites. The albite bearing rocks having quartz more than 20% have been classed as albite aplites/pegmatites from the same area. These latter types are beyond the scope of this work. Moreover, in the present case the syenitic albitites have been further classified on the basis of textural variations as (a) pegmatitic albitites (associated with granites), (b) medium-grained albitites (also associated with the granites), and (c) fine-grained albitites (found in the metamorphic rocks).

Distribution: The albitites are distributed in the area in the interior-lateral zone (Fig. 1), one of the lower most zones of three zones identified as (*i*) interior-lateral zone beween 525 to 1650 metres above sea level (*ii*) interior-marginal zone between 1500 to 2800 metres above sea-level and (*iii*) marginal exterior zone over 2700 metres above sea-level.

The albitites are mainly present within the Mansehra granite and the associated metamorphics while there are scanty bodies associated with the Susalgali granite gneiss. Some of the albitites occur as composite bodies. They are pegmatitic albitites and medium-grained albitites (Seri, Mansehra) and they also form composite bodies with albite-aplite, albite-microcline aplite and pegmatites. The albitite bodies associated with Mansehra granite and the metamorphics are concentrated near the following localities : Seri, Batrasi, Jaba, Chitta Batta, Maira J. Ali, Mansehra, Lassan, Ahl and Manglour.

Size, Shape, Form, External Structure and Relationship with the Enclosing Rocks: Almost all types of albitites present in the area are tabular and lensoid and occur along the foliation plane of the granite and the metamorphics. The foliation plane of the major bodies is less than 25° to 80° to the vertical and in some cases may be exactly 90°. Some of the bodies are dyke-like. The stringer and streak-like bodies are also very common. The stringer types are quite common in the granitic rocks along foliation and joints while streak types occur in the metamorphics particularly in the quartzites, oriented almost parallel to the foliation of the quartzite. The usual width of albitite and aplite bodies is generally between 1.5 to 10 metres and are exposed for a length of some five to seventy metres, but full length of the bodies is not exposed in many cases due to the alluvial cover. Most of the bodies emplaced in the granite are concordant and their contact is very sharp as shown by fairly large number of albititic bodies. At places slight chilling is also observed in the albitites. The fine grained albitites which are emplaced in the metamorphics show gradational or irregular contact as seen in the bodies near Manglour, Lassan, Batrasi and Giddarpur. At some places, like Batrasi and Seri, much shearing and crushing around the contact of albitite and granite has produced a sort of gradation. On the whole albitites occur as massive, compact, layered, banded, sheared and well jointed bodies. The albitites and albite-aplites are sometimes closely associated together either showing gradation or sharp contact relations. The albitites which have sharp contact with the host rocks show fairly un'form composition right from contact towards the centre because there is hardly any exchange of material across the contact. The contact in composite pegmatitic albitite, medium-grained albitite and albite aplite is usually very sharp. The grain size suddenly changes from coarse to medium.

Internal Structure : Most of the albitite bodies are unzoned where the mineral composition and texture from wall inwards remains unchanged except minor secondary variations. In the albitite bodies which are emplaced in the metamorphics, an irregular border+wall zone is formed and a uniform zone is present inside. Such albitite bodies are present near Maira J. Ali, Giddarpur, Jaba, and Manglour. The border+wall zone (about 10 to 35 cm thick) in these bodies is very fine-grained with some coarser grains of the metamorphics while the main body is usually 1.75 to 7 metres thick and is fine to extremely fine-grained. The albitites do show zonation in those bodies which are emplaced in the granites. In the bodies of Seri, Mansehra and Batrasi a zone of coarse-grained (pegmatitic) albitite is developed from the wall inward and becomes medium-grained having sharp contact with the former. This sort of zonation is tabular to lensoid in some cases and concentric to irregular in others. These bodies are symmetrical as well as asymmetrical and sometimes composite with albite aplite. The thickness of the different zones is from 1.5 to 3 metres. There is no evidence of internal replacement of minerals except the development of chlorite along the sheared planes in some albitites.

PETROGRAPHY

Pegmatitic albitites. They are much coarser than the medium-grained albitites. The grains are usually in the range of 1 to 5 cm. They show inhomogeneity due to random distribution of the different grain sizes in them. They form composite bodies with medium-grained albitites, having sharp contact and distinct change in grain size and the amount of quartz. They are white looking rocks with a few specks of some darker grains.

The coarse grains are in the range of 2.5 to 6.5 mm (as much as seen in the limits of thin sections, Fig. 2). The medium grains are 1.5 to 2.5 mm in size. Sericite is the finest grained material in the rocks and is an alteration product of albite. This finer material is hardly more than 2 to 5% in most of the rocks but is upto 10% in some rocks.

From the modal analyses (Table-2) it is clear that these rocks are fairly rich in albite (normal and chessboard) i.e., albite in most of these rocks is 90 to 93% whereas quartz amounts to 1 to 3.75% in four of them, 7 to 9% in three and 13% in only one in the samples studied. This shows that the rocks are albititic and, being coarse enough, could be called pegmatitic albitite rocks. The chessboard albite in these pegmatitic rocks ranges from 20 to 62%. Both albites alter to sericite and kaolinite on a small scale.

Normal albite occurs mostly as coarse grains 2.5 to 8mm) with occasional medium to fine grains (1.5 to 2mm). Its form is generally euhedral and, sometimes subhedral to anhedral. The composition of albite in these rocks is from $An_{2.5}$ to An_7. Some of the finer tablets of normal albite are enclosed in chessboard albite. Normal albite is distributed from 41 to 65% in most of the rocks but exceptionally high amount is present in A-84,

Fig. 2. Photomicrograph of Pegmatitic Albitite showing chessboard and Normal Albite Twinned Grains.
(X 21, x.p.)

upto 91%. Sometimes normal albite twin lamellae coalesce to form broad secondry lamellae (Capedri, 1970) in these rocks.

Chessboard albite is an essential mineral in these rocks like normal albite as its contents vary from 20 to 46% with the exception of A-84 where it is very low (0.8%). Unlike medium-grained albitites it is throughout present in the form of coarser grains. Apatite and muscovite are poikilitically enclosed in the chessboard albite.

Quartz occurs as 0.4 to 1 mm grains in most cases but in some of them upto 2 mm anhedral grains are also present. Sometimes fine-aggregates of quartz occur randomly distributed. It is strained in some rocks.

Muscovite is present in the form of (0.1 mm to 0.8mm) needles, tablets and flakes. It occurs along the grain contacts and within the normal and chessboard albites. Its amount ranges from 0.08 to 2.69% in these rocks. Sericite occurs as an alteration product of albite.

Biotite occurs as small (0.05 to 0.5 mm) tablets and needles : it shows light to very light brown pleochroism.

MODAL ANALYSES TABLE 1

Pegmatitic Albitites

	A—54 (Batrasi)	A—83 (Mansehra)	A—84 (Mansehra)	A—191 (Mansehra)	A—407 (Mansehra)	A—507 (Batrasi)
Albite	54.70	46.51	91.05	65.37	41.24	57.91
Chessboard albite	27.62	33.30	0.80	20.71	46.35	26.62
Quartz	6.95	13.08	3.05	9.22	3.75	7.78
Muscovite	0.93	2.69	0.45	0.08	1.67	1.81
Sericite	3.51	2.62	1.95	2.52	5.47	1.01
Biotite	0.00	0.53	0.00	0.13	0.46	0.12
Apatite	1.59	0.81	0.35	0.85	0.40	1.72
Epidote	0.00	0.00	0.00	0.17	0.00	0.00
Sphene	2.25	0.45	1.45	0.94	0.66	2.10
Rutile	0.00	0.00	0.00	0.00	0.00	0.68
Schorl	0.00	0.00	0.75	0.00	0.00	0.00
Indicolite	0.00	0.00	0.15	0.00	0.00	0.00
Ore	0.00	0.00	0.00	0.00	0.00	0.25
Chlorite	2.45	0.00	0.00	0.00	0.00	0.00

MODAL ANALYSES TABLE 2

Medium Grained Albitite

	A—2 (Batrasi)	A—60 (Seri, South)	A—61 (Jaba, South)	A—67 (Jaba)	A—68 (Jaba)	A—184 (Jalgali)	A—490 (Ahl)	A—73 (Batrasi)
Albite	92.90	56.42	82.47	89.11	53.91	77.62	91.75	83.94
Chessboard albite	1.02	41.54	8.56	4.89	42.09	0.00	0.00	0.34
Quartz	1.68	0.00	0.45	0.66	0.91	6.48	5.85	1.61
Muscovite	0.54	0.00	1.89	1.15	0.33	1.35	1.02	0.00
Sericite	2.52	1.36	2.89	3.19	1.48	12.90	0.31	0.98
Biotite	0.00	0.00	0.00	0.00	0.12	0.00	0.35	0.00
Apatite	0.84	0.00	3.09	0.44	0.58	1.11	0.42	1.61
Sphene	0.48	0.00	0.00	0.00	0.58	0.53	0.32	1.32
Rutile	0.00	0.68	0.00	0.00	0.00	0.00	0.00	0.00
Ore	0.00	0.00	0.65	0.55	0.00	0.00	0.00	0.00
Chlorite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.29
Epidote	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.91

Sphene occurs as dusty, 1.5 mm and rarely upto 3.5 mm, skeletal grains. The grains are dark to light brown in colour. Sometimes rutile is closely associated with it in the form of fine needles, 0.2mm, and aggregates upto 0.8 mm. It is brown to dark brown in colour with distinct cleavage traces.

Apatite occurs as very fine (0.05 to 1mm) grains. Zircon ranges from 0.03 to 0.05 mm in size.

Chlorite is in the form of radiating flakes in cavities about 0.2 to 0.25 mm in size.

Schorlite is 0.1 to 0.5 mm in size, light brown to brown pleochroic and replacing quartz and feldspar. The indicolite is 0.2 mm in size, blue coloured. and pleochroic in the same shades.

Medium grained albitites : The medium-grained albitites are dominantly saccharoidal medium-grained with a fine-grained ground mass. They are fairly homogeneous bodies right from their contact to the centre. The medium-grained albitites also occur associated with pegmatitic albitites as composite bodies. The medium-grained albitites have not been found associated with the fine-grained variety except in one case near Batrasi R.H. where layered to fine, medium-grained albitite and layered aplite occur together as composite body near the contact of granite and metamorphics. The medium-grained albitites are generally snow white to white with a few randomly distributed fine dark spots in some of them. They are foliated and sometimes sheared. In some albititic bodies later hydrothermal quartz veins (Ashraf et al., 1974) and pods are occasionally present.

The rocks are medium-grained (Fig. 3), usually in the range of 1 to 2.5 mm with occasional grains from 3 to 3.5 mm and about 0.5 to 0.8mm in size. In almost all the thin sections studied the grains are usually euhedral to subhedral, but chessboard albite mostly shows anhedral form and is rarely subhedral. Normal albite is seen changing from chessboard on the margins of the grains. Some

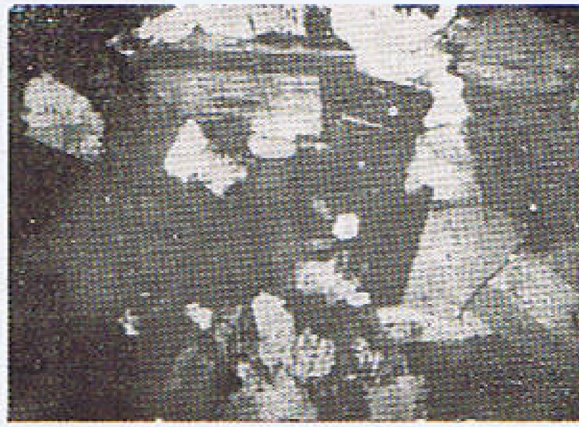

Fig. 3 Photomicrograph of Medium Grained Albitite (X 21, x.p.)

carlsbad or albite twinned tablets of albite are usually poikilitically enclosed in the chessboard albite. The orientation of these tablets may be inclined to the twin planes of the chessboard pattern.

The composition of normal albite is in the range of An_4 to An_9. From Table-2 it is clear that modal composition of normal albite is between 54 to 93%, but in most cases is between 80 to 90% normal albite. Twinning is very common on the albite law but pericline, carlsbad or sometimes manebach types are not uncommon. This albite in most of the bodies is altering on a minor scale to sericite and kaolinite, but relatively fresh grains are also present. Chessboard albite developed dominantly in A-60 and A-68 in the range of 41 to 42%. In some others it is either absent or is present in minor amounts. Its amount also varies from place to place in the same body. In some medium-grained albitites the smaller grains (0.3 to 0.8 mm) are twinned on chessboard law while comparatively medium grains (1 to 2 mm) are twinned on albite law and vice versa. But this is not a rule. The chessboard albite lamellae (Barth, 1970) twin according to roc tourne laws, characterized by arrays of narrow discontinuous albite lamellae. The twin boundaries are usually stepped and terminate abruptly. This albite encloses more apatite poikilitically than normal albite. Sometimes tiny needles of muscovite are present in the chessboard albite as inclusions or recrystallized mass from sericite.

The ubiquitous accessory minerals are quartz, muscovite, sericite, chlorite, apatite, rutile and ore These minerals are usually finer-grained than the albite.

Fine-grained albitites : These are fine to very fine-grained rocks and are fairly homogeneous in the middle and heterogeneous near the contact with host rocks. The colour of the fine-grained albitites is generally white to greyish-white with occasionally greenish tinge in the contact zone. They are compact and the grains are highly welded together. However, in some cases the rock is brittle and with little pressing becomes powdery and gives a gritty feel. Near the contact due to shearing and realignment, the darker grains of the rocks give a layered appearance.

Its grain size is very fine to fine-grained (0.02 to 0.15 mm, Figs. 4, 5, 6) with some 20%

Fig. 5 Photomicrograph of Fine-Grained Albitite Occurring in the Metamorphics at a Distance of about 800 Metres from the Contact of Granite and Metamorphic Rocks. (X 60, x.p.)

Fig. 4 Photomicrograph of Fine-Grained Albitite Occurring in the Metamorphics at a Distance of about 30 Metres from the Contact of Granite and Metamorphic Rocks. (X 60, x.p,).

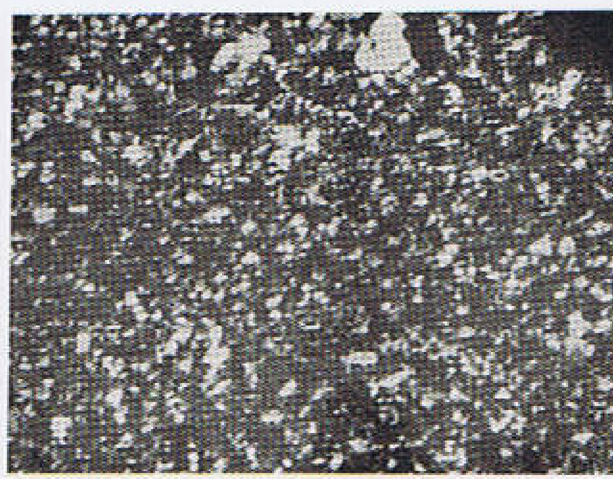

Fig. 6. Photomicrograph of Fine-Granied Albitite Occurring about two Kilometres away in the Metamorphics from the Contact of Granite and Metamorphic Rocks. (X 60, x.p.).

MODAL ANALYSES TABLE 3

Fine-Grained Albitite

	A—3 (Maira J. Ali)	A—13 (Giddarpur)	A—18 (Lassan)	A—66 (Jaba)	A—72 (Batrasi)
Albite	93.92	93.10	79.96	92.76	67.22
Chessboard albite	0.00	0.00	0.00	0.00	25.36
Quartz	2.69	1.64	0.00	2.01	1.60
Muscovite	0.28	0.00	1.02	0.26	0.00
Sericite	0.00	0.00	7.14	0.00	0.97
Biotite	0.00	0.00	0.00	1.19	0.00
Apatite	0.35	0.49	0.36	0.12	0.39
Epidote	0.00	0.82	0.24	0.00	0.19
Sphene	1.34	3.94	3.59	2.88	0.00
Chlorite	0.00	0.00	7.68	0.78	3.67
Zircon	1.41	0.00	0.00	0.00	0.00

grains in the range of 0.2 to 0.3 mm and occasionally upto 5% are in the range of 0.5 to 0.6 mm (The common accessories). The grains are usually equant anhedral to subhedral and rarely euhederal. Chlorite in some albitites is present as flaky and radiating aggregates. Other accessories are randomly distributed. Some of the bodies do show internal foliation.

As shown in modal composition (Table-3) most of the bodies are rich in albite i.e. 67 to 94% having a composition An_5 to An_7. Quartz is 1 to 2.69% in most rock studied. In one rock sample it is 80%. Chessboard albite is observed in one rock (A-72) which is slightly coarser than other rocks of this type. Amongst the flaky minerals chlorite is present in almost all of them and is more abundant than muscovite, biotite and sericite. The other common accessory minerals are apatite, sphene and epidote ; a small amount of zircon is present in one section.

GEOCHEMISTRY

Twenty albitite samples were analysed for their major elements, the alkalies being determined flame photometrically. However, only eight samples covering full range and variations are presented in Table-4. The comparative chemical characters of albitite bodies have been discussed and correlated with one another as under :

(*i*) SiO_2 : average SiO_2 is 66.81, 66.07, and 66.54% in the three types of albitites) (pegmatitic, medium-grained, and fine-grained, respectively). It is less than the average SiO_2, calculated from Joplin (1957) 67.68%, and Tanner and Tobisch (1972-68.22%.

(*ii*) Al_2O_3 is 18.73% in pegmatitic-albitite, 21.19% in medium-grained albitites and 19.93% in fine-grained albitites. The average Al_2O_3 in these rocks is comparable to albitites of Queensland (Joplin, 1957; average 20%) and Scotland (Tanner and Tobisch, 1972 ; average 19.30%).

(*iii*) Na_2O: the average Na_2O in the three types of albitites is fairly uniform i.e. 9.65, 10.15 and 9.72% respectively.

(*iv*) K_2O : the average K_2O contents of albitites in the pegmatitic, medium and fine varieties are 0.31, 0.20 and 0.50% respectively.

(*v*) Fe_2O_3+FeO are 0.40, 0.26 and 1.29% respectively in albitites of respective types.

(*vi*) TiO_2 contents are 0.79, 0.30 and 0.32% respectively in the three types of albitites.

(*vii*) MgO, CaO, P_2O_5 and MnO do not show distinct distribution in the various types.

Geochemical Correlation : Correlation co-efficient (r) and student (t) of the 20 albitites were calculated by a Fortran IV programme which was run on an IBM 360 modal 44 computer.

Table-5 and Fig. 7 show correlation co-efficient data and plots of some oxides in albitites. In the various albitites it is found that SiO_2 shows significant negative correlation with Al_2O_3. K_2O shows significant negative correlation with Al_2O_3 and Na_2O. Correlation co-efficient between Na_2O and CaO is negative and significant. MgO has positive correlation with FeO, which is due to their co-existance in chlorites of the albitites.

Trace elements : Trace elements were determined spectrographically for three samples, taking each one as representative of the three types (Table-6). The following elements were looked for Cr, Sc, Co, Zr, Ni, Y, V, Ga, Sn, Pb, Ba, Sr, Rb, Li, Cs, Cu, and Mo, but as shown in Table-6 only Cr, Zr, Y, Ga, Ba, Sr, Li and Cu were found in significant amounts.

Cr occurs in albitites from 14 to 450 ppm. The relatively high Cr value (450ppm) in the fine-grained albitite probably represents some contamination with metamorphic rocks. In A-356 sample

CHEMICAL ANALYSES TABLE 4
THE ALBITITES

	Pegmatitic albitites			Medium-grained albitites		Fine-grained albitites		
	A—64	A—84	A—52	A—60	A—184	A—3	A—13	A—73
	(Batrasi)	(Manschra)	(Seri)	(Seri, South)	(Jalgali)	(Maira J. Ali)	(Giddar-pur)	(Batrasi)
SiO_2	66.49	67.20	67.22	66.87	65.05	66.62	65.97	66.32
TiO_2	1.45	1.01	0.48	0.53	0.26	0.27	0.41	0.07
Al_2O_3	19.33	19.68	20.38	21.58	20.58	21.53	21.30	20.16
Fe_2O_3	0.19	0.15	0.04	0.05	0.08	0.64	0.82	0.71
FeO	0.18	0.13	0.21	0.14	0.05	0.07	0.07	0.75
MnO	0.07	0.01	0.00	0.00	0.00	0.00	0.00	0.00
MgO	0.30	0.36	0.10	0.00	0.35	0.05	0.20	0.51
CaO	1.54	0.98	0.85	0.20	3.92	0.49	0.81	0.28
Na_2O	8.62	9.20	10.15	9.62	9.10	10.12	10.28	10.00
K_2O	0.70	0.63	0.20	0.23	0.19	0.20	0.17	0.32
P_2O_5	0.90	0.12	0.09	0.02	0.14	0.09	0.05	0.03
H_2O+	0.38	0.29	0.17	0.10	0.08	0.03	0.09	0.94
H_2O-	0.00	0.02	0.06	0.00	0.05	0.05	0.05	0.09
Total:	100.15	99.78	99.95	99.34	99.85	100.76	100.32	100.18

TABLE 5

Linear Correlation Coefficient Between Major Components of the Albitites

	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	P_2O_5
SiO_2	..	0.10	—0.78	0.22	0.14	—0.00	—0.37	—0.05	—0.37	—0.20
TiO_2	0.45	..	—0.32	—0.31	—0.15	0.20	—0.06	—0.02	0.23	0.52
Al_2O_3	—5.30*	—1.43	..	—0.32	—0.43	—0.44	0.21	0.25	—0.48	0.03
Fe_2O_3	0.952	—1.37	—1.448	..	0.35	0.19	—0.03	—0.03	—0.19	—0.19
FeO	0.61	—0.65	—2.01	1.60	..	0.52	—0.28	—0.11	0.29	—0.19
MgO	0.01	0.86	—2.07	0.83	2.60*	..	0.06	—0.36	0.07	—0.13
CaO	—1.69	—0.24	0.91	—0.14	—1.24	—0.25	..	—0.69	0.25	0.14
Na_2O	—0.20	—0.87	1.08	—1.33	—0.49	—0.65	—3.99*	..	—0.58	—0.09
K_2O	1.70	1.03	—2.31*	0.83	1.29	0.28	1.09	—2.77*	..	0.30
P_2O_5	—0.86	2.57	0.14	—0.83	—0.81	—0.54	0.61	—0.37	1.33	..

For-n=20 (r) is significant if corresponding value of student (t) is greater than 2.101 at 5%. Significant (t) is marked (*).

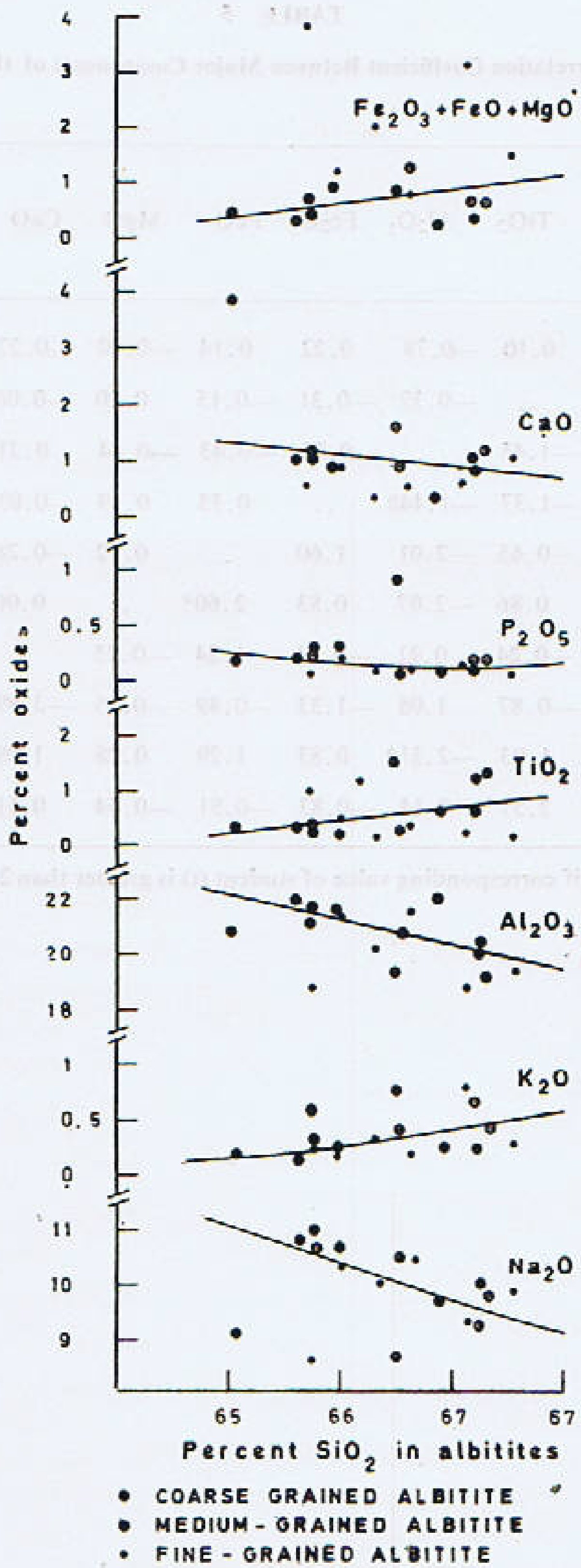

Fig. 7 Linear Correlation Diagram Between SiO_2 and Principal oxides.

possibly side preference energy (Duncan and Taylor, 1968) of trivalent element Cr) exceeds that of Fe^{+3}. in some mineral grains present in this rock.

Zr in the fine-grained albitite sample is 140 ppm. 5 ppm in medium-grained and 300ppm in pegmatitic varieties. This variation may be dependent on the occurrence of zircon in these rocks, as Mason and Graham (1970) have found that Zr does not readily substitute for any of the major cations. Kempe and Deer (1970) have noted unusually large amounts of Zr in the feldspars and also found it substituting for Ti. But in the present case petrographic studies show that the distribution of Zr in the fine-grained albitite is due to zircon but in the pegmatitic albitite where zircon is not present is possibly due to substitution of Ti in the feldspar.

Y is present only in fine-grained albitite where it is 22 ppm.

Ga is almost uniformaly distributed in most of the rocks from 10 to 14 ppm. MacDonald and Edge (1970) suggest that Ga is usually associated with the albitizing fluids.

Ba enters Na and Ca minerals in small amounts; the bulk of the element is being captured by K. In the present case 10 to 70 ppm Ba has been found in the albitites. This favours the hypothesis put forward by Goldschmidt (1964).

Sr is often regarded as a close associate of Ca. It occurs in albitites from 30 to 80 ppm which contain Ca bearing minerals like epidote, apatite and sphene. Kempe and Deer (1970) also advocated Sr substituting for Ca.

Li, the albitites contain insignificant amount of Li as only 1 ppm is found in pegmatitic albitite.

Cu is more or less uniformly distributed in albitites i.e. from 4 to 10 ppm. According to MacDonald and Edge (1970) the geochemistry of Cu is complicated ; it entres Ca-bearing minerals such as apatite and plgioclase, and can substitute forFe^{+2} (Taylor, 1965).

TABLE 6

Trace Elements in the Three Types of Albitite (In PPM)

	Pegmatitic albitite.	Medium-grained albitite	Fine-grained albitite.
Cr	14	0	450
Zr	300	5	140
Y	0	0	22
Ga	10	10	14
Ba	10	70	0
Sr	80	30	35
Li	1	0	0
Cu	4	4	10

PETROGENESIS

The albitite bodies evolved from the granitic rocks of the area after the migmatization process had more or less been completed. The origin of the granitic rocks of the Mansehra-Amb State area is discussed by Shams (1967). According to him the granitic complex seems to have formed by a process of magmatic granitization of the pre-existing metasediments through the agency of hot permeating fluids of ultimate magmatic parentage.

The albitites are rare bodies in the world and they have been recorded mostly from the basic and ultrabasic rocks, and rarely from the acidic rocks. Following are some examples of their occurrence. Larsen (1928) has postulated hydrothermal origin for corundum and albitite bodies. Walker (1932) noted an albitite body from Shetland Isles. Anderson (1937) found albitite bodies in northern Inyo Range which were formed by replacement of the metasediments. Joplin (1957) reported serveral albitites associated with K-granite and has commented that K-granite magma assimilated NaCl of the sediments to give rise to soda rich differentiate of small volume. Goldin (1965) gave an example of magnetite-sphalerite albitite of metasomatic origin from quartzite. Boguslavskiy et al. (1965) found some albitites of metasomatic origin in Russia. Gladyshevakaya et al. (1966) reported an albitite from drill hole in Russia and classed it as a syenite. Leonardos and Fyfe (1966) reported albitites developed by contact metasomatism during serpentinization. Albitites are thought to have been derived from volcanic rocks and sediments. Bodart (1968) and Shimron (1975) put up the idea that gabbroic magma rich in volatiles, which with crystal fractionation, gave rise to peridotite and with liquid immiscibility formed soda silica phase-(albitite).

In the present studies albitites have been recorded from the granites and the associated metasedimentary rocks. It has been established (unpublished work) that the albitites have a strong genetic relationship with the granitic complex of the area. This is in line with the results of experimental work by Luth et al. (1964). These authors studied the phase equilibrium relations in the granite system ($NaAlSi_3O_8$—$KAlSi_3O_8$—SiO_2—H_2O) at 4 to 10 Kbs and state that position of the isobaric quaternary minimum on the quartz-feldspar field boundary in the granite system shifts progressively with the increasing PH_2O downward in terms of temperature and towards $NaAlSi_3O_8$ and H_2O.

The water vapour-pressure must have increased in the granitic system gradually with the formation of major granitic gneiss and the Mansehra granite of the area at PH_2O 500 bars or less (Shams and Rehman, 1966). As the vapour pressure increases further in the granite systems the sodium-rich members are typically generated (Hall, 1972a ; 1972 b ; 1973). These comparatively sodium-rich members in the Mansehra and Batgram area are tourmaline granites (Hakle), the granite prophyry, and Chail Sar micro-granite (Shams, 1967, and Ashraf unpublished work). The formation of these latter granites and the prophyry fall in the region of PH_2O 5Kbs. From these observations it could be concluded that with the upcoming of younger rocks the general trend of the acidic rock-forming fluids shifted towards the sodium-rich members of the granitic system. But this trend in the granitic complex must have initiated in a tightly closed system before the upwelling and expansion of the granitic complex where the complex must have had gradually attained a maximum PH_2O more than 10 Kbs with gradual cooling, where the vapour pressure may exceed the critical pressure corresponding to the composition of system at this stage of cooling (Turner and Verhoogen, 1960). Keevil (1962) also found that as the temperature fell the vapour pressure rose. In the water-albite system, with the cooling of the system the water content increases (Goranson, 1938 ; Burnham and Jahns, 1962) gradually approximating 16.8%. This is the maximum amount of water that can be held in the melt (upto 10 Kbs for an albite melt). This amount could also be increased with further rise in vapour pressure which is helpful in bringing about crystallization (Tuttle and Bowen, 1956). The second boiling point phenomenon as reported by Turner and Verhoogen (1960) results essentially with the beginning of crystallization of the non-volatile (albite-rich, in this case) component which cause the solution to become gradually enriched with respect to the other component ; whose vapour pressure therefore, increases. But as the temperature is lowered further, the effect of falling temperature on vapour pressure becomes noticeable: and vapour pressure having risen to a maximum begins to decrease. The temperature at which the maximum vapour pressure occurs will depend on the chemical nature of the system i.e. the effect of increasing concentration of which might predominate so that the vapour pressure would rise continuously until the whole amount of non-volatile component has crystallized and will decrease thereafter.

As reported by Luth et al. (1964) Shams and Rehman (1966) and Hall (1972a, 1972b, 1973), the increase in water vapour pressure in the granitic system shifts the quarternary minimum towards the albite corner (Fig. 8). Thus the release in external pressure at places within the interior lateral zone will give rise to sodium rich liquids by the removal of silica due to excessive water present at highest possible PH_2O, being deposited in the fissures. These fissures provide the local release in pressure by the opening of tension fissures parallel to the foliation of the granites and the metasediments during the welling up and the expansion of the granite in the diapiric and mushroom-like structure. But as the temperature falls further the effect on vapour pressure becomes noticeable and the vapour pressure having risen to a maximum begins to decrease. The decrease in temperature and vapour pressure is very gradual within the limits of enormous size of the granitic batholith. This decrease in the vapour pressure therefore will reverse the behavour in the system and SiO_2 which was soluble at highest PH_2O and K_2O will be released along with the volatiles, and will depend on the release in PH_2O giving rise albite aplites/pegmatites, albite-(microcline) aplites/pegmatites, albite-microcline-aplites/pegmatites and the complex pegmatites. In the present case the vapour pressure decreases in the structurally higher levels. In the metasediments the fissures were developed contemporaneously with those in the granites and follow the same trend. So if these fissures were filled with the albititic liquids the crystallization would start in a close chamber and would give rise to the albitite bodies, at high PH_2O conditions. As the bodies are coarse, medium and fine-grained from place to place and as members of composite bodies the physico-chemical conditions must have been the controlling factors. The coarse or pegmatitic albitites were formed in an environment of close system with the surroundings. This is why the grain size of this albitite type is generally 3 to 30 mm. The albitites which were subjected to a greater temperature gradient than the coarser variety crystallized in the range of 1 to 3 mm grains—a medium-grained variety. In the case of albitites which are present in the metasediments the quenching is much more than those present in the granitic rocks as the relative temperature of the granites was greater than that of the metasediments because the acid minor bodies came into being just after the development of the granitic rocks. It is observed in the field that as one moves away from the contact towards the metasediments the grain size of the albitite bodies decreases so much that the distinction of the albite grains from quartz becomes difficult since twinning is absent or very vague and the grains are quite anhedral as compared to subhedral to euhedral grains in the bodies near the contact of the granite and the metasediments. The identity of this fine-grained albitite was proved by chemical analyses and X-ray diffraction methods.

The above hypothesis is supported by laboratory (Fig. 4, 5, 6) and field observations : (i) an albitite body about 30 metres from the granite contact

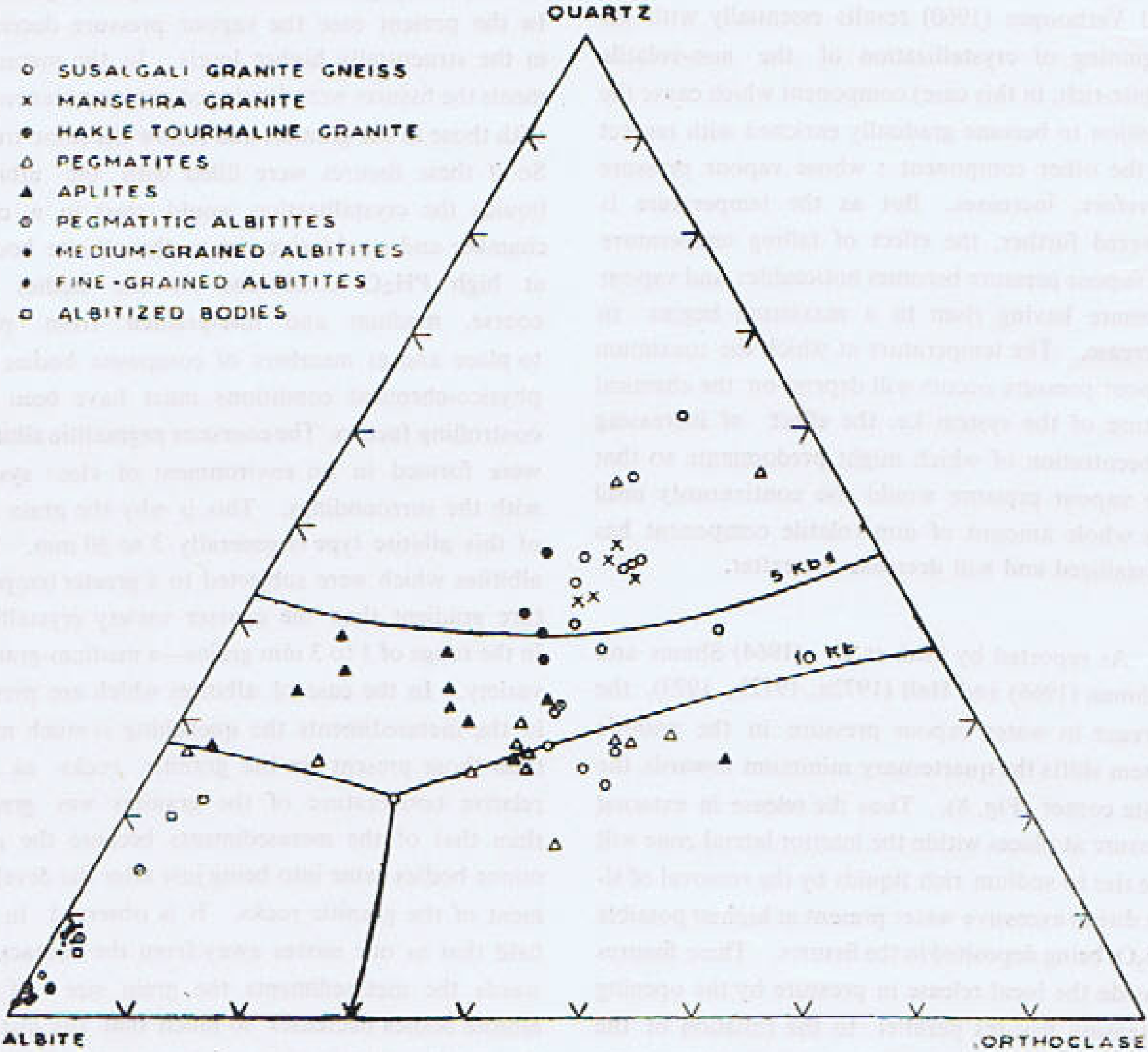

Fig. 8 Normative Albite, Orthoclase and Quartz Diagram of the Analysed Acid Minor Bodies (and Granites after Shams, 1967) Recalculated 100% (Luth et al., 1964).

in the metasediments near Batrasi rest house on road cut has grain size 0.13 to 0.30 mm in general, (*ii*) a body near Maira J. Ali about 800 metres away from the contact has grains 0.1 to 0.15 mm with nearly 1% grains 0.2 to 0.3 mm, and (*iii*) in this case the albitite body is about 2 kilometres away from the contact in the metasediments near Giddarpur and has grain size 0.02 to 0.04 mm.

The contact relations of the albitites with the granites are sharp which show that the nature of the bodies is intrusive and there is no exchange of material across the contact. Even with the composite pegmatitic albitite, medium-grained albitite the contact is comparatively sharp which shows a sudden change in the local environmental conditions. The contact of fine-grained albitite with metasediments is sharp to somewhat diffused. This diffusion phenomena is due to Na-metasomatism, simultaneous with the emplacement of albite or occured just after the crystallization of the albitite.

The role of volatiles is very slight in the development of albitite. Tourmaline was observed in one case only. Moreover, the introduction of muscovite is very minor but hydrothermally formed sericite is in a few cases upto 7% in the albitites.

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EVALUATION OF GLASS SAND DEPOSITS OF PEZU, BANNU DISTRICT, N.W.F.P.

BY

MOHAMMAD RAFIQUE, MOHAMMAD ASHRAF,* AHMAD DIN

AND

F.A. FARUQI

Glass & Ceramic Division, PCSIR Laboratories, Lahore

Abstract : *Eight different silica sand samples (of Jurassic age) collected from Pezu region were investigated for their grain size distribution, chemical analysis, removal of* Fe_2O_3 *contents and melting behaviour. It has been found that sand Nos. 9S and 10S from Chunda after water washing and grading are among the best sands of the country. Sand Nos. 1S (Nar Kasha Tangi), 5S and 6S Terkhobai Ster are the medium quality sands. Most of the iron oxide present in the sands in the form of heavy minerals is of para-magnetic nature and magnet treatment is unnecessary. Sand Nos. 9S and 10S exhibit a good melting behaviour.*

INTRODUCTION

The quality of glass depends largely upon the quality of raw materials used. Since sand constitutes 70-75% by weight of the glass formulations, its purity plays a major role in the development of fine sheet and container glasses. The usual colour imparting impurity in glass is the iron oxide which, if present above 0.07%, renders the sand unsuitable even for flint containers. Because of the infra red rays absorbing tendency of the ferrous ions in sheet glass, a considerable amount of Fe_2O_3 can be tolerated as compared with flint glass products. Due to the pressing demand from Sarhad Development Authority for good quality raw materials an extensive survey of the Pezu area has been carreid out. This investigation is a part of the programme (Faruqi, 1967) of these laboratories to survey, evaluate and beneficiate the good quality raw materials available in the country for their utilization in glass industry.

GEOLOGY OF THE GLASS SANDS

A new huge glass sand deposit of Jurassic age (Datta Formation) has been discovered near Pezu. Previously known Pezu sand in fact is being mined from western extremity of Marwat and Surghar Ranges (of the D.I. Khan district) at a distance of 10 to 35 Km (Chunda and Paniala) from Pezu. This sand is very fine-grained and is not suitable for glass manufacture. The fine to medium-grained sand occurs in these localities in the form of 30 to 150 cm thick sheets or layers. They are in turn interlayered with ferruginous sandstones and shales which would contaminate the white sand if not mined properly and can therefore render it unsuitable for making good quality glass-ware.

In the present reconnaissance studies around Pezu (in Bannu district) a new deposit of white sand has been discovered. This deposit is in the vicinity of Pezu at a distance of 1.5 to 10 Km. The general trend of the sand deposits is in an east—west trending zone. The thickness of the good quality glass sand is 6 to 7.5 metres. The top most zone of the Datta Formation, which extends for more than one mile from coordinates 826300 towards east along the Nar Kasha Tangi in the topographic sheet 38 L/15 of the Survey of Pakistan, have a mineable depth of 30 metres or more. The sand is snow white and light grey coloured. The middle portion of the sand deposit

*Present address : Engineers Combine Ltd., 19-C III Gulberg 3, Lahore.

is about 3 metres thick. It is also of good quality with intercalations of thin yellowish and pinkish grey sandstone and shales. The basal part of the sand deposit is 15 metres in thickness which consists of grey to white sands and patches of yellowish and reddish colour. The basal zone needs quarrying on the gentler surface to explore the quality of sand. The north-south exposures of the same zone are extremely muddled up and are not suitable for more than one Km because the deposits are of a highly disturbed nature due to the extensive faulting and folding in the said area. The deposits are also unsuitable due to mixing with scree, debris and alluvium. In the Tarkhobai Ster area at coordinates 835785 (38 L15), the deposits are again of a good quality and in the form of white friable and brittle sand. The total thickness of deposit, is about 30 metres with intercalations of ferruginous sands and shales. The thickness of the individual layers varies from 3 to 6 metres which can be economically exploited for about one Km with a mineable depth of more than 15 metres and for an altitude of more than 30 metres.

In the same area good quality limestone of Eocene age and dolomite of Triassic age are also available to be used alongwith sand for the manufacutre of good quality glasswares, and for optical glasses as well. Fairly large amount of water for washing the sand and for the proposed glass factory is also available in the Tarkhobai Ster. Moreover, water may also be drilled near Ahmad Khan at a distance of 4 Km (South of Pezu) where due to general trend of pervious and impervious rock layers water might be hit at a depth of ground 75 to 90 meters.

EXPERIMENTAL

1. Minerology : The thin section studies revealed that the white sands of Pezu occurring at coordinates 826300 and to the east are quite pure and in majority of samples quartz grains are about 96% in the rock. The minor amount of deleterious or heavy minerals are in the form of magnetite, haematite, limonite, ilmenite, rutile, zircon and tourmaline. The heavy minerals (Table 1) were separated by gravity methods (Rashid et al. 1964).

2. Grading of the Sand : The sands were passed through 18 mesh B.S.I. sieves and the amount passing through 120 mesh was weighed. The amounts passing 18 mesh and retained on 120 mesh B.S.I. sieves and the washing losses were also determined. The results are given in Table 2.

3. Chemical Analysis of the Sands : 100 gms of the sand was ground to a fine powder and analysed using standard methods of chemical analysis (British Standards, 1958). The constituents determined were SiO_2, Fe_2O_3, Al_2O_3, CaO, MgO, etc. The results are presented in Table 3.

4. Beneficiation of the Sands :

(*i*) *Water Washing* : 700 gms of the sand was stirred with 1 litre water in 2 litre beaker and allowed to settle for 30-40 seconds. The dirty water was decanted off : washing of the sand was continued with 1 litre water every time until there was no change in colour of the freshly added water on the subsequent stirring. The washed sand was dried at 110°C and then analysed as above. The results are also given in Table 3.

(*ii*) *Magnetic Treatment* : The dry sand samples were spread in layers and were treated with magnet. The sand samples after magnetic treatment were analysed using standard methods of chemical analysis. The results are given in Table 5.

5. Melting of the Sheet Glass : Based on 1000 gms of the Pezu sand typical sheet glass composition (American Ceramic Batches, 1970) was melted in a fireclay pot at 1450°C. The samples were taken from time to time until the batch was almost free from the seeds. The temperature was then lowered to 1260°C and maintained for further 3 hours to dissolve the occluded gases in the glass. The melt was then cooled to room temperature and was examined visually. A container glass composition was also melted the results of which are given in Table 4.

TABLE 1

Amount of the Heavy Minerals in the Sands

Sample Nos.	1S 3S 4S 5S 6S 8S 9S 10S 12S
Amount of the Heavy Minerals present.	0.11%, Traces, Traces, 0.09%, 0.36%, 0.7%, 0.24%, Trace, 0.41%.

TABLE 2

Useful Fraction of the Sands.

Sample Nos.	Amount retained on 18 mesh B.S.I.Sieve. (A)	Loss on water washing of -18 fraction (B)	Useful sand fraction 100-(A+B).
1S	20.5	15.0	64.5
3S	2.5	29.2	68.3
4S	0.1	34.0	65.9
5S	1.11	11.5	87.4
6S	0.6	8.0	91.4
8S	3.5	16.7	79.8
9S	14.3	3.0	82.7
10S	0.5	15.2	84.3
12S	4.2	10.7	85.1

TABLE 4

Improvement of the Iron Contents of Pezu Sands after Grading and Water Washing.

Sample Nos.	Fe_2O_3 in the raw sands.	Fe_2O_3 in the washed graded sands	Reduction of Fe_2O_3
1S	0.26	0.09	65.6
3S	0.59	0.16	71.6
4S	0.16	0.15	6.25
5S	0.09	0.09	0.0
8S	0.15	0.06	58.1
9S	0.08	0.06	25.8
10S	0.05	0.04	13.7
12S	0.31	0.25	20.5

TABLE 5

Percentage Reduction of Fe_2O_3 Content of the Sands after Magnet Treatment.

Sand Nos.	Fe_2O_3 in the washed graded sand.	Fe_2O_3 in the magnet treated sand	reduction of Fe_2O_3
1S	0.0899	0.880	2.1
3S	0.1678	0.1674	0.2
4S	0.1513	0.1407	7.0
5S	0.0898	0.0771	14.1
6S	0.1001	0.0972	2.9
9S	0.0601	0.0600	0.2
10S	0.0495	0.0440	0.1
12S	0.2536	0.2200	1.3

TABLE 3

Chemical Analysis of Raw and Washed Sands

Sample	I/L	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Total
1S—Raw	1.26	96.25	1.24	0.26	1.00	Traces	100.01
Washed Graded —18+120	0.67	98.43	0.90	0.09	Traces	Nil	100.09
3S—Raw	0.97	94.33	0.29	0.59	1.83	Traces	100.01
Water Washed—18+120	0.43	97.97	1.19	0.16	0.33	Traces	100.08
4S—Raw	0.87	96.61	1.46	0.16	1.01	Traces	100.10
Washed Graded—18+120	0.38	98.42	0.76	0.15	0.28	Nil	100.00
5S—Raw	1.08	95.80	2.02	0.09	1.00	Traces	99.99
Washed and Graded —18+120	0.80	96.96	1.54	0.09	0.59	Traces	99.98
8S--Raw	0.73	96.73	1.32	0.15	0.98	Traces	99.91
Washed Graded —18+120	0.33	98.85	0.62	0.06	0.15	Traces	100.01
9S—Raw	0.60	98.05	0.82	0.08	0.44	Traces	99.99
Washed Graded	0.37	98.85	0.54	0.06	0.22	Traces	100.04
10S Raw	0.29	98.98	0.26	0.05	0.29	Traces	99.87
Washed Graded 18+120	0.16	98.49	0.24	0.04	0.06	Traces	99.99
12S	2.20	94.76	2.56	0.31	0.20	Traces	100.03
Washed Graded—18+120	0.42	97.95	1.17	0.25	0.20	Traces	99.99

TABLE 6

Chemical Contents of the Glasses Melted

Bach In-gredients	Sand	Soda ash	Lime-stone	Dolo-mite	Salt Cake	Fled-spar	Arsa-nic	Flour-spar	Decolo-riser (10% Sc.)	Neither Decolo-riser (10% Sc.)	Type of glasses	Col ur
Amount (g)	1000	300	143	146	109	39	4½	—	—	—	Sheet glass	Colourless with slight bluish tinge.
	1000	340	275	—	10	140	1	2	2	10	Con-tainer-glass	Colourless

TABLE 7

Chemical Analysis of Black Particles

Si_2O	Fe_2O_3	Al_2O_3	CaO	MgO	I/L	Total
31.88%	47.76%	15.84%	1.17%	7.70%	2.58%	100.04

DISCUSSION

According to B.S.I., the useful fraction of a good glass making sand should exceed 94%. In case of Pezu sands, 6S is the only sand which contains upto 91.4% useful fraction while 1S, 3S, and 4S have below 70% and the rest of the samples i.e., 5S, 8S, 9S, 10S and 12S have useful sand contents of about 80%. It means that only those samples which contain useful fraction more than 80% can be considered for their use in glass industry. Therefore to make the sand deposits economically viable the material should be sieved (between 18 and 120 standard mesh) to remove useless fraction and clayey material. Moreover, water washing may also be carried out at the site of the deposit to further improve the quality of the sand.

All these sand samples from Pezu contain heavy black particles, a rich source of Fe_2O_3 ; the main colour imparting impurity in the finished glass. The chemical analysis of these heavy black particles show that percentage of Fe_2O_3 is 47.78. As on grading a large amount of these particles passes through 120 B.S. test sieve, the Fe_2O_3 content is reduced considerably. The chemical analysis of useful fraction is given in Table 3, which is discussed in the followings :

1. Except 12S, Fe_2O_3 is within such limits that the sands can be used not only for sheet glass and ordinary glasswares but even for colourless glass.

2. SiO_2 content, the main constituent of glass, is more than 95%. These sands can, therefore, compete with other good quality local sands.

3. Al_2O_3 in the washed and graded sands does not exceed 2.0% and hence does not interfere with the properties of the finished glass.

4. Sand samples 3S, 4S, and 12S contain Fe_2O_3 content more than 0.1%, therefore they are recommended for coloured glasses i.e., amber and green glasses because the colour due to Fe_2O_3 does not affect appreciably. Sand samples 8S, 9S, and 10S having Fe_2O_3 0.06, 0.06 and 0.04% respectively in the washed and graded form are the most suitable sands for the glass industry.

5. These sand samples are as good as sands found in Daudkhel and Hazara regions (Din et al., 1963) being used extensively in the industry.

The percentage of Fe_2O_3 cannot be reduced by a strong magnet when rotated through them as it is clear from Table 4. It shows that iron oxide present in the heavy black particles is of paramagnetic nature. Magnetic treatment is, therefore, not recommended for Pezu Sands.

Two standard glass melts were prepared taking composite samples of the 8S, 9S, and 10S. The results are given in Table 4. The melting tendency of these sands is normal. The sheet glass due to the presence of FeO and Fe_2O_3 and without oxidation have a slightly bluish green tinge. This colour is not complemented because iron oxide present in the ferrous form absorbs infra red rays. After oxidation the container glass was decolourized with a combination of cobalt oxide and selenium in the presence of an oxidising agent i.e., KNO_3 etc., and hence the resulting glass was found to be colourless.

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ORIGIN OF CHESSBOARD ALBITE PRESENT IN THE ACID MINOR BODIES OF MANSEHRA AND BATGRAM AREA HAZARA DIVISION PAKISTAN

By

MOHAMMAD ASHRAF*

Glass and Ceramic Division PCSIR Laboratories, Lahore

and

M. NAWAZ CHAUDHRY

Department of Geology, University of the Punjab, Lahore

Abstract : *Primary chessboard albite is widely developed in the albitites and albite-aplites/pagmatites. Replacement and stress or deformation is also postulated for the development of chessboard albite on a minor scale. Exsolution chessboard albite is found only in a few complex pegmatites in the outer intermediate zone. Exsolution is shown by microcline.*

INTRODUCTION

Chessboard albite is widely present in decreasing order in the pegmatitic albitites, medium-grained albitites and albite-aplites/pegmatites and in a few complex pegmatites. On a minor scale it occurs in the albite-(microcline)-aplites/pegmatites and albite-microcline-aplites/pegmatites of simple composition. The above mentioned bodies are sporadically present in the Hazara granitic complex and the associated metasedimentary rocks studied by Shams (1969). The chessboard albite bearing rocks in 99% cases are associated with the granitic rocks. Chessboard albite is rarely developed in the fine-grained albitites which are usually found in metasedimentary rocks very close to the contact of granite. Chessboard albite was reported earlier from the same area by Shams (1967) which according to him is of replacement origin. His interpretation was based on the studies of albite aplites only whereas in the present case conclusions are given after thorough studies of the acid minor bodies of the whole area.

The origin of these acid minor rocks has been discussed by Ashraf (1974a). The acidic rocks have been evolved from the granitic rocks of the area after the magmatic granitization process has more or less been completed (Shams, 1967). From this, some conclusions of fundamental importance were drawn :

(*i*) Magmatic to rest magmatic liquids were available for the development and crystallization of the acid minor bodies in a close system. Thereby crystallizing chessboard albite in the albitites, albite-aplites/pegmatites.

(*ii*) Their regional zonal distribution is related in time and space to the granitic and the associated rocks.

(*iii*) The albititic rocks were formed at highest possible water vapour pressure (Ashraf, 1964b) may be more than 10 Kbs (Luth et al. 1964) and with decrease in water vapour pressure enrichment in potassium started gradually and thus formed complex pegmatites at the later stage.

CHESSBOARD ALBITE

The chessboard albite is extensively developed in the pegmatitic, medium-grained albitites and the albite-aplites/pegmatites. It is a minor constituent of the K-feldspar bearing aplitic/pegmatitic rocks.

*Present address : Engineers Combine Ltd., 19-C III Gulberg, 3, Lahore.

Chessboard albite is twinned according to the roc tourne's laws (Barth, 1969) and is morphologically characterized by dense arrays of narrow discontinuous albite lamellae. The twin boundaries are usually stepped or lenticular and commonly terminate abruptly. The composite crystal is, therefore, distinguished by an unusually large area of incoherent twin boundary surface.

Following theories on the origin of chessboard albite have been proposed by previous workers with four possible mechanisms. These theories are discussed in the light of occurrences and presence of chessboard albite in the acid minor rocks of the Mansehra and Batgram area of Hazara Division.

(*i*) Primary origin is claimed by Tilley (1919), by irregular deposition of the plagioclase during the formation of the crystals, and Battey (1955) proposed origin by segregation and coalescing together of small albite lamellae in axial parallelism.

(*ii*) Replacement origin has been reported by De Lapperent (1909), Anderson (1937), Stutz (1940), Bearth (1948), Exner (1949), Niggli (1954), Ogniben (1956), Shams (1967), Nawaz (1967), Callegari and De Pieri (1970) and Fisher (1971).

(*iii*) Stress or deformation origin is supported by Emmons (1953), Gates (1943), Starkey (1959) and Shams (1967).

(*iv*) Exsolution origin is designated by Exner (1949).

Primary origin

Tilley (1919) has regarded chessboard albite as characteristic of late magmatic crystallization in the presence of abundant volatiles. Battey (1955) calls it a mosaic of grains in slightly different orientation, the effect being of a single crystal, formed by the welding together of independent laths and continuing to incorporate groundmass laths about its margins approaching axial parallelism by successive recrystallization.

Fig. 1 Primary Chessboard Albite in the Pegmatitic Albitic

It has been found by the writers that primary chessboard albite is widely distributed in the albites and albite-aplites/pegmatites (Fig. 1, Table 1). The chessboard pattern in these rocks is very uniform in most of the grains which are usually anhedral and look like filling the interstices of the normal albite grains. The chessboard albite did not develop in the fine-grained albitites due to their quick cooling. On the other hand pegmatitic and medium-grained-albitites cooled gradually from the rest liquids to form coarser grains and thereby the latter residual fluid might be still rich in Na-alumino silicate to deposit chessboard albite containing more poikilitic apatite than normal albite.

In some grains instead of chessboard pattern reverse phenomenon has been found, i.e., the chessboard lamellae have again coalesced under shearing effect to look like a normal albite. This effects is well pronounced on the boundaries of the grains whereas inner portion of the grains are still perfectly intact. Cartsens (1966) thinks that there is a definite tendency for chessboard albite to crystallize during post tectonic annealing conditions. Moreover, (Cartsens, 1966) the internal energy of albite twinned in a chessboard pattern is considerably higher than that of untwinned albite or abite having normally spaced and coherent twin lamellae.

Modal Analysis Table—1

	A—63	A—54	A—424	A—59	A—347	A—354	A—464A
Albite	78.66	54.70	43.91	59.31	40.25	32.16	15.33
Chessboard albite	12.86	27.62	20.58	0.37	0.88	0.22	18.21
Microcline	0.00	0.00	0.00	1.92	6.69	24.82	58.31
Quartz	2.72	6.95	25.59	23.12	32.96	25.89	2.11
Muscovite	2.65	4.44	9.38	11.33	16.04	7.52	4.92
Biotite	0.39	0.00	0.00	1.49	0.00	0.00	0.08
Apatite	1.16	1.59	0.27	0.92	0.12	0.22	0.82
Sphene	0.22	2.25	0.27	0.00	0.00	0.00	0.16
Chlorite	0.00	2.45	0.00	0.00	0.00	0.00	0.00
Rutile	1.33	0.00	0.00	0.00	0.00	0.00	0.00
Tourmaline	0.00	0.00	0.00	1.54	2.82	8.84	0.00
Magnetite	0.00	0.00	0.00	0.00	0.24	0.33	0.06

A—63 : Medium-grained albitite.

A—54 : Pegmatitic-albitite.

A—424 : Albite-aplite.

A—59 : Albite-(microcline) aplite.

A—347 : Albite-(microcline)-pegmatite.

A—354 : Albite-microcline-aplite.

A—464A: Intermediate zone of the complex pegmatite.

Strain energy is stored along the twin boundaries, especially along those which are incoherent. Startsev (1963) has shown that the twinning is accompanied by point defects, stacking faults, and perfect dislocation in addition to the twinning dislocations. Thus very large strain may be introduced in the mineral during the act of twinning. It is this excess energy which is believed to be deriving force for recrystallization in the chessboard albite.

The poikilitic normally twinned albite tablets in the chessboard grains are thought to be trapped grains.

Origin by replacement :

Evidence of the replacement origin of chessboard albite is on a minor scale in the albite-(microcline)-aplites/pegmatites and albite-microcline-aplites/pegmatites (Table-1). The soda aplites (albite-aplites) do not show any evidence of replacement as advocated by Shams (1967). In some thin sections (A-59, A-354) normal albite, microcline and chessboard albites occur together. The chessboard albite grains look like microcline but have more resemblance to chessboard albite (Fig. 2). The major replacement of K by Na in the formation of chessboard albite in the microcline-albite-aplites/pegmatites can be deferred due to increasing K-activities and restricted Na activities as found by Ashraf (1974a).

Nawaz (1967) has reported the phenomena of chessboard albite formation by mild and very localized sodium replacement at low temperature (lower than the temperature at which normal albite crystallized, for the latter occurs as inclusions in the chessboard albite) in the presence of volatiles in a moderate stress field. Nawaz does not favour replacement of microcline or orthoclase by sodic solutions.

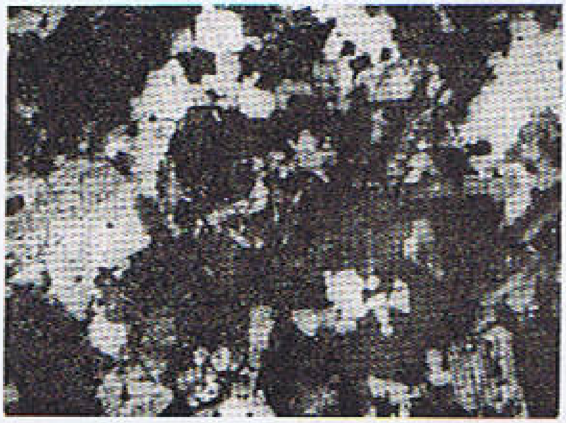

Fig. 2 Replacement Chessboard Albite Crystals (nearly 2×3 mm and 3×5 mm in size) in the Albite-(Microcline)- Aplite.

Fig. 3. Chessboard like Pattern Produced by Shearing on the Margin of Normal Twinned Albite.

Stress or deformation origin :

Chessboard pattern in albite of some sheared albitites and albite-aplites/pegmatites is present. Shearing has produced nearly chessboard like pattern on some normally twinned albite grains (Fig. 3) on a minor scale. According to Shams (1967), the earliest stage is represented by albite crystals that are traversed by narrowly spaced fractures which might have been developed along (001) cleavage planes to produce pieces of albite. These broken pieces seem to have rotated along axis parallel to the fracture planes under the action of stress with the result that alternating pieces had acquired different optical orientation to look like chessboard pattern.

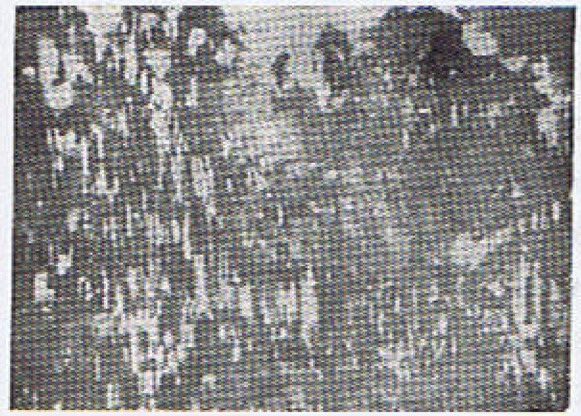

Fig. 4 Chessboard Albite Formed by Exsolution of Microcline and Albite. Microcline in the Middle and Extends to the Lower and Left Area.

Origin by exsolution :

Exner (1949) designated most probably for the first time exsolution phenomenon to chessboard albite from K-feldspar. This sort of chessboard albite is found in the late stage zoned pegmatites in the intermediate zone where unmixing of both K and Na-feldspars (chessboard abite) has occured (Fig. 4). The chessboard albite forms perthitic lamellae as patches and veinlets. The evidence in favour of exsolution is strong as cleavelandite is replacing microcline in the same body in the inner intermediate zone. This also indicates, an increase in activity of soda at late stage, the excess amount of which either exsolved like normal perthitic lamellae or replaced microcline in the intermediate zone.

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A PRELIMINARY STUDY OF LANDSLIDES AND BRIDGE FAILURES ALONG MUZAFFARABAD-NAUSERI-TITHWAL ROAD OF AZAD KASHMIR

BY

ABDUL SHAKOOR

Department of Geology University of the Punjab Lahore

Abstract : *A 35 miles long stretch of Nilum valley road, from Muzaffarabad to Jargi, has been investigated to study landslides, bridge failures, and other problems associated with this important but badly maintained road. A map showing geology on both sides of the road has been prepared and the areas which are most susceptible to slope failure are delineated along the road. Also the portions where retaining walls are needed have been marked. Suggestions for improving the present condition of the road are also made at the end of the paper.*

INTRODUCTION

Muzaffarabad-Nauseri-Tithwal road, also known as the Nilum Valley road, joins Muzaffarabad with Athmuqam which is a small town about 60 miles north of Muzaffarabad. This is the only road in Nilum Valley area on which public transport, including buses and trucks, ply upto Athmuqam. One or two other roads have also been constructed by the army from defence point of view but they are too steep, narrow, and zig-zag for ordinary use. Although Nilum valley road provides the only link between Muzaffarabad and the samll scattered villages of Nilum Valley its present condition is not good. It is narrow and its riding surface is very rough. It is frequently blocked by landslides especially during the rainy season. Bridge failures are reported to be quite common. No proper drainage has been provided to keep the road dry. An idea of the present condition of the road can be had from the fact that it takes about 3 hours and 3 gallons of petrol in a Jeep to reach Nauseri which is only 26 miles from Muzaffarabad.

In 1975 a study of the problems associated with Muzaffarabad-Tithwal road was undertaken. This study was cofined only to the first 35 miles (upto the village Jargi) of this road because the landslide problem is most intense in this portion. On the request from The Frontier Works Organization preliminary investigations of Nauseri bridge site were also undertaken. The field study was done jointly by the writer and the three M.Sc. students of Engineering Geology who were Messers Abdul Fattah Shami, Mohammad Tariq, and Ibrat Anwar.

PROBLEMS & DISCUSSIONS

Possibilities of Alternate Routes and the Problems Associated with the Existing Road.

While locating roads in the mountainous country the choice is generally made between three alternatives :

(*i*) Valley route which runs parallel to the stream and close to it.

(*ii*) Ridge top route which runs over the top of the ridge where the ridges are low with gentle slopes and with relatively flat tops and where they are more or less in continuity.

(*iii*) The third possibility is to place the road along some contour between the valley floor and the ridge top. It ascends or descends along the contour.

The Nilum Valley area is characterised by high relief, mountainous rugged topography, steep and unstable slopes, dense dendritic drainage especially in the upper reaches, and undulating discontinuous ridge tops. Under these circumstances the existing valley road is the best and perhaps the only possible route Fig. 1A. It is the shortest possible distance, does not pass through agricultural land or villages, and does not have steep gradients or many sharp turns. It crosses minimum number of streams and the cutting and filling involved in the construction of this road has also been minimum.

However, some very serious problems and draw backs are associated with this road. They are :

(*i*) For most of its length the road is very narrow and therefore dangerous.

(*ii*) The road surface is very rough and therefore the fuel consumption is more.

(*iii*) Proper drainage is not provided because of which the road becomes very slippery at some places.

(*iv*) Landslides and rock creep are very common because of which it remains in a bad condition for a greater part of the year.

(*iv*) It is not carpeted.

(*v*) Retaining walls have not been built even where they are an absolute necessity.

(*vi*) Bridge failures are common.

Out of these the problems of landsliding, bridge failures, and poor drainage facilities are the most serious and require immediate attention. They are briefly discussed below.

Landslides along Muzaffarabad-Nauseri-Tithwal Road.

The most perplexing and the most serious problem associated with the Nilum valley road is that of landslides. Landslides frequently block the road and sometimes the road remains blocked for a few days. The accompanying map shows the geology along the road, the portions which are more vulnerable to landsliding, and the places where retaining walls are required. Except the hard granite gneiss alomst all other rocks are prone to landsliding but the one most susceptible is the Murree Formation. Limestone is next in order and then come the slates and schists. Out of the total length of 35 miles from Muzaffarabad to the village Jargi, the road passes through Murees for about 22 miles.

Types of Landslides and Slope Failures :

The following types of slope failures have been observed.

1. *Creep* : The creep of debris, talus, and loose unconsolidated soil cover is quite common on the slopes facing the road. It is more prominently observed in slates, brecciated Muzaffarabad Limestone, and Tithwal schists. Photo 1 shows creep of unconsolidated weathered soil cover on slopes of Tithwal schists north of Nauseri.

2. *Sheet Sliding* : This type of slope failure is most common in Murrees. The failure is generally rotational or translational. Rotational slides, which have a curved surface of failure, are characteristic of homogeneous cohesive clays while the translational slides, where one stratum slips over another have a plain slip surface and take place in stratified rocks.

In Murrees, where clays are highly abundant, sliding is of rotational type but the shear surface is not always curved. It is generally irregular.

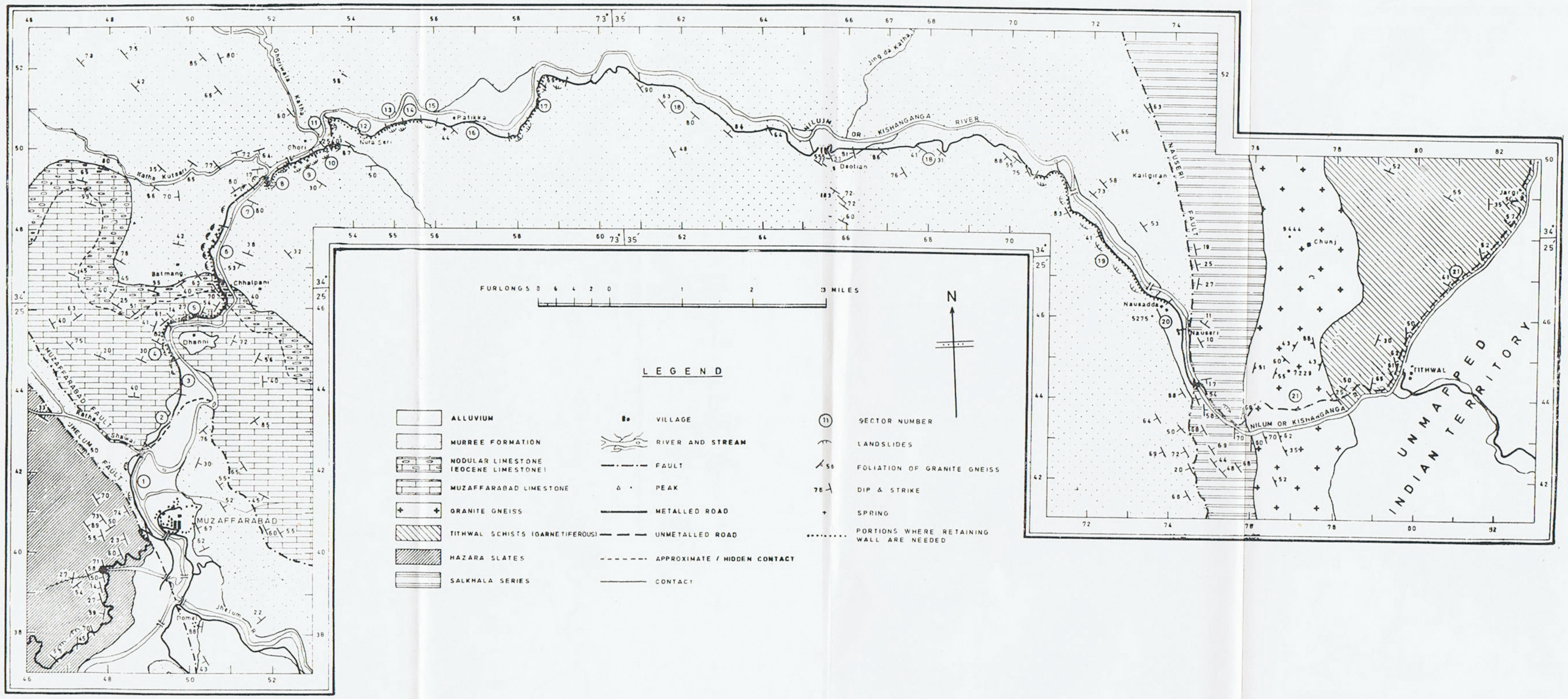

Fig. 1A. Geological Map of Muzaffarabad—Nauseri Area, Azad Kashmir.

Fig. 1. Unstable slope in Tithwal schists on Naoseri-Tithwal road showing creep of scree.

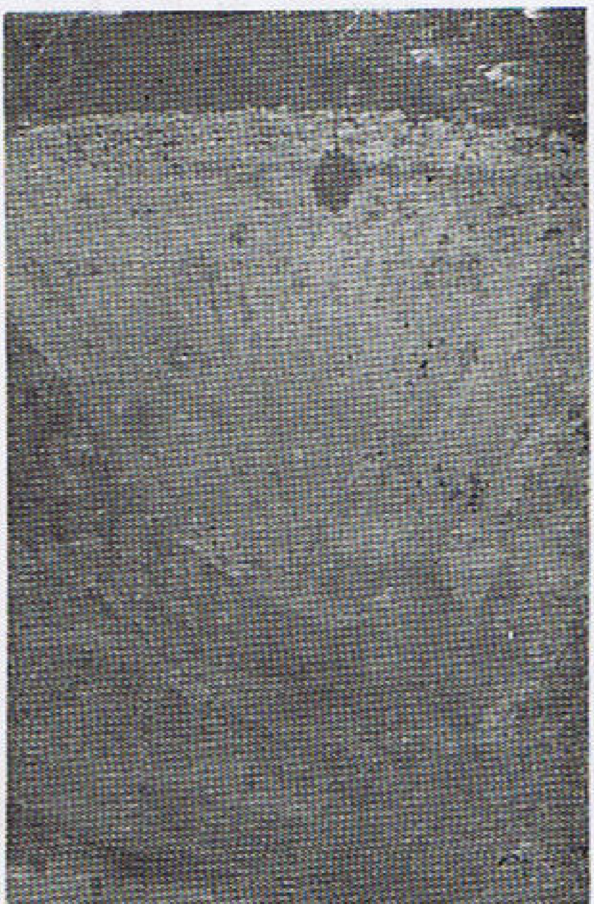

Fig. 2. A big landslide in Murrees south of Nausada with a more or less curved surface of failure.

Where sandstone is common in Murees and where the strata dip toward the road translational slides have also developed.

Most slides in Murrees represent a shear failure. Where the fissured and weak clays of Murrees get wet the cohesion is decreased considrably and the shearing strength is reduced as a result of which a big mass slumps down.

Photos number 2 and 3 show typical sliding in Murree Formation. In the fomer the plane of failure is very steep and somewhat curved and in the latter the sliding took place along an irregular shear surface largely straight but partly curved. This slide extended along the road for about 300 feet and affected the slope to an height of about 30 feet from the road level. The sliding shown in photo 2 is south of Nausada and that in photo 3 is a little north of Pattikka.

Fig. 3. Slope failure in Murrees North of Pattika with a lot of broken talus and scree.

3. *Slumping and Falling down of Overburden* : This is perhaps the most common and widely developed form of slope failure along Muzaffarabad-Tithwal road, especially in limestone and Murrees. The slopes in this area, at many places, are covered with thick deposits of loose, unconsolidated, glacial and stream deposits. They

contain boulders and gravels embedded loosely in a relatively finer soil and some of the boulders are very big. Boulders and loose material of this overburden keep on rolling down the slopes spoiling the road and demanding a constant clean up. At many places where the overburden stands at steeper angles and where the water gets an access to it, the material slumps down in big chunks. Photo 4 shows this type of failure a little north of Ghori bridge. Here the road has been cut through overburden for many furlongs and ground water can also be seen oozing out of this loose material.

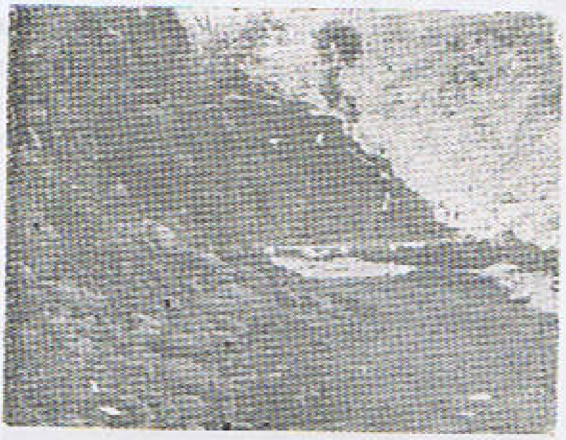

Fig. 4. Highly unstable slopes north of Ghori. The slopes are covered with thick overburden containing big boulders which keep on rolling down.

4. *Rock Fall* : Rock falls are common in badly jointed rocks where they stand at steep angles. In the area of study rock falls were observed both in limestone and Salkhalas (a series of different types of schists, phyllites, and marble). This is because both limestone and Salkhalas are well jointed and badly sheared at places. Photos 5 and 6 show rock falls in limestone and Salkhalas respectively. The rockfall shown in photo 6 destroyed three different levels of the road.

Causes of Landslides in Muzaffarabad-Nauseri Area.

The following factors are considered responsible

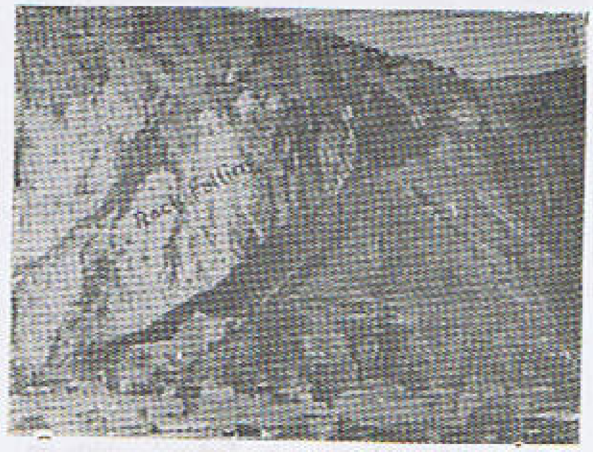

Fig. 5. Photograph shows rock falling on the facing slopes of Muzaffarabad Limestone opposite to the village Bandi Mir Saumdani.

Fig. 6. Rock fall and sliding in Salkhalas north of Nauseri.

for excessive slope failures along Nilum Valley road.

(1) Abundance of thick cover of loose, uncosolidated overburden containing big bouldres.

(2) Abundance of soft, weak and sheared clays and shales in Murree Formation through which the road passes for most of its length in this area.

(3) Highly sheared and brecciated nature of limestone and slates because of severe tectonic forces to which they have been subjected.

4. Groundwater moving along joints and bedding planes acts as a lubricant.

5. *Execssive Moisture Content :* Muzaffarabad is an area of heavy rains. It rains both in summer and winter and sometimes continuously for a few days. Also there is a lot of melt water from snow during spring. This excess of moisture softens the already weak rocks like clays and overburden aiding in landsliding.

6. *Poor Drainage Facilities :* Although Murrees are highly prone to landsliding no steps have been taken to channelize and drain out rainwater. It either penetrates in or flows over the clayey slopes and the road surface thus greatly weakening the former and spoiling the latter.

7. Another cause of slop failure is the removal of lateral support. Where a formely continuous slope has been cut at some level for road making the equilibrium was disturbed and such slopes are now unstable to some degree. The forested slopes near Pattika, Ratra, and Nausadda are stable at their upper reaches but somewhat unstable along the road because of the vertical cut that was made during road construction.

8. Insufficient number of retaining structures.

Treatment Suggested :

The following remedies are suggested for minimizing the sliding along Muzaffarabad-Nauseri road.

1. Retaining walls should be constructed wherever a slope is considered to be unstable.
2. Drainage channels and drainage galleries should be provided over the slopes which are most likely to fail during the rainy season.
3. Plantation should be done on unstable slopes.
4. Where possible, the angle of inclination should be reduced.
5. Overburden should be removed wherever it is possible to do so.

Problem of Bridge Failures

Muzaffarabad-Tithwal road crosses a large number of streams and at many of these bridges have been constructed. Where the road passes through Murrees failure of the bridge foundations is a common problem. There are two major reasons for this.

1. Most of the streams of the area have a steep gradient and during rainy season the water flows through them at a very high speed. The fast flowing water carries a lot of load which includes boulders as big as 10 feet diameter or even more. The fast flowing water with all its load scours the bridge abutments and its foundations and in many instances completely breaks and washes away the very structure of the bridge. Photo 7 shows the destruction of bridge on Basantkot stream a little south of Nuaseri.

2. The second cause of bridge failure is the weak foundation provided by the Muree Formation. The clays and shales of Murees are badly sheared and weathered and with increase of moisture

content they become very soft. So during the rainy season the foundation fails because of shear failure and land-sliding.

Remedies :

Three remedies are suggested to overcome the problem of bridge failure.

1. To avoid bridges, construct culverts with a provision for a sufficient quantity of water to pass under the slab of the culvert.

2. Where the road crosses a stream it takes a V-shaped bend. The new bridges should be constructed away from the closed end of the V as is shown by the rope NS in photo 7 which marks the centre line of the proposed Nuraseri bridge. This will allow greater space for the load to pass under the bridge. This practice is already being followed at some places in the area.

3. To reinforce the abutments artificially as much as possible.

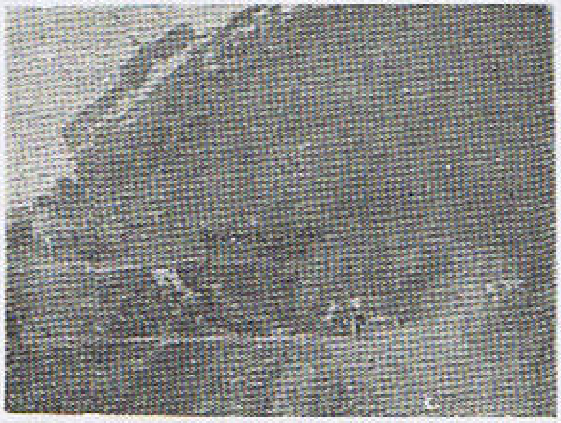

Fig. 7. The Photo shows the proposed Nura-Seri bridge site. The centre line of the proposed bridge is marked by the roop N.S. The remains of the old broken bridge can also be seen.

Drainage Problem :

Most landslides of area occur during rainy season. The water that falls on the slopes is not channelized. It infiltrates and helps to weaken the material. The rain water as well as the ground-water that comes out on the slopes also wet, the road surface making it muddy and slippery at many places.

Two types of drainage arrangements are suggested :

1. Drainage galleries over the slopes should be provided to collect and channelize the water where the slopes are most vulnerable to sliding.

2. A wide and a deep ditch should be provided all along the road on the side of the slope and where the slopes are on both sides it should be dug on both sides. This ditch will collect water flowing down the slopes and not let it spread on the road. The loose material rolling down the slopes will also be collected in this ditch. The ditch should be regularly cleaned.

Suggestion for Improving the Present Condition of the Existing Road.

The Nilum valley area is highly backward and underdeveloped inspite of the fact that it contains a wealth of economic minerals, thick forests, a large variety of fruit trees, and good species of sheep. For the exploitation of these resources and also from the defence point of view it is imperative that the development of the means of communications in this area should be given due importance and the present condition of the road be improved. The following measures are suggested in this connection.

1. The existing road is quite narrow and dangerous. It should be widened. This is not difficult because for most of its length it passes through soft rocks.

2. The riding surface should be levelled out and all the stones which are protruding out should be removed.

3. The road should be mettled through out

as abudant aggregate material is available for this prupose.

4. Retaining walls should be constructed wherever slopes are likely to fail and especially at the places shown on the map.

5. Proper drainage facilities, as mentioned before, should be provided.

6. Culverts should be constructed at all those streams where bridges are not present. The culverts should have sufficient open space below them for the flood water to pass under them.

7. Extensive plantation on the unstable slopes should be done.

8. Overhangs, where present, should be removed.

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NOTICES, ABSTRACTS AND REVIEWS

MICROPALAEONTOLOGY AND INVERTEBRATE PALAEONTOLOGY OF NAMMAL GORGE "SALT RANGE" PAKISTAN

INTRODUCTION

The geological mapping of Nammal-Chhidru area, located between 71° 41′ and 71° 51′ E. and 30° 33′ and 32° 40′ N, Mianwali. District Western Salt Range, was carried out by the first author as part of the M.Sc. examination, see Field Report, Shami 1973, under the supervision of the later. Main stress in the report was laid on the micro and invertebrate fossil investigations. Samples were collected from almost all the units exposed in the area.

STRATIGRAPHIC SUCCESSION IN NAMMAL—CHHIDRU AREA OF "SALT RANGE" PAKISTAN

Group	Formation	Member	Age
....	............Unconformity............		
Havelian			Pleistocene
Rawalpindi	Murree		Miocene
....	............Unconformity............		
Galis	Sakesar Limestone Nammal		Eocene
	Patala Lockhart Limestone Hangu		Paleocene
....	............Unconformity............		
Thandiani	Sammana Suk Shinawari Datta		Jurassic
....	............Unconformity............		
	Kingriali		
	Tredian	Khatkiara Landa	
	Mianwali	Narmia Mittiwali Kathwai	Triassic
....	............Unconformity............		
Zaluch	Chhidru Wargal		Permian
....	............Unconformity............		
	Salt Range		Late Precambrian
		Sahiwal Marl	To Cambrian
	Base not exposed		

Distribution of Fossils

The following microfossils and invertebrate fossils have been recorded from various formations given below.

Wargal Formation :

Microfossils : Boultonia cylindrica, Fusulinella sp, Profusulinella parachomboidies, Triticites-parvulus, Schubertella sp., Polydiexodina sp, Pseudoschwagerina sp.

Invertebrate fossils : Athyris capilata, Bellerophone, sp, Camerophoria purdoni, Costifernia grandicosta, Eumetria indica, Leptodus sp, Martinia semiplana, Neodelthyris sp ; Productus grandicosta, Productus lineatus, Products semi reticulatus, Retaria sp, Retzia grandicosta, Rhynchonella morahensis, Spirifer musakhelensis, Spiriferina ornata, Spirigerella derbyi, Spirigerella hybrida, Terebratuloidea davidsoni, Uncinulus theoboldi, Warthia sp, Dictyoclostus sp.

Chhidru Formation :

Microfossils : Boultonia cylindrica, Fusulinella sp, Profusulinella parachomboides, Triticites parvulus, Millerella sp, Nankinella sp, Yangchienia sp, Fusulinella bocki.

Invertenrate fossils : Bellerophone sp, Costiferina indica ; Dictyoclostus sp, Enteletes-tschernyscheffi, Leptodus sp, Martinia chhidruensis, Neodelthyris sp, Notothyris warthi, Productus gratiosus, P. Lineatus, P. semireticulatus, Rhychonella Morahensis, Spirifer musakheylensis Spiriferina ornata, Spirigerella derbyi, S. grandis, S. hybrida, Terebratuloidea davidsoni, Tropidolasma curtum, Paranautilus sp.

Mianwali Formation :

Invertebrate fossils : Pexidella strohymayeri, Discotoceras sp, Gyrophiceras sp, Ophiceras, Subflemingites.

Lockhart Limestone :

Microfossils : Asterigerina, Assilina dendotica, A. daviesi, A. granulosa, A. mamillata, Cassidulina californica, Cibicides americanus, C. blanpiedi, C. grimsdalei, C. isidroensis, C. lobatulus, C. madrugalensis, C. mauricensis C. mckannai, C. mensilla, C. newmanae, C. pseudo-ungerianus, C. venezuelanus, Discocyclina dispensa, D-javana, Elphidum subnodosum, E. macellum, Frondicularia inversa, Globigerina triloculinoides, Globorotalites michelmianus, Gumbilina trinitatesis, Lockhartia altispira, L. bermudezi, L. conica, L conditi, L. diversa, L. haimei, L. retiata, L. tipperi, Marginulina glabra, Miscellanea miscella, Nodosaria sp, Ornatanomalina elegantula, Orbulina sp, Pseudoclavulina pseudohumilis, Rectocibicides sp, Rotalia havanensis, Rotalia trochidiformis, Schubertella rata, Stafella-sphaeroides, Vaginulina longiformis, Valvulina namalensis,

Invertebrate fossils : Architectoica mainwaringi, Ampullospira constrica, Campanile brookmani, Conus sp, Euspira adela, E. Soriensis, Hippochrenes vredenburgi, Liotia coultardi, Pseudomiltha gigantea, P. noorpurensis, Turritella infrarimata, T. soriensis, Velatus perversus.

Patala Formation

Microfossils :

Allomorphina paleocenica, Ammonia sp, Anomalina midwayensis, A. praespissiformis, Assilina dandotica, A. daviesi, A. patalensis, A. placentula, A. praespira, A. pustulosa, A. ranikoti, A. spinosa, A. spubspinosa. Brachycythere ovatavecarina, Camerina catenula, C. fichteli, Cibicides isidroensis, C. lobatulus ; C. madrugaensis, C. newmanae, C. pseudoungerianus, Clavulina paxilliformis, Cytherura forulata, Cythromorpha warneri, Davisina phatiyahi, Discocyclina dispensa,

D. javana, D. pritti, D. sowerbyi, Eponides elevatus, E. lotus, E. Vanbelleni, Globigerina eocenica, G. triloculinoides, Globorotalia crater, G. ehrenbergi, Gyroidina subangulata, Glandulina laevigata, Lingulina wilcoxensis, Lockhartia altispira, L. burmudezi, L. conica, L. praehaimei, L. retiata, L. tipperi, Nonionella nammalensis, N. excavata, N. soldadensis, Nummulities atacicus, N. beaujonti, N. couisensis, N. granifer, N. lahirii, N. pangaroensis, Operculina canalifera, O. hardiei, O. jiwani, O. salsa, Pseudomassilina sp. Pseudeglandulina manifesta, P. pygmaes, Pyrulina cylindroides, Quinqueloculina peregerina, Q. pseudovata, P. pulcherrima, Robulus arkansasanus, R. midwayensis, R. pseudocostatus, R. pseudomamilligerus, R. turbinatus, R. wilcoxensis, Sakhiella nammalensis, Spiroplectamina wilcoxensis, Stafella sphaerodiea, Textularia missippiensis, T. natchitochensis, T. punjabensis, Triloculina albamensis, T. austriaca, Vaginulina longiformis, Valvulinaria extensa, Woodella nammalensis.

Sakesar Limestone

Microfossils :

Alveolina globosa, A. ovoidea, A. oblonga, A. vredenburgi, Ammobaculites paleocenicus, Cisalveolina lehneri,. C. fallax, Fasciolites, Heterostegina depressa, Lepidocyclina glabra, Neoalveolina haueri, N. pygmaea, Nummulites distans, N. douvillei, N. variolaris, N. vascus, praealveolina cretacea, Subalveolina perebaskini.

Nammal Formation

Microfossils :

Entosolenia apiculata, Lepidocyclina glabra, Nummulites atacicus, N. couisensis, N. chavannesi, N. distans, N. douvillei, N. granifer. N. variolarius, N. vascus, Planorbulinella nammalensis.

B. A. SHAMI & M. A. LATIF
Department of Geology
University of the Punjab,
Lahore.

NOTICES, ABSTRACT AND REVIEWS

AN EVIDENCE OF MAESTRICHTIAN ROCKS IN HAZARA

INDTRODUCTION.

In his first reference to the geology of Hazara VERCHERE, 1866-67, gave a rough description of the geology of Hazara without giving any reference to the occurrence of the Upper Cretaceous rocks in the area. Waagen and Wynne, 1872, in their succession of rocks mentioned a bedded limestone, without fossils apparently, possibly of Cretaceous age. Middlemiss, 1896, included the above referred thin bedded limestone as part of Tertiary rocks, as lowest bed of the Nummulitic Series. Latif, 1962, recorded the presence of microfossils of Upper Cretaceous age in the rock units referred above. Latif, 1970, identified more than 30 species of microfossils and dated the rocks as Upper Coniacin to Campanian, Upper Cretaceous. He further identified the rocks as Chanali Limestone and separated it from the overlying Tertiary formations.

The microfossil studies carried by Latif, 1970, were based on a study of five samples from Changlagali section. It was found to be necessary to advance the studies by measuring various sections in Hazara and studying the relevant samples. The investigations have shown the presence of twenty seven microfossils in addition to those of Latif, 1970. These microfossils are newly recorded from Hazara. The following additional microfossils have been recorded from the Khairagali section.

1. Globotruncana ventricosa
2. Globotruncana ventricosa carinata
3. Globotruncana arca
4. Globotruncana linneiana tricarinata
5. Globotruncana intermedia
6. Globotruncana gagnibini
7. Globotruncana renzi
8. Globotruncana scheegansi
9. Rotalipora greenhornensis
10. Anomalina pseudoarculata
11. Anomalina Sp.
12. Gaudryina bronni
13. Marsonella oxycona
14. Frondicularia Sp.
15. Frondicularia filocincta
16. Lagena oxystoma
17. Gublerina Sp.
18. Planoglobulina Sp.
19. Dentilina Sp.
20. Hedbergella delrioensis
21. Hedbergella planispira monomouthensis
22. Clavihedbergella subdigitata
23. Praeglobotruncana delrioensis
24. Praeglobotruncana stephani
25. Praeglobotruncana helvetica
26. Praeglobotruncana planispira
27. Lenticulina exerata.

DISTRIBUTION AND AGE

Most of these microfossils range in age from Lower Cretaceous to Upper Cretaceous, but a few forms are restricted to the Maestrichtian in different parts of the world.

Clavihedbergella subdigitata, for example, ranges from Aptian to Maestrichtian, while Globotruncana fornicata from Coniacian to Maestirichtian. Heterohelix globulosa ranges from Middle Coniacian to Maestrichtian and Pseudotexularia elegans from Upper Coniacian to Maestrichtian. The microfossils which are identified as Maestrichtian in age are as follows :

Glogotruncana intermedia Bolli—restricted to Maestrichtian. It evolved from Globotruncana stock by the development of a slightly convex test and keels closer together.

Pseudotexularia elegans fructicosa is also identified with the Upper Maestrichtian. It is an outgrowth of P. elegans by the proliferation of chambers at the summit of an initially biserial test.

Hedbergella planispira monomouthensis is restricted to the Upper Maestrichtian, showing five chambers in the final whorl with rapid increase in the chamber size.

Globotruncana gagnibini Tilev is possibly of Maestrichtian age. It has umbilical side convex and distinctly lobate periphery with two closely spaced keels.

On the basis of the above evidences, the upper age limit of the Chanali Limestone (now called Kawagarh Formation) is considered to be Maestrichtian.

HAMID MASOOD
Department of Geology
University of the Punjab,
Lahore.

STAFF LIST OF THE DEPARTMENT OF GEOLOGY UNIVERSITY OF THE PUNJAB, NEW CAMPUS LAHORE PAKISTAN AS IN DECEMBER 1976.

Name and Qualifications	*Subject*	*Appointed*
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Professor :		
Dr. F.A. Shams, M.A. (Cantab), M.Sc. Ph.D. (Pb) ..	X-Ray Crystallography Petrology Mineralogy	November, 1956
Associate Professors :		
Dr. M.A. Latif, M.Sc. (Pb.), F.P.T.C. (Vienna), M.Sc., Ph.D., D.I.C. (London) ..	Stratigraphy, Regional Geology, Micropalaeontology	July, 1957
Mr. A.H. Gardezi, M.Sc. (Pb.), D.M. (E.N.I.) (Rome), M.Sc., D.I.C. (London)[1]	Structure Petroleum Geology	March, 1962
Dr. S.F.A. Siddiqui, M.Sc. (Pb.), Ph.D. (London)[2] ..	Ore Microscopy Petrology	July, 1960
Assistant Professors :		
Dr. Aftab A. Butt, M.Sc., (Pb.), Ph. D. (Utrecht)[3] ..	Micropalaeontology Palaeontology	June, 1959
Mr.M.H. Malick, M.Sc. (Pb.), M.Sc., D.I.C. (London) ..	Engineering Geology	March, 1965
Mr. A. Shakoor, M.Sc. (Pb.), M.Sc. (Leeds). ..	Engineering Geology	May, 1965
Mr. Zulfiqar Ahmed, M.Sc. (Pb.)	Mineralogy Petrology	August, 1967.
Dr. M. Nawaz Chaudhry, M.Sc. (Pb.), Ph.D. (London) ..	Mineralogy Petrology Geochemistry	January, 1968.
Lecturers :		
Mr. Hamid Masood, M.Sc. (Pb.)	Stratigraphy Palaeontology	April, 1974
Mr. Aftab Mahmood, M.Sc. (Pb.)	Mineralogy Petrology	April, 1974
Mr. Birkhez Aslam Shami, M.Sc. (Pb.)	Palaeontology, Field Geology	October, 1975
Mr. Zahid Karim Khan, M.Sc. (Pb.)	Engineering Geology	October, 1975
Mr. Riaz Ahmad Shaikh, M.Sc. (Pb.)	Structure, Petroleum Geology	November, 1975
Mr. Umar Farooq, M.Sc. (Pb.).	Geophysics	November, 1975
Research Officer :		
Dr. Shafeeq Ahmad, M.Sc., Ph.D. (Pb.)	Petrochemistry	January, 1967
Part Time Lecturer :		
Mr. M. Iftikhar Ahmad	Mathematics	

Demonstrators :

Mr. Khalid Mahmood, B.Sc. (Hons.)	Structure	November 1976
Mr. Muhammad Anwar, B.Sc. (Hons.)	Structure	November 1976
Mr. Akhtar Iqbal Bhutta, B.Sc. (Hons.)	Mineralogy	November 1976
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Mr. Afzal Husain Syal, B.Sc.	Palaeontology	November 1976

Technical Staff :

Mr. M. Aslam, Chief Technician	June, 1964
Mr. Mahmud Ahmad, Geological Illustrator	January, 1967
Mr. Zafarullah, Draftsman	October, 1974
Mr. A. Rauf Rana, Junior Technician	April, 1958
Mr. Zafarullah Butt Junior Technician	August, 1969
Mr. Mohammad Yaseen, Store-Keeper	April, 1976

Ministerial and Auxiliary Staff :

Mr. Khurshid Ahmad, Librarian	June, 1959
Mr. A. Latif, Office Assistant	February, 1949
Mr. Mohammad Riaz, Senior Stenographer	February, 1965
Mr. Ghulam Mohyuddin, Senior Clerk (Accounts)	November,1964
Other Staff	21

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1. On leave without pay to Attock Oil Co. since November, 1975.
2. On leave without pay to Zambia since November, 1973.
3. On leave without pay to Algeria since April 1975.