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BEITRÄGE ZUR GEOLOGIE VON PAKISTAN SOWIE ZU AUSSCHNITTEN AUS DEM KRISTALLIN NIEDERÖSTERREICHS

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Vorwort

In den Jahren 1964—1969 haben insgesamt etwa 80 Geologen aus dem Bereich der Entwicklungsländer jeweils in Gruppen zu etwa 12 bis 16 für 8 Monate an Internationalen Hochschulkursen der Universität Wien/Geologische Bundesanstalt teilgenommen. Hierbei wurden aktuelle geologische Fragen, sowie sie sich aus der petrologischen oder stratigraphischen Kartierung ergeben, näher studiert und die Ergebnisse als Summary, im Teil IV des Jahresberichtes der Geol. Bundesanstalt festgehalten. Darüber hinaus konnten jedoch auch größere Bearbeitungen zum Abschluß gebracht werden, siehe Verh. Geol. B. A. 1966 und 1968, Jb. Geol. B. A. 1967.

Dieses Heft enthält vier Beiträge zur Geologie von Pakistan und drei kleinere Studien über österreichische Kristallinausschnitte. Es wird dem I. K. f. E. gedankt dafür, daß die Mittel, vor allem für die Herausgabe der Geologischen Buntdruckkarte und Profile und auch der Texte verfügbar gestellt werden konnten. Das Interesse Österreichs an internationaler Zusammenarbeit mit dem Bereich der Entwicklungsländer wird dadurch dokumentiert.

Wien, Oktober 1969
Dr. H. Küpper

Preface

The following four contributions to the Geology of Pakistan and also those on smaller sections of the kristalline rocks of Lower Austria, are related to the work and studies carried out in connection with the Post Graduate Training Center for Geology, Vienna 1964/1969.

The Austrian side hopes, that this publication might be considered as token of their willingness, to promote international cooperation wherever possible.

Vienna, October 1969
Dr. H. Küpper

Inhalt

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Explanatory notes on the Geology of South Eastern Hazara, to accompany the revised Geological Map

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With 1 plate, 1 map and 5 vertical sections

Contents

Abstract

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

1. Location of the area

The area under study is mainly composed of southeastern parts of the Hazara district, West Pakistan (see the map). Small portions of northwest of the Rawalpindi and southwest of the Muzzaffarabad districts, just fringing the above area have also been included because of the extension of the same rock types. The area lies between longitude 73.00 and 73.30 east and latitude 33.43 and 34.20 north, and is covered by the Survey of Pakistan toposheets 43 F/4, 43 F/8, 43 G/1, 43 G/5, 43 F/7, and 43 G/2. The main part of the area is bounded on the north west and west by the Hazara trunk road through Haripur, Havelian, Abbottabad, Mansehra and further beyond via Garhi Habibulah Khan to Muzzaffarabad; and on the southeast and east by the Rawalpindi-Srinagar road, through Islamabad, Tret, Murree and Kohala to Muzzaffarabad.

2. Introduction

The area under study ranges from just under 2,000 feet O. D. near Islamabad to 9,780 feet at Miranjani, near Nathiagali. More than half of the area lies above 4,000 feet O. D. The Galis lying between Murree and Abbottabad provide the highest regions in the area and serve as a water divide between the Indus and the Jhelum river systems. The relief is very high and is seen at it's maximum when the mountains rise abruptly from 1,937 O. D. near Kohala to 9,780 feet O. D. near Miranjani, a horizontal distance of about five miles.

3. History of Exploration

The first publication of any significance on the geology of Hazara is ALBERT VERCHERE's paper read before the Asiatic Society in 1866. This gives a brief outline of the north eastern end of the Sirban mountain near Abbottabad. He recognised Carboniferous limestone resting upon volcanic rocks. The beds above these he referred in a general way to the "Jurassic Formation" and the highest strata to the Nummulitic Limestone.

WAAGEN and WYNNE in 1872, put an order for the first time to the structurally complex rocks of monotonous similarity. They also produced a map of the Sirban Mountain, on a scale of one inch to a mile covering an area of about 20 square miles. They suggested the presence of rocks from Triassic to Eocene based on fossil evidence and found similarities of some with those from the Cambrian of the Salt Range. This information coupled with a series of papers during the late seventies of the last century, is still considered the soundest basis of rock classification in the area.

MIDDLEMISS, 1896, pieced together all the available information, published or unpublished, from all over Hazara, to produce a map of Hazara on a scale of ½ inch to a mile, together with a detailed account of the geology.

The present study was initially suggested, in 1956, by N. R. MARTIN, then a UNESCO advisor and Head of the Geology Department, University of the Panjab, Lahore. A few road side reconnaissance trips were made by the author in his company during the summer months of 1956, followed by a few independent trips in 1957. Following the footsteps of ALBERT VERCHERE, the Sirban Mountain was selected as a starting point, and a beginning was made in July, 1959. The main purposes of the study were to (a) revise the stratigraphy, (b) bring the unit names in line with modern stratigraphic nomenclature and (c) produce a new geological map, on a scale of one inch to a mile.

Though some short publications to advance the knowledge of Geology of Hazara have recently appeared from Lahore, this is the first of its kind since 1896, in which (a) an attempt has been made to bring the rock units in order, to suit the requirements of stratigraphic nomenclature (b) revise the ages of units based on faunal assemblages, (c) correlate the units with the adjoining areas and (d) produce a new map of the south eastern Hazara, on a scale of one inch to one mile. Publication of this map with short account of the stratigraphy marks the centenary of the first investigations started in the area by ALBERT VERCHERE, in 1866.

4. The basis of classification of rocks

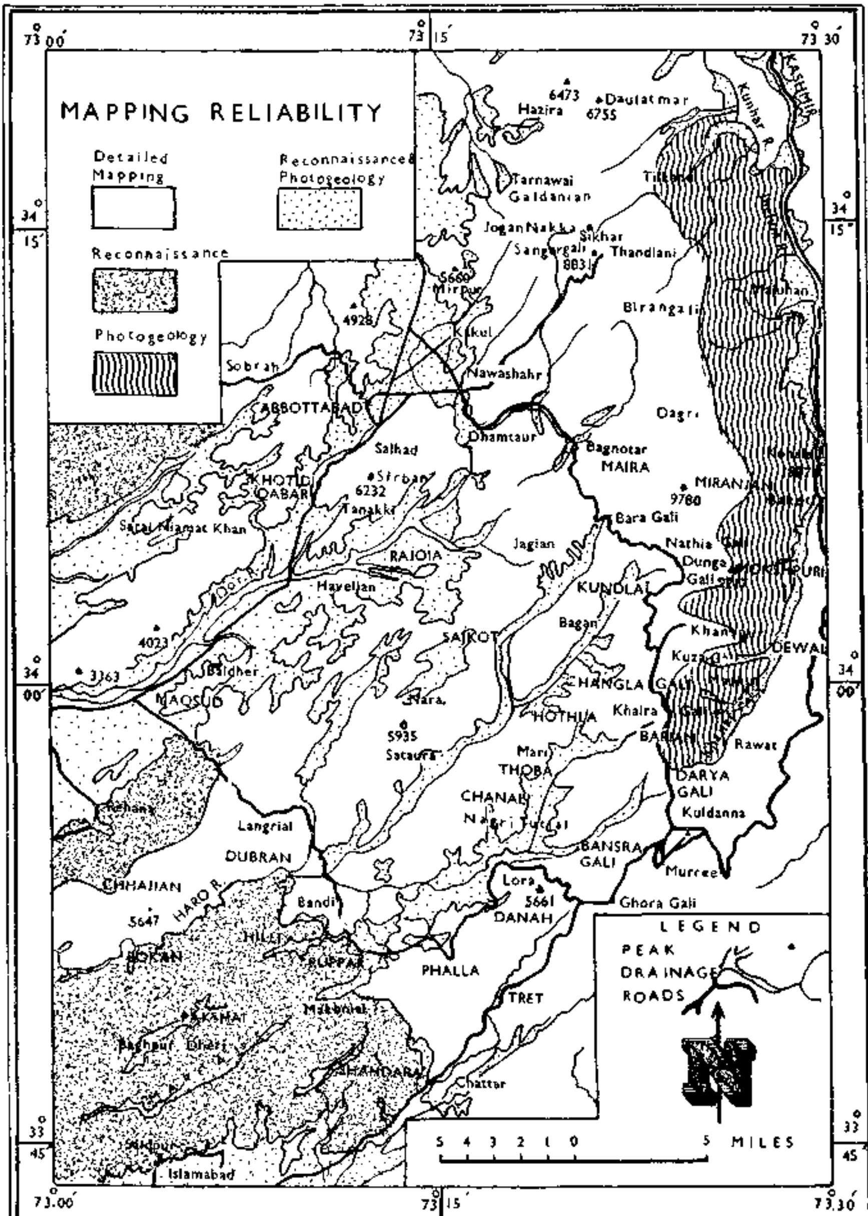
As most of the stratigraphic units in the area have not been formally defined by earlier workers, in accordance with the stratigraphic terminology, it is considered appropriate to do so in this study, wherever applicable. In recent years the nature and usage of stratigraphic units has been much discussed. The stratigraphic units newly erected and/or properly defined in this work follow the basis laid down by the Stratigraphic Committee of Pakistan in the Stratigraphic Code of Pakistan, 1967, which in turn follows the lines set by the Interational Subcommission on Stratigraphic Terminology, 1961.

The present study is based on the field mapping by recognition of the lithostratigraphic units, supported by the faunal and environmental studies wherever possible. The subdivisions and definitions of such units are based on the definition as laid down in the Stratigraphic Code of Pakistan, 1967. The subdivisions applied in this work are the Group, the Formation and the Member. The formation is considered as the fundamental lithostratigraphic unit, the Group and Member are the aggregates and the subdivisions respectively and are defined as such. The names of various units which have been proposed are based on a geographic feature or locality of it's maximum development in the area. Wherever a convenient geographical name is not available at the type locality a name has been chosen from an adjacent locality where the unit may not be so well exposed. An attempt has been made to retain the existing unit names in spite of the fact that some may not be represented at the localities and/or the locality is situated outside the area of present investigations. An attempt has been made to select the type localities with an easy access, as far as possible. The various formations and members have been shown on the map by various patterns as near as possible to their lithologic content. In some cases the groups which could not be subdivided on the map have been shown in a single pattern. Every group, with minor adjustments, has been shown by a distinct colour suiting its stratigraphic position and follows the colour scheme as published in 1958 by N. V. De Bataafsche Petroleum Maatschappi, Hague, Holland.

5. Limits of accuracy of mapping

Though most of the area has been mapped thoroughly, it was not possible to maintain a uniform standard everywhere due to the limited means of communication, accommodation, dense vegetation, high relief, and above all the structural and sedimentational problems. The standard of mapping in the area, can therefore be divided into the following categories in the descending order of reliability (see figure 1).

a) Detailed mapping
b) Reconnaissance mapping
c) Photogeology and field checking and
d) Photogeology only.



F I G. 1

The detailed mapping is from the regions of Tarnawai, Thandiani, Kakul, Abbottabad, Bagnotar, Sirban, Dubran, Nara, Mari, Lora, Islamabad, Murree and Muzzaffarabad. The mapping in the regions Miranjani, Mokshpuri, Kuzagali, Barian, Havelian, Margala and Rupper is partially detailed and partially of reconnaissance or photogeologic nature. The mapping from most of the Miranjani and Mokshpuri regions is purely of photogeologic nature. The Pleistocene and Recent alluvial deposits have mainly been marked by photogeology with some ground checking. The eastern and north eastern parts of the Bagnotar region towards the right bank of the river Jhelum are based purely on photogeology.

6. The stratigraphic succession

Group	Formation	Member	Age
Havelian			M. Pleistocene to Recent
		Unconformity	
Rawalpindi	Murree		Lower Miocene
		Unconformity	
Galis	Kuldana		L. & M. Eocene
	Lora		L. Eeocene
	Margala Hill Limestone		L. Eocene
	Kuzagali Shale		U. Paleocene
	Mari Limestone		L.?/M. to U. Paleocene
		Unconformity	
Hothla	Chanali Limestone		U. Cretaceous
	Giumal Sandstone		L. Cretaceous U. Jurassic to
	Spiti Shale		U. Jurassic
		Unconformity	
Thandiani	Sikhar Limestone		Middle Jurassic to U. Jurassic
	Maira		Lower Jurassic
		Unconformity	
(Tarnawai?)	Hazira		Permian and/or Triassic?
	Galdanian		Carb. and/or Trias. (?)
		Unconformity	
Abbottabad	Sirban		Upper Devon. to Lower Carboniferous (?)
	Kakul	Mirpur Mahmdagali Sangargali Tanakki	Silurian to Devonian (?)
		Unconformity	
Hazara	Tanol		Cambrian and/or Ordovician to Silurian (?)
	Upper Langrial Limestone Middle Miranjani Limestone Lower		Eo-Cambrian to Cambrian (?)

a) Hazara Group

Formerly known as the "Slate series", MIDDLEMISS, 1896, and recently identified as the "Hazara Slate formation", MOHAMMAD ALI, 1962, the rocks have provisionally been recognised as a group. The following provisional subdivisions are suggested.

5. Upper Formation
4. Langrial Limestone
3. Middle Formation
2. Miranjani Limestone
1. Lower Formation.

The above subdivisions are based on the occurrence of two limestone units of different geological horizons.

a) The Miranjani Limestone is a light grey algal limestone, on the weathered surfaces of which the stromatolites conspicuously stand up to form wavering uneven ridges.

b) The Langrial Limestone is a grey nodular limestone with dominant argillaceous matrix and weathering in grey to pale brown colours.

The Lower, Middle and Upper Formations all taken together are composed of low grade slates, argillites, silty shales, subgreywacke sandstones and siltstones, interbedded with gypsum and calcareous slaty shales. The subdivision is provisional subject to the detailed definitions of its constituent formations. Though a definite fossil evidence is lacking, the presence of some doubtfull inarticulate brachiopod fossils similar to *Protobolella* CHAPMAN and Acrotretid, go to prove that the group may not be pre-Cambrian and could be Lower Palaeozoic. The rocks extend in the south west and north east to join the Attock and Slates respectively. In Kashmir, the Dogra Slates underlie a definite Cambrian sequence and as such a Cambrian age for the group, at least in part, may be possible.

The lithology, sedimentary structures and distribution of identical rocks suggest a shallow to deeper water facies approximately extending from south east to north west respectively. The presence of gypsum, further suggests a possible partial extension of the Cambrian "Saline Series" facies of Salt Range to Hazara.

b) Tanol Formation

The Formation was first named as Tanol series by WYNNE in 1879 after its occurrence in the vicinity of Tanol. MOHAMMAD ALI, 1962, identified the unit as Tanol Formation.

The Formation is composed of well bedded to flaggy, light grey to yellowish and sometimes faintly reddish quartzites which are cross bedded and contain ripple marks. Siltstones and pebbly layers are common. The top of the Formation is marked by the presence of a badly sorted conglomerate containing pebbles derived from the quartzites as described above, embedded in a fine grained matrix. The conglomerate is followed by a sequence of rocks similar to the Abbottabad Group and the conglomerate is probably homotaxial to the Tanakki Member of the Abbottabad Group.

The Formation may be Cambrian and/or Ordovician to Silurian (?) in age.

The Lower Tanawal in Kashmir lying below the Muth Quartzites and Jaunsars and Nagthat of Himalayas are considered as homotaxial.

c) Abbottabad Group

MIDDLEMISS, 1896, introduced the term "Infra-Trias" to include rocks like conglomerate, shales, sandstones and limestones of a total thickness of up to 2,250 feet. MARKS and MOHAMMAD ALI, 1962, named the rocks as Abbottabad Formation. GARDEZI and GHAZANFAR, 1965, elevated the unit as Abbottabad Group with the addition of a new Hazira Formation overlying the rocks given above.

The group is named after Abbottabad, where it shows a maximum development. It overlies the Hazara group with a break in deposition represented by a basal conglomerate derived from the underlying rocks of Hazara Group. This is followed by a thick sequence of interbedded shales, sandstones, orthoquartzites, arenaceous dolomites, dolomites, volcanic materials, haematitic mudstones, quartz breccias, siltstones and silty shales. The group constitutes of four formations as given below:

Formation	Member
4. Hazira	
3. Galdanian	
2. Sirban	
1. Kakul	
	d) Mirpur
	c) Mahmdagali
	b) Sangargali
	a) Tanakki

1. Kakul Formation

The formation is named after its occurrence near Kakul and is composed of angular to subangular conglomerate identified as Tanakki Member at the base derived from the underlying HazaraGroup of rocks. The conglomerate is embedded in a silty and shaley matrix. The size of pebbles decreases higher up in the succession merging gradually into the overlying Sangargali Member, consisting of shales, sandstones and orthoquartzites of red and purplish colours. The overlying beds are composed of purple and red sandy dolomitic limestones and dolomites, named as Mahmdagali Member, followed by variegated shales and calcareous sandstones of Mirpur Member. The Formation is considered homotaxial to the Muth Quartzites and overlying shales of Kashmir; Pebbly shales, quartzites and Crinoidal limestone of the Swabi Chamla Group and the Siluro-

Devonian sequence in Nowshehra consisting of conglomerates, calcareous sandstone, purple quartzites and sandy dolomites.

2. Sirban Formation

Formerly known as limestones belonging to "Infra-Trias series", MIDDLEMISS, 1896, and Upper Cherty Limestones of Upper Formation, belonging to "Infra-Trias" Group, MARKS and MOHAMMAD ALI, 1961, the unit is named after its occurrence in the Sirban hill near Abbottabad. The lower part of the formation is slightly sandy, followed by a thick sequence of dolomites of buff, light greenish grey, greyish white and rarely of red and pink colours. The upper parts of the formation occasionally contain cherty patches and bands. The rocks show a striking similarity to the bluish white crystalline limestone of Upper Devonian-Lower Carboniferous (?) of Nowshehra; brecciated white dolomite of Swabi Chamla Group, Devonian-Lower Carboniferous (?) of Swabi. The Muth Quartzites of Devonian age in Kashmir are followed by fossilliferous Syringothyris Limestone of Lower Carboniferous age and are considered homotaxial.

3. Galdanian Formation

Formerly known as the "Volcanic material" at the base of the Triassic series, MIDDLEMISS, 1896, the "Lower Formation" of Triassic System, MARKS and MOHAMMAD ALI, 1961, and Haematite Formation belonging to the Abbottabad Group, GARDEZI and GHAZANFAR, 1965, it is named after its occurrence near Galdanian. It is a distinct unit consisting of volcanic rocks, haematitic mudstones and sandstones, quartz breccias etc.; of red, purple and dark grey colours. The adjoining region of Kashmir, received the volcanic activity from Upper Carboniferous to Triassic. A correlation with the Panjal Volcanic Series of Kashmir sounds quite reasonable, and it is considered that the formation may be of Upper Carboniferous (?) and/or Permian (?) to Triassic (?).

4. Hazira Formation

During the course of current mapping of the area the rocks were noticed in the Hazira region. They were studied in detail and named by GARDEZI and GHAZANFAR, 1965.

The formation is composed of dirty grey and yellowish brown calcareous shaly siltstones containing earthy concretions. It is considered as of Permian?/Triassic? age.

Three distinct environmental subdivisions of the Abbottabad Group can be noticed, a) a basal conglomerate, siltstone sandstone; b) an orthoquartzite, dolomite and c) a volcanic, oolitic haematite, siltstone. Though the name Abottabad is retained for the time being, a fresh regrouping seems necessary. The upper two formations namely the Galdanian and Hazira Formations, it is suggested, may be grouped to be known as Tarnawai Group, in any later regrouping.

d) Thandiani Group

Formerly known as the 'Triassic series', MIDDLEMISS, 1896, is recognized as a group and is named after its occurrence in the vicinity of Thandiani, where it sows a maximum development. It follows the Abbottabad Group with a break in deposition and is found in contact with its various formations and sometimes even the Hazara Group. A microconglomerate at the base has been noticed and is composed of fragments of the rocks belonging to the Abbottabad Group. The group constitutes of the following formations.

2. Sikhar Limestone
1. Maria Formation

1. Maira Formation

MIDDLEMISS, 1896, pointed to the occurrence of grey shales at the base of his 'Triassic series' in the Bagnotar region. He also recorded some fossils, though found them imperfect for identification. DAVIES and GARDEZI, 1965, identified the rocks as Maira Formation after their occurrence near Maira. The formation is composed of quartzite, orthoquartzite bands intercalated with shales marls and thin limestone bands. The quartzites are generally greyish white whereas shales, marls and thin limestone bands show a variety of colours apart from grey. The limestones show the occurrence of dolomitic patches of various shades. The patches are of irregular shape and size and in upper parts fuse together to form thin parallel bands of pale yellow colours. Fossils like *Bouleiceras* cf. *niticens* recorded from the marls show a Toarcian, Liassic age for the formation.

The formation may be compared with the Datta Formation of Kalachitta and northern Potwar, variegated shales of Salt Range and southern Potwar and upperparts of the Shinawari Formation of Kohat.

2. Sikhar Limestone

Formerly known as "Upper limestones" of the "Triassic series", MIDDLEMISS, 1896, it is recognised as a formation and is named after its occurrence in the Sikhar mountain near Thandiani, where it shows a maximum development. The formation is composed mainly of limestones though some marley intercalations are also present, in the lower part. The limestones are grey in colour and are quite massive. They are oolitic, arenaceous and occasionally shelly and are shallow water deposits.

The highest beds show the presence of fossils like *Nerinea* Sp. of Oxfordian-Upper Cretaceous affinities. Since the basal part of the overlying formation also shows an Upper Oxfordian assemblage, it is considered that the top beds of this formation are pre Upper Oxfordian.

The formation can lithostratigraphically be correlated with Samana Suk Limestone of Kalachitta, northern Potwar and Kohat and Baroch Limestone of Salt Range and southern Potwar.

The overall range of the Thandiani Group is from Lower Toarcian to Middle Oxfordian.

e) Hothla Group

The last detailed account of the area, MIDDLEMISS, 1896, shows the rocks like "Jurassic series", "Cretaceous" and "Grey limestones" as the basal part of the "Nummulitic series". All these rocks together have been identified as a group and named after Hothla, where they show a maximum development. The group overlies the Thandiani Group with a marked break in deposition. It is composed of the following formations.

3. Chanali Limestone
2. Giumal Sandstone
1. Spiti Shale

1. Spiti Shale

STOLICZKA, 1866, named the rocks as spiti shale after Spiti area in Himalayas. The name was applied for similar rocks in Hazara, by MIDDLEMISS 1896. The base of the formation shows a break in deposition and is marked by the presence of laterite. This is followed by dark drey arenaceous shales containing limonitic concretions and pyrite nodules. The shales are gradually replaced by sandstone bands higher up in the sequence and with a dradual change of material merge finally into the succeeding formation.

The basal beds contain fossils like *Perisphinctes frequens* of Upper Oxfordian and the later ones show the presence of *Hibolites subfusiformis* of Neocomiam.

The formation may be compared with the Spiti Shale of Himalayas. Somewhat similar rocks occur in Kalachitta, Potwar, Salt Range and Kohat and are known as Chichali Formation.

2. Giumal Sandstone

Name given by STOLICZKA, 1866, after Giumal in Spiti Himalayas, was applied to rocks of identical nature in Hazara by MIDDLEMISS, 1896.

The formation consists of glauconitic and calcareous sandstones respectively in the ascending order of sequence. They are grey in colour, but generally weather in the shades of brown and yellow. The lower part is more argillaceous and the upper more calcareous. The rocks are generally massive and hard. A rich assemblage of fossils is present, among them are *Virgatosphinctes* Sp., *Aulacosphinctoides* Sp. of Tithonian and *Oxytropidoceras* Sp. and *Douvilleiceras* Sp. of Albian.

The formation seems identical to the Giumal Sandstone of Spiti Himalayas. It may be compared with the Lumshiwal Sandstone of Kalachitta, Potwar, Salt Range and Kohat.

3. Chanali Limestone

MIDDLEMISS, 1896, identified the rocks as "Grey limestones" and described and mapped them as the basal part of this "Nummulitic series", The author, 1962, identified them as "Upper Cretaceous Limestone" on the basis of planktonic microfossils as seen in thin sections. The limestones are recognised as a distinct formation and are named after Chanali, where they show a maximum development.

The formation is composed mainly of fine grained light grey limestones which weather in grey to pale cream colours. The limestones are generally thinly bedded though occasionally they occur as thickly bedded as well. The lower part of the sequence is marley, the middle thinly to thickly bedded and upper slightly arenaceous. There is a conspicuous variation in lithology from one section to the other.

The fauna is composed of microfossils, see the other publication on Hazara in this issue. The diagnostic fossils include *Globotruncana concavata* of Upper Coniacian to Upper Santonian, *Globotruncana elevata calcarata*, of Campanian, *Heterohelix reussi* and *Heterohelix globocarinata* of Middle Coniacian to Middle Campanian. On the basis of the occurrence of above fossils, the formation is considered to be of Upper Coniacian to Upper Campanian in age.

The formation may be correlated with Kawagarh Formation of Kalachitta, Darsmand Limestone of Kohat and Chikkim Series of Himalayas.

f) Galis Group

First identified by WYNNE, 1874, as "Nummulitic limestone series" along with "Kuldanas", were combined by MIDDLEMISS, 1896, as "Nummulitic series". They have been recognised here as a group and named after their frequent occurrence in the Galis region situated between Murree and Abbottabad. It overlies the Hothla Group with a marked break in deposition which is represented by the absence of the uppermost part of Cretaceous at least in the eastern regions and the presence of coal and laterite. The group is divided into the following formations.

5. Kuldana Formation
4. Lora Formation
3. Margala Hill Limestone
2. Kuzagali Shale
1. Mari Limestone

1. Mari Limestone

MIDDLEMISS, 1896, identified variegated sandstone and coal followed by well bedded massive limestone, as the 2nd and 3rd units of his "Nummulitic series". Though it is quite possible to identify and map the two units separately, they have been taken together for the purposes of present work. The name of the formation is derived from its occurrence near Mari where it shows a maximum development.

The base of the formation overlies the Hothla Group with a marked break in deposition represented by the absence of the youngest Cretaceous rocks, presence of sandstone, coal, bituminous shales, laterite limonite and oolitic haematite. This is followed by a sequence of dark grey bituminous limestones of nodular appearance.

The fauna is composed of microfossils like *Lockhartia conica, Lockhartia haimei, Actinosiphon punjabensis* and *Globigerina triloculinoides*, thereby showing a Lower/Middle to basal Upper Paleocene age for the formation.

The basal part of the formation may be correlated with the Dhak Pass Beds of Salt Range, Potwar, and Kalachitta and Hangu formation of Kohat. The main part of the formation is homotaxial to the Khairabad Limestone of Salt Range and Lockhart Limestone Kalachitta and Kohat.

2. Kuzagali Shale

The formation constitutes of the lower part "shales" of the 4th unit of the "Nummulitic series" introduced by MIDDLEMISS, 1896. The unit is recognised as a formation and is named after its maximum development near Kuzagali.

The formation is composed mainly of buff and Khaki coloured shales with insignificant limestone bands.

The fauna is mainly composed of microfossils and show a continuation of the underlying Mari Limestone assemblages. They include *Globorotalia elongata, Globigerina saldadoensis, Miscellanea miscella* and *Operculina salsa* showing an upper Paleocene age for the formation.

Similar rocks occur in Salt Range, Kalachitta, Potwar and Kohat known as Panoba Shale.

3. Margala Hill Limestone

MIDDLEMISS, 1896, mentioned the presence of "concretionary and nodular limestone" apart from other rocks in the 4th unit of his "Nummulitic series". This has been identified as a formation and named after its maximum development in the Margala Hills, north of Islamabad.

The formation consists of grey to dark grey, nodular to massive limestones generally forming cliffs. It is differentiated from the Mari Limestone by the absence of argillaceous materials, a conspicuously large size of the nodules and large sized Foraminiferida.

The fauna is mainly composed of microfossils and includes *Assilina laminosa, Nummulites atacicus* and *Fasciolites eliptica* showing an early Lower Eocene age for the formation.

The calcareous beds of "Nammal Limestone and Shales" in the adjoining areas are considered homotaxial.

4. Lora Formation

MIDDLEMISS, 1896, just gave a passing reference to the presence of "marls" in the 4th unit of his "Nummulitic series". It is regarded here as a formation and is named after its maximum development in the vicinity of Lora.

The formation is composed of Limestone & marls of light to pale grey colours weathering in light yellow and cream colours. The rocks are generally thinly bedded and show a distinct platy appearance.

The fossil assemblage shows the presence of *Assilina daviesi, Globigerina prolata* and *Globogerina yeguaensis,* showing a Lower Eocene age for the formation.

The formation may be correlated with the Sakesar Limestone and Bhadrar Beds of the Salt Range, Shekhan Limestone of Kohat and Passage Beds of Kalachitta and Potwar.

5. Kuldana Formation

WYNNE, 1874, identified and named these rocks as Kuldana beds after their occurrence near Kuldana. MIDDLEMISS, 1896, called them Kuldana series. The rocks are recognised as a distinct formation.

The formation consists of variegated shales of crimson and purplish colours apart from Khaki, buff to pale grey shales and marls. The red shales are generally gypsiferous and/or arenaceous.

The fauna includes *Assilina granulosa, Assilina spinosa* and *Assilina exponens,* showing a range from the top of the Lower Eocene to the base of Middle Eocene.

Similar rocks are recognised in Kohat as Mamikhel Clay and Purple and variegated clays in Kalachitta and Potwar.

g) Rawalpindi Group

The group is recognised and named RASHID et al., 1965, after its occurrence in the Rawalpindi area and consists of a) Murree Formation and b) the Kamlial Formation. In the area under study only the Murree Formation is recognised.

1. Murree Formation

The rocks were first distinguished and mapped in the neighbourhood of Murree and named as Murree series by WYNNE, 1874. MIDDLESMISS included them in his "Murree beds". The formation consists of greyish green sandstones, weathering purplish, intercalated with purple coloured arenaceous shales. The basal beds contain reworked fossils.

The age of the formation as established by earlier workers is Lower Miocene.

The basal beds with reworked Foraminiferida and the overlying sandstones and shales have been recognised in Potwar, Kohat and Poonch in Kashmir and are known as Fatehjang zone and Murree sandstone & shale respectively.

h) Havelian Group

The river channels in the area are occupied by a variety of materials, loose or indurated, medium grained silt and clays to large sized boulders and cobbles. These rocks have together been provisionally identified as a group and named after their maximum development in the region of Havelian. The group may be subdivided into various formations, provisionally, composed of a) Gravels, b) Loess, c) Clays and Silts, d) Older alluvium and e) the Recent alluvium.

No fossil evidence is available. It is however suggested that the group may range from Middle Pleistocene to Recent.

The rocks may partly be correlated with the Lei Conglomerate and Loesic silt of northern Potwar as described by Gill, 1952.

7. Comparison of unit names used by different Workers

Verchere 1866—67	Waagen & Wynne 1872—79	Middlemiss 1896	Marks & Mohammad Ali 1961—62	Gardezi & Ghazanfar 1965	Latif 1969
					Havelian Group
					Rawalpindi Group
	Murree series	Murree beds			Murree Formation
					Galis Group
	Kuldana beds	Kuldana series			Kuldana Formation
Nummulitic Limestone	Nummulitic Formation	Nummulitic series			Lora Formation
		Shales, Marls, Lst., Coal & Variegated Sst.			Margala Hill Lst. Kuzagali Shale Mari Limestone
					Hothla Group
	Thin bedded Limestone	Grey Limestone			Chanali Limestone
Jurassic	Giumal Sst?	Giumal Sst.			Giumal Sandstone
	Spiti Shale	Spiti Shale			Spiti Shale
Carboniferous Limestone	Triassic Series	Triassic Series	Triassic System		Thandiani Group
		Trias Lst.			Sikhar Limestone
			Upper Fmn.	Maira Fmn.	Maira Formation
	Below the Trias			Abbottabad Group	Abbottabad Group
				Hazira Fmn.	Hazira Fmn. } Tarnawai Group?
Volcanic	3rd division	Volcanic etc.	Lower Fmn.	Haematite Fmn.	Galdanian Fmn. } Tarnawai Group?
		Infra-Trias Series	Abbottabad Formation	Abbottabad Formation	
	Upper Div.	Upper Lst.	Upper Fmn.		Sirban Formation
	Lower Div.	Lower Sst. & shale.			Kakul Formation
			Lower Formation		Mirpur Mbr. Mahmdagali Mbr. Sangargali Mbr.
		Tanakki Congl.			Tanakki Mbr.
	Tanol series	Tanol series	Tanol Fmn.		Tanol Formation
	Attock Slates	Slate Series	Hazara Slate Formation		Hazara Group
					Upper Formation
					Langrial Limestone
					Middle-Formation
					Miranjani Limestone
					Lower Formation

Abbreviations: Fmn. = Formation, Mbr. = Member, Lst. = Limestone and Sst. = Sandstone.

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GEOLOGICAL MAP OF S.E. HAZARA

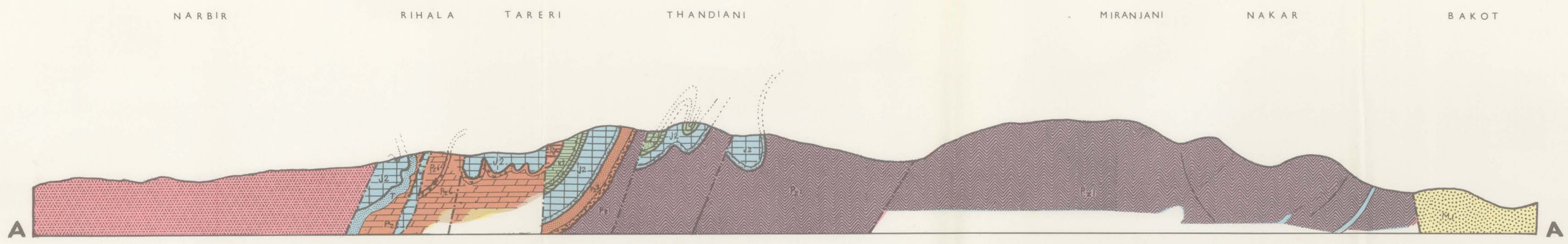
AND PARTS OF THE ADJOINING DISTRICTS OF RAWALPINDI & MUZAFFARABAD

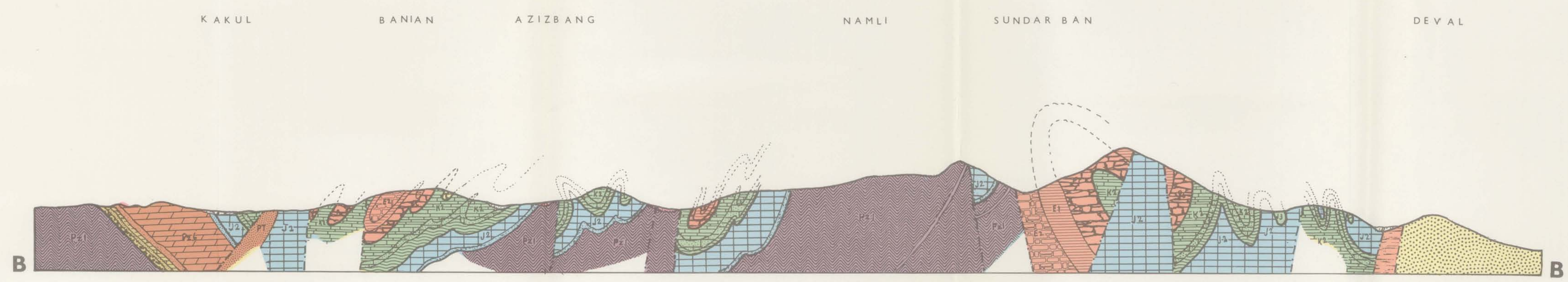
SCALE $\frac{1}{63360}$ OR 1 INCH TO 1 MILE

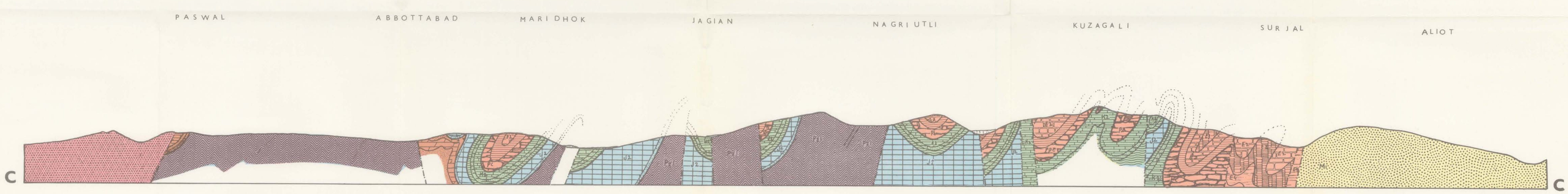
BY: M. A. LATIF.

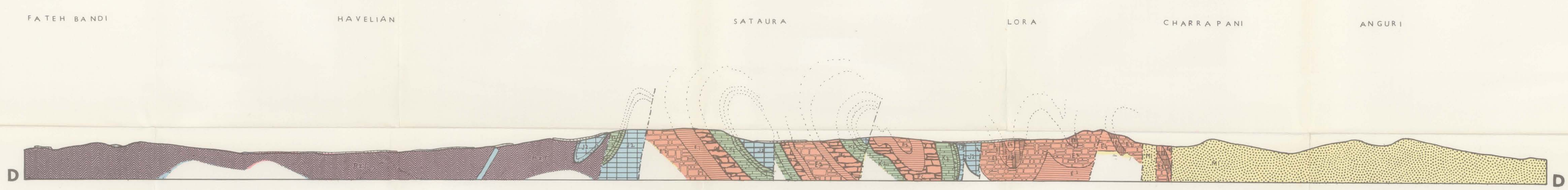
SEPTEMBER 1968

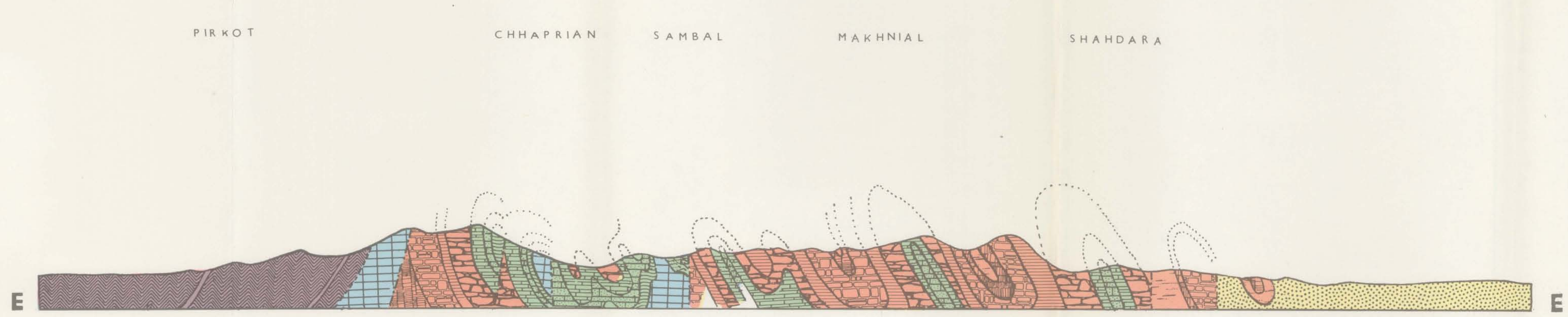
1 0 1 2 3 MILES

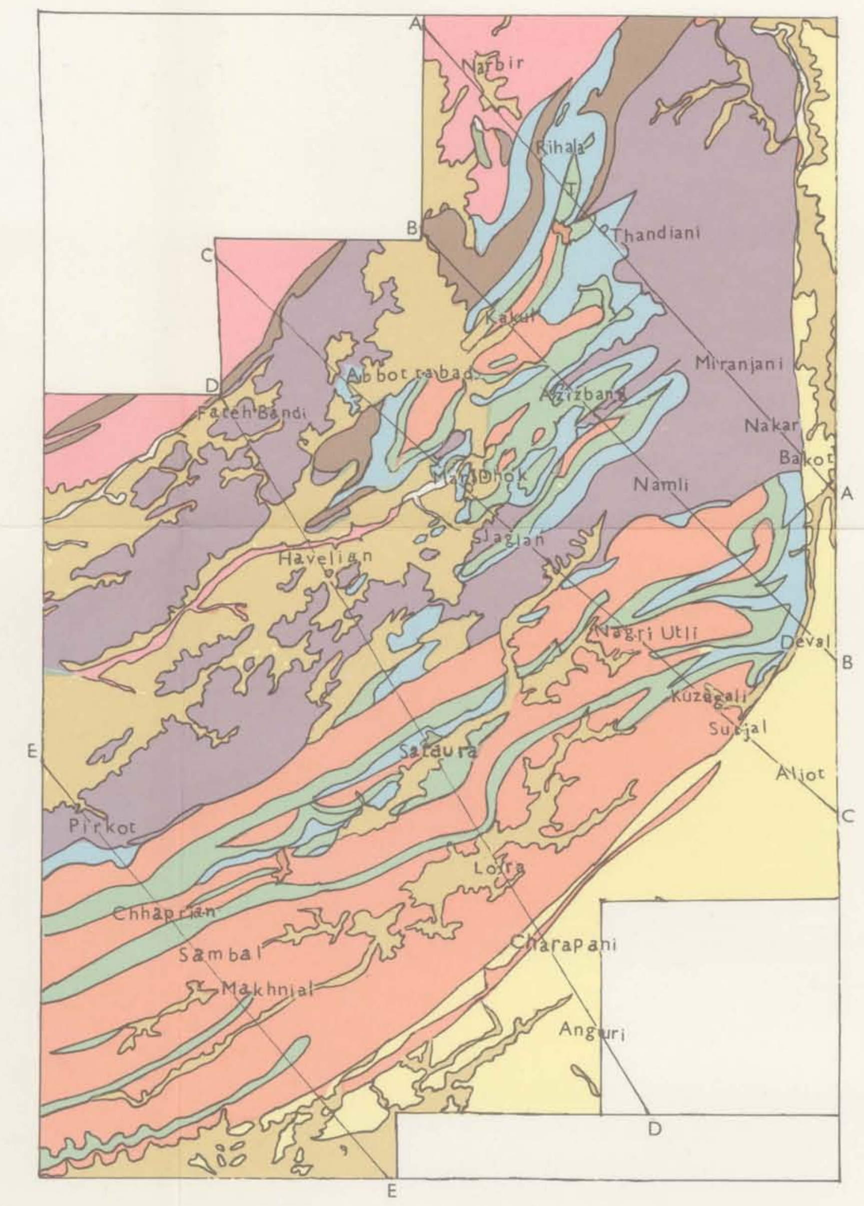












VERTICAL SECTIONS OF THE GEOLOGICAL MAP OF S. E. HAZARA ALONG LINES A-A, B-B, C-C, D-D & E-E.

BY: M.A. LATIF.

SEPTEMBER 1968

FOR LFGEND & EXPLANATION SEE THE GEOLOGICAL MAP OF S.E. HAZARA.

HORIZONTAL SCALE
1 INCH TO 1 MILE

1 0 1 2 3 MILES

VERTICAL SCALE
1 INCH TO 5000 Ft

5,000 0 5,000 10,000 15,000 FEET

Jb. Geol. B. A.	Sonderband 15	S. 21—23	Wien, Februar 1970

The Significance of Hazara to Himalayan Geology

By Gerhard Fuchs

The publication of the map of SE-Hazara by M. A. Latif is, though the explanatory text had to be rather brief, a valuable contribution to the geology of the Himalayan region. Hazara is one of the few well-known areas in the Himalayas, since the geological investigations started as early as of the second half of the last century.

M. A. Latif restudied the area with special interest in the investigation of the sedimentary sequence. For the reader who is not familiar with the most recent work of Pakistan geologists, comparison with other regions could be difficult. Following the Stratigraphic Code of Pakistan 1967 many new, formal names are introduced instead of old, well-known, but informal terms. We should therefore like to make some remarks on M. A. Latif's paper on the basis of our experience in other parts of the Himalayas.

Situated W of the North-West-Himalaya Syntaxis (Wadia, 1931) Hazara is in the neighbourhood of the Salt Range, Kashmir, and of the Lower Himalayas of the region SE of the syntaxis. This seems to be responsible for its unique sedimentary development. It is well-known that the succession of the Lower Himalayas is very poor in fossils, in contrast to the wealth of the palaeontological record in the Tibetan Zone, N of the Great Himalayan Range. Therefore we concluded that the trough of the Lower Himalayas was separated from the sea by a ridge (G. Fuchs, 1967). In Kashmir a fossiliferous Palaeozoic to Mesozoic succession comparable to that of the Tibetan Zone (e. g. Spiti), but containing some peculiarities of facies is found on that ridge.

In Hazara sedimentation seems to have been related closely to the Lower Himalayan basin throughout the Palaeozoic. From the highest part of the Triassic onwards the rocks of Hazara resemble those of the Tibetan Zone. Apparently there are more similarities between the Hazara rocks and those of Spiti than those of Kashmir.

The Hazara succession commences with the Hazara Group (former "Hazara Slates"), which corresponds to the Dogra Slates and the Simla Slates, all thick slate complexes of geosynclinal character.

The break in sedimentation between the Hazara Group and the following Abbottabad Group, stressed by Latif and other writers, seems to correspond to the unconformities found in the Palaeozoics of Kashmir (Wadia, 1934, p. 144—146) and the Salt Range. In the Lower Himalayas this break is represented by only a change in the conditions of deposition. The Abbottabad Group (former "Infra Trias", Middlemiss, 1896) apparently shows so many similarities to the Nagthat-Blaini-Krol (Shali) succession that we cannot doubt their equivalence. Even though it was shown by MARKS and MUHAMAD ALI (1961) that the Tanakki Boulder Bed was not a tillite, the author favours an Upper Palaeozoic age for the Abbottabad Group, a conclusion, which is not ruled out by the above observation *). In the lithologically equivalent Blainis glacial boulder beds are proved.

However, there is still dispute concerning the age of the successions and at present a definite statement cannot be given.

The stratigraphic significance of the Hazira Formation is another unsolved problem. Following GARDEZI and GHAZANFAR (1965) the Hazira Formation is still grouped as highest formation of the Abbottabad Group by LATIF. But this author suggests that in a later regrouping the Galdanian and Hazira Formations could form a separate group (Tarnawai Group). To me it seems reasonable to distinguish the flysch-like rocks of the Hazira Formation from the typical orthoquartzite-carbonate association represented by the underlying formations. However, the Galdanian and Hazira Formations may be of very different ages. Shale formations similar to the Hazira Formation are found in the Upper Triassic (Noric) of the Tibetan Zone (Kuti Shales, Tarap Shales). As shown by the map of LATIF the Hazira Formation is found in the N only, therefore the author suggests the possibility of a different interpretation. The sea which transgressed southern Hazara in the Jurassic could have reached the northern parts of Hazara already in the Upper Triassic.

There is not much doubt about the correspondence of the Maira Formation to the Quartzite Series, and the Sikhar Limestone to the Kioto Limestone. As these formations are represented in Hazara, Kashmir, and throughout the Tibetan Zone in the same development, they reflect rather uniform conditions in uppermost Triassic to Lower Dogger times. But it is not quite certain, that these rock units are of precisely the same age everywhere. It is interesting that gradations were observed from the marine Tarap Shales deposited in deeper water to the shallow-water deposits of the Quartzite Series (G. FUCHS, 1967). This means a shallowing of the Tethys sea. So the quartzitic beds reflecting transgression in southern Hazara indicate regression in the Tethys.

The Hothla Group with Spiti Shale, Giumal Sandstone and Chanali Limestone corresponds to the development of the Jurassic-Cretaceous in Spiti (HAYDEN, 1904), the Chanali Limestone probably being equivalent to the Chikkim Series.

LATIF has subdivided the Tertiary rocks by micropalaeontological means. He found a break in sedimentation below the Galis Group. E of Hazara the gap between the Tal Series and the Eocene Subathus seems to correspond to this unconformity.

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*) In a joint excursion Dr. M. A. LATIF and the author found striated and faceted boulders in the Tanakki Boulder Bed of Hazara. Thus the glacial origin is without doubt.

The break at the base of the Rawalpindi Group corresponds to the unconformity between Subathus and Dagshai. The latter resembles the Murree Formation of Hazara.

This brief review shows the importance of Hazara for the understanding of all the Himalayas. In the sedimentary record of Hazara we find the influence of different facies provinces. In consequence the palaeogeography of the area Kashmir-Hazara-Salt Range is apparently rather complicated. A better knowledge of the palaeogeography of this area is, however, essential for better understanding of the geology of all the Lower Himalayas. The work done by LATIF is an important step in that direction.

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Jb. Geol. B. A.	Sonderband 15	S. 25—61	Wien, Februar 1970

Micropalaeontology of the Chanali Limestone, Upper Cretaceous, of Hazara, West Pakistan

With 2 text figures and 8 plates

By Mir Abdul Latif

Departement of Geology, University of the Panjab, Lahore, West-Pakistan

Abstract

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

Introduction

The rocks under study are mainly spread over the district of Hazara and partly the Rawalpindi district of West Pakistan and Muzzaffarabad district of Kashmir. The area lies between longitude 73.00 to 73.30 east and latitude 33.43 to 34.20 north, fully covering the Survey of Pakistan sheets, 43 F/4, 43 F/8, 43 G/1, and 43 G/5 and partly 43 F/7 and 43 G/2, an area of about 1000 square miles, see Fig. 1. For the purposes of mapping within the area and correlation outside, a detailed study of the Geology and Micropalaeontology of the rock sequence of doubtful age lying above the Giumal Sandstone and at the base of the Eocene rocks, was considered a necessity. While the geological investigations were carried out in the whole area, the Changla Gali section, 43 G/5, 442949, was selected for the micropalaeontological studies, because of the relatively soft nature of the limestones in it's vicinty. The section is situated on the Murree-Abbottabad road, 10 miles north of Murree and five hundred feet south of the Changla Gali Police Station.

Acknowledgements

The studies were partly carried out at the Post Graduate Training Center for Geology, Vienna, Austria, jointly sponsored by the Government of the Republic of Austria, UNESCO and OAS and were made possible through the permission and duty leave granted by the Government of Pakistan and the University of the Panjab, Lahore, respectively.

The author is thankful to Prof. H. Küpper for his encouragement; to Dr. M. Schmid, Dr. R. Oberhauser and Dr. K. Kollmann, for their help in the faunal identifications; to Dr. G. Fuchs for his usefull suggestions on

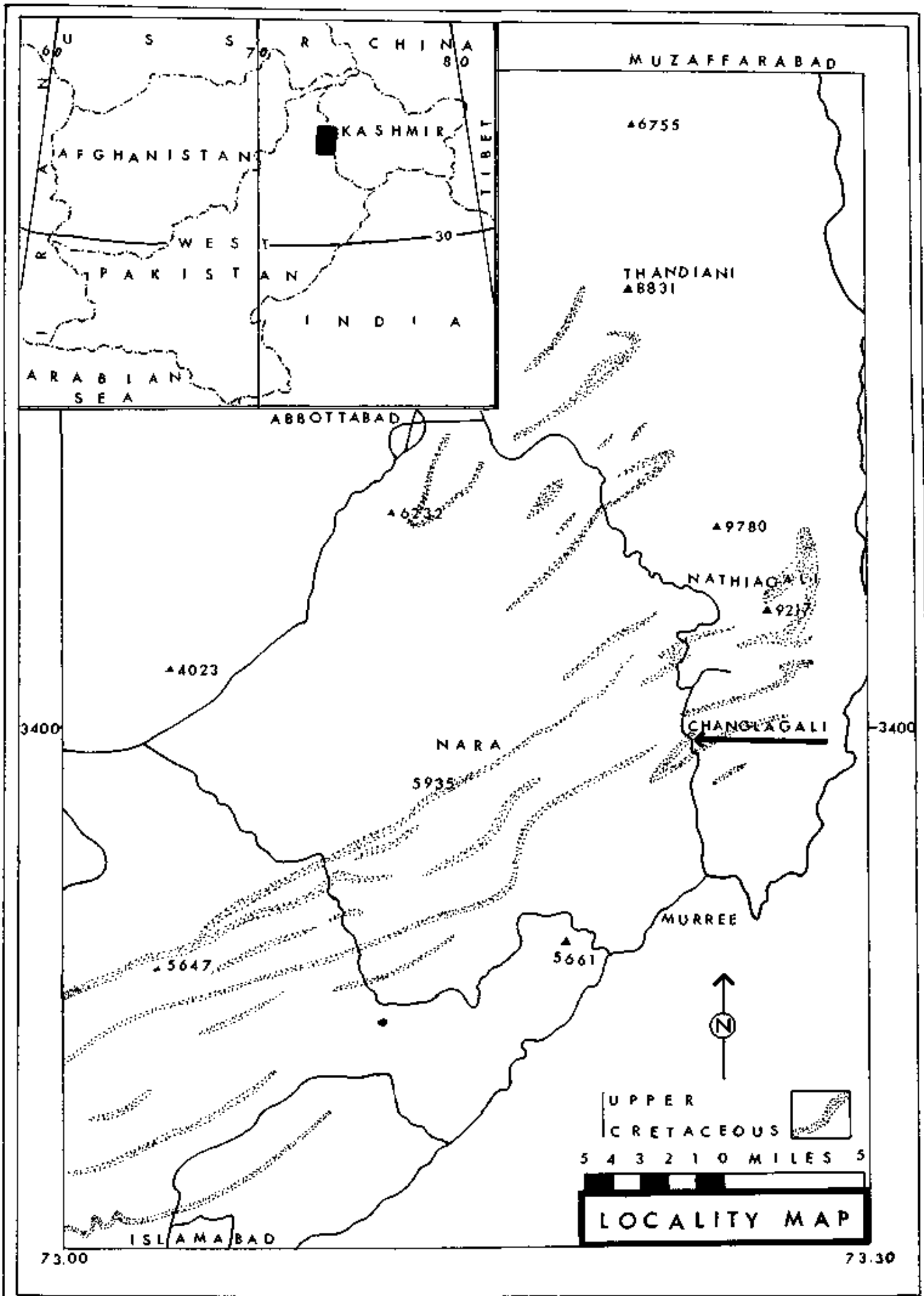
U S S R
CHINA
KASHMIR
TIBET
AFGHANISTAN
WEST PAKISTAN
INDIA
ARABIAN SEA
60
70
80
30
MUZAFFARABAD
ABBOTTABAD
6755
THANDIANI
8831
6232
9780
NATHIAGALI
9217
4023
3400
NARA
5935
CHANGLAGALI
MURREE
5661
5647
N
UPPER CRETACEOUS
5 4 3 2 1 0 MILES 5
LOCALITY MAP
ISLAMABAD
73.00
73.30

FIG. NO. 1

the stratigraphic part of the text and Dr. H. PLACHY for his helpful criticism.

Previous work

The first reference to the Geology of Hazara was made by Verchere 1866—67. In his paper, he gave a rough description of the north eastern end of Mount Sirban, rising east and south east of Abbottabad and identifying rocks from Carboniferous to Eocene. There was however no reference to the presence of the Upper Cretaceous rocks in the area.

WAAGEN and WYNNE, 1872, recognised the following succession:

6. Nummulitic
   Thick limestone with some shales, fossils in places.
5. Cretaceous
   b) Thin bedded limestone without fossils, apparently.
   a) Impure ferruginous, sandy, rusty weathering, with fossils.
4. Jurassic
   Black Spiti Shales
3. Triassic
   Thin bedded limestone and slaty shales, dolomite, limestone, fossiliferous beds.
2. Below the Trias
   Haematite, dolomite, quartzite, sandstone and breccia.

——————————— unconformity ———————————

1. Semi-crystalline
   Attock (?) Slate.

In the lower 10 to 20 feet part of the Cretaceous succession they described the rusty and orange coloured beds containing some Cretaceous fossils, followed by a group of thin bedded limestones, of grey colour with even bedding planes, but apparently without any organic remains, belonging either to the Cretaceous or the Nummulitic rocks. From their absence in other places at the base of the later formation, they considered it more likely to be a member of the former. Further on they found a probable correlation of these rocks together with the Giumal Sandstone and Chikkim Limestone and Shales together, of the Spiti area of Himalayas.

MIDDLEMISS, 1896, described the lower part as a slightly sandy limestone of bright orange colour, rarely grey, massive dotted all over with black cherty and ferruginous patches containing fossils, and considered them of Cenomanian age; followed by a series of well bedded limestones, 300 to 400 feet in thickness, of pale neutral grey colour weathering white. He described these limestones of very well and rather compact amorphous structure. There is a complete absence of fossils, except some extremely minute organisms, probably foraminifera. In the absence of proof, he prefered to place the grey limestones with the Tertiary, as the lowest bed of Nummulitic Series.

Recent Work

Between 1896 and 1959, there has been no work of any significance related to the above mentioned succession of rocks. During the recent remapping of Hazara, the author, 1962, recorded presence of limestones of Upper Cretaceous age, above the Giumal Sandstone of Lower Cretaceous age and below the Tertiary rocks. The following succession has been recognised in the Middle and Upper Mesozoic: —

Galis Group

——————— unconformity ———————

Chanali Limestone	Upper Cretaceous
Giumal Sandstone	Lower Cretaceous
Spiti Shale	Upper Jurassic

——————— unconformity ———————

Sikhar Limestone (Triassic of Middlemiss)	Middle Jurassic
Maira Formation	Lower Jurassic

——————— unconformity ———————

Abbottabad Group

More detailed studies of the said limestones reveal the following facts:

a) The limestones are a distinct mappable lithostratigraphic unit, easily distinguished from the underlying Giumal Sandstone separated by an orange yellow arenaceous limestone marker bed and the overlying *Nummulite* bearing dark grey limestones and shales, separated by a break in deposition as marked by a laterite bed.

b) They are widley distributed in the area, with exposures, occasionally up to 38 miles apart e. g. Saidpur, 43 G/2, 130636, and Sangar Gali, 43 F/8, 222770.

c) They contain a definite Upper Cretaceous microfauna, as against the Lower Cretaceous and Paleocene of the underlying and overlying formations respectively.

d) They show a development of over 700 feet near Chanali, 43 G/5, 334870.

On the basis of the facts noted above a new formation, namely the Chanali limestone is established for the rocks henceforth known as grey limestones.

Lithology of the Chanali Limestone

With a rapid increase in the calcareous content, the underlying Giumal Sandstone passes upwards into an arenaceous limestone, 5 to 25 feet thick, of bright orange colour and rich in oysters which conspicuously stand above their weathered surfaces. This bed serves as a marker between the Giumal Sandstone below and the limestones under study above.

There is a rapid increase in the argillaceous and calcareous content of the rocks which occasionally show pale and green dolomitic patches in a pale grey background with the occasional presence of oolites as seen near Bokan, 43 G/1, 105766. They are followed by thinly bedded fine grained limestone, with marly intercalations of few inches thickness. The limestones are light grey in colour, very fine grained and break with a conchoidal fracture. The weathered surfaces are conspicuously pale, cream grey and white. The platy habbit of these limestones is well developed in the type area near Chanali and Danna Nuralan, 43 G/1, 243877. The south eastern exposures in the area are softer marly limestones followed towards the middle of the area by thinly bedded to thickly bedded and in the north west by thickly to thinly bedded. The thickness of the limestones varies from 150 feet in the south east to over 700 feet in the middle of the area. The weathered surfaces of the limestones sometimes show some echinoid remains.

Correlation of the Chanali Limestone

The pre-Chanali Limestone formations, the Spiti Shale and Giumal Sandstone of Hazara may be compared in Kohat, with the Chichali formation and Lumshiwal Sandstone, comprising respectively of 60 feet of rusty brown to dark green soft friable glauconitic and ferruginous sandstones and shales and 640 feet of hard quartzitic, glauconitic, ferruginous and calcareous sandstones. A similar sequence of rocks has been identified in Kala Chitta. In trans Indus parts of Salt range, a thick succession of brown, yellow, grey sandstones, gypseous clays and marls has been recognized as equivalent to the above sequence. The sequence of rocks in Spiti area seems to be quite identical to that of Hazara.

The overlying Chanali limestone of Hazara is represented by almost identical limestones in Kohat, Samana area and is of 370 feet thickness. A sequence of 150 to 230 feet thick, brownish, yellowish, light blue calcareous shale and sandstone ranging from Albian to Upper Cretaceous is represented in Kala Chitta. There is no record of the presence of such rocks in the Salt Range though it is interesting to note that according to KRISHNAN, 1960, "RAO has recorded the foraminifera *Globotruncana rosetta* of Maestrichtian age from limestone band of Nammal gorge". In Spiti, the Giumal series is followed by a sequence of 250 to 300 feet of grey or whitish limestones and calcareous, sandy, grey and green shales of Upper Cretaceous age, collectively known as Chikkim series.

Micropalaeontology and age of the Chanali Limestone

The microfaunal study of the above limestones is based on 5 rock samples, evenly distributed over a thickness of 150 feet and have been collected from Changla Gali, 43 G/5, 442949, area of Hazara. They reveal

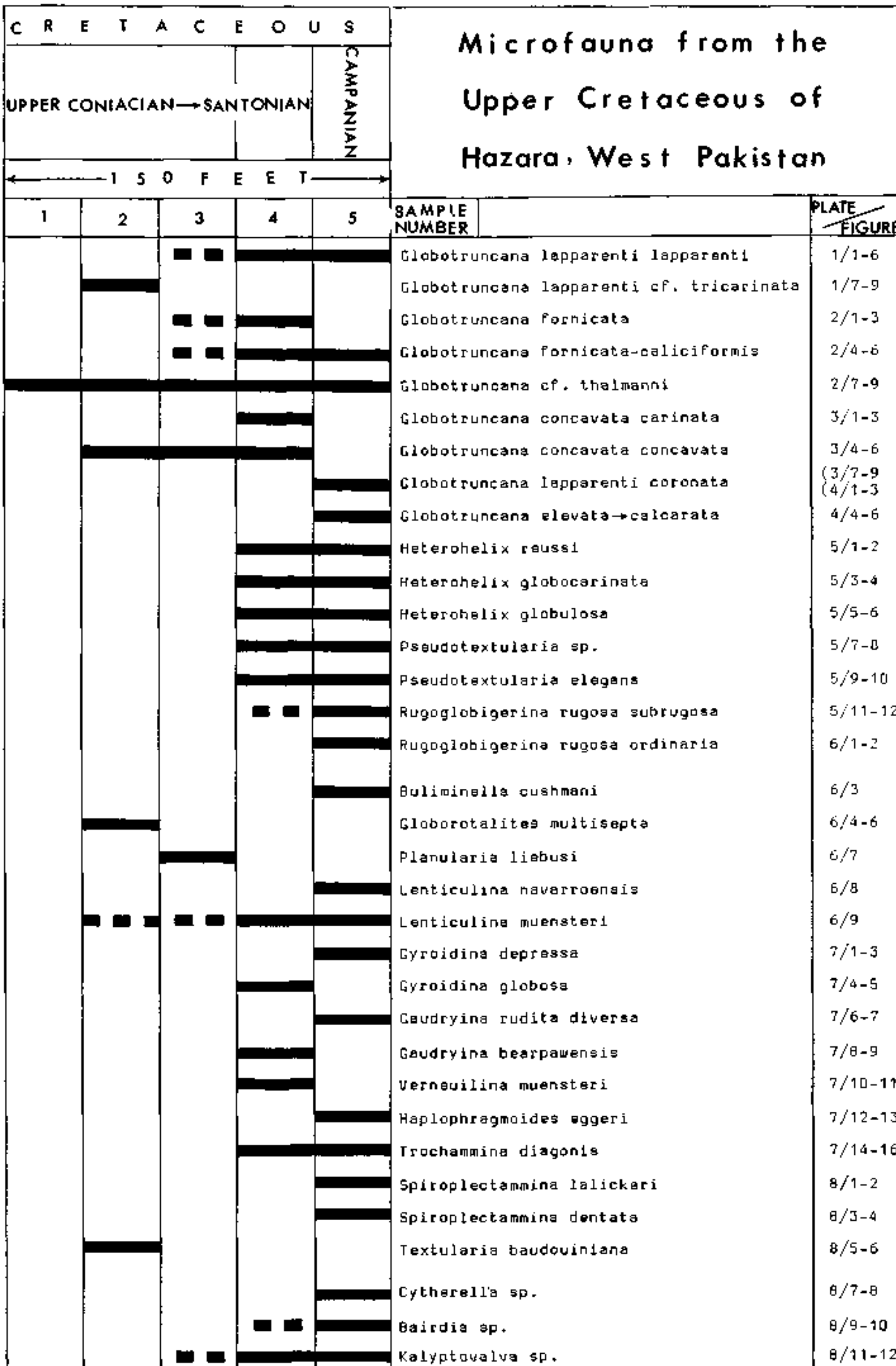
C R E T A C E O U S
UPPER CONIACIAN→SANTONIAN
CAMPANIAN
←150 FEET→
1
2
3
4
5
Microfauna from the Upper Cretaceous of Hazara, West Pakistan
SAMPLE NUMBER
PLATE / FIGURE
Globotruncana lapparenti lapparenti 1/1-6
Globotruncana lapparenti cf. tricarinata 1/7-9
Globotruncana fornicata 2/1-3
Globotruncana fornicata-caliciformis 2/4-6
Globotruncana cf. thalmanni 2/7-9
Globotruncana concavata carinata 3/1-3
Globotruncana concavata concavata 3/4-6
Globotruncana lapparenti coronata (3/7-9 (4/1-3
Globotruncana elevata→calcarata 4/4-6
Heterohelix reussi 5/1-2
Heterohelix globocarinata 5/3-4
Heterohelix globulosa 5/5-6
Pseudotextularia sp. 5/7-8
Pseudotextularia elegans 5/9-10
Rugoglobigerina rugosa subrugosa 5/11-12
Rugoglobigerina rugosa ordinaria 6/1-2
Buliminella cushmani 6/3
Globorotalites multisepta 6/4-6
Planularia liebusi 6/7
Lenticulina navarroensis 6/8
Lenticulina muensteri 6/9
Gyroidina depressa 7/1-3
Gyroidina globosa 7/4-5
Gaudryina rudita diversa 7/6-7
Gaudryina bearpawensis 7/8-9
Verneuilina muensteri 7/10-11
Haplophragmoides eggeri 7/12-13
Trochammina diagonis 7/14-16
Spiroplectammina lalickeri 8/1-2
Spiroplectammina dentata 8/3-4
Textularia baudouiniana 8/5-6
Cytherella sp. 8/7-8
Bairdia sp. 8/9-10
Kalyptovalva sp. 8/11-12

FIG. NO. 2

the presence of more than 30 species of microfauna recorded from this area for the first time. Though the preservation of the material was not good, it was found possible to compare them with the microfaunal assemblages from Europe and America, most particularly from Austria.

Globotruncana concavata is restricted from Upper Coniacian to Santonian in other areas. In the present study it ranges from sample No. 2 to 4. As such sample No. 2 is recognized as Upper Coniacian and No. 4 as Upper Santonian. The sample No. 1 is poorly represented in fauna and is arbitrarily placed at the base of Upper Coniacian till a definite evidence of its age is available, thereby settling the lower boundary for the time being. No species of *Globotruncana calcarata*, which in other areas is restricted to Upper Campanian, could be found in the section under study. Only intermediate forms between *Globotruncana elevata* and *Globotruncana calcarata*, showing spinal extension of one of the chambers has been recorded from sample No. 5 and is considered to be of Lower / Middle Campanian age, as the *Globotruncana elevata* is abundant in Lower Campanian, thereby settling the Upper boundary of the section under study. *Heterohelix reussi* and *Heterohelix globocarinata* range in other areas from Middle Coniacian to Middle Campanian and Upper Santonian to Lower Maestrichtian respectively. In this section they range from sample No. 4 to 5 and are considered to be from the overlap in their ranges in other areas, i. e. Santonian to Middle Campanian, confirming the above age derived with the help of the species of *Globotruncana*.

A further confirmation is provided by the species of *Rugoglobigerina subrugosa* and *Rugoglobigerina ordinaria* found from sample Nos. 4 to 5, and which in other areas range from Campanian to Lower and Middle Maestrichtian.

Though most of the benthonic Foraminiferida and Ostracoda have longer ranges, the recorded species have been found identical to those described from the Upper Cretaceous deposits of other European and American localities. The species of *Buliminella cushmani, Globorotalites multisepta, Planularia liebusi* and a few others have been found particularly useful.

The above discussion of the fauna from the Chanali Limestone of Hazara, shows a distinct Upper Coniacian to Lower Campanian age.

Systematic descriptions

Family *GLOBOTRUNCANIDAE* Brotzen, 1942

Genus *Globotruncana* Cushman, 1927

Globotruncana lapparenti lapparenti Brotzen

(Plate 1, Figures 1—6)

1944 *Globotruncana lapparenti lapparenti* nom. nov. H. Bolli, Ecolog. Geol. Helv. 37, p. 230, Fig. 1, Abb. 15, 16, pl. 9, Fig. 11.

1955 *Globotruncana mayaroensis* Bolli, R. Gandolfi, Bull. Amer. Pal. 36, p. 18, pl. 1, Fig. 2.

1957 *Globotruncana (Globotruncana)* cf. *lapparenti* BROTZEN, H. S. EDGELL, Micropal. 3, pl. 1, Fig. 2.
1962 *Globotruncana lapparenti* BROTZEN, D. HERM, Bayer. Akad. Wiss., mathem.-naturw. Kl., Abh., N. F. 104, p. 82—84, pl. 6, Fig. 2.
Globotruncana (Globotruncana) lapparenti linneiana D'ORBIGNY, E. A. PASSAGNO, Micropal. 8, p. 360, pl. 3, Fig. 7—9.
1963 *Globotruncana (Globotruncana) linneiana linneiana* (D'ORBIGNY), J. V. HINTE, Jb. Geol. B.-A., Sonderb. 8, p. 75, pl. 5, Fig. 1—2.
1966 *Globotruncana lapparenti lapparenti* BROTZEN, U. WILLE, Jb. Geol. B.-A. 106, p. 108—110, pl. 1, Fig. 1—13.

Periphery lobate, spiral side flat, umbilical side flat to slightly convex, bicarinate. Chambers rhomboid, 12—13, arranged in 2½ whorls, the 6 of the last whorl increase gradually in size. Suture curved to sinous, elevated. Umbilicus narrow.

Dimensions of the figured hypotype:

Larger diameter: 0.57 mm. and 0.66 mm.
Smaller diameter: 0.49 mm. and 0.56 mm.
Thickness: 0.16 mm. and 0.17 mm.

Sample No. of the figured hypotype: No. 5 and 4 respectively.
Stratigraphic range: Santonian to Campanian.

Globotruncana lapparenti cf. *tricarinata* (QUEREAU)

(Plate 1, Figures 7—9)

1936 *Globotruncana lapparenti* n. sp., F. BROTZEN, Sverig. Geol. Unders. Ser. C. 396, p. 175.
1944 *Globotruncana lapparenti tricarinata* (QUEREAU), H. BOLLI, Ecolog. Geol. Helv. 37, p. 232, Fig. 1, Abb. 19, 20, pl. 9, Fig. 13.
1957 *Globotruncana (Globotruncana) lapparenti* BROTZEN cf. *tricarinata* (QUEREAU), H. S. EDGELL, Micropal. 3, p. 113, pl. 3, Fig. 1—3.
1960 *Globotruncana lapparenti tricarinata* (QUEREAU), A. TOLLMANN, Jb. Geol. B.-A. 103, p. 193, pl. 21, Fig. 1.
1962 *Globotruncana tricarinata* (QUEREAU), D. HERM, Bayer. Akad. Wiss. mathem.-naturwiss. Kl., Abh., N. F. 104, p. 93, pl. 6, Fig. 4.
1963 *Globotruncana (Globotruncana) ventricosa* WHITE, J. V. HINTE, Jb. Geol. B.-A., Sonderb. 8, p. 86, pl. 7, Fig. 3.
1966 *Globotruncana lapparenti tricarinata* (QUEREAU), U. WILLE, Jb. Geol. B.-A. 106, p. 110, 111, pl. 2, Fig. 1—11.

Periphery lobate, spiral side flat to faintly convex, umbilical side convex, bicarinate with a third keel like edge on umbilical side. Chambers rhomboid, 10 to 11 arranged in 2 whorls, the 7 of the last whorl increase gradually in size. Sutures, curved elevated. Umbilicus wide, open.

Dimensions of the figured hypotype:

Larger diameter: 0.57 mm.
Smaller diameter: 0.44 mm.
Thickness: 0.16 mm.

Sample No. of the figured hypotype: No. 2.
Stratigraphic range: Upper Coniacian.

Globotruncana fornicata PLUMMER

(Plate 2, Figures 1—3)

1931 *Globotruncana fornicata* n. sp., H. PLUMMER, Univ. Texas Bull. 3101, p. 198, pl. 13, Fig. 4—6.
1955 *Globotruncana fornicata fornicata* PLUMMER, R. GANDOLFI, Bull. Amer. Pal. 36, p. 40, pl. 2, Fig. 2.
1957 *Globotruncana (Globotruncana) fornicata* PLUMMER, H. S. EDGELL, Micropal. 3, p. 112, pl. 3, Fig. 10—12.
1962 *Globotruncana fornicata* PLUMMER, D. HERM, Bayer. Akad. Wiss. mathem.-naturwiss. Kl., Abh., N. F. 104, p. 78, pl. 7, Fig. 2.
1966 U. WILLE, Jb. Geol. B.-A. 106, p. 105, 106, pl. 4, Fig. 1—9.

Periphery rounded, spiral side convex, umbilical side slightly convex, bicarinate, Chambers angular rhomboid, 12—13, arranged in 2½ whorls, the 5 of the last whorl increase gradually in size. Sutures elevated, curved on spiral side, curved to sinuous on the umbilical side. Umbilicus narrow.

Dimensions of the figured hypotype:

Larger diameter: 0.55 mm.
Smaller diameter: 0.50 mm.
Thickness: 0.25 mm.
Sample of the figured hypotype: No. 4.
Stratigraphic range: Sample No. 3—4, Upper Santonian.

Globotruncana fornicata PLUMMER — *caliciformis* (LAPPARENT)

(Plate 2, Figures 4—6)

Periphery rounded, spiral side convex, umbilical side slightly convex bicarinate. Chambers angular rhomboid, 13, arranged in 2½ whorls, the 5 of the last whorl increase gradually in size. Sutures curved elevated on spiral side, curved to sinuous on the umbilical side. Umbilicus, narrow, open.
Dimensions of the figured hypotype:
Larger diameter: 0.58 mm.
Smaller diameter: 0.54 mm.
Thickness: 0.27 mm.
Sample of the figured hypotype: No. 5.
Stratigraphic range: Sample No. 3, to 5, Santonian to Campanian.

Globotruncana cf. *thalmanni* GANDOLFI

(Plate 2, Figures 7—9)

1955 *Globotruncana thalmanni thalmanni* GANDOLFI, Bull. Amer. Pal. Vol. 36, No. 155, pp. 60—61, pl. 4, Figures 4 a—c.

Periphery rounded, spiral side convex, umbilical, slightly convex, unicarinate. Chambers crescentic, 10 to 11, arranged in about 2 whorls, the 4½ of the last whorl, increase rapidly in size. Sutures, elevated, curved on spiral side, curved to meandring on umbilical side. Umbilicus medium, open.

Dimensions of the figured hypotype:

Larger diameter: 0.69 mm.
Smaller diameter: 0.60 mm.
Thickness: 0.23 mm.
Sample of the figured hypotype: No. 5.
Stratigraphic range: Upper Coniacian to Lower Campanian.

Globotruncana cf. *concavata carinata* DALBIEZ

(Plate 3, Figures 1—3)

1955 *Globotruncana (Globotruncana) ventricosa carinata* DALBIEZ, p. 168, text fig. 8.

Periphery lobate, spiral side flat to slightly convex, umbilical side, convex, bicarinate (?). Chambers semicircular with a keeled edge on umbilical side, the last chamber being very large, and elliptical, 10, arranged in 2 whorls, the 6 of the last whorl increasing gradually in size, except the last very large chamber. Sutures depressed, keels elevated, radial. Umbilicus large, deep wide open.

Dimensions of the figured hypotype:

Larger diameter: 0.67 mm.
Smaller diameter: 0.53 mm.
Thickness: 0.37 mm.
Sample No. of figured hypotype: No. 4.
Stratigraphic range: Sample No. 4, Upper Santonian.

Globotruncana concavata concavata (BRÓTZEN)

(Plate 3, Figures 4—6)

1955 *Globotruncana (Globotruncana) ventricosa ventricosa* WHITE, DALBIEZ, p. 168, Figures 7 a—c.
1957 *Globotruncana concavata* (BROTZEN), BOLLI, p. 57, pl. 13. Figures 3 a—c.
1962 *Globotruncana concavata* (BROTZEN), D. HERM, p. 70, pl. 5, Fig. 4, Bayr. Paleont. Vol. 4, pt. 4, p. 569, pl. 71, Figures 4 a—c.

Periphery rounded to lobate, spiral side flat to convex, umbilical side convex, bicarinate. Chambers rhombic on spiral side, rounded on umbilical side, 13, arranged in 2 whorls, the 7 of the last, increase gradually in size. Sutures depressed, keels elevated, curved to radial. Umbilicus, deep, wide open.

Dimensions of the figured hypotype:

Larger diameter: 0.63 mm.
Smaller diameter: 0.57 mm.
Thickness: 0.33 mm.
Sample No. of figured hypotype: No. 4.
Stratigraphic range: Sample No. 2—4, Upper Coniacian to Santonian.

Globotruncana lapparenti coronata Bolli

(Plate 4, Figures 1—3)

1944 *Globotruncana lapparenti coronata* nom. nov. H. Bolli, Ecolog. Geol. Helv. 37, p. 233, Fig. Abb. 21, 22, pl. 9, Fig. 14—15.
1960 A. Tollmann, Jb. Geol. B.-A. 103, p. 194, pl. 21, Fig. 2.
1966 *Globotruncana lapparenti coronata* Bolli, 1944, U. Wille, Jb. Geol. B.-A. 106, p. 108, pl. 3, Fig. 1—10.

Periphery lobate, spiral side flat, umbilical side slightly convex bicarinate. Chambers, rhomboid, 11—13, arranged in 2¼ whorls, the 7 of the last whorl increase rapidly in size. Sutures curved, to sinuous, umbilicus, wide open.

Dimensions of the figured hypotype:

Larger diameter: 0.75 mm.
Smaller diameter: 0.67 mm.
Thickness: 0.16 mm.

Sample of the figured hypotype: No. 5.
Stratigraphic range: Lower Campanian.

Globotruncana elevata (Brotzen) — *calcarata* Cushman

(Plate 4, Figures 4—6)

Periphery lobate, spiral side flat, umbilical side convex, unicarinate. Chambers semicircular, except for the third but last chamber, which shows a spiral extension of the chamber. 11 chambers arranged in 2 whorls, the 6 of the last increase unevenly in size. Sutures depressed, curved to radial. Umbilicus narrow, open.

Dimensions of the figured hypotype:

Larger diameter: 0.83 mm.
Smaller diameter: 0.70 mm.
Thickness: 0.35 mm.

Sample of the figured hypotype: No. 5.
Stratigraphic range: Lower Campanian.

Genus *Rugoglobigerina* Brönnimann, 1952.

Rugoglobigerina rugosa subrugosa (Gandolfi 1955)

(Plate 5, Figures 11, 12)

1952 *Rugoglobigerina rugosa rugosa* (Plummer), Brönnimann, p. 28, Figs. 11, 12, 13.
1955 *Globotruncana (Rugoglobigerina) rugosa rugosa* (Plummer), Gandolfi. Bull. Amer. Pal. Vol. 36, p. 72, Fig. 6, a—c, text fig. 11 c.
1967 *Rugoglobigerina rugosa subrugosa*, Bandy, Micropal. Vol. 13, No. 1, p. 21, text figs. 10/2.

Periphery lobate. Chambers hemispherical, inflated, 10, arranged in two whorls, 4½ of last whorl, increase rapidly in size. Surface rugose.

Dimensions of the figured hypotype:

Larger diameter: 0.45 mm.
Smaller diameter: 0.36 mm.
Sample No. of the figured hypotype: No. 5.
Stratigraphic range: Upper Santonian to Lower Campanian.

Rugoglobigerina rugosa ordinaria (SUBBOTINA)

(Plate 6, Figures 1—2)

1953 *Globigerina rugosa ordinaria,* SUBBOTINA, Vses. Neft. Nauch. Isslad. Geol. Razved. Inst. Trudy., n. Ser., vypusk. 76.
1967 *Rugoglobigerina rugosa ordinaria* (SUBBOTINA), BANDY, Micropal. Vol. 13, No. 1, p. 21, text fig. 10/3.

Periphery lobate, Chambers hemispherical, 14, arranged in 2½ whorls, the 6 of the last whorl increase unevenly in size. Sutures depressed, surface rugose.

Dimensions of the figured hypotype:

Larger diameter: 0.56 mm.
Smaller diameter: 0.52 mm.
Sample of the figured hypotype: No. 5.
Stratigraphic range: Sample 4—5, Upper Santonian to Lower Campanian.

Family *HETEROHELICIDAE* CUSHMAN, 1927

Genus *Heterohelix* EHRENBERG, 1841

Heterohelix reussi (CUSHMAN)

(Plate 5, Figures 1—2)

1938 *Gümbelina reussi* CUSHMAN, Cush. Lab. Foram. Res. Contr. Vol. 14, p. 11, pl. 12, Figs. 6—9.
1942 CUSHMAN & DEADERICK, Cush. Lab. Foram. Res. Contr. Vol. 18, p. 63, Pl. 15, Figs. 5—7.
1944 CUSHMAN, Cush. Lab. Foram. Res. Contr. Vol. 20, p. 90, pl. 14, Fig. 2.
1946 CUSHMAN, U. S. G. S. Prof. Pap. 206, p. 104, pl. 44, Fig. 18—19.

Test biserial, Chambers hemispherical, gradually increasing in size, Aperture a crescentic arch at the base of last formed chamber.

Dimensions of the figured hypotype:

Length: 0.31 mm.
Breadth: 0.17 mm.
Thickness: 0.10 mm.

Sample of the figured hypotype: No. 5.
Stratigraphic range: Upper Santonian to Lower Campanian.

Remarks: The recorded form carries some features of *Heterohelix moremani* and may have developed from the later. It can be differentiated from *Heterohelix globulosa* by the lesser inflation of the chambers and the flat test.

Heterohelix globocarinata (CUSHMAN)

(Plate 5, Figures 3—4)

1938 *Gümbelina globocarinata* CUSHMAN, Cush. Lab. Foram. Res. Contr. Vol. 14, p. 10, pl. 2, Figs. 4—5.
1942 CUSHMAN & DEADERICK, Cush. Lab. Foram. Res. Contr. Vol. 18, p. 63.
1946 CUSHMAN, U. S. G. S. Surv. Prof. Pap. 206, p. 107, pl. 46, Figs. 8 a—b.

Test biserial, early portion flat later inflated, rapidly increasing in width, Chambers, globular rapidly increasing in size, the last two covering most of the test, more than half. The last chamber has a tendency to extend laterally. Aperture a crescentic arch.

Dimensions of the figured hypotype:

Length: 0.38 mm.
Breadth: 0.35 mm.
Thickness: 0.26 mm.

Sample No. of the figured hypotype: No. 5.
Stratigraphic range: Upper Santonian to Lower Campanian.

Remarks: The last two chambers cover more than ½ of the test and as such are easily distinguished from *Heterohelix reussi*. The lateral extension of the last chamber is not sufficient enough to place the form with *Pseudotextularia*.

Heterohelix globulosa (EHRENBERG)

(Plate 5, Figures 5—6)

1946 *Gümbelina globulosa* (EHRENBERG), CUSHMAN, U. S. G. S. Prof. pap. 206, p. 105, 106, pl. 45, Figs. 9—15.
1967 *Heterohelix globulosa* (EHRENBERG), BANDY, Micropal. Vol. 13, No. 1, p. 22—24, text fig. 10/3, 12/5.

Test biserial, Chambers globular, increasing rapidly in size. Aperture a low arch at the base of last chamber.

Dimensions of the figured hypotype:

Larger diameter: 0.35 mm.
Smaller diameter: 0.24 mm.
Thickness: 0.17 mm.

Sample No. of the figured hypotype: No. 5.
Stratigraphic range: Upper Santonian to Lower Campanian.

Genus *Pseudotextularia* Rzehak, 1891

Pseudotextularia sp.

(Plate 5, Figures 7—8)

Test biserial. Chambers rounded compressed laterally. Wall calcareous perforate, surface rough. A crescentic arch at the base of last chamber.

Dimensions of the figured specimen:

Length: 0.45 mm.
Breadth: 0.30 mm.
Thickness: 0.28 mm.
Sample of the figured specimen: No. 5.
Stratigraphic range: Upper Santonian to Lower Campanian.
Remarks: It differs from *P. elegans* in its much larger size, lesser lateral compression and absence of any surface ornamentation.

Pseudotextularia elegans (Rzehak)

(Plate 5, Figures 9—10)

1936 *Pseudotextularia elegans* Rzehak, M. F. Glaessner, Prob. of Palaeont. 1, p. 99, pl. 1, Figs. 1—2.
1966 *Pseudotextularia elegans* Rzehak, U. Wilλe, Jb. Geol. B.-A. 106, p. 120—121, pl. 8, Fig. 10.
1967 *Pseudotextularia elegans elegans* Rzehak, Bandy, Micropal. Vol. 13, No. 1, pp. 24—25, text fig. 12/12.

Test biserial. Chambers rounded in early stages, compressed laterally in later stages. Last two chambers show faint development of striations. Aperture a Crescentic arch.

Dimensions of the figured hypotype:

Length: 0.37 mm.
Breadth: 0.24 mm.
Thickness: 0.26 mm.
Sample No. of the figured hypotype: No. 4.
Stratigraphic range: Upper Santonian to Lower Campanian.

Family *TURRILINIDAE* Cushman, 1927

Genus *Buliminella* Cushman 1911

Buliminella cushmani Sandidge

(Plate 6, Figure 3)

1932 *Buliminella cushmani Sandidige,* Journ. Pal. Vol. 6, No. 3, p. 280, pl. 42, Figs. 18—19.
1946 Cushman, U. S. G. S. Prof. Pap. 206, p. 119, pl. 50, Fig. 15.
1964 Martin, Jb. Geol. B.-A., Sonderb. 9, p. 89, pl. 11, Figs. 13 a—b.

The test sharply acute at the initial end, rounded at the apertural end. The maximum width is towards the middle of the test. Chambers 4—5 to a whorl, slightly inflated in the last whorl. Sutures distinct depressed. Aperture at the base of last chamber.

Dimensions of the figured hypotype:

Larger diameter: 0.33 mm.
Smaller diameter: 0.20 mm.
Sample No. of the figured hypotype: No. 5.
Stratigraphic range: Lower Campanian.

Family *OSANGULARIIDAE* Loeblich and Tappan, 1964

Genus *Globorotalites* Brotzen 1942

Globorotalites multisepta (Brotzen)

(Plate 6, Figures 4—6)

1936 *Globorotalia multisepta* Brotzen, Sver. Geol. Under. Ser. C. No. 396, pp. 161—164, pl. 11, Figs. 7 a—c.

Test planoconvex, spiral side flat, umbilical side strongly convex, carinate. Chambers, 14—15, arranged in two whorls, the 7½ of the last whorl increase gradually in size. Last chamber partly enveloping the umbilicus. Suture depressed oblique on spiral side, radial to curved on the umbilical side. Aperture interiomarginal umbilical.

Dimensions of the figured hypotype:

Larger diameter: 0.26 mm.

Smaller diameter: 0.23 mm.

Thickness: 0.12 mm.

Sample of the figured hypotype: No. 2.

Stratigraphic range: Upper Coniacian.

Family *NODOSARIIDAE* Ehrenberg 1838

Genus *Planularia* Defrance 1826

Planularia liebusi Brotzen

(Plate 6, Figure 7)

1936 *Planularia liebusi* Brotzen, Sver. Geol. Under. Ser. C. No. 396, p. 60, 61, pl. 4. Figs. 6 a—b.

Pyriform with a distinct thick keel. Planispiral, much compressed, bilaterally symmetrical. Sutures elevated.

Dimensions of the figured hypotype:

Length: 0.58 mm.
Breadth: 0.35 mm.
Thickness: 0.14 mm.
Sample No. of the figured hypotype: No. 3.
Stratigraphic range: Sample 3, Lower Santonian.

Genus *Lenticulina* LAMARCK 1804

Lenticulina navarroensis extrauatus CUSHMAN

(Plate 6, Figure 8)

1946 *Robulus navarroensis* (PLUMMER), var. *extrauatus* CUSHMAN, U. S. G. S. Surv. Prof. Pap. 206, p. 52, pl. 17, Fig. 2.

Test planispiral, involute, periphery sharp, keeled. Chambers increase gradually in size. Sutures curved to radial fused into the test and visible only when wet. Surface not smooth. Aperture radial.

Dimensions of the figured hypotype:

Larger diameter: 0.87 mm.
Smaller diameter: 0.70 mm.
Sample No. of the figured hypotype: No. 5.
Stratigraphic range: Sample No. 5, Lower Campanian.

Lenticulina muensteri (RÖMER)

(Plate 6, Figure 9)

1932 *Robulus münsteri* RÖMER, CUSHMAN, Joun. Pal. Vol. 6, p. 334, pl. 50, Figs. 2 a—b.
1946 *Robulus münsteri,* RÖMER, CUSHMAN, U. S. G. S. Prof. Pap. 206, p. 53, pl. 17, Figs. 3 a—c.

Test planispiral, involute, periphery keeled. Chambers increase gradually in size. Sutures radial thick, ending in a central boss both fused with the test and visible only when wet. Surface not smooth. Aperture radial.

Dimensions of the figured hypotype:

Larger diameter: 0.60 mm.
Smaller diameter: 0.47 mm.
Sample No. of the figured hypotype: No. 5.
Stratigraphic range: Upper Coniacian to Lower Campanian.

Family *ALABAMINIDAE* HOFKER 1951

Genus *Gyroidina* D'ORBIGNY, 1826

Gyroidina depressa (ALTH)

(Plate 7, Figures 1—3)

1929 *Gyroidina depressa* (ALTH), CUSHMAN and CHURCH, Calif. Acad. Sci. Proc. 4th. Ser. Vol. 18, p. 515, pl. 41, Figs. 4—6.

Test compressed, spiral side nearly flat, umbilical side convex, periphery rounded. Chambers numerous, 10, in the last whorl. Sutures fused with the test to faintly depressed, radial to slightly curved. Wall smooth. Aperture interiomarginal umbilical.

Dimensions of the figured hypotype:

Larger diameter: 0.25 mm.
Smaller diameter: 0.23 mm.
Thickness: 0.11 mm.

Sample No. of the figured hypotype: No. 5.
Stratigraphic range: Sample No. 5, Lower Campanian.

Gyroidina globosa (HAGENOW)

(Plate 7, Figures 4, 5)

1931 *Gyroidina globosa* (HAGENOW), CUSHMAN, Journ. Pal. Vol. 5, p. 310, pl. 35, Figs. 19.
1946 CUSHMAN, U. S. G. S. Prof. Pap. 206, p. 140, pl. 58, Figs. 6—8.

Test trochoid, spiral side flat, umbilical side distinctly convex, periphery rounded. Chambers, 12—13 arranged in 2 whorls, the 6½ of the last increase gradually in size. Sutures fused with the test. Umbilicus very narrow. Aperture interiomarginal umbilical.

Dimensions of the figured hypotype:

Larger diameter: 0.28 mm.
Smaller diameter: 0.23 mm.
Thickness: 0.16 mm.

Sample No. of the figured hypotype: No. 4.
Stratigraphic range: Upper Santonian.

Family *ATAXOPHRAGMIIDAE* SCHWAGER, 1877

Genus *Gaudryina* D'ORBIGNY 1839

Gaudryina rudita diversa CUSHMAN and GOUDKOFF

(Pl. 7, Figures 6—7)

1944 *Gaudryina rudita* SANDIDGE var. *diversa* CUSHMAN and GOUDKOFF, Cush. Lab. Foram. Res. Contr. Vol. 20, pt. 3, p. 55, pl. 9, Fig. 6.
1964 MARTIN, Jb. Geol. B.-A., Sonderb. 9, p. 53, pl. 3, Figs. 5 a—b.

Test elongate, initial stage triserial, triangular in cross section, later biserial. Chambers gradually increasing in size, the last few slightly inflated. Sutures faintly depressed. Wall finely arenaceous. Aperture distinct at the base of last chamber.

Dimensions of the figured hypotype:

Length: 0.50 mm.
Breadth: 0.24 mm.
Thickness: 0.22 mm.

Sample No. of figured hypotype: No. 5.
Stratigraphic range: Lower Campanian.

Gaudryina bearpawensis WICKENDEN

(Plate 7, Figures 8—9)

1932 *Gaudryina bearpawensis* WICKENDEN, Roy. Soc. Canada, Trnas. 3d Ser. Vol. 26, Sec. 4, p. 88, pl. 1, Fig. 7.
1937 CUSHMAN, Cush. Lab. Foram. Res. Specl. Pub. 7, p. 44, pl. 7, Figs. 5—7.
1946 CUSHMAN, U. S. G. S. Prof. Pap. 206, p. 34, pl. 7, Figs. 20—22.

Early portion triserial, later biserial. Chambers globular. Sutures distinct, depressed.

Dimensions of the figured hypotype:

Larger diameter: 0.33 mm.
Smaller diameter: 0.24 mm.
Thickness: 0.20 mm.

Sample No. of the figured hypotype: No. 4.
Stratigraphic range: Sample No. 4, Upper Santonian.

Genus *Verneuilina* D'ORBIGNY 1839

Verneuilina muensteri REUSS

(Plate 7, Figures 10—11)

1937 *Verneuilina münsteri* REUSS, CUSHMAN, Cush. Lab. Foram. Res. Specl. Publ. No. 7, p. 9, pl. 1, Figs. 9—13.
1964 MARTIN, Jb. Geol. B.-A., Sonderb. 9, p. 51, 52, pl. 3, Figs. 1 a—b.

Test pyramidal with sharp angles, sides flat to slightly concave, Chambers distinct. Sutures not very distinct particularly in early stages. Wall finely arenaceous. Aperture a slit at the base of the last chamber.

Dimensions of the figured hypotype:

Larger diameter: 0.30 mm.
Smaller diameter: 0.24 mm.
Thickness: 0.19 mm.

Stratigraphic range: Sample No. 4, Upper Santonian.

Family *LITUOLIDAE*, D'BLAINVILLE 1825

Genus *Haplophragmoides* CUSHMAN, 1910

Haplophragmoides eggeri CUSHMAN

(Plate 7, Figure 12—13)

1943 *Haplophragmoides eggeri* CUSHMAN, CUSHMAN & TODD, Cush. Lab. Foram. Res. Contr. Vol. 19, p. 51, pl. 9, Fig. 2.
1946 CUSHMAN, U. S. G. S. Prof. Pap. 206, p. 20, pl. 2, Fig. 9—10.

Test rounded, Chambers increase gradually in size, Sutures faintly depressed. Wall coarsely arenaceous. Aperture an arch at the base of the last chamber.

Dimensions of the figured hypotype:

Larger diameter: 0.36 mm.
Smaller diameter: 0.31 mm.
Thickness: 0.22 mm.
Sample No. of the figured hypotype: No. 5.
Stratigraphic range: Lower Campanian.

Family *TROCHAMMINIDAE* SCHWAGER, 1877

Genus *Trochammina* PARKER and JONES, 1859

Trochammina diagonis (CARSEY)

(Plate 7, Figures 14—16)

1927 *Trochammina diagonis* (CARSEY), CUSHMAN and WATERS, Cush. Lab. Foram. Res. Contr. Vol. 2, pt. 4, p. 84, pl. 10, Fig. 7 a—c.
1946 CUSHMAN, U. S. G. S. Prof. Pap. 206, p. 49—50, pl. 15, Figs. 1—3.

Test trochoid, somewhat compressed, spiral side almost flat, umbilical side convex. 7 chambers of the last whorl increase gradually in size. Sutures depressed. Wall distinctly arenaceous. Aperture a narrow slit at the base of the last chamber.

Dimensions of the figured hypotype:

Larger diameter: 0.37 mm.
Smaller diameter: 0.31 mm.
Thickness: 0.11 mm.
Sample No. of the figured hypotype: No. 4.
Stratigraphic range: Sample No. 4 to 5, Upper Santonian to Lower Campanian.

Family *TEXTULARIIDAE* EHRENBERG 1838

Genus *Spiroplectammina* CUSHMAN 1927

Spiroplectammina lalickeri ALBRITTON and PHLEGER

(Plate 8, Figures 1—2)

1937 *Spiroplectammina lalickeri* ALBRITON and PHLEGER, Journ. Pal. Vol. 11, p. 353, Figs. 2—3.
1946 CUSHMAN, U. S. G. S. Prof. Pap. 206, p. 29, pl. 6, Figs. 28, 29.

Test elongate, flat, initial chambers planispiral, later biserial, Chambers gradually increasing in size. Sutures depressed. Wall arenaceous. Aperture at the base of the last formed chamber.

Dimensions of the figured hypotype:

Length: 0.80 mm.
Breadth: 0.29 mm.
Thickness: 0.16 mm.
Sample No. of the figured hypotype: No. 5.
Stratigraphic range: Sample No. 5, Lower Campanian.

Spiroplectammina dentata (ALTH)

(Plate 8, Figures 3—4)

1932 *Spiroplectammina dentata* (ALTH), CUSHMAN and JARVIS, U. S. Nat. Mus. Proc. Vo. 80, art. 14, p. 14, pl. 3, Figs. 7 a—b.
1946 CUSHMAN, U. S. G. S. Prof. Pap. 206, p. 27, pl. 5, Fig. 11.

Test much compressed, conical at the initial stages. Periphery sharp angular. Centre of the test raised into a ridge. Chambers many, increasing in width more than height. Sutures very faintly depressed to fused in the test to be noticed when wet. Wall finely arenaceous.

Dimensions of the figured hypotype:

Length: 0.60 mm.
Breadth: 0.37 mm.
Thickness: 0.18 mm.
Sample No. of the figured hypotype: No. 5.
Stratigraphic range: Lower Campanian.

Genus *Textularia* DEFRANCE, 1824

Textularia baudouiniana D'ORBIGNY

(Plate 8, Figures 5—6)

1839 *Textularia baudouiniana* D'ORBIGNY, Mem. Surles. foraminiferes.
1902 EGGER, Abh. d. 11/C. D. K. Akad. Wiss. XXI, Bd. 1, Alith. p. 24, pl. 2, Fig. 10—11.

Test conical, biserial, sutures indistinct apertural side flat. Aperture a slit at the base of the last chamber. Wall finely arenaceous.

Dimensions of the figured hypotype:

Length: 0.60 mm.
Breadth: 0.44 mm.
Thickness: 0.18 mm.
Sample No. of the figured hypotype: No. 2.
Stratigraphic range: Upper Coniacian.

OSTRACODA

Due to poor state of preservation of the Ostracods, occuring frequently in the above mentioned samples, it was not possible to find an exact determination. Any how the author thinks of the necessity to mention their presence. The following genera are suggested:

Cytherella	Plate 8, Figures 7—8
Bairdia	Plate 8, Figures 9—10
Kalyptovalva	Plate 8, Figures 11—12

It is for the first time that Ostracods are being reported from the section and it is hoped to specify them if a better preserved material is available.

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PLATE 1

1—6	*Globotruncana lapparenti lapparenti*
7—9	*Globotruncana lapparenti* cf. *tricarinata*

PLATE NO. 1 X 100

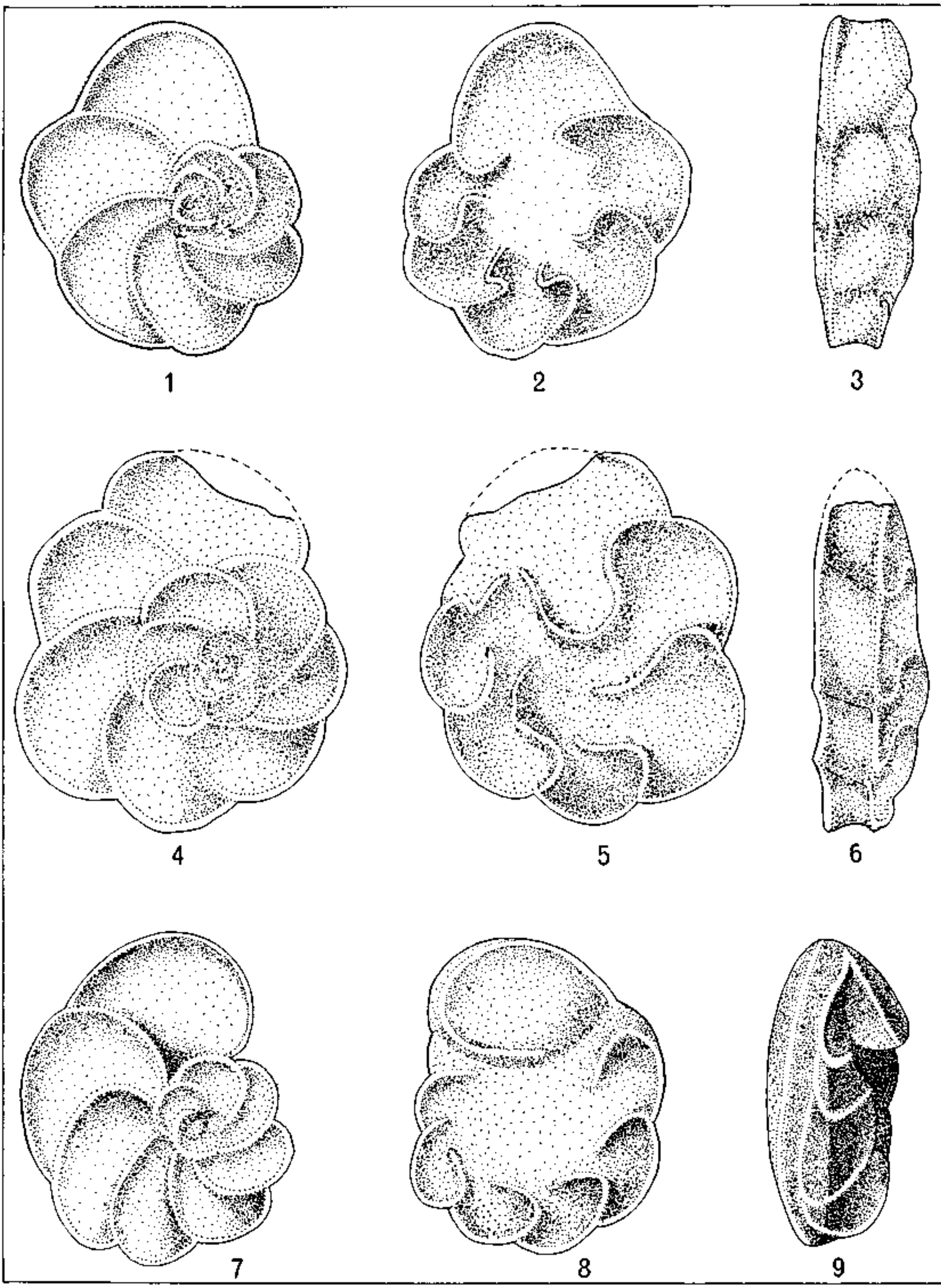


PLATE 2

1—3	*Globotruncana fornicata*
4—6	*Globotruncana fornicata-caliciformis*
7—9	*Globotruncana* cf. *thalmanni*

PLATE NO.2 X 100

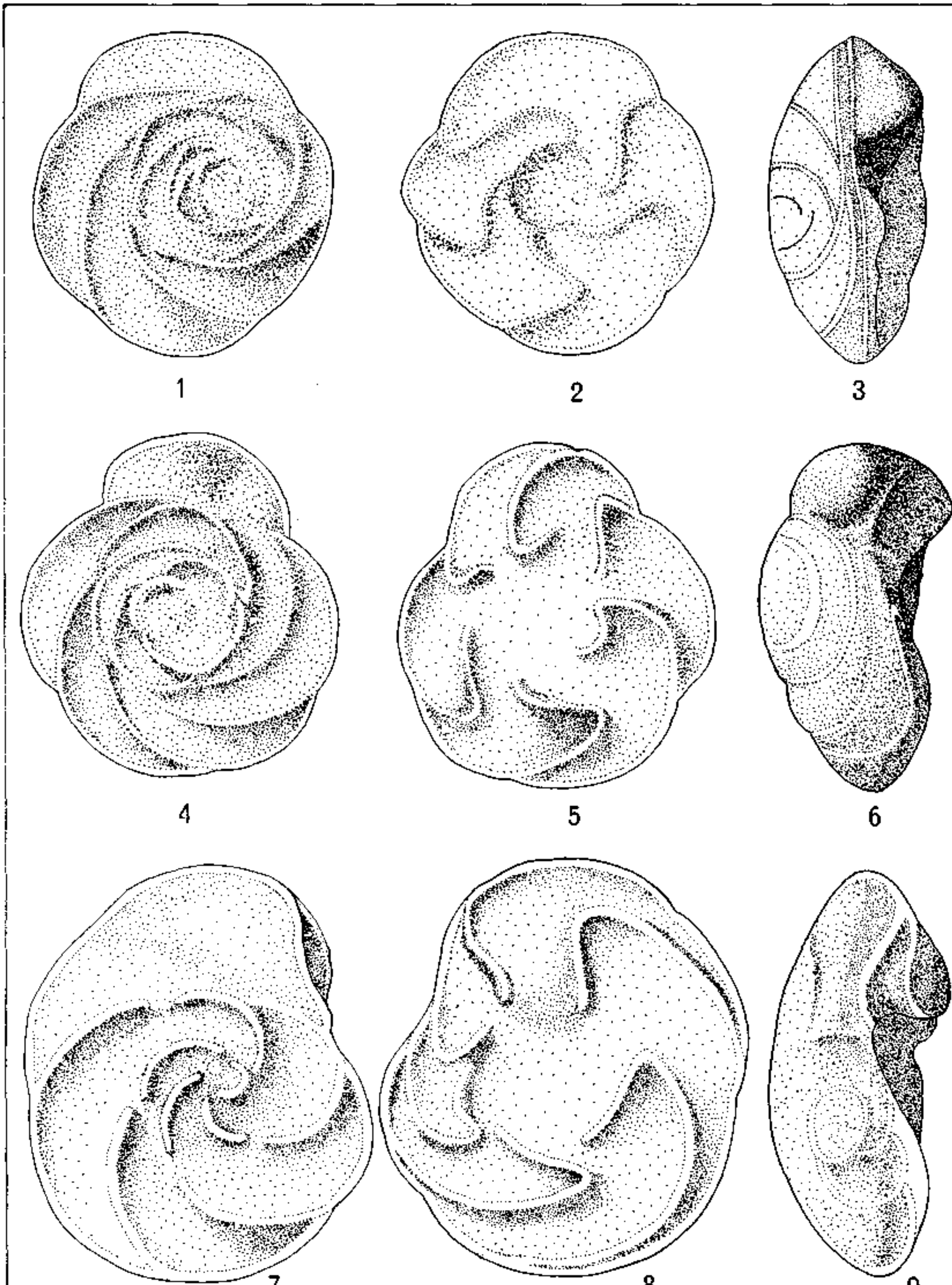


PLATE 3

1—3	*Globotruncana concavata carinata*
4—6	*Globotruncana concavata concavata*
7—9	*Globotruncana* cf. *lapparenti coronata*

PLATE NO.3 X 100

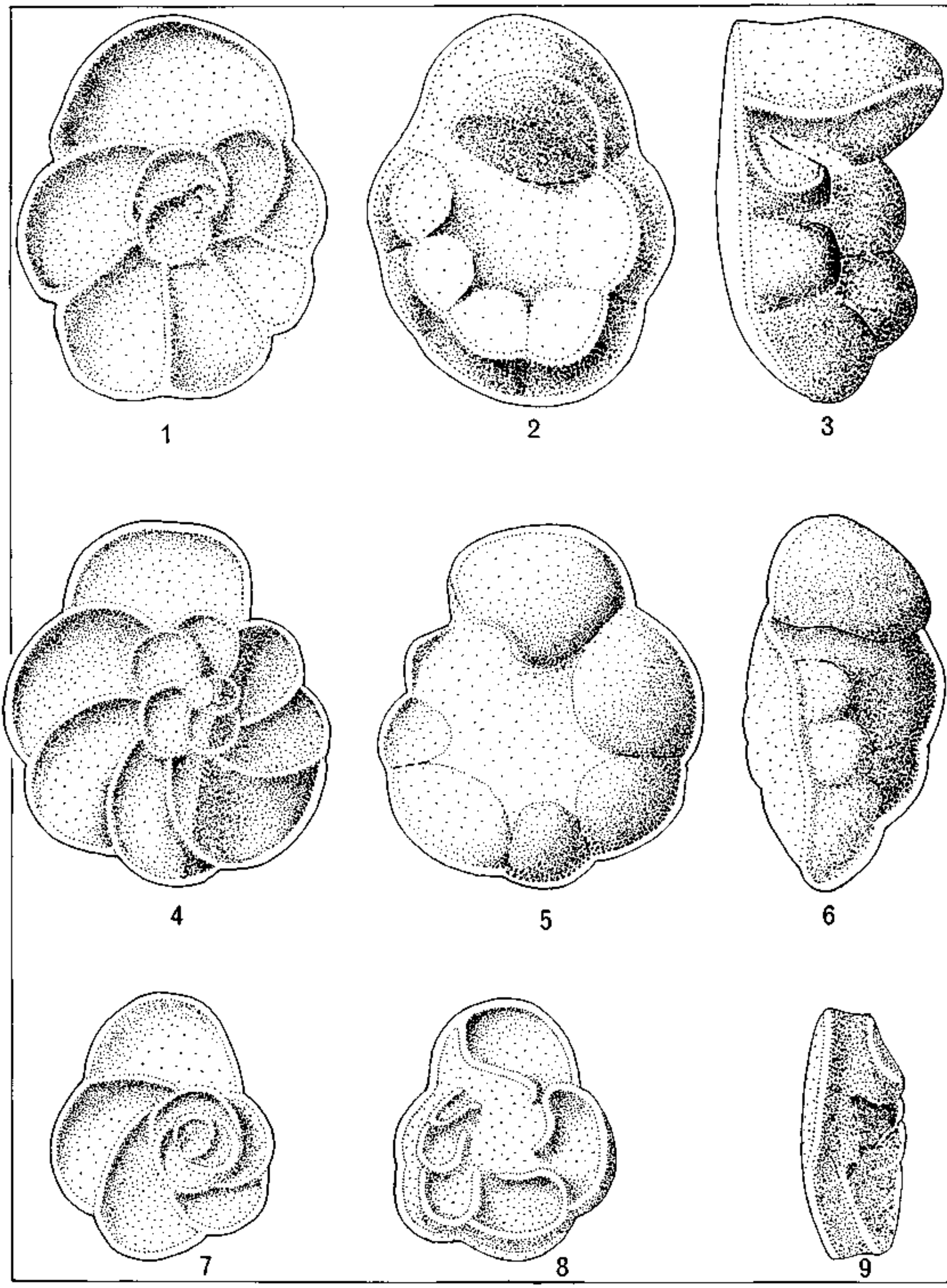


PLATE 4

1—3	*Globotruncana lapparenti coronata*
4—6	*Globotruncana elevata-calcarata*

PLATE NO. 4 x 100

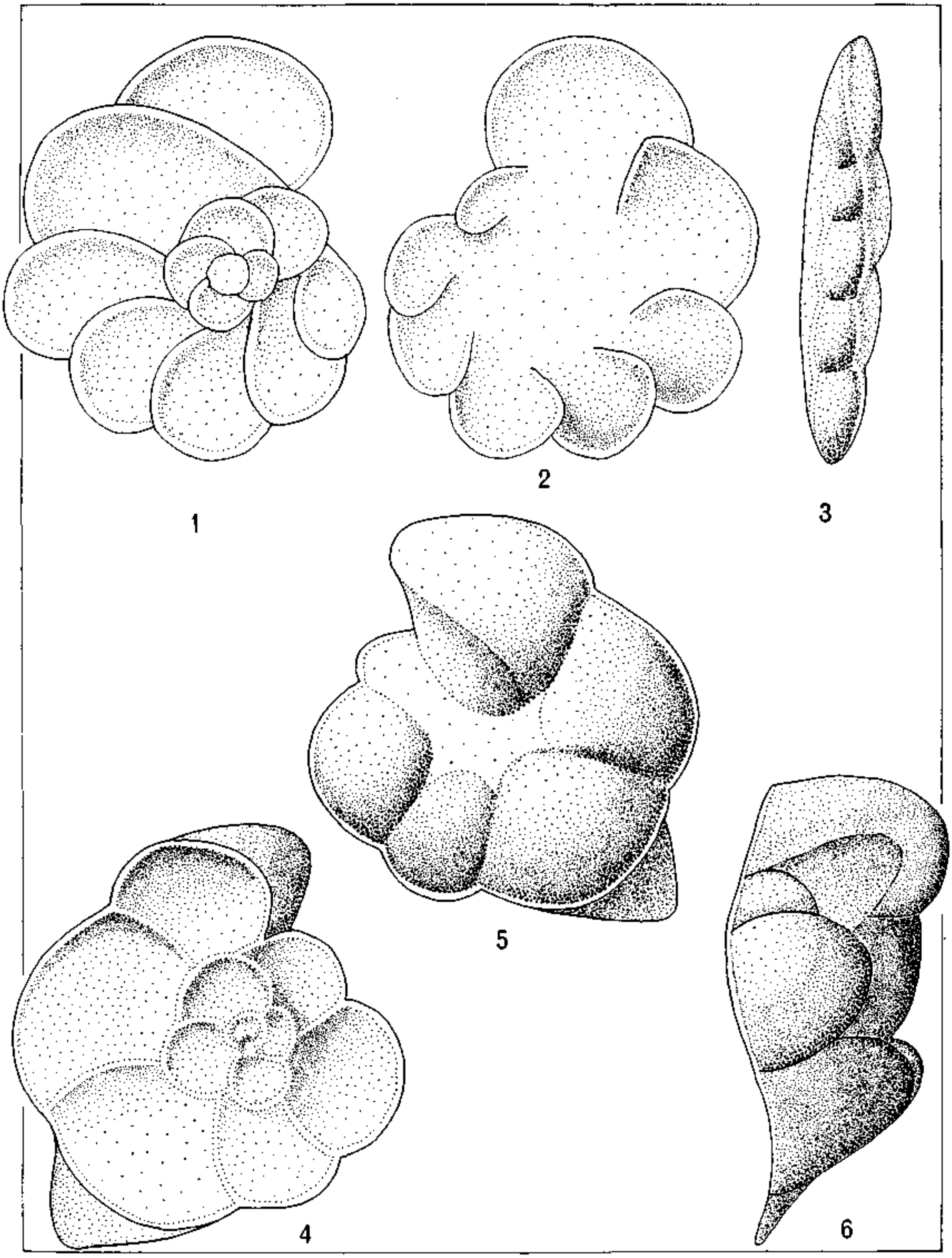


PLATE 5

1—2	*Heterohelix reussi*
3—4	*Heterohelix globocarinata*
5—6	*Heterohelix globulosa*
7—8	*Pseudotextularia* sp.
9—10	*Pseudotextularia elegans*
11—12	*Rugoglobigerina rugosa subrugosa*

PLATE NO.5 X 100

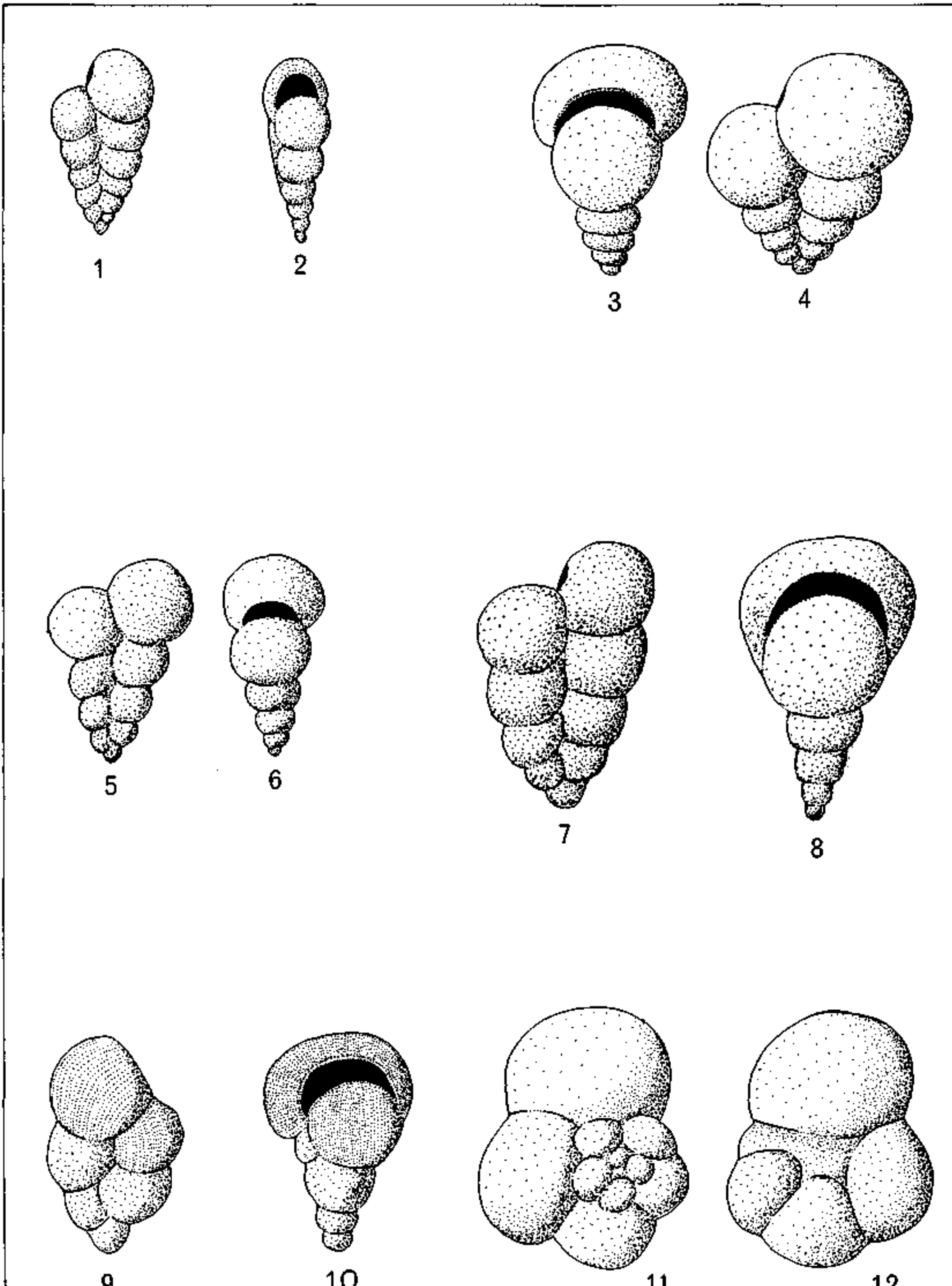


PLATE 6

1—2	*Rugoglobigerina rugosa ordinaria*
3	*Buliminella cushmani*
4—6	*Globorotalites multisepta*
7	*Planularia liebusi*
8	*Lenticulina navarroensis extravatus*
9	*Lenticulina muensteri*

PLATE NO. 6

x 100

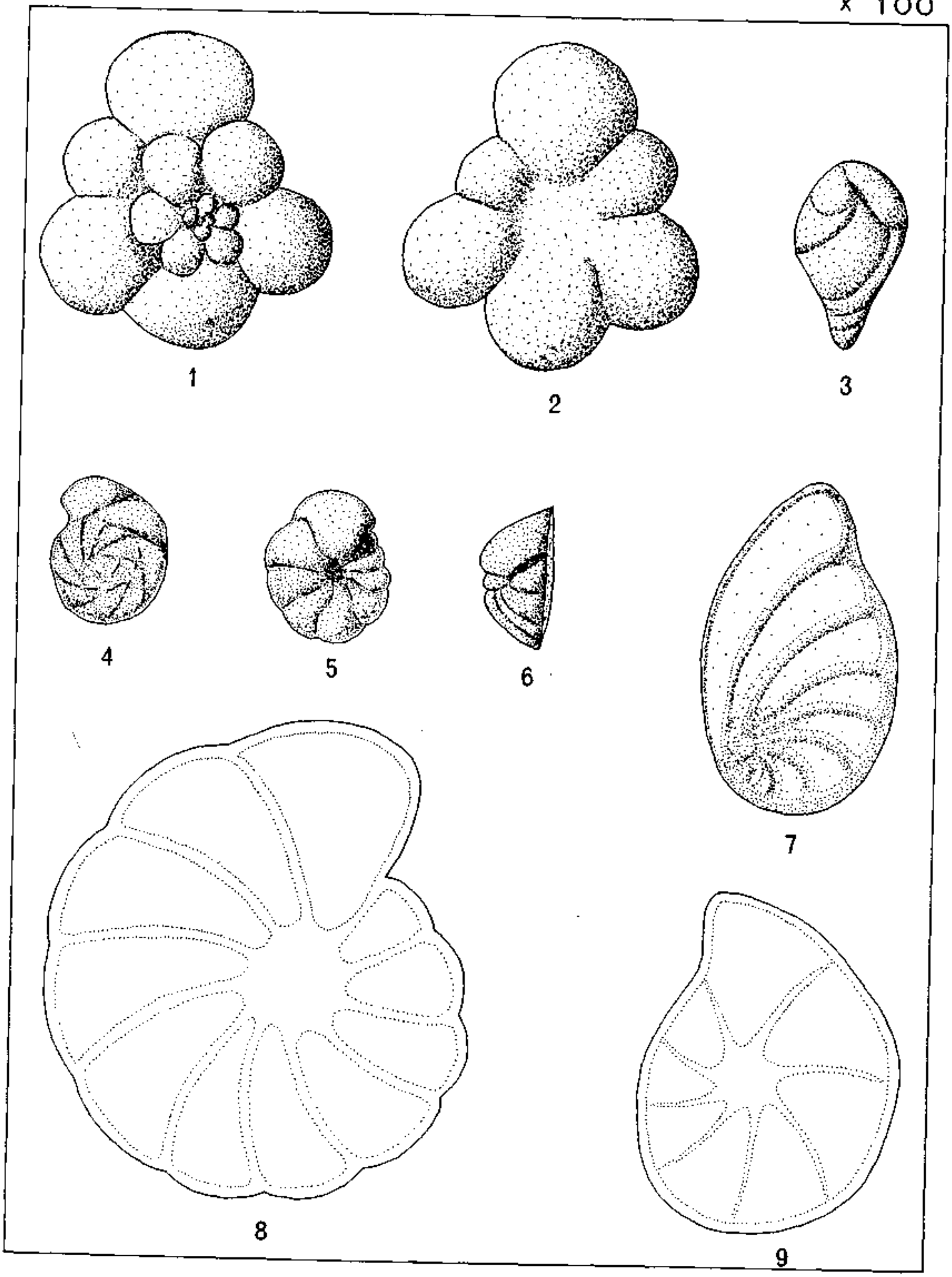


PLATE 7

1—3	*Gyroidina depressa*
4—5	*Gyroidina globosa*
6—7	*Gyroidina rudita diversa*
8—9	*Gyroidina bearpawensis*
10—11	*Verneuilina muensteri*
12—13	*Haplophragmoides eggeri*
14—16	*Trochammina diagonis*

PLATE NO. 7

X 100

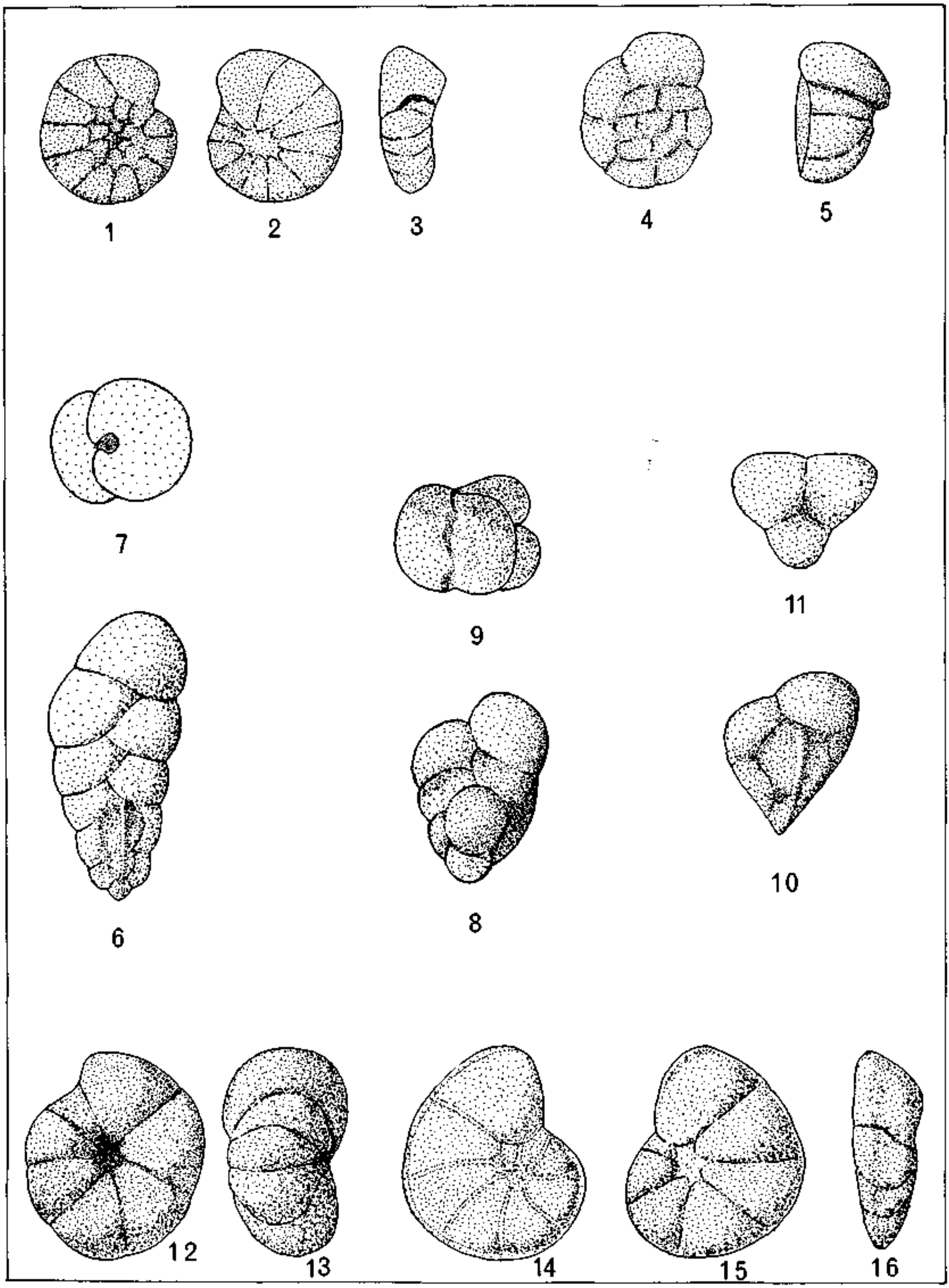
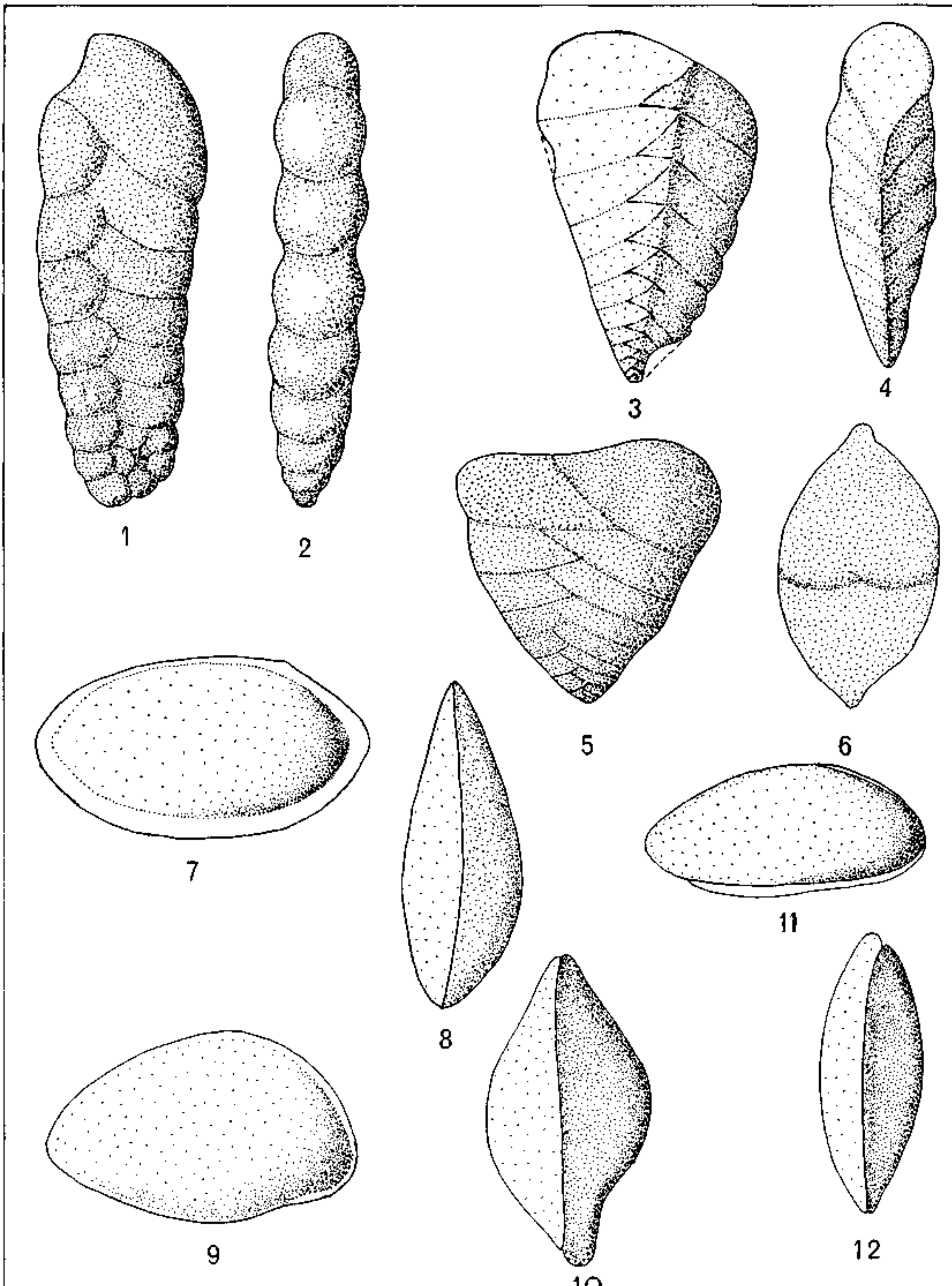


PLATE 8

1—2	*Spiroplectammina lalickeri*
3—4	*Spiroplectammina dentata*
5—6	*Textularia baudouiniana*
7—8	*Cytherella* sp.
9—10	*Bairdia* sp.
11—12	*Kalyptovalva* sp.

PLATE NO. 8

x 100



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Micropalaeontology of the Galis Group, Hazara, West Pakistan

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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 & Wynne 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 limestones at the base which have now been clearly identified as being of Cretaceous age (Latif 1962), and of a distinctly different lithology, relatively more closely related to the preceding Hothla Group than to the succeeding one. Other workers, however, just referred to the units earlier definitions as descriptions, without any significant alteration.

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 nomenclature, which require the use of a geographic term for a unit. Moreover, there is a major rearrangement of the formations. The Grey Limestones at the base of the Nummulitic Series, have been separated as part of the underlying Hothla Group, and the overlying Kuldana Series so far excluded from the Nummulitic Series, have been taken as the uppermost unit of the group.

5. The group is very well represented in the Galis, 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.

Subdivisions

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 Limestones below and includes the Kuldana Series above (pp. 39—40 and 42—43 respectively). The following subdivisions are recognised:

5. Kuldana Formation	± 200 feet	Lower to / Middle Eocene
4. Lora Formation	± 150 feet	Lower Eocene
3. Margala Hill Limestone	± 350 feet	Lower Eocene
2. Kuzagali Shale	± 600	Upper Paleocene to Lower Eocene
1. Mari Limestone	± 900 feet	Lower / Middle to Upper Paleocene

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 Foraminifera of very small size. These are followed by grey nodular to massive limestones, marly limestones and marls containing larger Foraminifera up to 5 mm. in size. The top of the group is marked by marls, shale, clay, sandstone and gypsum bands, dominantly of reddish colours.

Distribution of Microfossils

The following microfossils have been recorded from various formations of the Galis Group.

1. Mari Limestone

Globorotalia uncinata, *Globigerina* aff. *linaperta*, *Globigerina triangularis*, *Globigerina triloculinoides*, *Globigerina velascoensis*, *Bigenerina* sp., *Textularia* sp., *Textularia smithvillensis*, *Dorothia oxycona*, *Pyrgo lupheri*, *Triloculina trigonula*, *Miliolidae*, *Pseudogloborotalia khairabadensis*, *Pseudogloborotalia ranikotensis*, *Cibicidina walli*, *Pleurostomella rimosa*, *Pleurostomella greatvalleyensis*, *Chilostomella ovoidea*, *Charltonina madrugaensis*, *Rotalia perovalis*, *Rotalia trochidiformis*, *Lockhartia conditi*, *Lockhartia conica*, *Lockhartia haimei*, *Daviesina khatiyahi*, *Kathina delseota*, *Miscellanea miscella*, *Eoannularia eocenica*, *Linderina* sp., *Acinosiphon punjabensis*, *Bairdia* sp., *Brachycythere* sp., and *Nephrokirkos* sp.

2. Kuzagali Shale

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

3. Mangala Hill Limestone

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. *flosculina.*

4. Lora Formation

Globorotalia reissi, Globorotalia wilcoxensis, Globanomalina ovalis, Globigerina prolata, Globigerina yeguaensis, Glandulina laevigata, Discorbis calyptra, Gyroidina globosa, Rotalia crookshankiana, Rotalia eocena, Rotalia trochidiformis, Lockhartia conditi, Lockhartia hunti, Lockhartia tipperi, Assilina daviesi, Assilina aff. *laminosa, Assilina subdaviesi, Assilina subspinosa, Assilina globulus, Assilina mamilla, Bairdia* sp., *Pontocyprella* sp., *Parakrithe* sp., *Henryhowella* sp., *Quadracythere hornibrookella, Quadracythere* sp., *Xestoleberis* sp., and *Cytherella* sp.

5. Kuldana Formation

Assilina expones, Assilina granulosa, Nummulites sp.

Age of the Galis Group

The Galis Group is composed of 5 distinct formations:

a) The Mari Limestone, b) Kuzagali Shale, c) Margala Hill Limestone, d) Lora Formation and e) Kuldana Formation. The microfaunal study of these formations is based on 20 rock samples. Eight of the Mari Limestone come from Changlagali; 5 of Kuzagali Shale from Kuzagali; 3 of Margala Hill Limestone from Shahdara; 2 of Lora Formation from Phallagali and 2 of Kuldana Formation from Bansragali. They reveal the presence of 75 species of Foraminifera 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 numbers 6 to 8 from the Mari Limestone contain *Kathina delseota, Daviesina khatiyahi, Lockhartia conica* and *Actinospiphon 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. *Assilina exponens* has been recorded from sample number 25 of the Kuldana Formation. The species is supposed to appear above the Lower Eocene.

The Middle / Upper Paleocene boundary is placed between samples 11 and 12 both from the Mari Limestone. *Globigerina triloculinoides, Pseudo-*

globorotalia 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 Kuzagali Shale and Margala Hill Limestone respectively.

The Lower and Middle Eocene are separated on the first appearance *Assilina exponens* of the Middle Eocene in sample number 25 from the Kuldana Formation.

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

Acknowledgements

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The Genesis of the Spitzer Gneisses and the Para-Rock Series of the Kamp Valley in the Lower Austrian Waldviertel

Part 1: Geology and structures
(With 1 plate and 16 diagrams)

By MAHMOUD KHAFFAGY *)

Abstract

The studied area represents the western limb of a major syncline with highly metamorphosed gneisses, schists, amphibolites, marbles, and quartzites. These rocks occur in two units: the Spitzer gneisses and the para-rock series which merge into each other without any sharp contact. New nomenclature: the "Dobra complex" and the "Krumau complex" is suggested for both units respectively. The area is mapped on the scale 1 : 10,000. The obvious state of prefered orientations of the principle minerals of the main rock types is studied.

Zusammenfassung

Das bearbeitete Gebiet stellt den Westteil einer großen Synclinale dar und weist hochmetamorphe Gneise, Schiefer, Amphibolite, Marmore und Quarzite auf. Diese Gesteine treten in zwei Einheiten auf: die Spitzer Gneise und die Paragesteinsserien, die ohne ausgeprägte Kontakte in einander übergehen. Neue Nomenklatur: „Dobra Komplex" und „Krumauer Komplex" werden für die beiden Einheiten vorgeschlagen. Das Gebiet wurde im Maßstab 1 : 10.000 kartiert. Die Verhältnisse der gesteinsbildenden Mineralien wurden untersucht.

Introduction

The investigated area covers an almost east-west strip of about 50 km² between latitudes 48° 35,13' & 48° 37,27' and longitudes 33° 1' & 33° 9,5', and is to be found on the topographic sheet "20 Gföhl, Wien 1960", with the Kamp river cutting its course in WE direction as a main topographic feature.

The area lies in the western part of the Moldanubian zone of the Bohemian Massif and is composed of the Spitzer gneiss body to the west and the para-rock series to the east. J. CZJZEK (1849 & 1854), F. BECKE (1882), A. MARCHET (1924), L. WALDMANN (1938 a & b and 1949) and A. KÖHLER (1941) dealt with these rocks in a general way as an integral part of the Austrian Waldviertel. They suggested an orthoorigin for the

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Spitzer gneisses, which are constantly intercalated by amphibolite bands and sheets, which are considered by them as younger intrusions of basic magmas.

CH. EXNER (1953) offered valuable observations concerning the gradual transition between the two rock units, together with the occurance of some paragneiss intercalations and a marble band in the body of the Spitzer gneisses at Schöberlberg. He attributed the transitional contact to granitisation due to metasomatic processes. According to him, the amphibolite intercalations in the gneisses are older and might be rests of precambrian formation. He also stated that the Spitzer gneisses might be of pure magmatic origin or a granitization product of the para rock series itself.

The present work is the first part of a series of publications dealing with the genetic problems of these rocks. In this part the geology and structures of both rock units are discussed on the basis of a detailed geological map drawn on the scale of 1 : 10.000 (Plate 1), together with a series of petrofabric analyses. The second part (M. KHAFFAGY, 1969 b) deals with the mineralogy and petrography of these rocks, while the third part (M. KHAFFAGY and E. SCHROLL, 1969) deals with their geochemistry.

General Geologic Settings

The studied area represents a highly metamorphosed rock series composed mainly of gneisses and schists, amphibolites, marbles and quartzites. Also minor intrusions, as fine grained granites, aplites, pegmatites and lamprophyre dikes are occuring.

As shown by the attached geologic map (Plate 1), the area represents two main rock units: A) the Spitzer gneiss body, extending from the contact of the Rastenberger granite pluton to the west to the Genitzbach area, and B) the para-rock series extending from the area around the Genitzbach to the contact of the Gföhler gneiss at the eastern end of the area. Both rock series are having some common geologic features:

1. Both are having the same structural trend, striking NS with a general dip to the east, though some local variations are there.

2. Similarity in lithology is existing as far as the major rock types are concerned.

3. The gradual transition at their contact suggests a strong genetical relation between them.

Consequently, it seems unfair to put a sharp demarcation between the two rock units, than to consider them two members of a major unit which underwent the same course of metamorphism and deformation.

The nomenclature "Spitzer gneiss" seams to be unfortunate, as it is applied to a gneiss body which extends from the Danube valley up to Waidhofen/Thaya (60 km) with a thickness ranging from 4 to 10 km. The name impresses the homogenity and uniformity of the whole body which is not the case. EXNER (1953) recorded the absence of the Fleckamphibolites from the studied area, which were encountered by WALDMANN and others, together with other basic rocks which reserve the eruptive textures, in the gneiss body around Göpfritz and Allensteig. Moreover, the considerable difference in composition of the gneisses from granitic (also aplitic) to granodioritic and sometimes dioritic (WALDMANN, 1952) is worth consideration. Also, the frequent occurrence of typical para-rock intercalations together with marbles which are conformable and concordent with the Spitzer gneisses is another feature crying against the orthoorigin and the homogenity of the Spitzer gneiss rocks. On the other hand, the amphibolites occuring in the studied area, also those belonging to the para-rock series, are not yet proved to be of definite paraorigin. Consequently, the author suggests the following terminology for these rock units: 1. The "Dobra complex" for the Spitzer gneisses and 2. the "Krumau complex" for the para-rock series of the studied area. This might serve for avoiding any confusions especially the genetic indications impressed by former names. This nomenclature will be further applied in this work.

The Dobra complex is composed mainly of gneisses which form with their schistose varieties about 70% of the field exposures. Other rocks are the amphibolites, marbles in the form of intercalations ranging in thickness from some centimeters to a few meters, the reason why these rocks were mapped as one unit. The contact between the Rastenberger granite and the Dobra complex to the west is masked by younger intrusions of finegrained granitic and aplitic dikes which may reach the thickness of 20 m. The contact follows a NS trend with a transition zone of crushed mylonitic granite (25 m) and migmatites (100 m) separating the typical rock types. While the normal Rastenberger granite contains Knaf (alkalifeldspars) porphyrocrysts as big as 2 × 5 cm, the porphyrocrysts in the mylonitic zone do not exceed 1 × 2 cm. The migmatitic zone that follows is formed essentially of banded gneisses due to the alternation of granitic and gneissic bands, not only of megascopic, but also of meso- and microscopic dimensions. These migmatites strike generally NS and dip either vertically or very steep (75°—85°) to E, and grade into an augen gneiss variety with big porphyroblasts of Knaf reaching 3 to 4 cm in length, oriented parallel to the strike of the rock. These rocks are irregularly cut by a set of fine-grained granitic and aplitic dikes with sharp contacts. It is not seldom to find some xenoliths from the country rocks and the Rastenberger granite in these intrusions. From this contact zone eastwards, the Dobra complex occurs in its typical form as regular, more or less rhythmic alternations between gneisses and amphibolites sometimes intercalated with marble bands. It comes to its end around the Genitzbach area where it gradually merges to the Krumau complex, which starts to occur as alternations between paragneisses and schists, marbles, amphibolites and quartzites. The marbles and amphibolites are more flourishing in this complex and acquire greater thickness if compared with those of the Dobra complex. Thickness of 100 m for the marbles and 200 m for the amphibolites are recorded. The amphibolites show a pronounced gradual increase in thickness from west to east. Another feature of this complex is the increase in grain size of its gneisses, schists, quartzites and partially the marbles from fine to medium grained in the western and middle parts, to coarse grained in the eastern part of the complex. At a distance of about 1.5 km in the contact zone to the Gföhler gneiss body, which cuts the Krumau complex very sharply, the whole series is injected by aplitic veins and dikes. This phenomenon is discussed by EXNER (1953), who stated that a similar injection zone lies symmetrically with this, immediately west to the Gföhler gneisses and that both of them might have resulted through the emplacement of the Gföhler gneiss body.

Field Descriptions of Main Rock Types

I. The Gneisses and Schists

These form the major rock type of the area in both complexes reaching about 70% of the Dobra complex and about 45% of the Krumau complex. Some of the field names applied here, after EXNER (1953), are purely descriptive and have no genetical indication.

A. The Dobra Gneisses

These gneisses are further classified in two main groups:

a) The typical Dobra gneisses which represent the major part of the gneiss exposures of the Dobra complex and can be estimated by 80% of the gneisses. The following varieties are recorded.

1. The granitic biotite gneiss is a medium to fine grained, hard and compact gneiss having besides its main constituents (feldspars and quartz) a considerable amount of biotite, hence giving it a granitic appearance. It exhibits an excellent lineation and foliation. Lineation is mainly due to the parallel alignment of the biotite in the s-planes of the rock.

2. The biotite-free aplitic gneiss is comparable with the above mentioned gneiss, but almost biotite-free, finer in grain size and lighter in color.

3. The banded gneiss that results from alternations of thin bands of the two above mentioned varieties in mesoscopic and microscopic dimensions.

4. The augen gneiss is a special case of the granitic biotite gneiss with Knaf augen ranging in length from 1 to 3 cm. Pegmatitic dimensions more than 5 cm are rare. The augen are mostly aligned parallel to the lineation of the rock.

It is to be noted that these gneiss varieties do merge into each other and also in the other gneiss varieties of the Dobra complex described hereafter.

b) The typical Dobra para-gneisses are mainly sillimanite bearing gneisses and schists, two mica or muscovite rich varieties and calc-silicate rocks generally associated with marbles. Besides the already known occurance at Schöberlberg (EXNER, 1953), these findings are recorded by the writer:

1. The major occurance of these rock types extends along the road-wall cut on the road Ottenstein—Dobra from the mouth of the Dobrabach to opposite the Ruine Dobra, intercalating the previously mentioned typical types of the Dobra gneisses. Some of these gneisses are sillimanite bearing whose amounts vary between accessory — at the peripheries — and increase to reach the maximum opposite to the Schloteinbach mouth. These gneisses are highly weathered, if compared with the other varieties, fine to medium grained, yellowish brown in color and relatively more friable. Other para-gneisses are garnet-bearing or graphitic. The whole series is cut by aplitic veins.

2. The second occurance is along the Schloteinbach itself in the form of two-mica and muscovite-rich gneisses and schists. These are highly feldspathic, very light colored and acquire a wide range of grain size from medium to coarse grained, sometimes also obviously augenised.

3. Another new finding is about 1 km NW of Franzen, in the form of mica and two mica gneisses overlying a marble band (15 m). The gneisses are intercalated by biotite schists and are cut by pegmatitic quartz veins. An extension 250 m to the south for this occurance was lately noticed by the author in summer 1968 when a new road cut was done running WE. The same rock varieties occur again in several alternations over 200 m distance. Moreover a 30 cm graphite band does occur.

B. The Krumau Gneisses and Schists

These are the predominating rock types of this complex. They acquire a wide range of composition and show a pronounced rapid change in lithology. However, they are unique in proving to be of definite para origin, occuring in the form of parallel beds, which reserve the stratigraphic nature of the parent rocks. They are formed of the following main varieties, though intermediate varieties do occur.

1. The pelitic gneisses and schists are rich either in biotite or muscovite or in both micas distributed all over the complex and differ in grain size from fine to medium grained in the western side to coarse grained in the eastern contact. Their colors differ according to the dominating mica from dark grayish brown to milky white. Some schists are garnet bearing sometimes with porphyroblasts up to 6 mm in diameter. Sillimanite also occurs in noticeable amounts. Other minerals are feldspars (mainly plagioclase) and quartz.

2. The quartzo-feldspathic gneisses and schists composed mainly of quartz and feldspars very poor in mica. Some of

them are even mica free. Others are very quartz rich forming a transition to quartzites. They often bear garnet but rarely sillimanite.

3. The augite rich gneisses are fine to medium grained, mostly light gray to greenish in color. They acquire an extraordinary grain size at the eastern contact to the Gföhler gneiss, and occur mostly at the contacts of marbles.

4. The graphite and graphite rich schists represent the least abundant types and occur in the form of thin bands intercalating the other rock types. Some of them are composed mainly of graphite, others are graphite rich but very often pyrite bearing.

II. The Amphibolites

The amphibolites in the whole area are ubiquitous and appear whereever gneisses are recognised, constituting the second major rock type. They increase both in abundance and thickness in a WE direction from the Dobra complex to the Krumau complex. In the Dobra complex, they occur in the form of thin intercalated bands and sheets ranging in thickness from a few centimeters to maximum one meter, quite concordant and simultaneously folded with the enclosing gneisses. In the Krumau complex, they occur in the form of thick bands, gradually increasing in thickness in the eastern direction till they reach a maximum thickness of 200 m at the contact to the Gföhler gneiss. They are almost uniform in thickness and persistant along the strike and lie parallel to the lineation of the gneisses. At the contact zone to the Gföhler gneiss, the amphibolites show a remarkable increase in their garnet content.

In the more obviously deformed parts of the gneiss complexes, the amphibolites occur in the form of lenses, boudins, intricately folded forms and sometimes breccias. Their textures vary from granoblastic, gneissose and schistose where most of the amphibolites are distinctly foliated and lineated. The very thin layers and the margins of thicker sheets are finer grained and are more schistose than the cores of the thick sheets. Commonly these schistose margins have a stronger lineation due to the parallel orientation of the hornblende prisms. This phenomenon gives the appearance of relict chilled zones, or it may be due to crushing and incipiant crystallisation during metamorphism.

The difference in thickness of the amphibolites in both complexes seems to be an early premetamorphic phenomenon. There is also no evidence of a third, pre-existing rock type, intercalated with or separating gneisses from amphibolites. Also there is no indication along or across the strike of the amphibolites to a parent rock of a composition that muchly differs from them.

The interlayered form of the amphibolites is typical all over the area. This coupled with the similarity in the bulk mineral composition throughout suggests a common origin for them.

A worth mentioning feature is the occurance of an abnormally thick dike like amphibolite body (15 m) in the Dobra complex opposite to the Ruine Dobra. It cuts the Dobra gneisses together with its amphibolite intercalations discordantly with an angle of 60°. It is also protruding the gneisses with a tongue (9 m) which is nearly concordant with the general strike of the gneiss. It is a black, fine grained, granoblastic and biotite free variety. 300 m to the west of this occurance, there are also two other similar amphibolite bodies in the form of concordant walls (sills?) lying parallel to the local strike. Both are relatively thick (each about 4 m). Between them is a distance of 7 m composed of the typical Dobra gneiss bands (5—50 cm) intercalated and simultaneously folded with the normal amphibolite sheets (5—20 cm). These three occurances may represent a younger generation of amphibolites which differs in origin from the normal amphibolite intercalations.

III. The Marbles

The distinctly layered form of the Krumau complex with its famous marble occurances furnished the earliest clues to its metasedimentary origin. Meanwhile, the occurance of considerable amounts of such marbles in the Dobra complex, may lead to the conclusion that the parent rock of the Dobra complex must have been also formed under similar sedimentary conditions. This is actually the only possibility to explain the occurance of these marbles in the body of the Dobra complex.

The major belts of marbles, insofar as they are known in the studied area, occur in the Krumau series, with special predominance around Krumau town, the Töpenitzbach and along the road Tiefenbach—Thurnberg. In this complex, they are more flourishing and acquire greater thickness than those in the Dobra complex, reaching sometimes 100 m. Their contacts with the associated rocks are fairly straight. It can happen that they capture some boudins from other rock types especially the amphibolites. Minor folds with gentle to moderate plunge are abundant. They show also very often prominent lineation parallel to that of the associated gneisses and amphibolites.

The marbles in both complexes show an appreciable variation in grain size and color. Most of them are fine to coarse grained but some are also coarse grained. Their colors differ from snow white (Töpenitzbach) to gray to dark gray where banded varieties (white and gray) do also occur (Schöberlberg).

The marbles of the Dobra complex occur mainly in the following localities:

1. Around the main meander of the Kamp river opposite to the mouth of Schloteinbach along the road Ottenstein—Dobra dam. Five main bands of marbles can be recognised intercalating the previously mentioned paragneisses and schists. They are quite concordant with the general trend of

the rocks and vary in thickness from 1 m to 10 m. The following sequence can be traced from west to east:

a) Fine grained white compact variety.

b) Medium grained, brownish, highly friable variety with brown mica flakes.

c) Medium grained grayish graphite bearing variety.

d) Fine grained compact variety with greenish bands and spots of forsterite.

e) Fine grained grayish marble band.

2. In the northern part of the area, near Franzen in the previously mentioned quarry in which para gneisses were also discovered. It occurs in the form of medium grained, compact, finely banded, gray marble of about 15 m thickness.

3. In the neighbourhood of Strones in a quarry 200 m in diameter (Exner, 1968, oral discussion). This marble is milky white, medium grained and intercalated in some places with amphibolite bands.

4. At the mouth of the middle tunnel Dobra-Krumau intercalating an amphibolite band. This is a medium grained, gray, tremolite bearing marble band, about 1 m thick.

5. In the Schöberlberg para-rock occurance in the form of three thin intercalations, similar to that of occurance 4.

East of the Genitzbach, the marbles start to flourish suddenly giving the Krumau complex its stratigraphic and metasedimentary nature, and acquire different compositions, being sometimes graphite, pyrite, augite, hornblende and/or diopside bearing. Siliceous and highly siliceous varieties as a transition to quartzite do occur. These contain quartz either as disseminated grains or as coagulated nodules. Occurances of stinkstone marbles were often detected. At the contact of two marble occurances, in Krumau and at the Töpenitz Graben (Exner, 1953), two diopsidite bands (1 m & 10 m thick respectively) were detected, composed of big prismatic crystals of diopside reaching 5 cm in length and 3 cm in breadth.

IV. The Quartzites

The quartzites are restricted to the Krumau complex in the form of narrow interlayers with maximum thickness of 50 cm. Virtually, every known belt of marble contains thin laminae and thicker beds of quartzite intercalating the carbonates. It is worth mentioning here that such fine quartzitic intercalations were nowhere recorded in the amphibolites. The quartzites include relatively pure quartz types as well as feldspathic, micaceous, graphitic but never hornblendic. Cross-bedding is not noticeable in them, though it could have been existing prior to metamorphism.

V. The minor Intrusions

The minor intrusions which cut the above mentioned types of rocks in the form of dikes and/or veins are the following:

1. Fine grained gray and pink granites occur with special predomenance at the contact to the Rastenberger granite, otherwise they were seldom detected.

2. Aplitic veins and dikes are widely distributed all over the area especially at the contact to the Gföhler gneisses where they are often ptygmatically folded.

3. The pegmatitic dikes and veins accompany the aplites wherever they occur. A thick pegmatitic quartz vein (50 cm thick) is found behind the Dobra dam at the beginning of the Ottenstein road.

4. Lamprophyre dikes detected in three localities, opposite to the Schloteinbach mouth, near the mouth of the middle tunnel Dobra-Krumau and near Krumau. The first is an odinite 70 cm thick, the second and the third are minette-kersantites and are 50 and 60 cm respectively. The three dikes differ in grain size from fine to middle to coarse grained.

Structural Features

As shown on Plate 2, the rocks strike generally NS with a general dip to the east, forming the western limb of a major syncline whose eastern limb crops out east of the Gföhler gneisses (EXNER, 1953). However, local differences in dip and strike are not seldom.

An asymetric anticline in the area is detected opposite to the Schloteinbach mouth. Where the rocks at the western contact to the Rastenberger granite strike NS and dip vertically, the strike in this area has a NW-SE direction with a dip of 30—60° SW. Following the outcrops to the east of this locality, the strike is found to be NE-SW with a dip of 35° SE. From this locality eastwards to the Gföhler gneiss, the general trend of the rocks remain without significant changes, except around the Ruine Dobra where the s-planes exhibit some rotated dirctions resulting in the formation of some local folds reaching sometimes the range of 100 m.

The development of microfolds is commonly observed all over the area especially in the marbles. They are of small amplitudes varying between a few centimeters and 50 cm. Their axial planes show various attitudes, but generally they strike NS and dip either to the east or to the west, sometimes also to the S and very rarely to the N. Their axes are mostly plunging to the S with angles between 20 & 40°.

Together with folding, rupturing of the rocks is commonly exhibited by crush zones indicated by mylonitic bands and joints. Two main sets of joints are predominant, strike-joint and dip-joint systems.

Minor structural features are the ptygmatic folding and the boudinage structures. The ptygmatic folding is mostly represented by aplitic veins in the gneisses and the associated rocks at the contact to the Gföhler gneiss. The boudinage structures are represented by rounded and lenticular segments of amphibolites in the associating marbles and gneisses.

Both rock series exhibit a well defined lineation which is generally parallel to the strike, mostly horizontal, or slightly dipping with 4°—10° either to N or S. Very seldom this dip angle exeeds 30°, as along the Dobrabach and Schloteinbach and in the north along the Töpenitzbach. This indicates local folding of the b-axis of the major fold.

Petrofabric analyses

The obvious state of prefered orientation of the principal constituent minerals of the main rock types is studied. The optic axes of quartz, the poles of cleavage in biotite and muscovite, and the optic axes together with twinning lamellae in carbonates (calcite and dolomite) were measured, and represented in 16 diagrams. The first 6 diagrams were kindly offered by G. Deshpande (1966, personal communication).

D i a g r a m 1 represents the poles of (001) cleavage of 300 grains of biotite in an augen gneiss variety of the Dobra gneisses occuring in the big quarry at the western part of the area (Waldreichs). The rock strikes NS and dips almost vertically, with obvious gneissose structure due to the parallel arrangement of biotite, feldspar and quartz. Myrmekitic and perthitic intergrowths are frequent. The diagram shows an excellent maximum with a high density without any girdles or elongated aggregations. The fabric symmetry is axial. The maxima of the biotite cleavage coincide with the pole of the s-plane. This indicates that the mica flakes are concentrated and elongated in the s-plane with their cleavage parallel to it.

D i a g r a m 2 represents also the poles of (001) cleavage of 300 biotite flakes of a banded gneiss variety of the Dobra gneisses from the same locality as the previous sample with the same strike and dip. The rock is obviously gneissose and composed mainly of quartz, alkali and plagioclase feldspars and biotite. The diagram shows monoclinic symmetry determined by two maxima (major and minor) lying so close together that a & b cannot be exactly constructed.

D i a g r a m 3 represents the optic axes of 200 quartz grains of a biotite muscovite gneiss occuring nearly opposite to the Schloteinbach mouth, striking 145° and dipping 50° SW. It is composed mainly of quartz, feldspars, biotite, muscovite, and sillimanite. The gneissose structure is mainly due to the prefered orientation tendency of the mica flakes and sillimanite aggregates. The diagram shows a girdle with monoclinic symmetry indicated by two close maxima with 5% density each, lying nearly in a symmetrical position with reference to the plane of symmetry. The position of one of them is 012°/60° and that of the other is 355°/35°. This gives the "a" direction parallel to which the quartz grains oriented themselves during deformation. The girdle pole is in the center of the diagram having the position 180°/40°. This means that the lineation is NS with a dip of 40° to the S, which is slightly different from the field measurement and may indicate that local variations have taken place in the attitude of the lineation.

Diagram 4 represents the optic axes of 300 quartz grains in a gneiss occuring 1 km N 52° W of the Ruine Dobra, striking 125° and

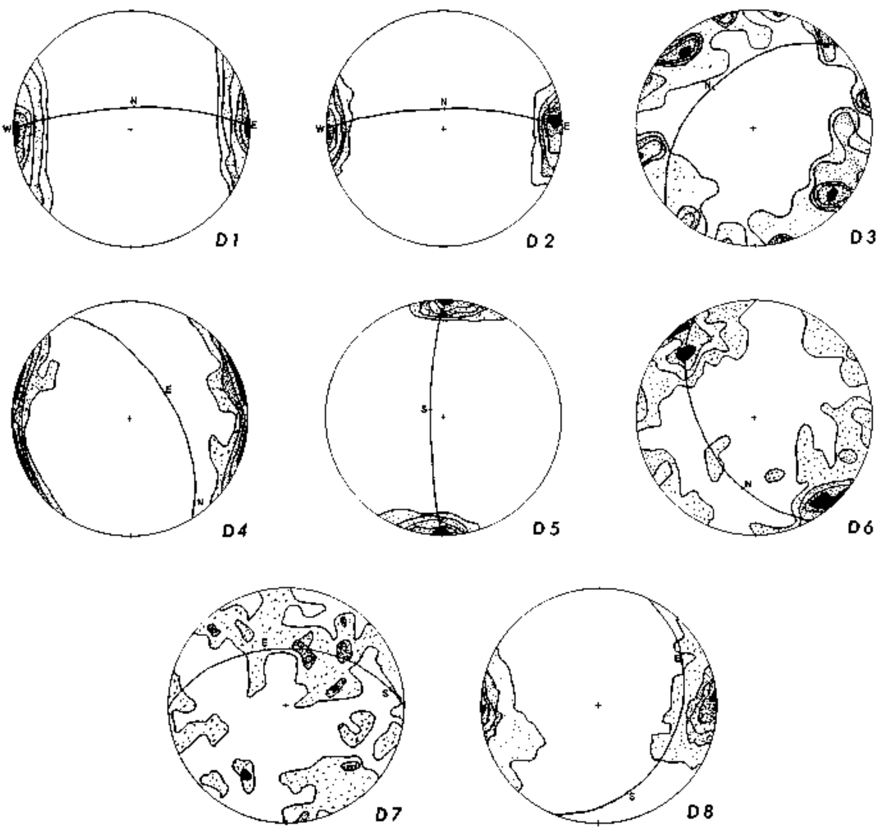

Diagram 1: Contours are 18, 15, 12, 9 and 3%.
Diagram 2: Contours are 14, 12, 8, 4, 2 and 1%.
Diagram 3: Contours are 5, 4, 3, 2 and 1%.
Diagram 4: Contours are 8, 6, 4 and 2%.
Diagram 5: Contours are 20, 16, 12, 8 and 4%.
Diagram 6: Contours are 4, 3, 2 and 1%.
Diagram 7: Contours are 3, 2 and 1%.
Diagram 8: Contours are 20, 15, 10 and 5%.

dipping 38° SW and composed mainly of quartz, alkali and plagioclase feldspars and biotite. The diagram shows girdlelike elongated aggregations with two symmetrically distributed maxima. The fabric symmetry is nearly orthorhombic. Both maxima lie in the "a—c" plane symmetrically on both sides of "c" (147°/50°). The pole of the girdle has the attitude 272°/30°. If the field positions of the s-plane and the fold axis are considered, the pole of this girdle will be the "a" direction. This is a typical example of petrofabric coordinates which indicate that, due to the presence of the former s-plane, the former "a" acted as "b" during later deformation.

D i a g r a m 5 represents the poles of (001) cleavage of 250 muscovite flakes in a banded muscovite- sillimanite bearing gneiss occuring 500 m west of the Ruine Dobra, striking NS and dipping vertically. It has an obvious gneissose structure characterised by alternations of biotite poor and biotite rich bands, and mainly composed of quartz, alkali and plagioclase feldspars, biotite, muscovite, and sillimanite. The diagram shows no girdle or no elongated aggregations. The maximum has a high density, and the fabric symmetry is axial, where the poles of the muscovite cleavages coincide with the pole of the s-plane, indicating the concentration of the mica flakes in the s-plane.

D i a g r a m 6 represents the optic axes of 300 quartz grains in a biotite gneiss occuring near the Dobra dam, striking N 20° E and dipping 42° SE, and composed mainly of quartz, alkali and plagioclase feldspars and biotite. The diagram shows an imperfect girdle. Only some minor maxima are arranged along the circumference, giving a triclinic symmetry. Two close maxima with a density of 4% in the positions 260°/00° and 250°/10° are to be seen, which should lie in the "a—b" plane. This may be due to the presence of a former s-surface which influenced the orientation of quartz axes during the later deformation, suggesting the superimposition of a later deformation on the former s-plane.

D i a g r a m 7 represents the optic axes of 300 quartz grains of a quartzite sample occuring in Schmerbach valley, striking N 15° E and dipping 40° E. It is composed of quartz, plagioclase with biotite, muscovite, tourmaline as accessories. The diagram shows triclinic symmetry with an aggregation of some maxima in the direction E 30°—50° S, which is nearly perpendicular to the b-axis in the field (N 15° E/5° N). Also if the s-plane is considered, this maxima aggregation can be interpreted as the "a" direction. Three other minor maxima with random positions are also present.

D i a g r a m 8 represents the (001) poles of 300 biotite flakes of a paragneiss variety occuring in Krumau, striking N 20° E and dipping 60° E, composed of quartz, biotite and plagioclase feldspars as essentials, and tourmaline, chlorite, opaques, and apatite as accessories. The diagram shows a well developed distribution density, giving a pronounced orientation of (001) biotite poles of N 15° E/60° E. The overoccupied field of the diagram shows a remarkable elongation around a pole of N 50° E/ 45° E. This should be the direction of the "b" axis, but it does not coincide with the field measurement.

Diagrams 9, 10, 11 and 12 represent the poles of (0001) of 200 dolomite grains (diagrams 9 & 10), and the poles of "f" lamellae of 266 dolomite grains (diagrams 11 & 12) in two perpendicular thin sections from a marble sample respectively. It occurs in Krumau striking 340°/ 38° E, and is composed of dolomite with tourmaline and muscovite as

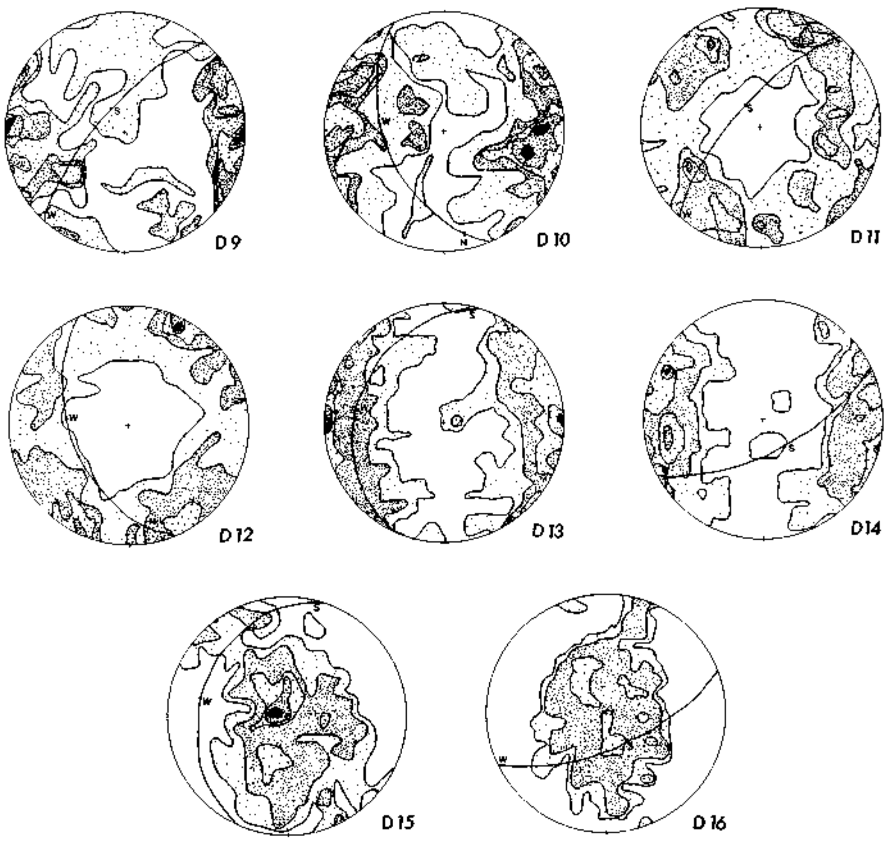

Diagram 9: Contours are 5, 3, 2, 1 and 0.5%.
Diagram 10: Contours are 5, 3, 2, 1 and 0.5%.
Diagram 11: Contours are 5, 3, 2, 1 and 0.5%.
Diagram 12: Contours are 5, 3, 2, 1 and 0.5%.
Diagram 13: Contours are 7, 5, 3, 1 and 0.5%.
Diagram 14: Contours are 7, 5, 3, 1 and 0.5%.
Diagram 15: Contours are 7, 5, 3, 1 and 0.5%.
Diagram 16: Contours are 3, 1 and 0.5%.

accessories. The c-axes (0001) measurements show in one thin section (diagram 9) two maxima lying near 270°/60° E and in the other thin section (diagram 10) one maximum near 220°/60° E. The real difference in the angle between them is 24°. Usually the c-axes maxima orientation of calcite and dolomite coincide with the poles of s-surfaces. In this rock the "a—b" plane is N 25° W/30° E, which approximately coincides with the field measurement which is 340°/38° E. The poles of the twinn lamellae (f lamellae) of the dolomite grains in both thin sections (diagrams 11 & 12) show more or less a random orientation.

Diagrams 13, 14, 15 and 16 represents the measurements done in two perpendicular thin sections of a second marble sample occuring at the northern bank of the Kamp river near Gföhler Hütte, striking N 15° E and dipping 65° E. It is composed of calcite and dolomite with apatite and sphene as minor accessories. Diagrams 13 and 14 represent the measurements of the c-axes of 250 calcite and dolomite grains, while diagrams 15 and 16 represent the plots of $(2\bar{1}\bar{1}0)$ of 247 calcite and dolomite grains in the two perpendicular thin sections respectively. The $(2\bar{1}\bar{1}0)$ pole is the pole of the plane containing the c-axis and the pole of "e" or "f" lamella of the same carbonate crystal.

The c-axes plots show a maximum distribution density of 295°/20° E in diagram 13 and of 285°/20° E in diagram 14. This difference can be due to the existence of other few minor maxima which occupy slightly extended patchs in both diagrams. The zones which are free from any plots assume the trend of the s-surface to be N 15° E/65° E. It is also clear from both types of diagrams that the areas occupied by $(2\bar{1}\bar{1}0)$ are the same areas free from the c-axis. These zones give general trend of the s-plane. The $(2\bar{1}\bar{1}0)$ poles show an elongated concentration in this zone where a maximum is well developed only in diagram 15 with a trend of 084°/50° E. This does not coincide with the "b" trend given by the field measurement.

Relation between Crystallisation and Deformation

In the gneisses studied for petrofabric analyses, also in the quartzite sample, the quartz exhibits nearly always an obvious undulose extinction due to strain effects. It also occurs in the form of elongated crystals with a special orientation, being sometimes one of the reasons of the remarkable gneissosity of these rocks. It is also often found that the twinning lamellae of the plagioclases are clearly bent. The same happens also to the biotite and muscovite flakes, in the biotite and two-mica gneisses studied. In the sillimanite bearing gneiss, the sillimanite is intensively microfolded. Also in the studied marbles, the twinning lamellae of the calcite and dolomite are often bent. These observations indicate that deformation was post crystalline.

Acknowledgements

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Geology and Structure of Steinegg Area, Lower Austria

By R. V. R. Rau *) and K. Sethuraman **)

Abstract

This paper pertains to the geology of the area around Steinegg in Lower Austria. The rocks of the region belong to a metamorphic complex, the grade of which is about amphibolite-granulite facies of regional metamorphism. The various observations and results of the structural analysis and petrographical investigations of the region in general, and on the rocks in particular are herein recorded.

Auszug

Diese Arbeit beschäftigt sich mit der Geologie des Gebietes um Steinegg in Niederösterreich. Die Gesteine dieses Gebietes gehören einem metamorphen Komplex an, dessen Grad ungefähr Amphibolit-Granulit-Fazies einer regionalen Metamorphose ist. Die verschiedenen Beobachtungen und Ergebnisse der Strukturanalysen und der petrographischen Untersuchungen dieses Gebietes im allgemeinen und der Gesteine im besonderen werden hier aufgezeigt.

Introduction

The area under investigation is around Steinegg (Lat. 48° 37' 30" and Long. 33° 13' 30"), a small town on the banks of the river Kamp in Lower Austria. The main link of transportation is the St. Leonhard—Fuglau road which passes through the area. The general geological setting of the area is that it lies on the Eastern flank of the Bohemian massif and forms a part of one of the three granulite bodies to the north of the river Danube in the Moldanubicum zone. This work in its geological and petrological aspects is carried out on the firmament of the earlier works of Waldman, 1951; Exner, 1953 and Scharbert, 1964.

During this study, a detailed geological map of the region on a scale of 1 : 10.000 is prepared. To evaluate the structure, the data of the mesoscopic analysis are correlated with the microfabric diagrams constructed from the oriented specimens collected at various localities. The integration ocular is used in estimating the mineral composition of the rocks and a correlation is made of the different mineral assemblages with the facies of the regional

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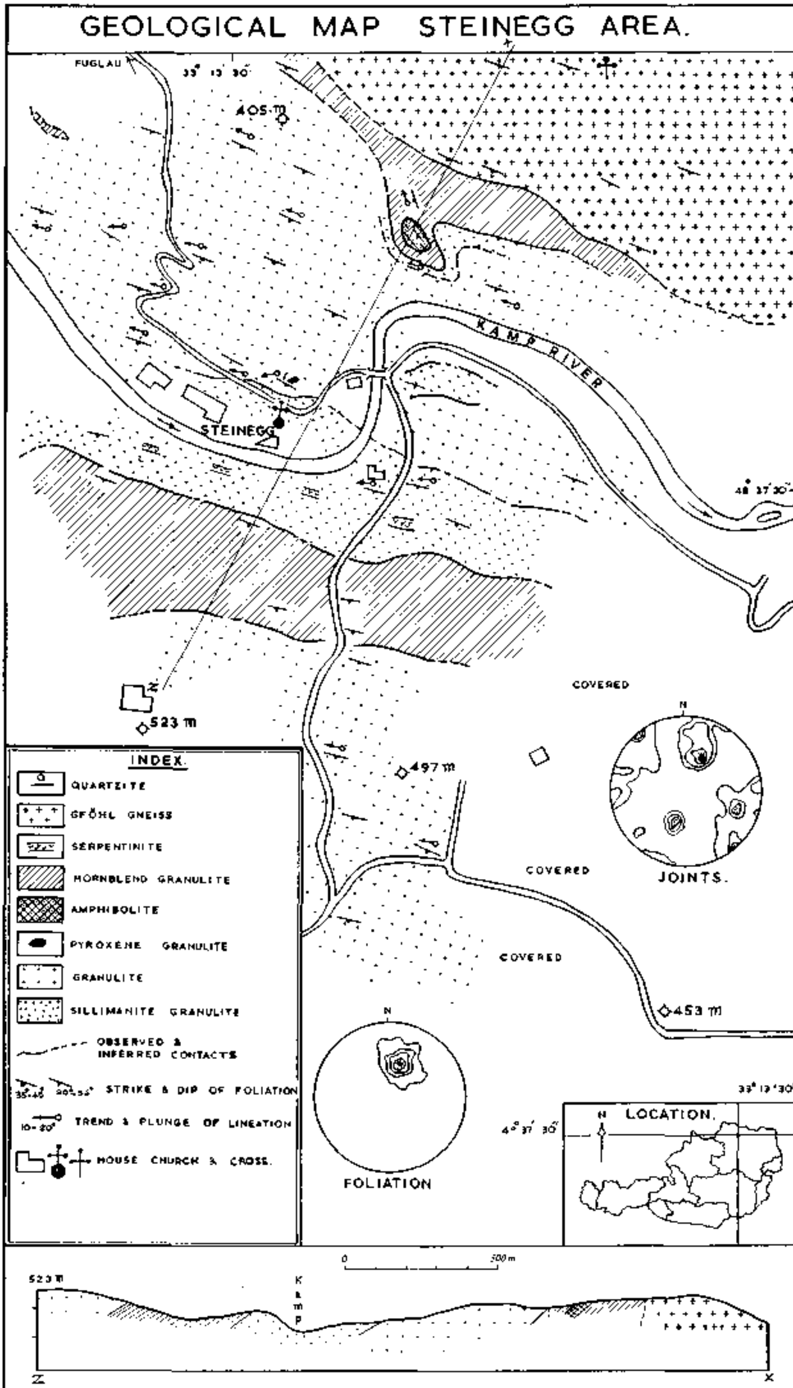
GEOLOGICAL MAP STEINEGG AREA.
FUGLAU
405 m
KAMP RIVER
STEINEGG
48° 37' 30"
523 m
497 m
COVERED
COVERED
COVERED
453 m
JOINTS.
N
INDEX.
QUARTZITE
GFÖHL GNEISS
SERPENTINITE
HORNBLEND GRANULITE
AMPHIBOLITE
PYROXENE GRANULITE
GRANULITE
SILLIMANITE GRANULITE
OBSERVED & INFERRED CONTACTS
STRIKE & DIP OF FOLIATION
TREND & PLUNGE OF LINEATION
HOUSE CHURCH & CROSS.
FOLIATION
LOCATION.
500 m
523 m
Z
X

metamorphism. The Universal stage is used in making the confirmative determinations of the minerals.

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The authors take this opportunity to express their sincere gratitude to Prof. Dr. H. Küpper, Director, Geological Survey of Austria, for the encouragement and facilities offered during this work. They also wish to thank Prof. H. Wieseneder and Prof. Ch. Exner for the guidance received during the investigations. Due acknowledgements are also offered to Dr. and Mrs. Scharbert and Dr. Matura for suggestions and help given at various levels of the work. The fellowships offered by the Government of Austria and the UNESCO are duly acknowledged. This work was carried out at the Training Center for Geology, Geological Survey of Austria, Vienna.

Field Relations

The three principal rock units of the area are granulites, amphibolitic rocks and Gföhler gneiss. These have been subdivided into seven distinct mineral assemblages on the presence, absence and dominance of certain minerals like biotite, chlorite, sphene, rutile, diopside and sillimanite. These mineral assemblages are recorded in the accompanying table. The enclosed geological map shows the geographical distribution and the geological setting of the different rock units.

The granulites are essentially medium grained quartzo-feldspathic rocks with garnet, biotite and sillimanite. Marked orientation of the constituent minerals, in particular of platy quartz, mica flakes and sillimanite needles result in a strong lineation in these rocks. Prominent development of s-planes and gneissosity is generally observed in the upper reaches and is not so profound in depth. Banding of these rocks due to the localisation of dark minerals with minor foldings are noted at some places (W. H.). The contacts of these rocks with other rock units are tectonic in nature. Gradational contacts are observed at some places.

The amphibolitic rocks are equigranular, medium grained and dark colored. They are in general banded and present a layered appearance. Their contacts with the granulites are gradational at some places but they have sharp contacts with the Gföhler gneiss. Extensive migmatisation is noted in the contact of Gföhler gneiss. Localisation of garnets is also noted.

The Gföhler gneisses are medium grained equigranular quartzo-feldspathic rocks with a distinct metamorphic impress. The minor constituents are generally mica and garnet which are evenly distributed throughout the rock. They have a well developed gneissosity. The contact zone with the granulites is not traceable but the trend of the rocks coincide with the trend of the granulites. The gneissosity is obliterated at the contact but is developed to a good degree at some distance away from the contact.

Pyroxene granulite outcrop, a small lens shaped body within the sillimanite granulite with sharp contacts is located near the Church. The rock is even grained, dark coloured and appears fresh.

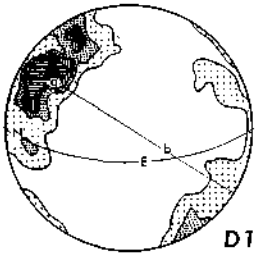
The serpentinites occur in a narrow zone to the south of the river Kamp. This zone may be representing one of the former shear zones of the region. The quartzites and the pegmatites are generally fillings in the widened joint planes and there is no regular oriented pattern of their occurrence.

Structure

The fabric diagram of 100 foliations showed that the general strike of the region is 110° and that the formations have a southerly dip of 40°. A change in the strike direction to N 30° W is recorded in the northeastern part of the area but it is presumed to be essentially local in nature and does not have a bearing on the regional structure. The foliation appears to be due to the compressive forces acting at right angles to the plane of the foliation (Harker, 1932). The mean value of 30 lineations is plotted on the s-plane and it is 290°/15°. The lineation is parallel to the axes of the minor folds, particularly observed in the granulites (near W. H.). The lineation is regarded as intersection of two former active s-planes. The fabric diagram of the differently oriented joint planes (poles are plotted) show two maxima whose positions in space are 20°/50° and 200°/50°. They are interpreted as strike (parallel to the mesoscopic b) and cross (a—c) joints respectively. These joint systems seem to have originated during the last stages of deformation (Cloos, 1937). Limited occurrences of mica segregations and alkali feldspar crystals are found in the s-planes.

To carry out the micro fabric analysis, the area is divided into three domains: I. Granulites, II. Sillimanite granulites and III. Amphibolites. A number of oriented specimens are collected in these domains and are shown on the geological map as A, B, C etc. The preferred orientation of the tectonite minerals — quartz (optic axes) (Figs. 1, 2 and 3), mica (poles of cleavages) (Figs. 4 and 8), sillimanite (c axes) (Fig. 7) and hornblende (interpolated b and c axes) (Figs. 5 and 6) are measured on the Universal stage. The plottings are made on the lower hemisphere. Some of these diagrams (8 figures) are presented here.

The oriented diagrams of the quartz optic axes show a sharply defined girdle around the b axis. The b axis is the mesoscopic lineation. The symmetry of these diagrams is near orthorhombic symmetry observed in some cases and may be attributed to the pre-existing anisotropy of the parent rock. The mica subfabric diagrams have an axial symmetry and the axes of the diagram coincide with the axes of the fabric. The undulose extinction of the quartz grains and the lengthwise extension of the mica flakes along the s-planes which are noted at a number of places may be regarded as evidences of post-crystalline deformation and mimetic crystallisation respectively.



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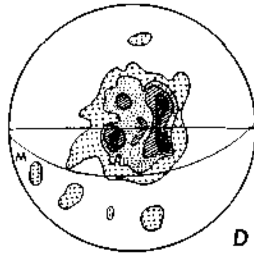

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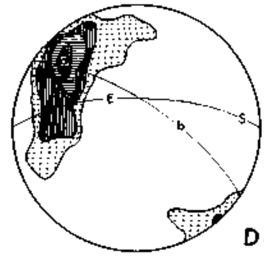

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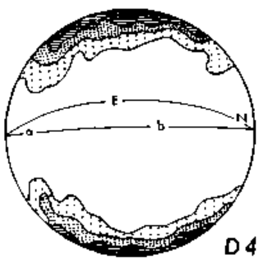

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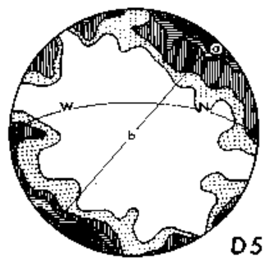

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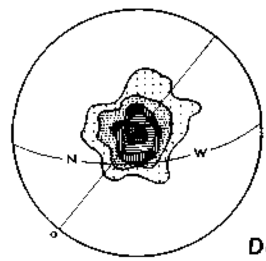

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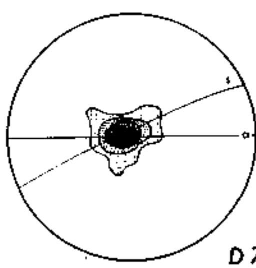

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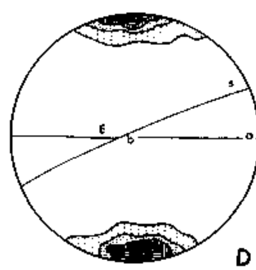

D8

D. 1. Domain I. Quartz. Optic axes of 300 grains. A = Contours at 9, 7, 5, 3 and 1% per 1% area.

D. 2. Domain I. Quartz. Optic axes of 270 grains. C = Contours at 8, 7, 5, 3 and 1% per 1% area.

D. 3. Domain I. Quartz. Optic axes of 250 grains. D = Contours at 8, 6, 4, 2 and 1% per 1% area.

D. 4. Domain I. Biotite. Poles of 200 (001) cleavages. F = Contours at 12, 9, 6, 3 and 0% per 1% area.

D. 5. Domain II. Hornblende. B axes of 150 grains. G = Contours at 8, 6, 4, 2 and 0% per 1% area.

D. 6. Domain II. Hornblende. C axes of 150 grains. G = Contours at 20, 16, 10, 8, 4 and 0% per 1% area.

D. 7. Domain III. Sillimanite. C axes of 70 grains. H = Contours at 40, 30, 20, 10 and 0% per 1% area.

D. 8. Domain III. Biotite. Poles of 200 (001) cleavages. H = Contours at 25, 20, 15 10, 5 and 1% per 1% area.

The plot of the c axes of the sillimanite with the maximum coinciding with the mesoscopic b shows that the grains tend to orient themselves in the s-plane. The well developed maxima of the (001) cleavages of hornblende coinciding with the constructed lineation but showing no tendency to spread in the s-plane may be attributed to the syntectonic crystallisation of the mineral. The microfabric data in general coincide with the mesoscopic observations.

Petrography

The granulites have granoblastic texture tending to be gneissic, the amphibolites and the pyroxene granulites have equigranular medium grained textures and the Gföhler gneiss has well developed gneissosity. This gneissosity is regarded as an impress of metamorphism.

G r a n u l i t e s : Quartz exhibits two contrasting shapes and sizes — platy and granular. The platy grains have minute cracks developed at right angles to the direction of elongation. All the grains show brushy extinction indicating that they are subjected to stress. The large grains contain minute inclusions of rutile and plagioclase feldspar. It is also found to occur as poikilitics in the large alkali-feldspar grains. Alkali feldspar present in these rocks has dusty appearance and is generally altered to sericite and kaolin. Plagioclase feldspar ranges in composition from An 27 to An 30. Lamellar twinning as per the simple albite law is the most common. Myrmekitic intergrowths are also observed. Biotite has strong pleochroism and has perfect (001) parting and is generally not altered. Pleochroic haloes are also observed in them. Almandite represents the garnet group in these rocks. The mineral attains considerable percentages in the assemblages 2 and 3. The crystals are euhedral, well developed and are traversed by a number of cracks. Rutile present in these rocks varies in shape from acicular to granular. Sillimanite is present in the assemblage 3, and has the characteristic needle shape. Some instances of this mineral localising in zones along with magnetite is also noted. A few grains of ortho-pyroxenes generally enclosed by garnets are found to be distributed sparsely in these rocks. The composition as determined from the optical data is between enstatite and hypersthene. The formation of muscovite and chlorite from alkali feldspar and biotite in the otherwise stable assemblages of 1 and 2 is also noted.

A m p h i b o l i t i c r o c k s: The mineral assemblages of these rocks show only minor variations. The quartz and feldspar are in minor amounts except in the assemblage 5. They are fresh and granular in shape. The plagioclase feldspar with An 42% $\pm$ 3% is present in good amounts and the alteration products are sericite and kaolin. Garnets are almandite in composition. They are traversed by a number of cracks and magnetite is localised in these cracks. The principal mineral of these rocks is hornblende and the interpolated composition of the mineral from the optical data is that it is magnesium rich. The diopside present in these rocks has little amount of Fe. The chlorite present is largely an alteration product. The interpolated composition is towards Mg end. It occurs generally as a pseudomorph of garnet, biotite and hornblende. Relics of hornblende in the chlorite are also observed.

Gföhler gneiss: The mineral composition of these rock resembles to a great extent the composition of a granite. The alkali feldspar dominates and the microcline present shows the characteristic polysynthetic twinning resulting in the gridiron structure. Two types of perthitic intergrowths are commonly observed — bleb and string perthites. The presence of sphene and rutile in the same sections of the rocks is an interesting observation. The garnets are very evenly distributed throughout the rocks and are minute in size.

The formation of chlorite from hornblende, biotite and garnet, and muscovite from alkali feldspar are regarded as an indication of retrograde metamorphism or they could in all probability be representing adjustment to the changes in the conditions of metamorphism during the stabilisation stages. However, the large amount of chlorite present in the amphibolitic rocks (hornblende granulite) favours the setting up of the conditions of retrograde metamorphism.

The granulites which are generally regarded as poor in mica, have in certain cases 9% of biotite. This enrichment in biotite can well be explained thus — biotite with good amounts of Ti can exist in the granulite facies, the necessary Ti for this purpose being taken from the formation of rutile from sphene (after Ramberg). The presence of sillimanite in good amounts may be taken as indicative of the high Al content of the original material (SCHARBERT).

Modal analysis of rock types around Steinegg.

Minerals	1	2	3	4	5	6	7
Quartz	49.00	46.00	50.00	2.50	2.00	37.00	30.00
Alkali feldspar	27.00	29.00	29.00	1.50	2.00	20.00	45.00
Plagioclase feldspar	10.00	7.00	7.00	30.00	20.00	13.50	1.00
Garnet	2.00	8.00	6.00	8.00	18.00	12.00	2.00
Biotite	9.00	7.00	4.00	—	6.00	8.00	8.00
Rutile	1.00	1.25	1.25	—	—	—	—
Iron ore	0.75	0.50	0.75	0.50	2.50	1.50	1.00
Apatite	0.75	0.50	0.50	—	—	—	1.50
Hypersthene	0.25	—	—	—	—	3.00	—
Sillimanite	—	—	1.25	—	—	—	—
Hornblende	—	—	—	54.00	35.00	—	—
Diopside	—	—	—	1.50	12.00	5.00	—
Sphene	—	—	—	2.00	2.50	—	—

1. Granulites rich in mica and poor in garnets (+ rutile).
2. Granulites with mica and garnet (+ rutile).

3. Granulites with mica, garnet and sillimanite (+ rutile).
4. Amphibolite (+ sphene) — sensu stricto.
5. Hornblende granulites (+ sphene) — amphibolite with diopside.
6. Pyroxene granulites — two pyroxene garnet rocks.
7. Gföhler gneiss — granitic gneiss.

Conclusions

1. The foliation (110°/40° S) is due to a stress system acting in the directions of NNE-SSW.

2. The growth of alkali feldspar crystals and segregation of mica are limited to the plane of foliation.

3. The joint systems have originated during the last stages of formation.

4. The grade of metamorphism of the rocks is equated to the almandite amphibolite-granulite facies on the mineralogical composition.

5. The original sediments appear to be Al rich.

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About the Origin of Aplitic Gneiss and Amphibolite Inclusions in Silicate Marble, Calc-silicate-gneiss and Spitz Gneiss near Spitz/Donau (Austria)

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Abstract

The different rock groups outcropping in Schlossberg area include Spitz gneiss, paragneiss, marbles, calc-silicate gneisses, amphibolites, aplitic gneisses and pegmatites. Particular attention has been given to the amphibolites and aplitic gneisses which occur as bands and boudinages concordant to the S-planes of the older rocks of the area.

Two main varieties of amphibolites are distinguished: spotted amphibolites and non-spotted amphibolites. Petrographic studies proved the igneous origin of the spotted amphibolites, whereas trace element studies confirmed this view and proved the same origin for the non-spotted variety.

The abnormal abundance of pyroxene (9%) and accessory sphene and apatite (14%) in the pyroxene bearing aplitic gneisses is due to the fact that the aplite could have been contaminated by assimilation of calcareous sediments.

The orthoamphibolites and aplitic gneisses have been originally intruded as doleritic? and aplitic sills respectively.

Introduction

The present work deals with geological problems of Schlossberg area which covers about 4 sq. km. and is located NW of Vienna around Spitz/Donau.

The area lies within the Bohemian Massif and is built up by rocks belonging to the Moldanubian Zone, which is the internal zone of the Middle-European branch of Hercynian system (Exner 1966).

The different rock groups outcropping in the area under consideration include Spitz gneiss, paragneiss, marble, calc-silicate gneiss, amphibolite, aplitic gneiss, and pegmatite. The general trend of the S-planes of all the rock groups of the area is almost NNE—SSW and the general dip is towards the east.

Previous work

The fact that amphibolites are intercalated in Spitz gneiss and aplitic gneiss as well as amphibolite layers occur within the calc-silicate marbles near Spitz is well known since long time. L. WALDMANN mentioned this in his contribution to the „Geologie von Österreich" („Das außeralpine Grundgebirge Österreichs"). In later investigations SCHARBERT (1959) showed that the Fleckamphibolites near Spitz intercalated in a Spitz gneiss represent metamorphosed basaltic (doleritic) sills. JANDA, SCHROLL and SEDLAZEK (1965) analysed an amphibolite sample from Spitz quantitatively by spectrochemical methods among 43 samples of amphibolites, augite gneisses and related rocks from the Austrian Waldviertel and the Eastern Alps.

Method of Study

Mapping of the area under consideration was carried out on the scale 1 : 5.000. Different rock types were studied under the microscope.

Special attention was given to the origin of the amphibolites and accordingly quantitative determination of the trace elements was done by means of spectrochemical method.

X-ray diffraction pattern of representative samples of marbles and aplitic gneisses was carried out. Potash feldspar from an aplitic gneiss was seperated by heavy liquids (a mixture of tetrabromäthan and xylol, specific gravity 2.59) and was investigated by X-ray powder pattern method.

Field Observations

Detailed descriptions by L. WALDMANN about field relations in this area one can find in the field reports of Verh. Geol. B. A., 1956 and 1958. For the special aspect of this paper it is necessary to repeat the following features.

Amphibolites:

The amphibolites occur as band like bodies intercalating the Spitz gneiss and paragneisses and also as boudinage bodies within the marbles (pl. 1 A). The amphibolite bands vary in thickness from a few cms to 60 cm and rarely do they reach one meter thickness. The amphibolite bands and boudinages usually lie along the S-planes of the enclosing country rocks.

Two main varieties of amphibolites are distinguished in the field. A fine grained non-spotted variety which is dark greyish green in colour and which is rich in amphibole; and a spotted variety with leucocratic ovoids of plagioclase up to 7 mm across, set in a finer grained matrix identical to the non-spotted amphibolites. Some spotted amphibolites are rather rich in garnet, the latter seems to replace the feldspar spots as it forms rims around them. In some outcrops the amphibolites are seen to be crossed by gently folded leucocratic veins of gneissose character consisting of abundant plagioclase, orthoclase, biotite and hornblende.

Leucocratic aplitic gneisses like the amphibolites occur as boudinage bodies and bands concordant to the S-planes of the marbles and Spitz gneiss (pl. 1 B). Although most of the aplitic gneiss boudinages lie parallel to the S-planes of the marbles, yet irregular masses of aplitic gneisses showing no distinct orientation with the enclosing marbles are also recorded.

Xenoliths of Spitz gneiss (?) are found included in one of the aplitic gneiss boudinages. Also, pebble-like masses of quartz are found enclosed in the aplitic gneiss material.

The thin aplitic gneiss bands that intercalate the marbles commonly contain pyroxene and accessory sphene and apatite. Parts of the aplitic gneisses show coarse quartz and rare mica.

Petrography

The description of the following rock types should be selected for the problem under discussion.

Amphibolites:

In thin sections, the amphibolites consist mainly of hornblende and plagioclase (0.4 mm average grain size) and subordinate biotite, quartz, garnet, and microcline. Sphene, iron oxide, and apatite are common abundant accessories, whereas zircon is rather rare. The hornblende crystals are preferrably oriented and pleochroic with X = yellow, Y = brown, Z = brownish green. Plagioclase is commonly normally zoned, and has an average composition of andesine (An 40%). Relic pyroxene with subophitic texture is occasionally met.

Spotted varieties of amphibolites show spots up to 5 mm across that lie in preferred orientation parallel to the hornblende prisms. The spots consist either of variably altered plagioclase porphyroblasts (2 mm across) of labradoritic composition (An 66%) and rimmed with finer grained mosaic plagioclase aggregate or consist totally of such a mosaic aggregate of strongly zoned plagioclase crystals.

Aplitic Gneisses:

Two main varieties are distinguished: pyroxene and amphibole bearing aplitic gneiss and biotite bearing aplitic gneiss.

Pyroxene and amphibole-bearing aplitic gneiss: this variety is confined to the thin leucocratic bands, that occur within the marble formation. The rock is composed of phenocrysts of potash feldspar (up to 5.2 mm across) embedded in a finer grained groundmass (grain size about 0.7 mm). The latter consists of quartz, potash feldspar, oligoclase, variable amounts of diopsidic augite, and actinolitic hornblende and rare biotite. Accessories include sphene, apatite, zircon, epidote, clinozoisite, and iron oxide. Relic porphyritic texture survive in complete preservation, whereas newly developed gneissose texture is less distinct.

Potash feldspar was investigated by X-ray diffraction pattern method, and was found to consist of orthoclase changing to microcline with a maximum angle of obliquity of 0.71 (determined by the position of 131 and $1\bar{3}1$ peaks in X-ray powder diagram). Potash feldspar and oligoclase are partly altered to sericite and kaolin. The former is sometimes microperthitic. Oligoclase (An 20%) tends to form idiomorphic tabular crystals. Quartz occurs in mosaic aggregate and shows undulose extinction. Diopsidic augite occurs as irregular grains and stout crystals and has $2V = 56°$. It is partly altered to amphibole especially along cleavage planes and around the peripheries of the crystals. Actinolitic hornblende forms stout prisms, and is pleochroic with X = pale yellows, Y = greenish yellow, Z = green. Biotite forms resorbed, partly chloritised flakes.

Biotite-bearing aplitic gneiss:

The rock is fine grained and equigranular and consists essentially of abundant quartz, feldspar, subordinate biotite and accessory zircon and epidote. Gneissose texture is marked by parallel alignment of biotite flakes. Relic micrographic texture is observed in some examples. Quartz and feldspar show strain extinction. Feldspars include orthoclase, microcline, and oligoclase (An 22%).

Modal composition of aplitic gneiss

costituent	biotite-aplitic gneiss S 7	pyrox.-amph. aplitic-gneiss S 50	pyrox.-amph. aplitic-gneiss S 52
	%	%	%
quartz	37.3	31.5	30.0
potash-fields	43.2	45.3	48.1
oligoclase	14.0	10.8	10.4
biotite	5.5	0.7	0.5
diopsidic augite	—	9.0	6.1
actinolitic hornblende	—	1.3	4.8
apatite	—	1.4	tr.
sphene	—		tr.
epidote	tr.	tr.	tr.
zircon	tr.	tr.	tr.
total	100%	100%	99.9%

Study of Distribution of Trace Elements in Amphibolites

To throw some light on the origin of spotted and non-spotted varieties of amphibolites, study of distribution of trace elements was carried out. Two average samples of spotted amphibolites and three average samples of non-spotted amphibolites have been analysed spectrochemically on their contents of Ni, V, Cu, Co, and Cr.

Jarrell U. Ash spectrograph was used for this purpose. The method adopted is given below:

Finely crushed material was mixed with a 0.01% pd-coal mixture in a proportion of 1 : 2. The conditions of exposure were as follows:

Spectrograph:	3.4 mm Ebert-Gitterspectrograph (Jarrell U. Ash) 30,000 lines/inch, 1 order, wave length range 4350—3175.
Optical conditions:	Filter 20/100%, slit 10
Electrical conditions:	220 V/10 A, Schaltung: Anodic
Photographical conditions:	Exposure time 180 Sec. Photoplate: Gevaert scientia 34B—50
Measurements of lines:	Quantitativ with background correction Microphotometer Jarrel U. Ash.

Calculating board was used to calculate the values obtained. The values were compared with standard samples, which were controlled by international standards form U. S. Geological Survey DTS-1.

The results of the trace element studies are tabulated below:

Sample No.	name of rock	Ni ppm.	V ppm.	Cu ppm.	Co ppm.	Cr ppm.
S 14	spotted amph.	58	380	100	43	62
S 33	spotted amph.	42	360	87	42	43
S 6	non-spotted amph.	44	430	70	50	88
S 26	non-spotted amph.	49	480	39	46	115
S 18	non-spotted amph.	42	355	115	43	49

Discussion and Concluding Remarks

Origin of the Amphibolites:

1) The preservation of basic plagioclase (labradorite An 66%) porphyroblasts in the spotted amphibolites reflects their igneous origin.

2) Mineralogically, both spotted and non-spotted amphibolites are identical. Moreover, they almost show the same distribution of trace elements. This indicates that spotted amphibolites and non-spotted amphibolites have the same origin.

3) The high contents of the elements Ni, V, Co, Cr, and Cu in both varieties of amphibolites reflect their igneous origin.

As all the amphibolite bands and boudinages lie along the S-planes of the country rock, it is apparent therefore that the *ortho*-amphibolites have been intruded originally as sills.

Origin of the Aplitic Gneisses:

1) The mineralogical and modal composition of the biotite bearing aplitic gneisses together with the preservation of relic igneous textures in

the aplitic gneisses, in general, indicate the original aplitic or microgranitic nature of the rock.

2) As the pyroxene and amphibole bearing aplitic gneisses are only confined to those thin bands which intercalate the marbles, it is believed accordingly that the original granitic magma could have been contaminated by assimilation of calcareous sediments.

3) The aplitic gneisses usually occur as thin layers intercalated with the marble bands, as well as boudinages lying along the S-planes of the country rock. This indicates that these gneisses have been intruded originally as aplitic or microgranitic sills.

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PLATE 1

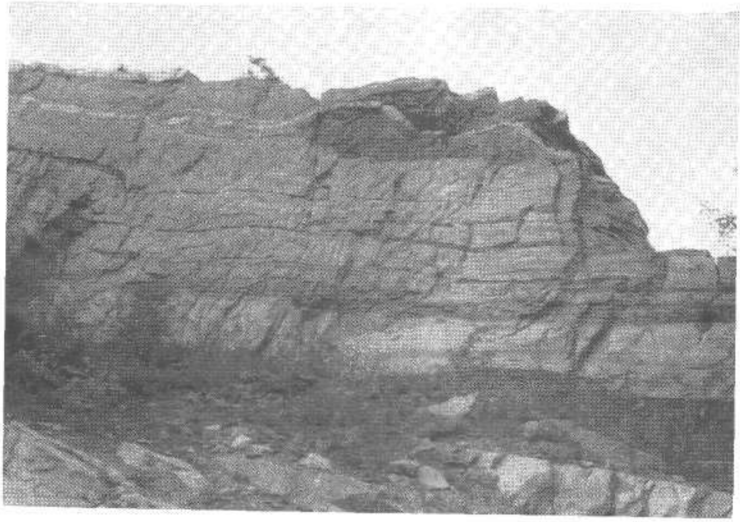

Fig. A. Amphibolite boudinages and bands (dark) running parallel to the S-planes of marbles near the Devil's wall.

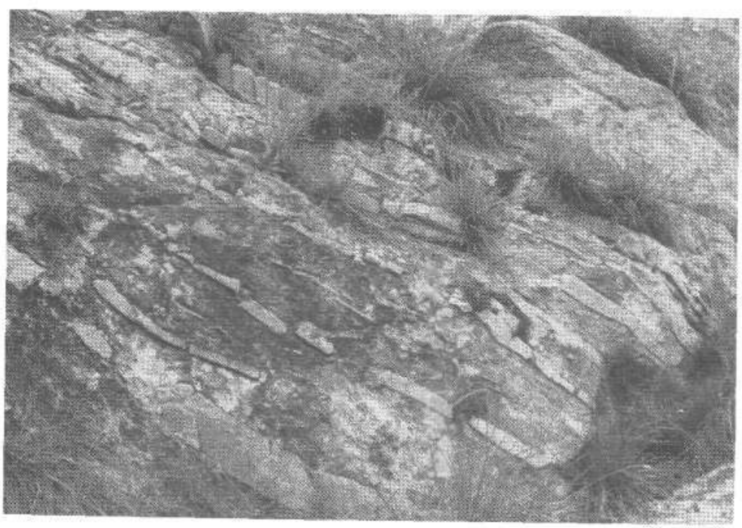

Fig. B. Thin pyroxene and amphibol-bearing aplitic gneiss bands in a marble country rock.

GEOLOGICAL MAP OF THE MIDDLE PART OF THE KAMP VALLEY BETWEEN WALDREICHS AND WEGSCHEID BY MAHMOUD KHAFFAGY 1967

USING THE SKETCH MAP OF CH. EXNER (1957)