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Rocks of the Murree formation in Northern Pakistan: indicators of a descending foreland basin of late Paleocene to middle Eocene age

By PAUL BOSSART[1]) and ROBERT OTTIGER[2])

ZUSAMMENFASSUNG

Bis zum heutigen Zeitpunkt wurden die roten Sand- und Siltsteine der Murree Formation Nord-Pakistans als kontinentale Ablagerungen miozänen Alters angeschaut. Eine neue und detailliertere Aufnahme eines ca. 8 km langen Profils durch die Apexregion der Hazara-Kashmir Syntaxis in Nord-Pakistan hat jedoch gezeigt, dass diese Gesteine in einem flachmarinen (sub-supratidal) Milieu, auf einer Gezeitenebene, abgelagert wurden. Diese Hypothese basiert auf der Interpretation sedimentärer Zyklen, die in den Murrees festgestellt wurden. Ein einzelner Zyklus beginnt mit typischen Ablagerungen aus Gezeitenkanälen und Prielen (Mikrokonglomerate und kreuzgeschichtete Sandsteine), die dann allmählich in Sedimente einer Gezeitenebene übergehen (laminierte sowie stark bioturbierte Sand- und Siltsteine). Der oberste Teil eines Zyklus besteht aus roten tonigen Silten mit lokalen Caliche-Horizonten. Hinweise auf eine mögliche Herkunft aus dem Norden (Kohistan Inselbogen) und nicht aus dem Süden, wie bisher immer angenommen, geben Chromspinelle aus den grobkörnigen Sandsteinen der Basis der Murree Formation. Altersbestimmungen basierend auf Nummuliten und Assilinen ergeben spätes Ilerdian für die Basis der Murree Formation sowie spätes Mittel-Lutetian für die Gesteine aus dem oberen Drittel des Profils. In der Hazara-Kashmir Syntaxis ist die Murree Formation demzufolge älter als im Süden (Kohat-Potwar Provinz) wo Fossilfunde ein frühmiozänes Alter angeben. Dieser Altersunterschied kann mit einer südwestwärtsgerichteten Verschiebung der «Himalayan thrust front» und der damit verbundenen kontinuierlichen Verschiebung des «foreland basins», und somit des Murree-Faziesgürtels, nach Südwesten erklärt werden. Für die Gesteine der Murree Formation bedeutet das, dass sie von Norden nach Süden kontinuierlich jünger werdende flachmarine Sedimente überlagern. Die Einführung eines neuen Formationsnamens bezüglich des marinen Teils der Murree Formation wird mittels einer Empfehlung an das «Stratigraphical Committee of Pakistan» vorgeschlagen.

ABSTRACT

The red clastic sand and shale deposits of the Murree formation have been regarded as continental deposits of Miocene age. A new and more detailed sedimentological and micropaleontological survey on a profile of about eight kilometers in length, in the apex region of the Hazara-Kashmir Syntaxis in Northern Pakistan, has shown that these rocks were deposited in a very shallow marine, tidally influenced environment. This hypothesis is based on the recognition and interpretation of the cyclic sedimentation seen in these rocks. One can interpret a single cycle as the product of meandering tidal channels in a continuously subsiding foreland basin. Each cycle starts with typical channel fill deposits (microconglomerates, crossbedded sandstones) and passes upwards into tidal flat deposits (laminated and strongly bioturbated sand and siltstones). The uppermost part of a cycle is composed of red clayey silt with local horizons containing calcareous concretions which are interpreted as a type of fossil Caliche. Chrome-spinels out of coarse grained sandstones from the base of the Murree formation, near Balakot, indicate the Kohistan complex as a possible source area. It therefore seems likely that the Murrees are derived from the North and not from the South as previously presumed. Age determinations based on syndepositional nummulites and assilines in-

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dicate an age of late Ilerdian (latest Paleocene) at the base of the Murree formation and late middle Lutetian at a position some two thirds from the base of the profile. In the North, the Murree formation is therefore much older than it is in the South (Kohat, Potwar) where data suggests an early Miocene age. This age discrepancy is explained by a southwestward migration of the Himalayan thrust front that led to a southwestward migration of the Himalayan foreland basin and the Murree facies belt. As a consequence the Murree deposits prograded on to progressively younger shallow marine deposits. The introduction of a new formation for the marine part of the Murree formation is recommended to the Stratigraphical Committee of Pakistan.

1. Introduction

Molasse sediments have a broad distribution in Northern Pakistan and Northern India (Fig. 1). Deposits of Quaternary age are found in the Peshawar- and Kashmir basins, while mainly Tertiary sediments build up a considerable part of the Sub Himalaya, forming a broad rim along the southern margin of the main Himalaya ranges, limited in the north by the Main Boundary thrust. Simply said these Tertiary molasse sediments are divided into the older Murree formation and the younger Siwalik deposits.

During a project of the Federal Institute of Technology Zürich on the geology of Northern Pakistan detailed tectonic, sedimentologic and micropaleontologic research in the apex region of the Hazara-Kashmir Syntaxis (HKS) was carried out (Fig. 1). The HKS is kind of a "half window" which consists of a complex series of overlapping nappes made up of various Precambrian, Paleozoic and Mesozoic formations of the

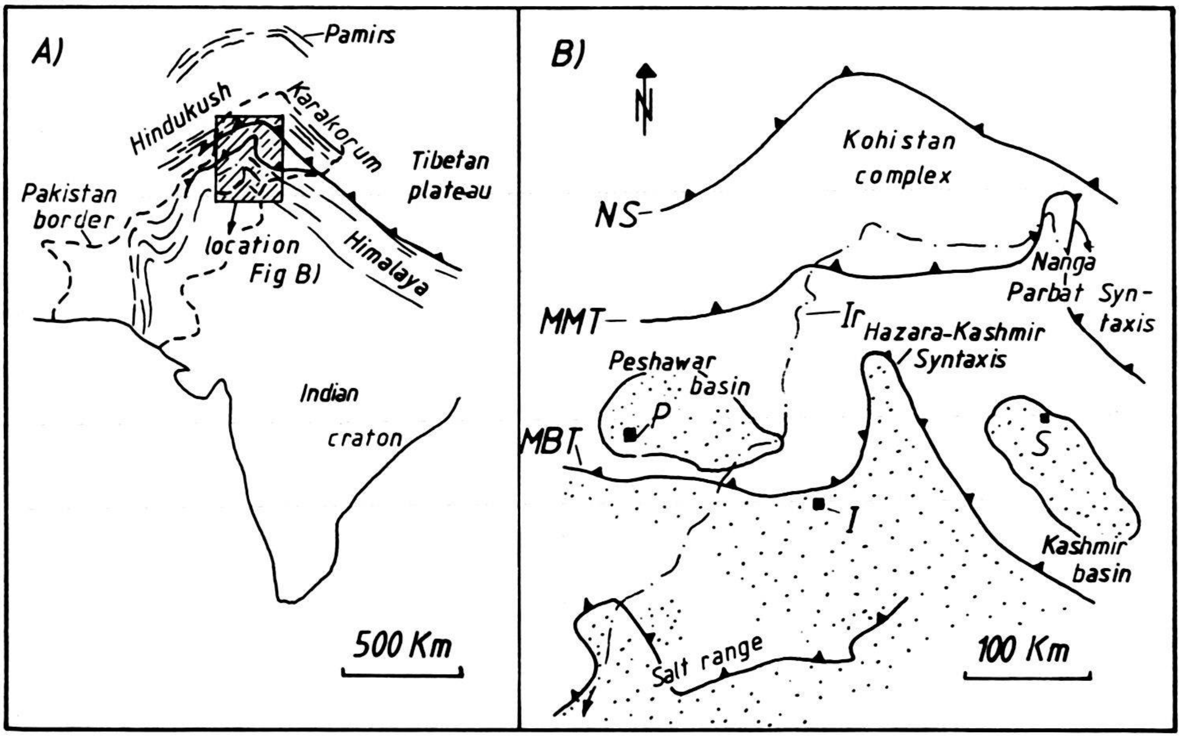


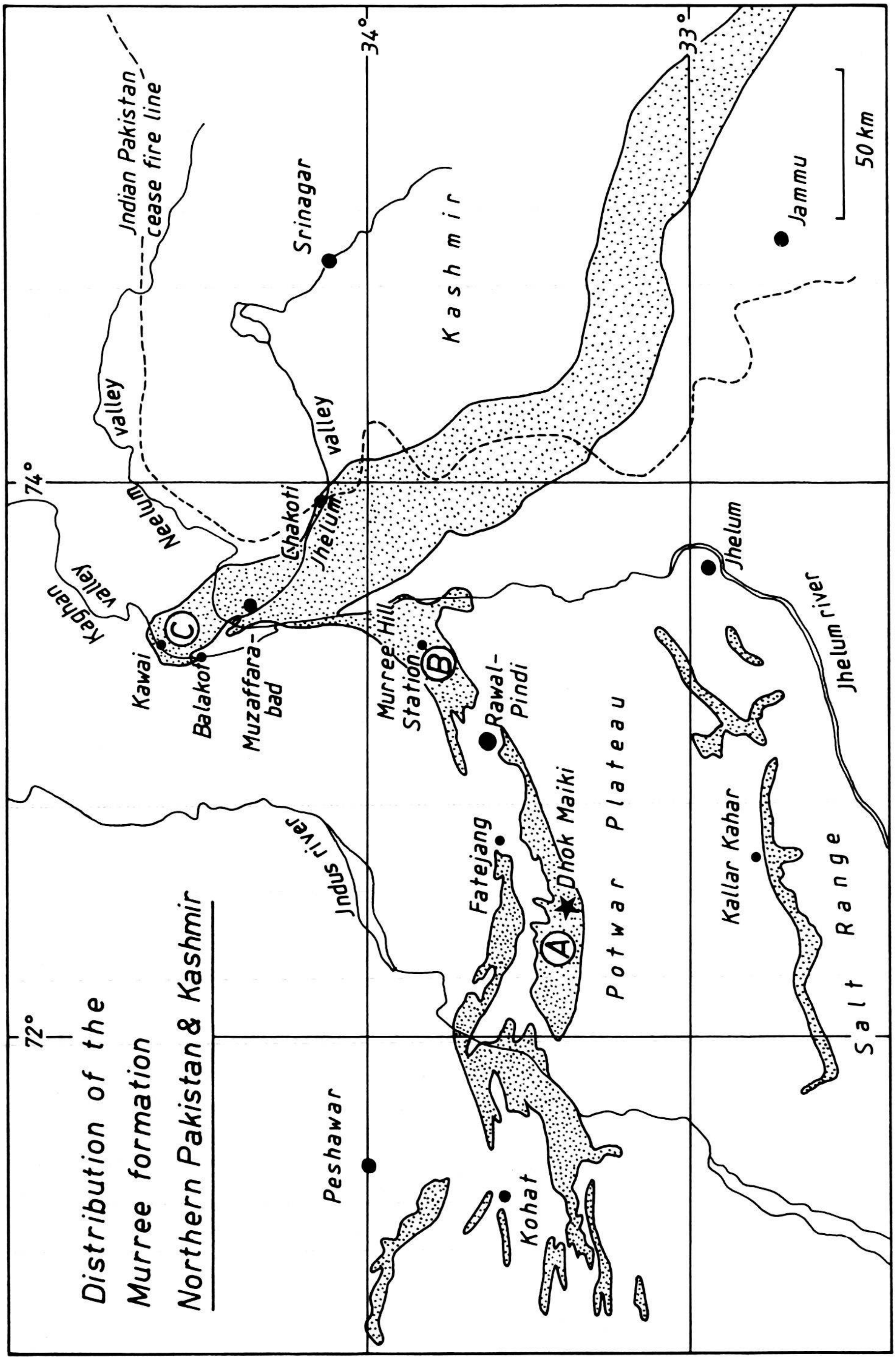
Fig. 1. Simplified map of Pakistan Himalaya: A) orogenic zones and Indian craton with location map (dashed). B) the main tectonic units, thrusts and basins in northern Pakistan and Indian Kashmir. Stippled areas indicate regions of predominantly postcollision molasse sediments (Murree formation and Siwaliks). MBT = Boundary thrust; MMT = Main Mantle thrust; NS = Northern Suture; Ir = Indus river; P = Peshawar; I = Islamabad (Rawalpindi); S = Srinagar.

Lesser Himalaya. These thrust units have been overthrust on a group of Tertiary sediments of the Subhimalaya, mainly rocks of the Murree formation. Our studies were concentrated on the northernmost outcrops of the Murree formation, building up the core of the Hazara-Kashmir Syntaxis (HKS), exposed in the southern Himalayan region of Hazara and Azad Kashmir, in Pakistan.

2. Geological review and a suggested new division of the Murree formation

Rocks of the Murree formation are tracable from West of Peshawar, over the Kohat-Potwar province and the Salt Range, to the Hazara-Kashmir Syntaxis and from there, to Jammu and the North Indian plain (Fig. 2). The Murree formation is composed of clastic, molasse-type sediments, mainly red and green shales, graywackes and subordinate conglomerates, forming characteristic fining-upward cyclothems. The red and purple colour of these deposits is in general the characteristic feature to relate these rocks to the Murree formation. In the Hazara-Kashmir Syntaxis between Balakot and Muzaffarabad (Fig. 2 and 3) the Murree formation lies conformably on Paleocene deposits, consisting mainly of the Lockhart limestones (black limestones with marl intercalations) and the shales and marls of the Patala formation, all part of the Kala Chitta zone of the Lesser Himalaya of TAHIRKHELI (1982). Going south and southwest, the Murree rocks overlie continously younger shallow marine deposits of very late Palaeocene to early Eocene age, as the black nodular limestones of the Maragala Hill formation and the purple shales of the Kuldana formation (WYNNE 1874) near Murree Hill Station, a locality sixty kilometers north-east of Rawalpindi and the Chorgali formation in the Salt Range. The youngermost sediments overlain by the Murree rocks are the middle Eocene, massive to nodular, light gray to green coloured limestones and olive green shales of the Kohat formation (MEISSNER et al. 1968) on the Kohat-Potwar Plateau. In 1874 WYNNE described the red sandstones and shales occuring in the neighbourhood of Mari Hill Station (present name: Murree Hill Station) and called them Mari Group. In his article he described a gradual passage from the Eocene Nummulite shales, through the Kuldana beds, to the Mari series. In 1877 he postulated a Miocene age for the Murree Group (WYNNE 1877) and designated them as passage beds from the marine sediments of the Nummulitic Series to the continental Siwalik Series. LYDEKKER (1882) described a relic of a palm leaf from the upper part of the Murree Group, which FEISTMANTEL (1882) determined as a *Sabal major* HEER 1855 of Miocene age.

Further work on the Murree Group was done by PILGRIM (1910) and PINFOLD (1918), who concluded that the Murrees were entirely continental deposits. PINFOLD proposed the name Fatejang zone for the conglomeratic base of the Murree group on the northern Potwar Plateau (Fig. 2, Fig. 3 column A). He postulated a time gap between the Fatejang zone and the underlying Nummulite shales. WADIA (1926, 1931) accepted this view for the Kohat-Potwar Province and Poonch. In the Hazara Kashmir region, however, he considered the passage to be almost transitional. In the same article he postulated a southern origin of the Murree rocks. Finally the Stratigraphical Committee of Pakistan (SHAH 1977) named these rocks Murree formation. They approved the term Rawalpindi Group, suggested by PINFOLD, for the Miocene rocks comprising Murree formation and Kamlial formation. These formations have a thick-


Distribution of the
Murree formation
Northern Pakistan & Kashmir
72°
74°
34°
33°
Jndian Pakistan
cease fire line
Srinagar
Kashmir
valley
Neelum
Kaghan
valley
valley
Chakoti
Jhelum
C
Kawai
Balakot
Muzaffara-
bad
Murree Hill
Station
B
Rawal-
Pindi
Jammu
50 km
Jhelum
Jhelum river
Indus river
Fatejang
Dhok Maiki
A
Potwar Plateau
Kallar Kahar
Salt Range
Peshawar
Kohat

ness of at least 3,300 m in the north and a section to the north of Dhok Maiki (lat. 33° 30′, long. 72° 35′), in the Campellpore district, has been designated as a type section.

Subsequent workers as Rashid (1965), Calkins (1966, 1975), Latif (1970), Fatmi (1973), Meissner et al. (1974) and Tahirkheli (1982) have accepted the Murree rocks to be continental deposits of Oligocene to middle Miocene age.

In chapter 3 we shall show that in the region of the Syntaxis the Murree deposits are of shallow marine origin (tidal flat deposits). In contrary, mainly in the Kohat-Potwar Plateau and the Salt Range to the SW, fluviatile continental facies do occur. In chapter 5 we shall demonstrate, that these shallow marine deposits in the Syntaxis belong to the late Paleocene-middle Eocene time span. On the other hand the fluvial Murree deposits in the SW are considered to be of Miocene age. One effect is that the term "Rawalpindi group" improved by the Stratigraphical Committee of Pakistan (Fig. 3 column A) is not valid for the Murree formation in the Syntaxis. This term comprises only the red beds of Miocene age in the SW, the Paleocene-Eocene in the North is neglected.

This diversity of sedimentary environments and the different ages would justify the separation of the Murree formation in the Hazara-Kashmir Syntaxis from those Murree deposits in the SW. We would like to recommend the Stratigraphical Committee of Pakistan to introduce a new formation name for the marine part of the Murree formation: we suggest the name *Balakot formation.* Balakot is the main village located in the NW of the Hazara-Kashmir Syntaxis where a splendid section through these tidal flat deposits starts eastwards along the Kaghan valley road (Fig. 2 and 8). A new type locality could best be stated at a site along the Kaghan road, where the fining upwards cyclothems are especially well exposed. We suggest a 200 m long section between the Coordinates 70.37/41.56 and 70.59/41.77 of topo sheet No. 43 F/10, 1:50 000 of the lower Kaghan valley (for details see Figure 8 where this section lies between sample localities D and E along the Kaghan road). This "Balakot formation" would be incorporated in a new defined *Murree supergroup* in the following way:

<table>
<tr><td rowspan="3">Murree supergroup</td><td rowspan="2">Rawalpindi group</td><td>– Kamlial formation</td></tr>
<tr><td>– Murree formation
(Fatejang zone)</td></tr>
<tr><td></td><td>– Balakot formation</td></tr>
</table>

The Murree supergroup would comprise a marine part at the base (Balakot formation) and a continental part at the top (Rawalpindi group). In the north, especially in the Hazara-Kashmir Syntaxis, only the marine Balakot formation is found (Fig. 3 column C) whereas in the Rawalpindi group towards SW, continental facies dominate

Fig. 2. Distribution of the Murree formation in Northern Pakistan and Western India. Dhok Maiki = type locality of the Murree formation defined by the Stratigraphical Committee of Pakistan (Shah 1977). Capitals A to C represent locations for the stratigraphic columns in Figure 3.

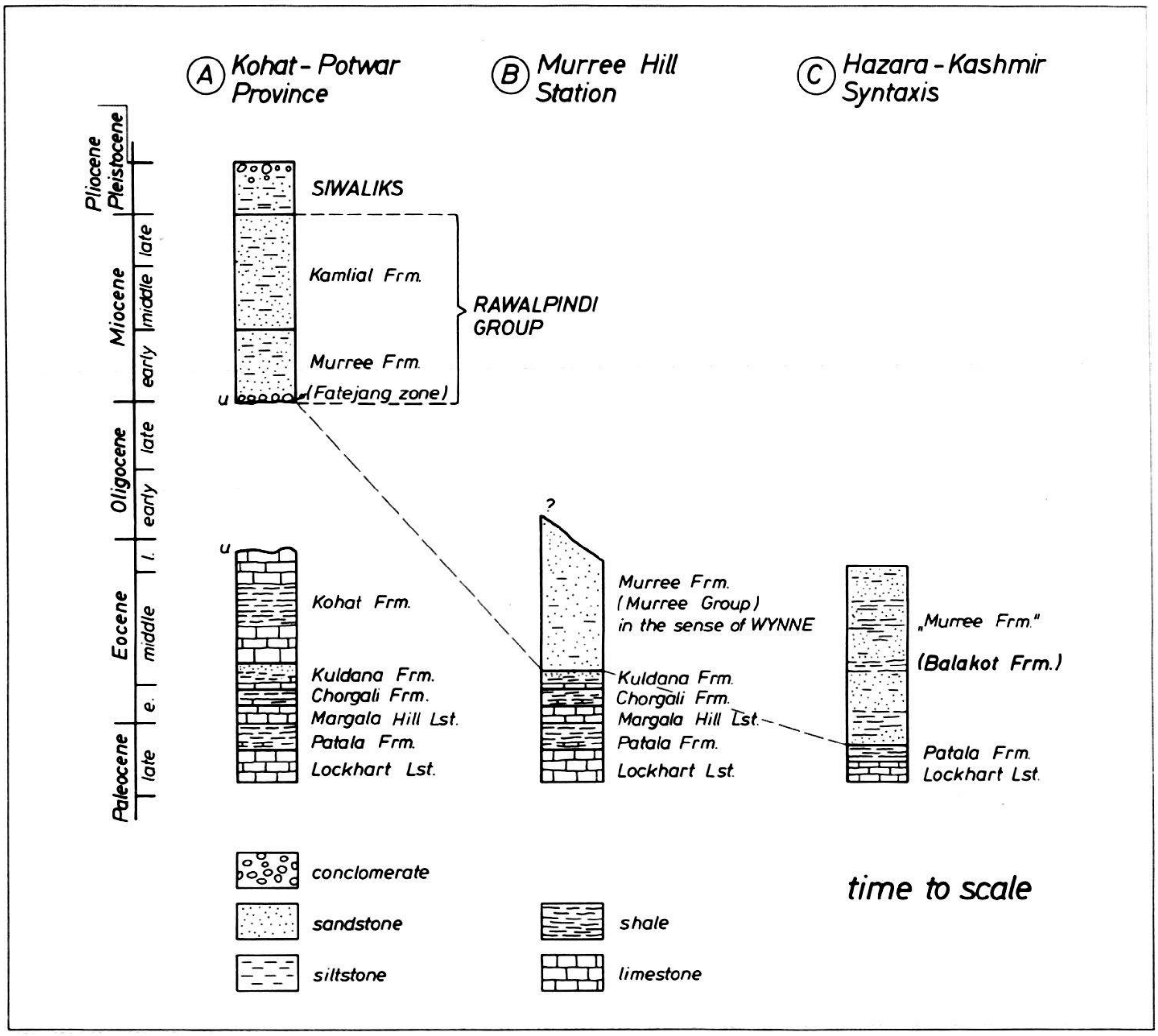


Fig. 3. Three simplified sections showing different Tertiary lithological formations (Frm) and the stratigraphical position of the Murree formation in the Himalayan fordeep of Northern Pakistan. For locations A to C see Figure 2. A detailed and more differentiated time scale for the Murree formation in the Hazara-Kashmir Syntaxis (Column C) is drawn in Figure 13. u = unconformity.

over marine ones (Fig. 3 column A). The transition zone from marine tidal flat deposits to fluvial continental deposits is located in the section of Murree Hill Station (Fig. 3 column B). This transition zone is not sedimentologically mapped and proper paleontological ages are missing. These red beds could be correlated either to the marine- or to the continental part of the Murree supergroup, depending on the dominant facies they expose. The division of the Rawalpindi group into a Murree formation with the Fatejang zone at the base and the Kamlial formation at the top, as defined by the Stratigraphical Committee of Pakistan (Shah, 1977), would be maintained. The time span of this Murree supergroup starts at the base with the late Paleocene to middle Eocene (Balakot formation) and ends with the formations of the Rawalpindi group comprising the whole Miocene. Inbetween, there is a time gap comprising the late Eocene and the whole Oligocene, where up to now no red beds are recorded. Possibly the red beds in the Murree Hill-transition zone could fill this time gap. The Murree supergroup cannot be compared with the Mari group in the sense of WYNNE (1877), because in his definition only the Miocene is included.

Until the Stratigraphical Committee of Pakistan will take notice of our suggestion, we would like to maintain the term Murree formation. In this paper we shall use a local definition for the Murree formation which is only valid in the Hazara-Kashmir Syntaxis: the Murree formation in the Syntaxis region is defined as shallow tidal flat deposits belonging to the late Paleocene-middle Eocene. Details of lithology and sedimentology will be discussed in the following chapter.

3. Sedimentology of the Murree formation in the apex region of the Hazara-Kashmir Syntaxis

The core of the Syntaxis (Fig. 4) is composed of rocks of the Murree formation, which are limited in the east, north and northwest by the Main Boundary thrust. In the apex region of the Syntaxis, the bedding as well as the cleavage of the Murree formation are steeply inclined towards northeast and north respectively. The dip of the bedding varies between sixty and seventy degrees. The beds become consistently younger in a northeastward direction, except in a few s-shaped minor folds near Balakot. Following the Kaghan road from Balakot to Paras, one can study a 8 km thick normal stratigraphical succession of Murree rocks (BOSSART et al. 1988). The section is composed of many fining upward cyclothems, containing sandstones and silts, with an average thickness of about ten meters.

This monotonous succession of clastic rocks is intercalated by four separate bands of marls and silts, which contain abundant Nummulites and Assilines.

Six main facies types are present in a standard cycle (Fig. 5).

From bottom to top:

type A: conglomerate

type B1: coarse grained cross-bedded sandstone

type B2: fine grained ripple-marked sandstone

type B3: laminated fine grained sandstone

type C1: cornstone facies

type C2: siltstone facies

1. Type A: conglomerate

Where present this facies gives rise to lense shaped bodies of up to 2 meters in thickness at the base of a cycle. These appear to represent channel fill deposits. They are distinguished by a great variety in nature of the pebbles and the composition of the matrix. The soles of the conglomeratic beds are invariably sharp and erosional and show load casts, flute casts and moulds of shallow channels. Three main types can be distinguished, these types never occuring together.

a) shale flake breccia: coarse grained graywacke containing thick flakes of reworked red silt up to 20 cm in diameter and derived from the underlying cycle.

b) Microconglomerates: rounded pebbles of silt and micritic limestone up to 3 cm in diameter probably representing reworked material from previously deposited

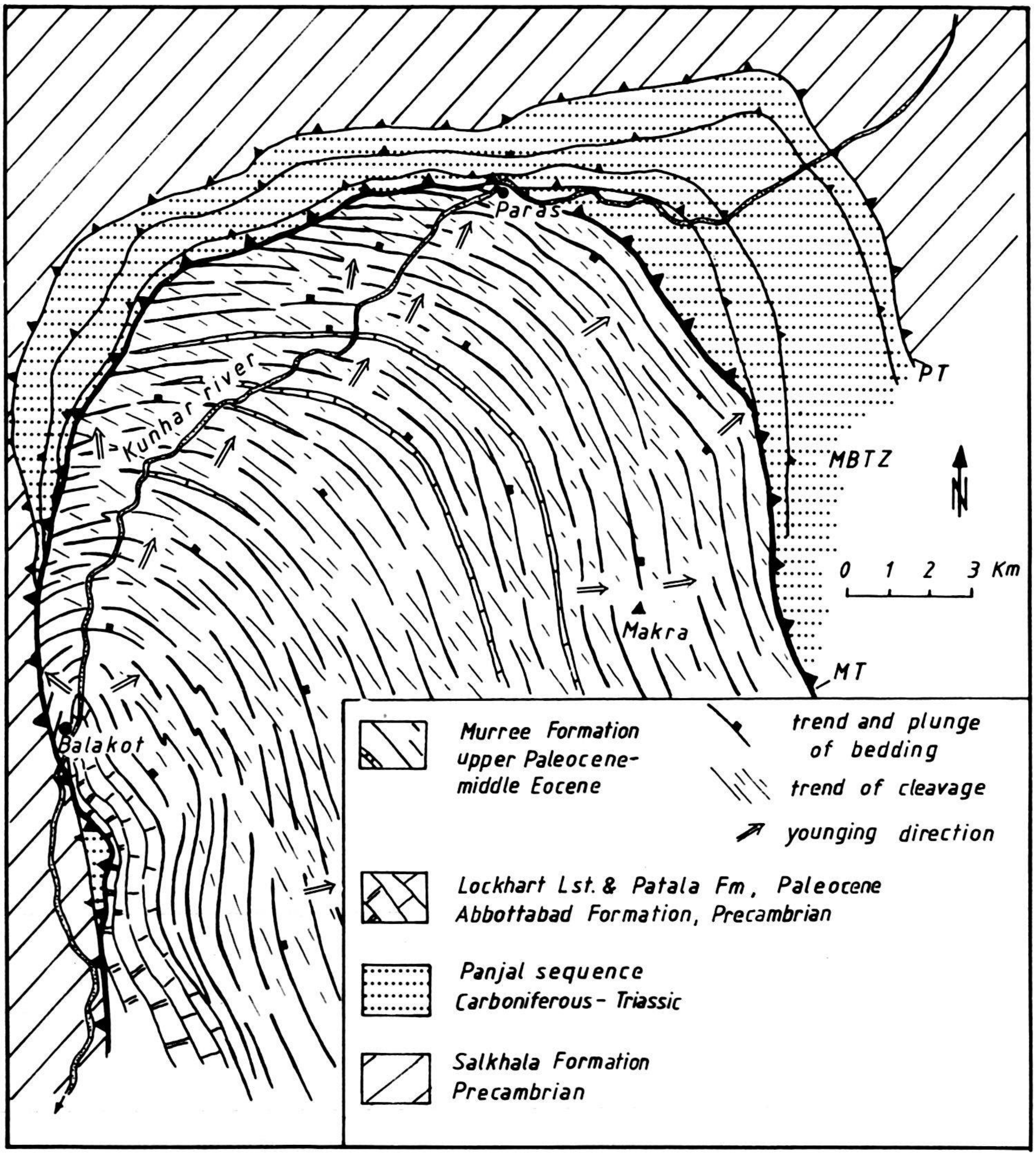


Fig. 4. Simplified geological map of the Syntaxis apex area: the Lockhart Limestone and Patala formation form a stratigraphical contact with the overlying Murree formation and are considered therefore as the base (bottom) of the latter. The top of the Murree formation is cut by the Murree thrust (MT) and not exposed. Bedding-cleavage strike trends as well as the constantly northeastward facing younging direction are indicated only in the Murree formation. – At least four Panjal thrust sheets are found in the Main Boundary thrust zone (MBTZ) limited by the older Panjal thrust (PT) and younger Murree thrust (MT). – Several Precambrian units are grouped together in the Salkhala formation.

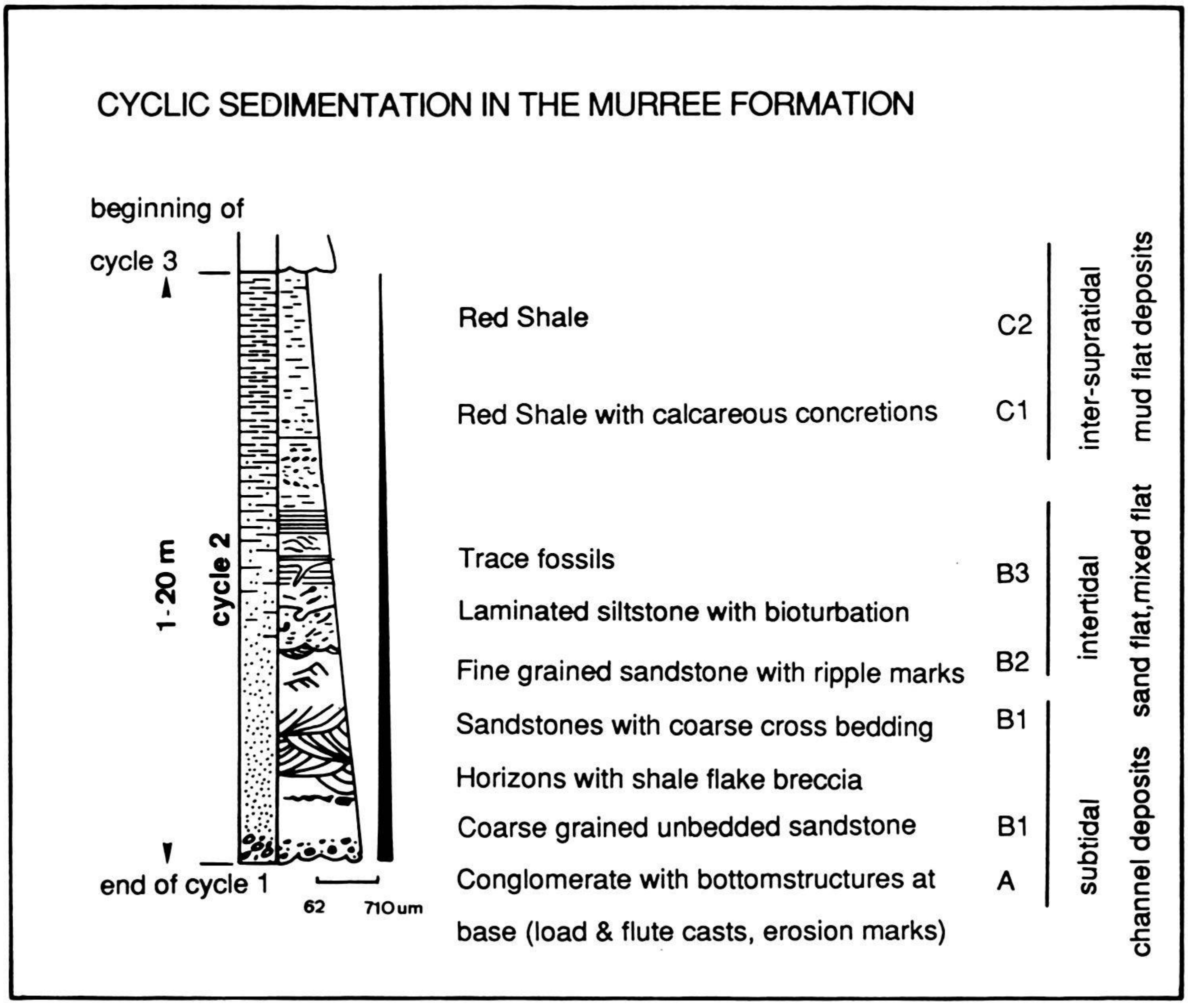


Fig. 5. Cyclic sedimentation in the Murree Formation.

cycles. Rarely one finds clasts of micritic limestone or bioclasts, mainly reworked nummulites and shell fragments.

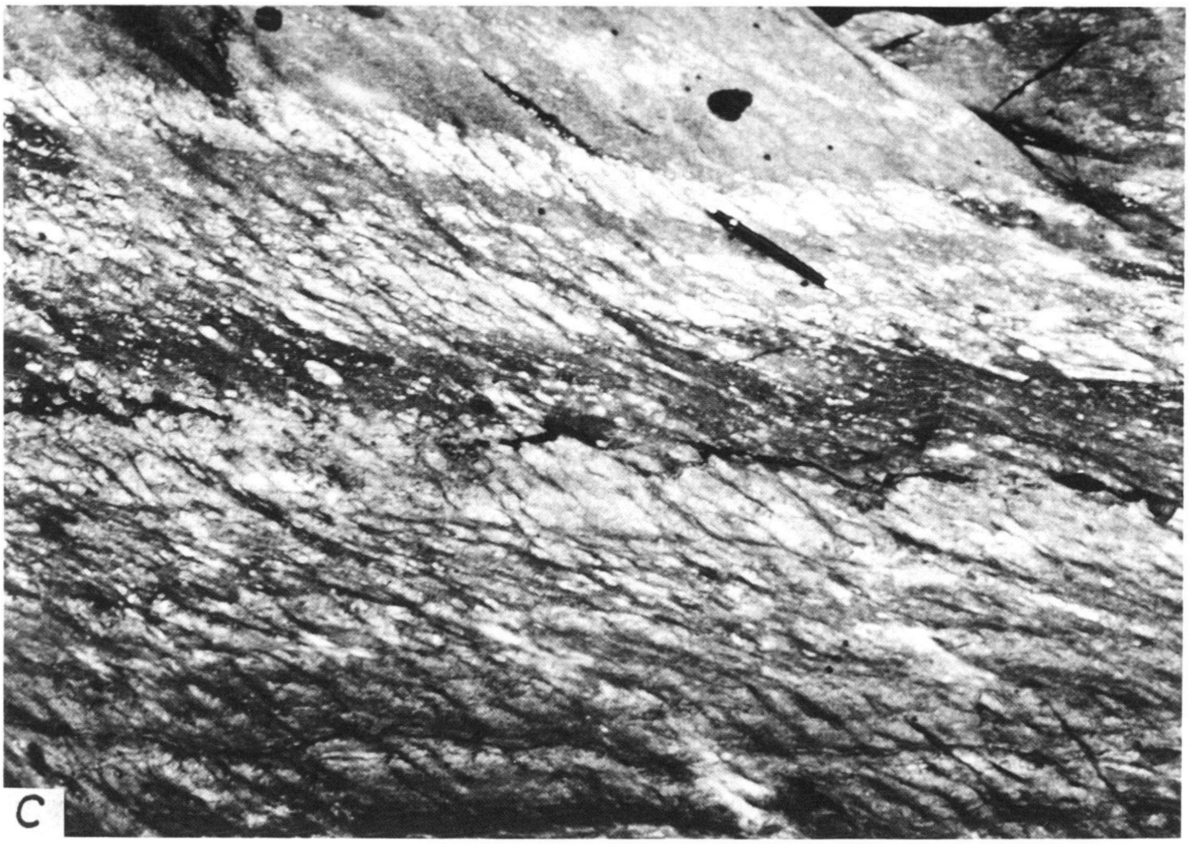
c) biogenic breccia: subangular breccias whose components are mainly reworked nummulites and assilines, which do not appear to have been transported for any great distance.

2. Type B1: coarse grained cross-bedded sandstone

This facies consists of beds of green and red, moderately sorted, coarse grained lithic subgraywackes up to 10 meters in thickness. The sandstone shows a very strong graded bedding (grain sizes between 180 μ and 500 μ) and often a coarse cross bedding. Trough cross bedding predominates over planar cross stratification. At a few places in the Jehlum valley one finds complete tidal bundle sequences showing a striking cyclicity. One can distinguish between thick relatively flat lying bundles, deposited at spring tide, and thinner, steeper ones, deposited at neap tide (Homewood & Allen


a


b



1981). If a depositional cycle starts directly with type B1, flute- and load casts, erosion marks and horizons with shale flake breccias are often found at the base. Bioturbation is very pervasive, especially at the contact zone with the underlying cycle. Besides very irregular dwelling and feeding structures, one finds regular u-shaped dwellings, very similar to Rhizocorallium of the Glossifungites ichnofacies. Plane laminated sandstones with heavy mineral concentrations along laminae are occasionally found. The heavy minerals are mainly hematite, magnetite, zircon, tourmaline, epidote and chromium spinel (see chapter 6).

Type B2: fine grained ripple-marked sandstone

This facies consists of fine grained (125 μ–180 μ) arkosic sandstones with ripple marks (Fig. 6a). The ripples commonly have heights of 0.5–1.5 cm and include highly asymmetrical, symmetrical and interference forms. Towards the top of type B2, flaser bedding occurs. There is a gradual transition to the overlying type B3.

Fig. 6. a). A fine grained sandstone of the type B2 with wave ripples. b) Laminated fine grained sandstone with bioturbation of the type B3. c) Caliche horizon in the siltstones of type C1.

Type B3: laminated fine grained sandstone

Main feature of this facies is the development of a thinly interlayered sand/mud lamination, a so called tidal bedding (REINECK & SINGH 1967). At some localities this structure is almost obliterated by pervasive bioturbation due to the activity of worms, crabs and bivalves (Fig. 6b). Where bioturbation effects are strong the contact to the overlying type C1 is gradational.

3. Type C1: cornstone facies

This facies consists of red silts, deposited in the inter- to supratidal range, containing many millimeter to centimeter sized concretions, which can be compared in morphology and lithology with cornstones. This facies appears to be best interpreted as a fossil caliche, such as has been described by STEEL (1974) in the New Red Sandstone of Scotland. In the Balakot-Paras section, most of the caliche horizons (Fig. 6c) are of a very immature state (Type 1 or 2 of the classification of STEEL 1974).

Type C2: Siltstone facies

The top of a cycle is composed of a monotonous succession of red and green argillaceous silts, up to five meters thick. Sedimentary structures are very rare. Only some slight traces of parallel lamination are visible. The uppermost part of type C2 is of some interest, because occasional dessication cracks are present, with the cracks occasionally penetrating downwards for a distance of up to one metre. The filling of the cracks is reworked material out of the siltstone facies and from the base of the overlying cycle. Salt marsh deposits containing evaporites and traces of roots are extremely rare.

Intercalated in this relatively monotonous succession of fining upward cyclothems are four zones of gray to black, very fossiliferous marly limestones and shales (Fig. 4 and 8). Some of them are up to thirty meters thick and tracable along strike over long distances. They contain many nummulites and assilines, the ages of which will be discussed later in this paper. The best outcrops of these rocks are located at the Sachcha river two kilometers west of Kawai (for location see Fig. 8).

Section Sachcha Katha (from bottom to top, Fig. 7)

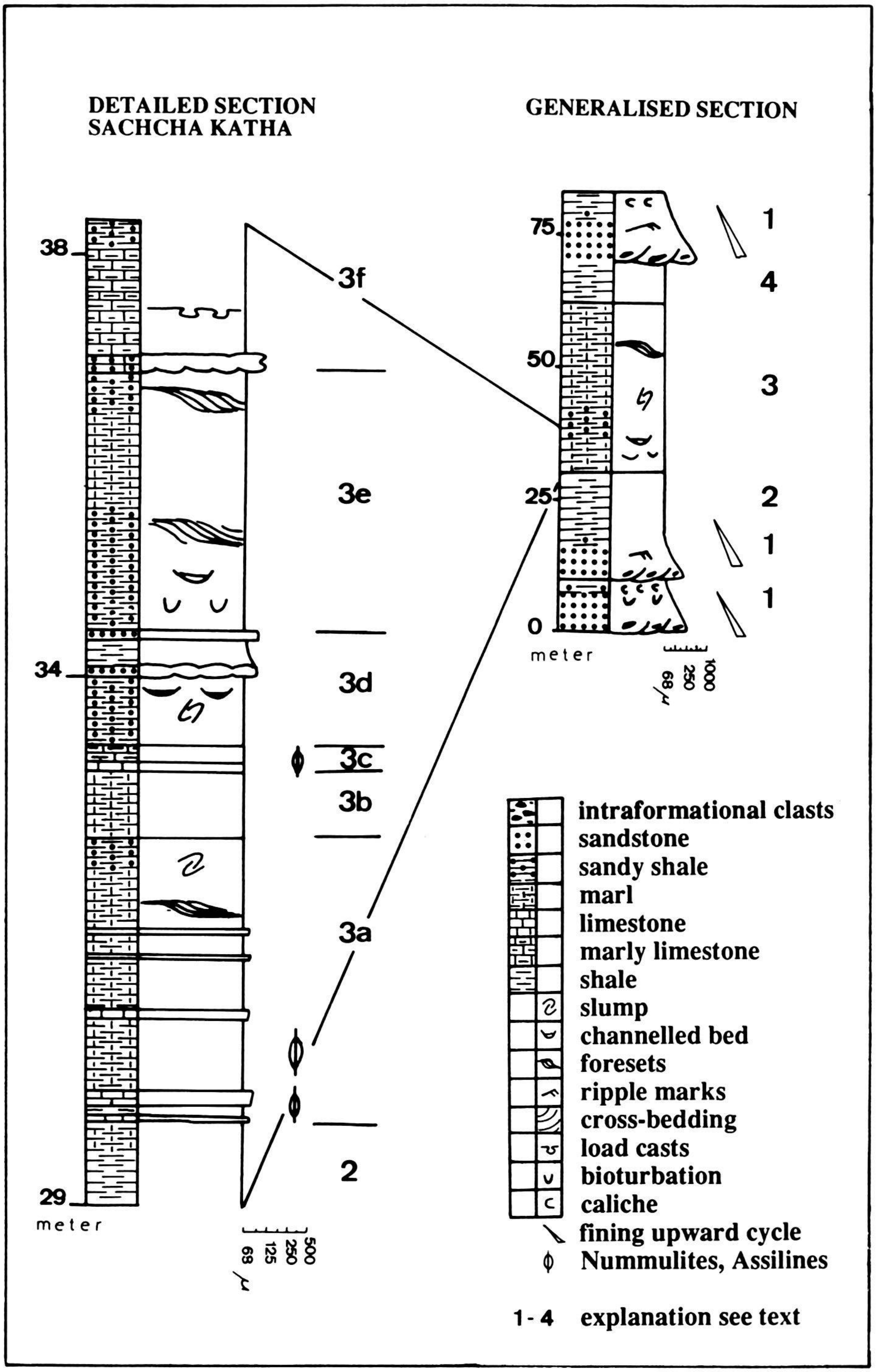
1) Murree type rocks, mainly red sandstones passing upwards into shales.

2) Red and green shales passing into grey to black marls.

3a) Dark grey, very fossiliferous marls with intercalations of black shales and lenses of grey sand bearing micritic limestones.

3b) Green to olive, pyrite bearing marls, containing clasts of reworked marls from the underlying unit.

Fig. 7. General relationship of the marly intercalations found in the Murree formation (right) together with a section on lithological details. (left; for explanation see text).


DETAILED SECTION
SACHCHA KATHA
GENERALISED SECTION
38
34
29
meter
3f
3e
3d
3c
3b
3a
2
68 125 250 500
μ
75
50
25
0
meter
68 250 1000
μ
1
4
3
2
1
1
intraformational clasts
sandstone
sandy shale
marl
limestone
marly limestone
shale
slump
channelled bed
foresets
ripple marks
cross-bedding
load casts
bioturbation
caliche
fining upward cycle
Nummulites, Assilines
1-4 explanation see text

3c) Thin band of yellow weathering dolomitic limestone followed by red brown argillaceous micritic limestone; very fossiliferous (especially Assilines of the Spira group).

3d) Green silt passing upward into red silt with flaser bedding and intercalations of sandstone layers.

3e) Green silt with very peculiar red, hazel-nut sized concretions, containing hematite, chlorite and clay.

3f) Dark grey sandy limestone passing upwards into a marly limestone and finally a marl containing abundant quartz.

4) Red argillaceous silts and sands, overlain by type 1 rocks.

4. General environmental interpretation

The spectrum of facies in the Murree standard cycle is similar to that observed in many ancient and modern tidal flat deposits. The model of a regressive sequence in a tidal flat (Reineck 1972) fits very well with our observations. The cyclic sedimentation of these rocks seems to be best interpreted as the product of meandering tidal channels in a continuously subsiding foreland basin.

Types A and B1 are interpreted as channel-fill deposits. One can distinguish between tidal channels, with shale flake breccias at their base and very rare fluvial distributary channels, whose channel lag deposits are characterised by quite large amounts of extraclasts, such as reworked micritic limestones. With decreasing channel size, the mud content increases. Large scale cross-bedding produced by ripples and at point bars are common in the environment of state B1. Bioturbation is uncommon and when present, is found only at the base of those channels without a basal conglomerate.

Type B2 represents sand flat deposits. Sand flats are located near the low-water line and are characterised by well-developed, small scale ripple cross bedding (both, current and wave types). Flaser bedding is often found towards the top. It passes upwards into a mixed zone represented by the top of type B2 and type B3. Characteristic bedding forms in the lower part of the mixed zones are flaser and lenticular bedding which pass upwards into a interlamination of sand and mud, the dominant feature of type B3. These features are probably best interpreted as the result of an alternation of deposition of tidal current bedload and suspension during slack-water periods (Klein 1975). This tidal bedding has commonly been reworked by deposit feeding organisms. Escape structures of bivalves and Diplocraterion type burrows are quite common (Reineck 1972).

Mud flats are represented by the upper parts of types B3 and C. Sand is rare and, if present, occurs in stripes within mud layers. In recent deposits it is known that very well-laminated clayey silt prevails on the intertidal flats between mean high and spring high water levels (Thompson 1968). The presence of mud cracks in the clayey silts of type C2 confirms that desiccation of these sediments occured during stages of nondeposition. Salt marsh deposits (intertidal and supratidal zone) occasionally form the top of type C2.

The area between the channels was probably only flooded by storms which forced water above the maximum high tide position. It was subjected to extensive periods of dry climate which resulted in sediment desiccation, and which, due to evaporisation, favoured the formation of the caliche horizons of type C1. Root mottled horizons as well as horizons with evaporites (notably gypsum) are found but are rare. In many cycles the uppermost part appears to have been eroded by meandering channels, which gave rise to the deposits forming the base of the following cycle.

The intercalations of marls and limestones described in the previous chapter appear to represent marine sediments of subtidal facies. The deposition took place in a quite water environment (lagoon) dominated by low energy traction currents. Water circulation, aeration and nutrient supply were mostly sufficient to support a benthonic fauna, especially nummulites, assilines and bivalves.

5. Paleontology and age of the Murree formation in the Hazara-Kashmir Syntaxis

The age is based on nummulites and assilines. Both foraminiferal groups were frequent in the intercalations of marls and shales between Balakot and Kawai (Fig. 8). Prehnit-pumpellyite facies metamorphism and relatively high finite strains (X:Z~6:1) in the Murree formation are responsible for the relatively poorly preserved fossils. For a determination of the species of nummulites, it is necessary to have either both equatorial- and axial cuts or an equatorial cut and the surface of the same individual. Samples were specially selected in the field to obtain both equatorial and axial cuts of nummulites. In contrast to the nummulites, most of the assilines were determined in thin sections. A short description of them is given on the following pages.

After Hottinger & Schaub (1960) and Hottinger et al. (1964) the position of the Paleocene-Eocene time limit was set between the Ilerdian- and Cuisian stage; the Ilerdian belongs to the latest Paleocene and the Cuisian to the early Eocene.

1. Sample section A (Fig. 8; Fig. 9a and 9b)

Samples of sites A belong to a stratigraphic section of the Lockhart Limestone and the Patala formation, which underlie conformably the Murree formation in the apex of the Syntaxis. Thin sections of these samples contain mostly unpillared nummulites with radial septal filaments (*Nummulites globulus* Leymerie, 1846 and *Nummulites atacicus* in the sense of Davies & Pinfold 1937) and small assilines (*Assilina* cf. *leymeriei* de Cizancourt, 1938 and *Assilina* cf. *dandotica* Davies & Pinfold, 1937).

Age: middle to late Illerdian.

Of special interest is a site from the Patala-Murree formation transition zone; alveolines found in thin sections belong to the *elliposoidalis* group and possibly the *canavarii* group.

Age: middle Ilerdian.

N. globulus Leymerie was also described by Davies & Pinfold (1937) (Salt Range and Sind, Pakistan) and by de Cizancourt (1938) (near Gardez, Afghanistan). *A. leymeriei* was described by de Cizancourt (1938) from near Gardez, Afghanistan. *N. atacicus* was described by Davies & Pinfold (1937) from the Kohat area (Salt range).

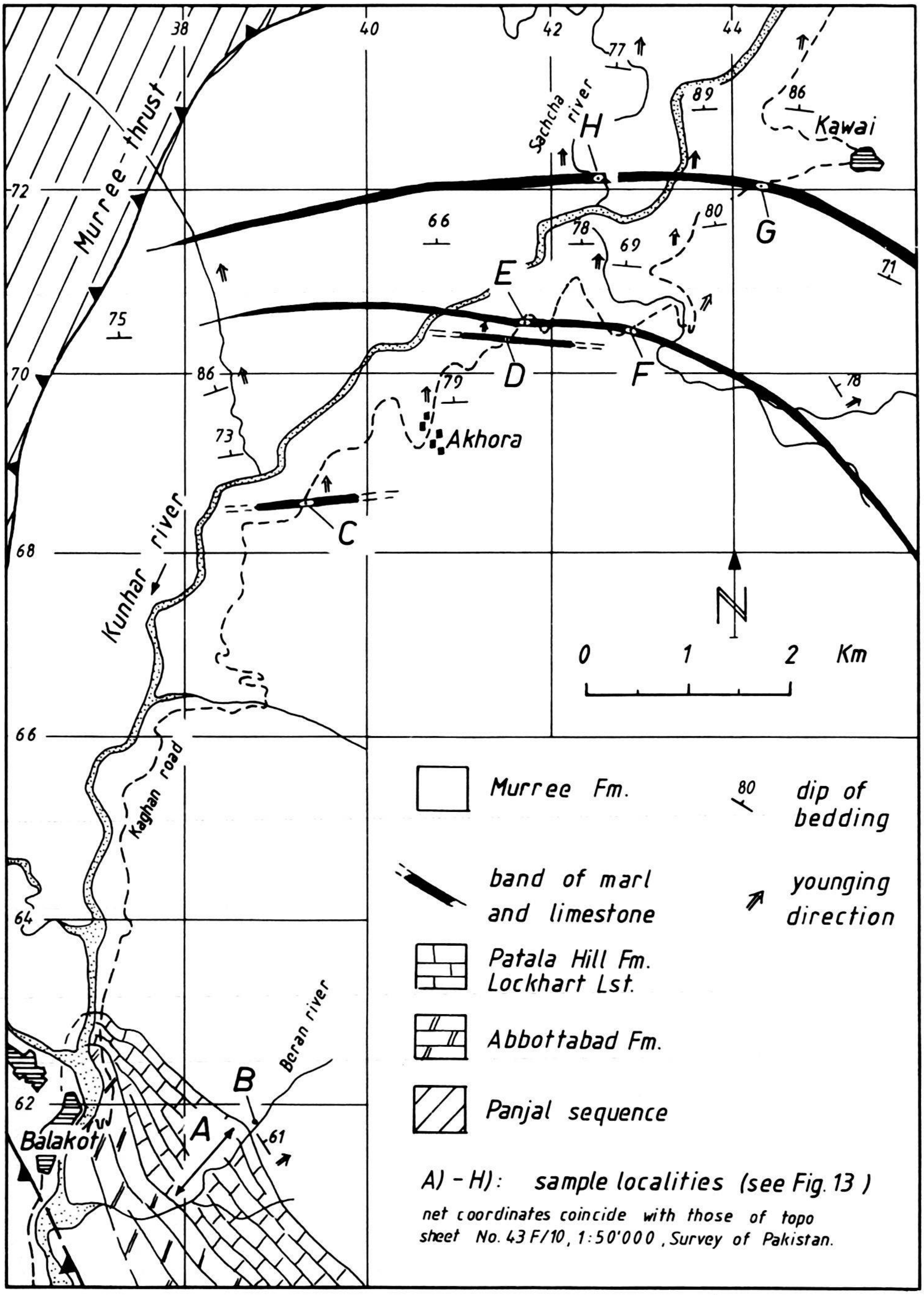


Fig. 8. Collection sites A–H of nummulites and assilines between Balakot and Kawai in the apex area of the Syntaxis. The younging direction is consistently to the north- and northeast.

2. Sample site B (Fig. 8)

Nummulites cf. *atacicus* LEYMERIE, 1846
(Fig. 9c and 9d)

A well preserved, lense shaped surface with slightly sinous septal filaments was found. The diameter of 9 mm (thickness 3.5 mm) indicates a B-form. An A-form (equatorial cut with preserved embryonal chamber, 4 whorls on a radius of 1.8 mm) is characterized by a regular, thick spiral wall.

Age: middle to late Ilerdian.

3. Sample site C (Fig. 8)

Assilina adrianensis SCHAUB, 1981
(Fig. 9e and 9f)

1981, SCHAUB, *A. adrianensis* nov. sp., p. 197, planche 72: 54–63; tableau 16: e.

In thin sections of this site (assiline limestone), A- and B-forms of the phylum *Assilina spira* were found. Caracteristic is the surface depression and concentration of the pillars at the centre. Diameters (4–4.6 mm) and thicknesses (0.7–0.8 mm) of A-forms relate the species to *Assilina adrianensis.*

Age: upper part of middle to late Ilerdian.

In the same sample, representatives of the *Assilina exponens* group were found.

Assilina leymeriei D'ARCHIAC & HAIME, 1853
(Fig. 9g and 9h)

Well preserved surfaces and axial cuts out of the *Assilina spira* phylum were found in a marly siltstone. They show a disc shaped form with a weak depression at the centre. The pillars are arranged in spiral manner in and around the depression. Diameters of different measured individuals vary between 3.3 and 4.5 mm, the thickness is less than 1 mm. Therefore, two species are indicated: *A. leymeriei* (D'ARCHIAC & HAIME, 1853) and *A. adrianensis* SCHAUB, 1981.

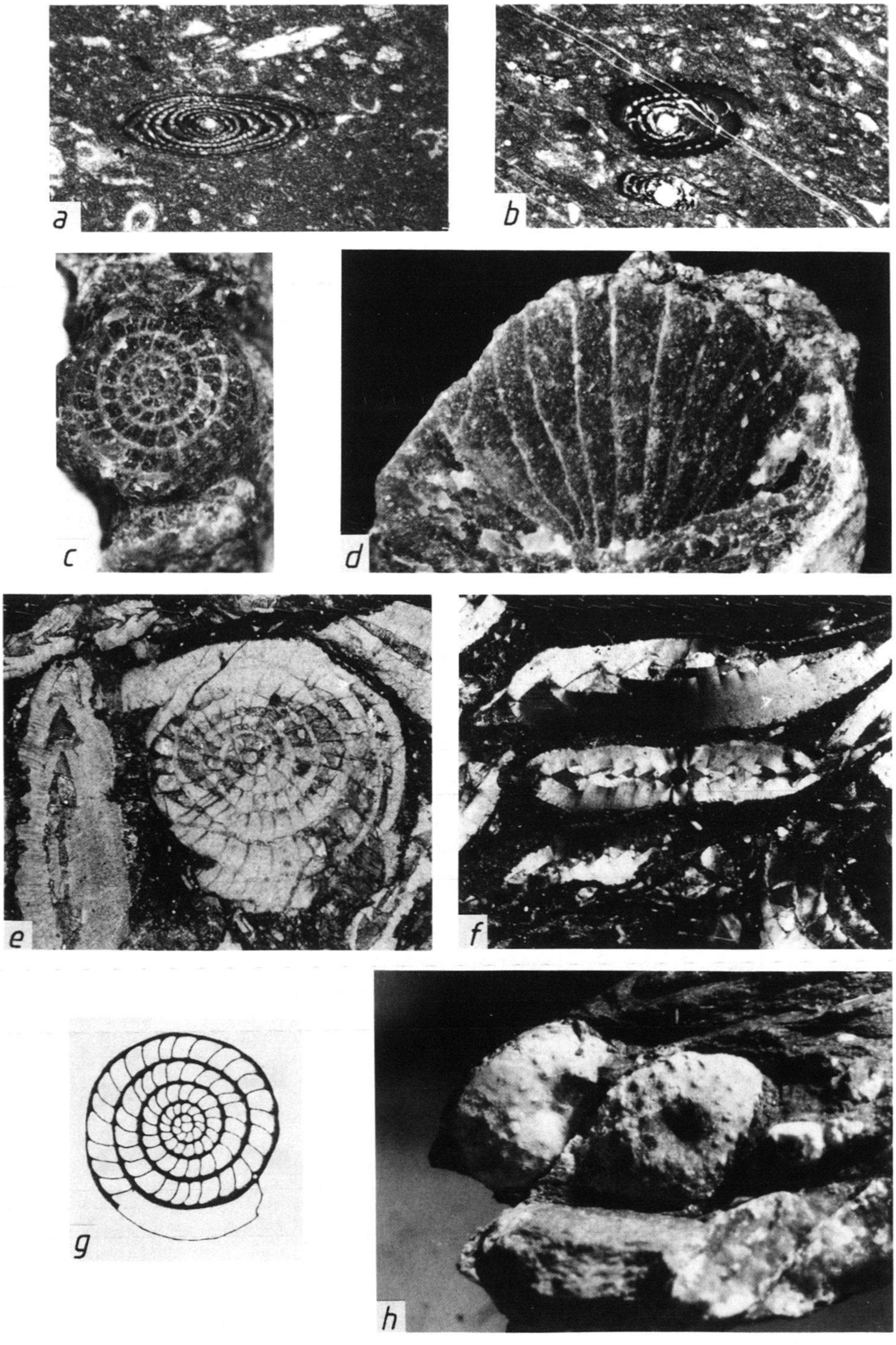
Age: both species belong to the upper part of the middle Ilerdian or late Ilerdian.

4. Sample site D (Fig. 8)

Assilina adrianensis SCHAUB, 1981
Assilina plana SCHAUB 1981
(Fig. 10a)

Diameters of A-forms (around 5 mm) and B-forms (around 8 mm) relate the species either to *A. adrianensis* or *A. plana.* Transition forms were also observed.

Age: transition Ilerdian – Cuisian.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Assilina cf. *pomeroli* Schaub, 1981

(Fig. 10b)

1981 *Assilina pomeroli* nov. sp. Schaub, p. 208, planche 85: 1–64; tableau 18: c.

In another thin section, representatives of the *Assilina exponens* group were identified: they are larger than the typical *A. pomeroli* and are determined as *A.* cf. *pomeroli.*

Age: latest Ilerdian or transition Ilerdian – Cuisian.

Nummulites afghanicus de Cizancourt, 1938

(Fig. 10c)

1938 *Nummulites afghanica* nov. sp., de Cizancourt, p. 15, pl. I, Figs. 3, 7, 8, 11; pl. II, Fig. 11, 12.

Nummulites praecursor ornatus Schaub, 1951

1951 *Nummulites praecursor ornatus* nov. sp., Schaub, p. 139, Figs. 157, 158; pl. 3, Figs. 12, 13.

Examples with well preserved lense-shaped surfaces with curved septal filaments and pillars concentrated along the septa were found. They were identified as *N. afghanicus* in the sense of de Cizancourt. It can be compared with *Nummulites ornatus,* Schaub 1951, which is the transition form between *Nummulites praecursor* de la Harpe, 1883 and *Nummulites partschi* de la Harpe, 1880.

Age: early Eocene (*N. afghanica,* de Cizancourt 1938).

Transition Ilerdian-Cuisian (*N. ornatus,* Schaub 1951).

5. *Sample site E* (Fig. 8)

Assilina subumbilicata de Cizancourt, 1938

1938 *Assilina subumbilicata* nov. sp., de Cizancourt, p. 24, pl. 3, Figs. 21–23.
1938 *Assilina umbilicata* nov. sp., de Cizancourt, p. 23, Fig. 2c, pl. 3, Fig. 19, 20, 27 (B form).

From this species axial cuts as well as equatorial ones of B-forms were found. The axial cuts show a characteristic depression in the centre and an angular periphery.

Age: early middle Cuisian.

This form has been described by de Cizancourt (1938) from the upper "Laki" beds in Afghanistan.

Fig. 9. *Sample site A:* a) *Alveolina ellipsoidalis* (10×), equatorial cut, b) Alveolina of the *canavarii* group (10×), oblique cut.
Sample site B: c) *Nummulites* cf. *atacicus* Leymerie (5×), equatorial cut, A-form, d) *Nummulites* cf. *atacicus* Leymerie (10×), surface, B-form.
Sample site C: e) *Assilina adrianensis* Schaub (10×), equatorial cut, A-form, f) *Assilina adrianensis* Schaub (10×), axial cut, A-form, g) *Assilina leymeriei* d'Archiac & Haime (10×), equatorial cut, A-form (Schaub 1981, BD I, tableau 16d as comparison for h) *Assilina leymeriei* d'Archiac & Haime (10×), surface, A-form.

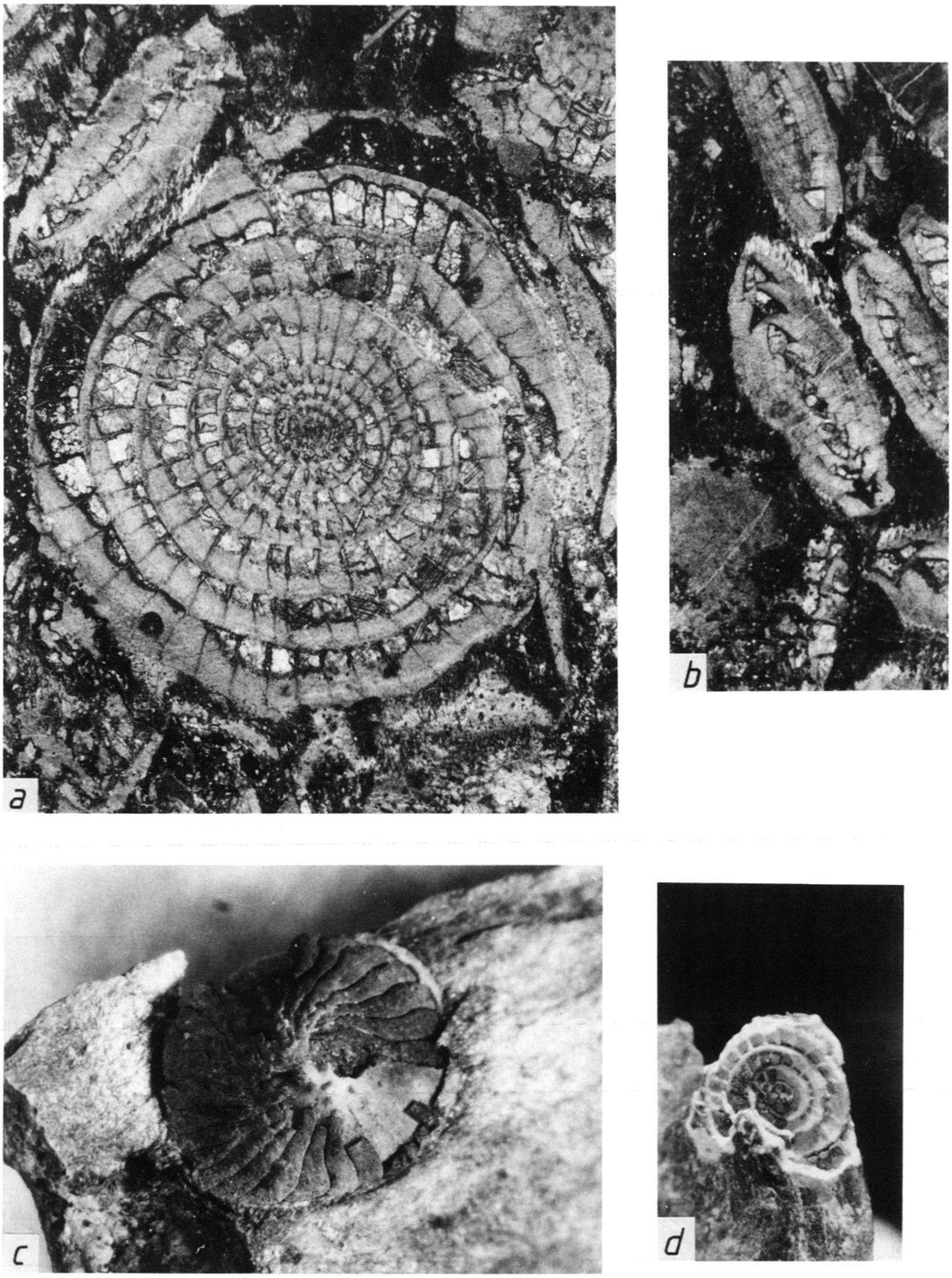


Fig. 10. *Sample site D:* a) *Assilina* cf. *adrianensis* Schaub (transition to *Assilina plana*) (10×), equatorial cut, B-form, b) *Assilina* cf. *pomeroli* Schaub (transition to *Assilina placentula* Deshayes (10×), axial cut, A-form, c) *Nummulites afghanicus* de Cizancourt (10×), surface.
Sample site E: d) *Assilina placentula* Deshayes (10×), equatorial cut, A-form.

Assilina placentula DESHAYES, 1838

(Fig. 10d)

1938 *Nummulites placentula* DESHAYES in VERNEIL & DESHAYES, p. 69, pl. 6, Figs. 8,9.

Figure 10d shows a fragment of an equatorial cut of an A-form and four whorls within a radius of 1.8 mm. The chambers are a little higher than wide and the walls are comparatively thick.

Age: early to middle Cuisian.

6. *Sample site F* (Fig. 8)

Assilina subumbilicata DE CIZANCOURT, 1938

(Fig. 11a and 11b)

From this locality very abundant specimens show only B-forms. Figure 11a shows an axial cut with the characteristic depression in the centre and angular edges and Figure 11b illustrates an equatorial cut.

Age: early to middle Cuisian.

Assilina cf. *laxispira* DE LA HARPE, 1926

(Fig. 11c and 11d)

Figure 11c shows an equatorial cut of an A-form with a diameter of 5.8 mm and a megalosphere of 0.3 mm. The surface is shown in Figure 11d. The form is flat with a slight depression in the middle. Sometimes the centre is somewhat thickened by a concentration of pillars.

Age: early middle Cuisian.

Assilina cf. *reicheli* SCHAUB, 1951

(Fig. 11e)

1951 *Assilina reicheli* nov. sp., SCHAUB, p. 215, Figs. 333, 334; pl. 9, Figs. 25–37.

Figure 11e shows a surface with the very characteristic accumulation of pillars in the centre. The specimen is a lense shaped A-form with a diameter of 3.2 mm and a thickness of 1.2 mm.

Age: middle Cuisian.

7. *Sample site G* (Fig. 8)

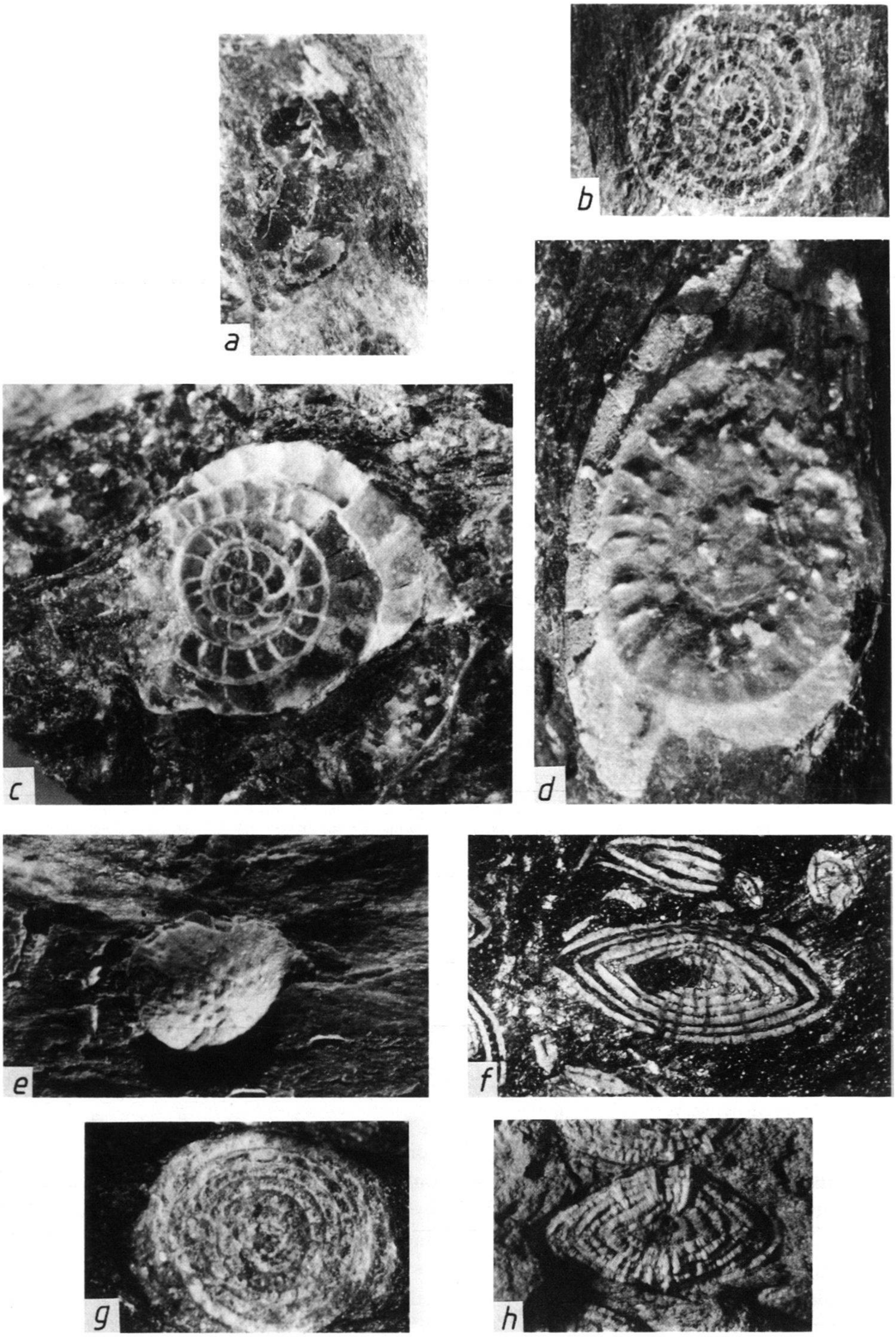
Nummulites cf. *laevigatus* BRUGUIERE, 1792

1792 *Camerina laevigata* BRUGUIERE, p. 399.

From this species only the A-form has been found. The surface shows the typical sinuous septal filaments. On the equatorial cut the spiral is regular with a diameter of 3.7 mm. The megalosphere is 0.55 mm. The thickness of the specimen is 2 mm. The chambers are higher than wide and very regular.

Age: early Lutetian.

This form has been described by NUTTALL (1926, pl. 1, Fig. 7) from the lower part of the middle Kirthar beds in Belouchistan and Sind.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Nummulites cf. *manfredi* SCHAUB, 1966

(Fig. 11f)

1964 Nummulites ≪nov. sp., ROSAZZO≫; HOTTINGER, LEHMANN & SCHAUB, plate II.

1966 *Nummulites manfredi* nov. sp., SCHAUB, p. 171, Figs. 6a–b, 7c, 9; pl. IV, Figs. 11–15; pl. V, Figs. 1–4; pl. VI, Figs. 1–3.

Thin sections show Nummulites with well developed pillars, which are of late Cuisian to early Lutetian age. One axial cut could be identified as *N.* cf. *manfredi.*

Age: late Cuisian.

Nummulites friulanus SCHAUB, 1962

(Fig. 11g and 11h)

1962 *Nummulites friulanus* nov. sp., SCHAUB, p. 538, Figs. 5b, 6; pl. 3, Figs. 1–13.

A few A-forms have been found at sample site G. Figure 11g shows an equatorial cut. Diameter 4 mm, megalosphere 0.5 mm. It has a relatively narrow spiral. The chambers are about two times longer than high. The axial cut represented in Figure 11h shows the typical lenticular form.

Age: late Cuisian.

8. Sample site H (Fig. 8)

Assilina spira abrardi SCHAUB, 1981

(Fig. 12a and 12b)

1981 *Assilina spira abrardi* nov. sp., SCHAUB, p. 202, planche 78: 6, 11–20; planche 79: 1–16; planche 80: 1–13; tableau 16: i.

A- and B-forms of the *Assilina spira* group were found. The thick spiral wall in the marginal part and the height of the chambers, as well as the diameters of A-forms (around 8 mm) and B-forms (vary between 20 and 30 mm) are characteristic for the subspecies *A. spira abrardi.*

Age: early Lutetian.

In general, the foraminiferal fauna of the apex area is mainly composed of a few assiline- and nummulite-species. Selective sampling of large specimens might have given a false view of the total species population. Assilina species numerically dominate over those of Nummulites. The fauna shows a complete sedimentary record of the Cuisian stage; this is surprising because sediments of middle Cuisian age have not been previously recorded in Pakistan (SCHAUB 1981).

Figure 13 shows the relation between ages of the fossils and the sample localities: at the base of the Murree formation (sample site B), the fauna indicates middle Ilerdian age, whereas higher up in the sedimentary pile (sample site G), the fauna reaches early

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Fig. 11. *Sample site F:* a) *Assilina subumbilicata* DE CIZANCOURT (10×), axial cut, B-form, b) equatorial cut, A-form, c) *Assilina* cf. *laxispira* DE LA HARPE (10×), equatorial cut, A-form, d) *Assilina* cf. *laxispira* DE LA HARPE (10×), surface, A-form, e) *Assilina* cf. *reicheli* SCHAUB (10×), surface, A-form.
Sample site G: f) *Nummulites* cf. *manfredi* SCHAUB (10×), axial cut, g) *Nummulites friulanus* SCHAUB (10×), equatorial cut, A-form, h) *Nummulites friulanus* SCHAUB (10×), axial cut.

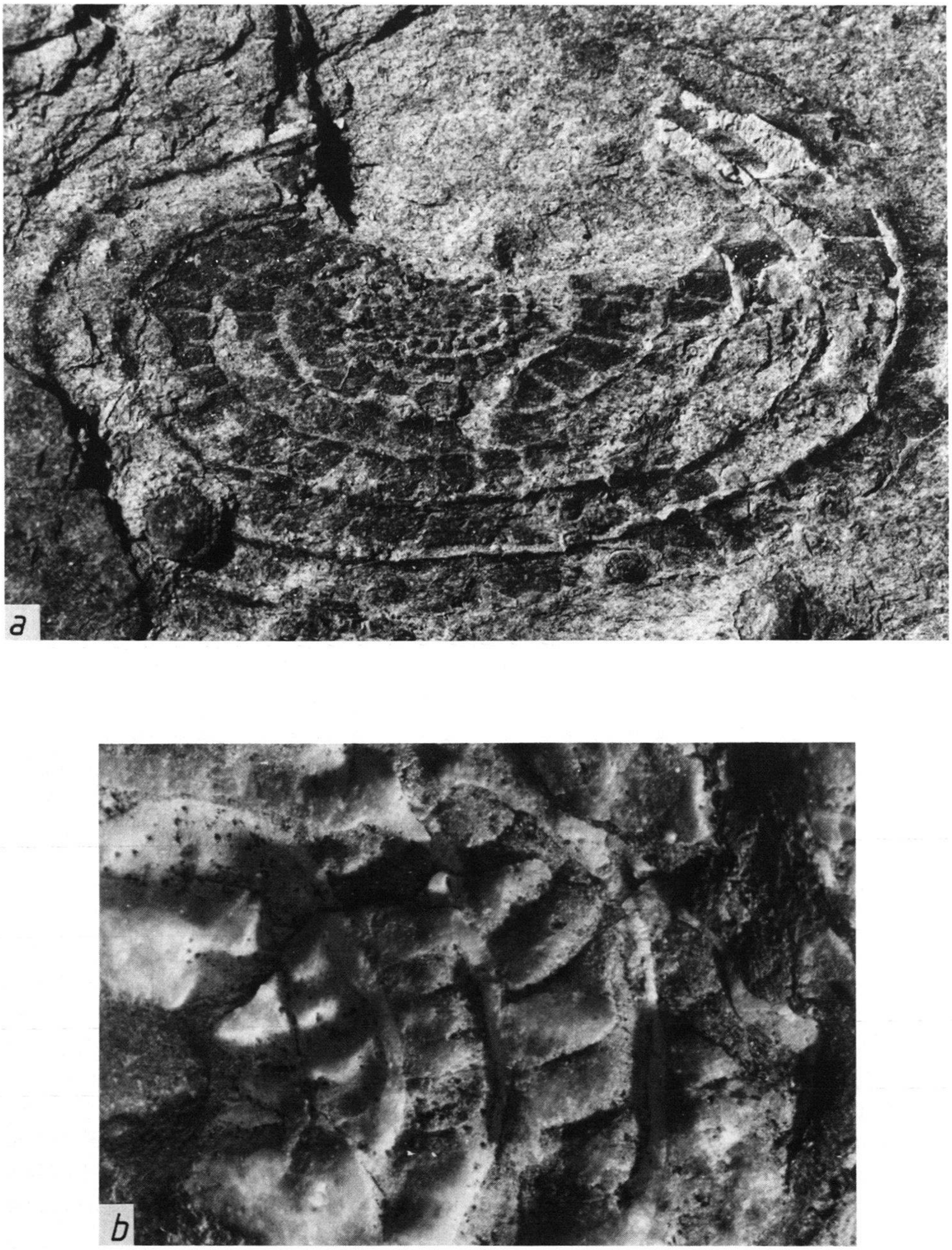


Fig. 12. *Sample site H:* a) deformed *Assilina spira abrardi* Schaub (5×), equatorial cut on weathered rock surface, B-form, b) a section of *Assilina spira abrardi* Schaub (10×), equatorial cut on weathered rock surface, B-form.

Lutetian age. Inbetween, the ages change quite systematically. The assiline-nummulite assemblages at a certain locality never indicate a "mixture" of ages. It is deduced that these fossils were living forms at the time of sediment deposition and it is concluded that the widespread idea of a reworked fauna in the Murree formation of the apex area seems very improbable.

On the other hand, no specific search for an evolutionary succession of species was made by us in the syntaxis. The relatively poorly preserved fauna did not allow for that. Future work needs to establish a proper parallelisation of Mediterranean nummulite- and assiline biozones with the Paleocene-Eocene stages in Pakistan.

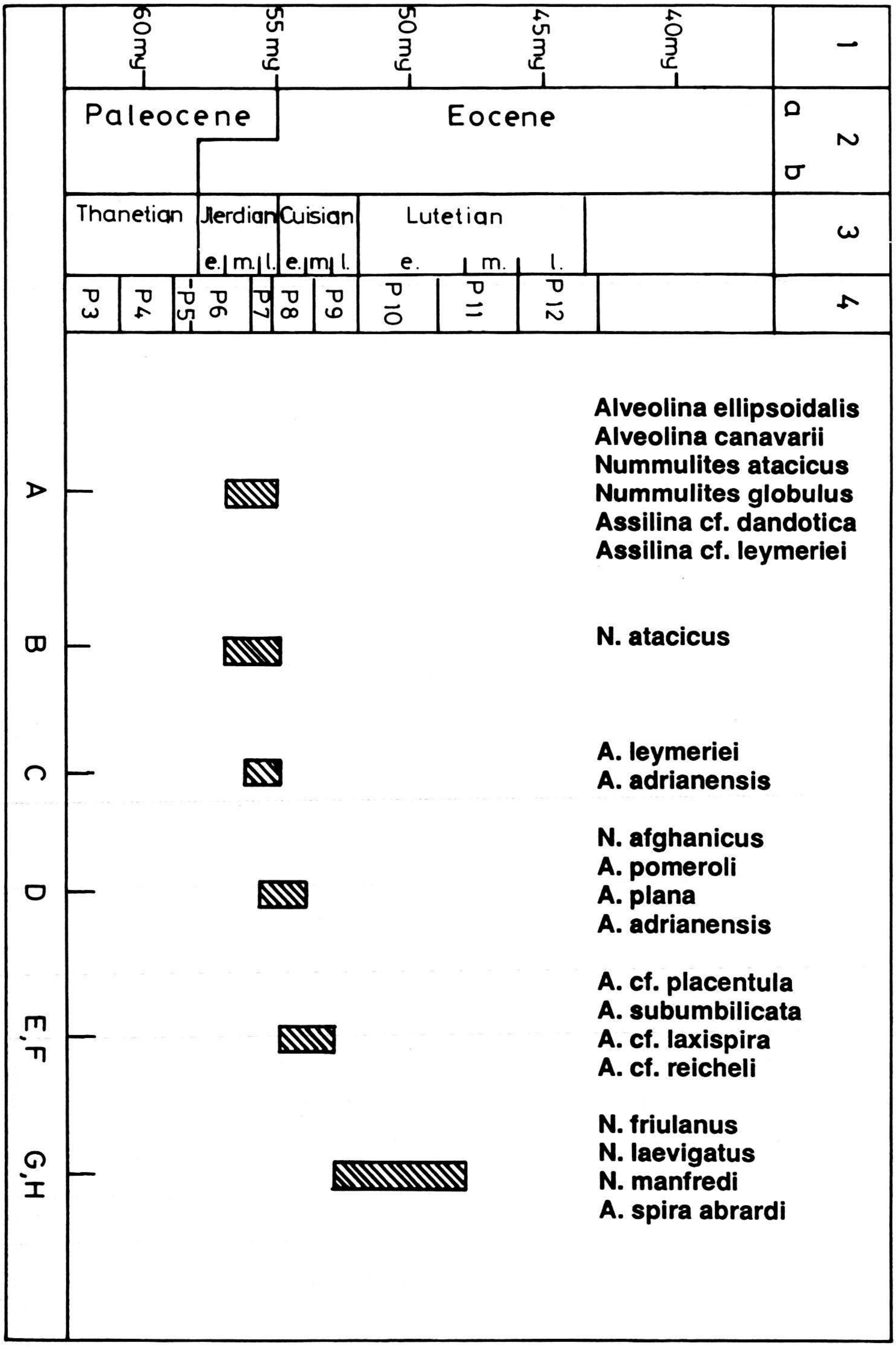
6. Origin of the Murree formation

Because of the predominant red and purple colours of the Murree deposits, it was believed (Pilgrim 1919 and Wadia 1931), that the iron content of the formation was quite high. It was concluded that the Murree's were derived from the Precambrian iron-bearing Dharwar- and Cuddapah rocks (Purana formation), which are found in the south of the actual Murree deposits on the Indian shield.

The total iron content of different silt- and sandstones was measured. In comparison with the view of Pilgrim and Wadia neither an anomalously high Fe_2O_3+FeO content (4–13%) nor a high Fe_2O_3/FeO ratio (1.2–7.3) was found. Iron bearing minerals are mainly diagenetic, fine particle pigments of hematite (> 90%) and subordinate detrital coarse grains of hematite, magnetite and spinel, especially at the base of a cycle. We thus conclude that the red colour and the high iron content is a weak argument for a southern source of the Murree deposits.

In sandstones (especially in greywackes at the base of a cycle), chrome-spinel grains and detrital zircon crystals were found. In siltstones (upper part of cycle), well rounded clasts of volcanic origin were frequently observed. These clasts are composed of a glassy matrix and small cristal inclusions. Chrome spinel grains (diameter between 200–450 μ) are well rounded, deep brown in thin sections and show cataclasis. The frequency of detrital chrome spinel suggests an environment of ophiolithic rocks as a source of the Murree formation. Most of the small zircon crystals (60–150 μ along the prism axis) show an euhedral, elongate appearance with well developed (110) prisms and (101) pyramids. This euhedral shape of the zircons requires a relatively short way of transport. The original minerals in the glassy volcanic clasts are mostly decomposed and it was not possible to identify them by X-ray diffractometer analysis.

These observations do generally agree with two possible sources for the Murree formation: a southern one supported by Gansser (1964) – and a northern one suggested by the authors. On the northwestern part of the Indian craton, only few ultramafic to ultrabasic rocks are present. The Kirana hills some 80 km south of the Salt Range represent the nearest outcrops for a southern source. The predominant rocks are slates and quarzites with intercalations of small bands of diabase and thin layers of rhyolites and tuffs (Gansser, 1964). A northern source is offered by the sections of the nearby Transhimalayas. Huge amounts of ultramafic and ultrabasic to acidic magma emplacements are known in the ancient Kohistan island arc in Northern Pakistan and Dras volcanics and Spongtang ophiolites in the Ladakh area. Paleogeographically a positive area of these ophiolitic bodies must be assumed in the late Paleocene.


60my
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50my
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Eocene
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Thanetian
Ilerdian
Cuisian
Lutetian
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e. m. l.
e. m. l.
3
P3
P4
P5
P6
P7
P8
P9
P10
P11
P12
4
A
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C
D
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G,H
Alveolina ellipsoidalis
Alveolina canavarii
Nummulites atacicus
Nummulites globulus
Assilina cf. dandotica
Assilina cf. leymeriei
N. atacicus
A. leymeriei
A. adrianensis
N. afghanicus
A. pomeroli
A. plana
A. adrianensis
A. cf. placentula
A. subumbilicata
A. cf. laxispira
A. cf. reicheli
N. friulanus
N. laevigatus
N. manfredi
A. spira abrardi

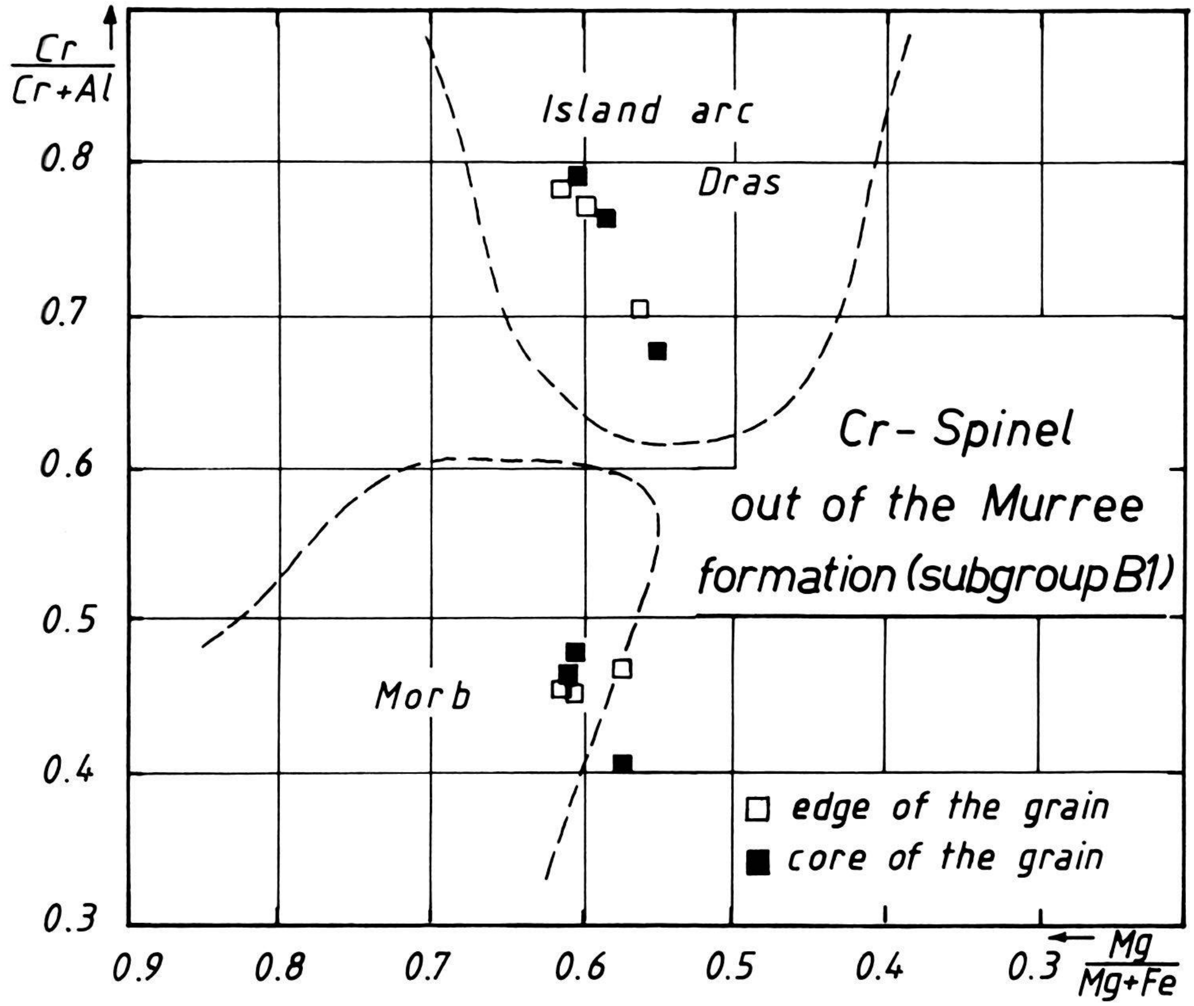

Fig. 14. Microprobe determinations of six chromium spinel grains. Filled squares represent values of the core-, open squares give values of the edge of a grain.

Microprobe determinations showed the existence of two different types of chromium spinels (Fig. 14). In chemical composition one resembles very much the spinels occuring in volcanic island arcs (Kohistan complex, Dras volcanics) while the other can be compared with spinels out of mid ocean ridge basalts. Therefore, a northern or northeastern source of the Murree deposits seems to be more likely than a southern one.

Fig. 13. The foraminifera-species and their related ages from the different collection sites A–H in the Hazara-Kashmir Syntaxis. For location A–H (horizontal axis) see Figure 8. Absolute and relative time scales are incorporated in the vertical axis:

1 = Geochronometric scale after Berggren (1985).

2 = Epochs and Paleocene-Eocene boundary after

a = Hottinger and Schaub (1960). The Ilerdian (scale 3) is included in the Paleocene (used in this paper).

b = after Cavelier and Pomerol (1986). The Ilerdian is included in the Eocene.

3 = Stage stratotypes after Hottinger and Schaub (1960).

4 = Planctonic foraminifera biozones after Berggren (1985).

7. Estimations of the sedimentation rates in the lower and middle part of the Murree formation

The rather well datable nummulitic and Assilina bearing horizons of marls and shales (Fig. 8) are good time markers which enable estimations of the sedimentary rates of the Murree formation. In Figure 15 the real thickness (dip corrected) has been divided by the age interval between bottom and top of a profile. The average sedimentation rate lies between 0.75 and 1.1 mm a year. The value for the profile B-C (Fig. 8 and 15) is apparently too high probably due to the fact that near the base of the Murree formation (Balakot region), minor folding gives rise to excess thickness. These estimates are minimum values because we did not distinguish between the individual sandstone and shale lithologies. A study of recent sedimentation leaves no doubt that the accumulation rate of channel deposits is much higher than that of inter- to supratidal deposits. The sedimentation rate necessary for the formation of a Caliche horizon was probably very low (Gile et al. 1967). Finally it is necessary to correct measured bed thicknesses by factors arising from tectonic shortening, because shortening normal to the bedding plane can be high (X:Z~6:1). Due to the above mentioned sedimentary and tectonic reasons, net accumulation rates and subsidence rate of the foreland basin are not directly comparable.

8. A model for the large scale evolution of the Murree formation

At first sight, there is a big contrast between previous estimates of the age of the Murree formation and the results presented here. Feistmantel (1882) described from the upper Jehlum valley (Chakoti, Figure 2) a relic of a *Sabal major* Heer, 1855 of early to middle Miocene age. Pilgrim (1910) found well preserved mammal bone re-

Location from - to	Thickness (km)	Span (my)	Net accumulat. rate (mm/y)
B - C	5	2	**2.5**
C - GH	5	4.5	**1.1**
C - D	1.5	1.5	**1.0**
C - EF	2	2.5	**0.8**
EF - GH	1.5	2	**0.75**

Fig. 15. Estimations of accumulation rates in the Murree formation of the Hazara-Kashmir Syntaxis. Capitals B to GH represent nummulite and assiline bearing marker horizons. For location see Figure 8.

mains of *Antracotherium bugtiense, Brachyodus africanus* and *Teloceras fatejangense* of Aquitanian age near Fatejang (Fig. 2). In chapter 5 it was shown that the Murree deposits in the Hazara-Kashmir Syntaxis indicate late Paleocene- to middle Eocene age.

The discrepancies between these previously published ages and those presented here is explicable if one considers the fact that at least the lower and middle part of the Murree formation are tidal flat deposits, deposited in a subsiding foreland basin. This basin could act as the western extension of the perisutural basin (Subathu) described by BLONDEAU et al. (1986): it represents the beginning of the deformation-transfer from the suture zone to the south. In the uppermost level of the detrital Subathu basin, *Nummulites atacicus* LEYMERIE is described as a characteristic fossil. We have found the same fossil at the base of the Murree formation in the Hazara-Kashmir Syntaxis (Fig. 9c and 9d).

The first indications for the formation of such a foreland basin occured in the middle Ilerdian (latest Paleocene) as a direct consequence of the formation of the Main Mantle thrust (MMT). Along this thrust the Kohistan island arc complex was obducted to the south onto the northern margin of the Indian shield (TAHIRKHELI et al. 1979, COWARD et al. 1982, 1985) in direct consequence of the continent-island arc collision (India and Kohistan). This movement caused the flexing down of the northwestern Indian lithosphere. In general this lithospheric bending can be explained by both the weight of the overthrusted Kohistan island arc complex and the rocks eroded off the rising Kohistan mountains and deposited in this early northwestern Himalayan foreland basin, called now the Murree foreland basin.

Outcrops east of Balakot show very well the transition from the Patala formation (backreef facies) to the Murree formation with basal argillaceous deposits passing upwards into more sandy deposits. In this tidal flat region a thick pile of clastic sediments was deposited whereas further south and southwest normal marine sedimentation continued (Margala Hill limestone, Chorgali- and Kuldana formation). The southward migrating thrustfront led to a southward migration of the foreland basin and the Murree facies belt. As a result the Murree facies deposits prograded on to progressively younger shallow marine deposits (Kuldanas, Murree Hill Station). The basin migration is shown in Fig. 16: here the ages of sediments underlying the Murree formation were determined at eight localities in northern Pakistan. The underlying sediments at localities (1)–(6) show stratigraphic discordance with the Murree formation, whereas locality (7) and especially (8) show a clear stratigraphical transition with the Murrees. The sediment ages at localities (1)–(6) indicate a maximum age for the starting deposition of the Murree formation; localities (7) and (8) give the true age. The deposition of the Murree formation in the northeast started in the middle Ilerdian (late Paleocene), whereas in the southwest Murree deposition started later than late Eocene, most probably in the early Miocene (PILGRIM 1910). The basin axis appears to have changed its position to a northeast-southwest direction from an initial north to south direction. The average migration velocity of the basin axis varies between ½–1 cm a year with maximal values up to 3 cm a year.

About in middle- to late Eocene, Kohat and part of the Potwar province became uplifted and no sedimentation took place. At the same time, the Murree facies belt shifted further south and at least 1.5 km of strata were deposited in the Kala Chitta Ranges (SHAH 1977). The sedimentation rate appears to have been remarkably lower

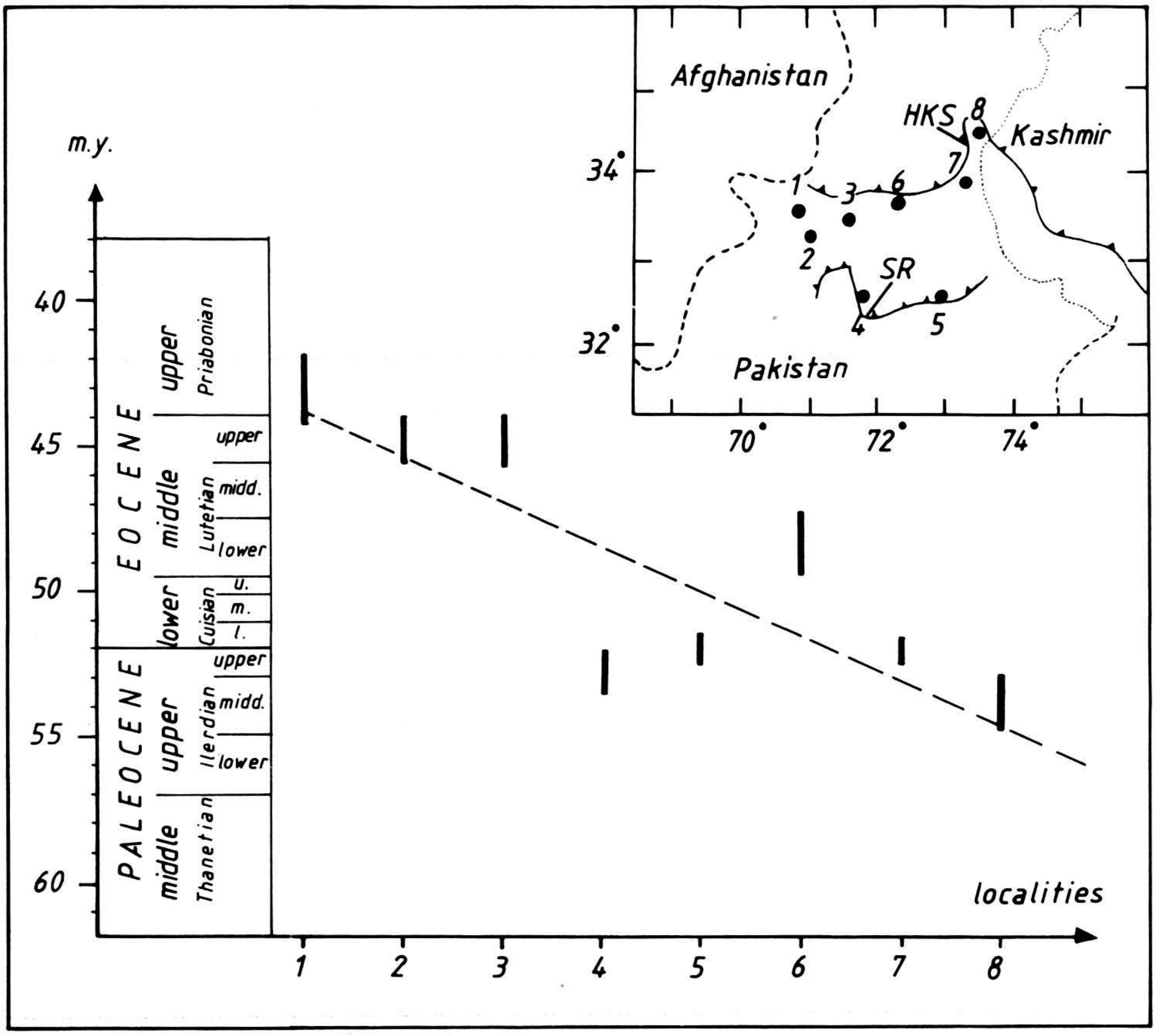

Fig. 16. The age of the youngest sediments underlying the Murree formation in different parts of northern Pakistan. 1–6: stratigraphic discordance with the regression line shows the onlap-trend of the older Murree's in the NE to younger Murree's in the SW.
1–7: data out of Shah (1977) "Stratigraphy of Pakistan, Memoirs of Geol. Survey of Pakistan, Vol. 12" with corrected geographical sites (the authors). 8: PhD theses Bossart (1986) and Ottiger (1986).

(0.2 mm/year), a feature which may be due to a gradual change from tidal flat to estuarine and finally to fluviatile conditions.

At the beginning of the Miocene, a new transgression took place, and Murree rocks were deposited in the Kohat-Potwar province. The edge of the Murree basin was near the southwestern part of the Kohat quadrangle (Meissner et al. 1974). The southern border must have been immediately south of the Salt Range (Pascoe 1920). The first sediments deposited at that time were the conglomerates of the Fatejang zone (Pinfold 1918) from which Pilgrim (1910) described fossils of early Miocene age. In the middle Miocene, the rocks of the Murree formation passed gradually into the Kamlial formation.

9. Conclusions

The observations summarized above allow the following conclusions:

1. It is recommended to the Stratigraphical Committee of Pakistan to introduce a new formation name for the marine part of the Murree formation. We suggest the name "Balakot formation" which would be incorporated together with the continental formations of the Rawalpindi group in a "Murree supergroup".

2. The Murree formation in the Hazara-Kashmir Syntaxis is, for its main part, of shallow marine (tidal flat) origin. Only in the southern most outcrops (Kohat-Potwar and Salt Range) fluviatile facies predominate.

3. The Murree deposits in the Hazara-Kashmir Syntaxis are composed of up to 20 meter thick fining upward cyclothems which appear to be best interpreted as deposits formed in meandering tidal channels in a continuously subsiding foreland basin.

4. Synsedimentary deposition of nummulites and assilines, found in marls intercalated in this relatively monotonous succession of fining upward cyclothems, indicate an age of late Paleocene to middle Eocene for the rocks of the syntaxis region.

5. The Murrees transgressed southwestwards in the Kohat-Potwar province, a region which had been a positive area during the Oligocene, in late Oligocene to early Miocene.

6. The age discrepancy between the Murree formation found in the apex region and in the Kohat-Potwar province is due to the southwestward migration of the Himalayan foreland basin.

7. The formation of this Himalayan foreland basin in the late Paleocene (55 my) is directly related to the continent-island arc collision of India and Kohistan.

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REFERENCES

Archiac, A.D., & Haime, J. 1983: Description des animaux fossiles du groupe nummulitique de l'Inde. Paris.

Berggren, W.A., Kent, D.V., Flynn, J.J., & van Couvering, J.A. 1985: Cenozoic geochronology. Geol. Soc. of Amer. Bull, 96, 1407–1418.

Blondeau, A., Bassoullet, J.P., Colchen, M., Han, T.L., Marcoux, J., Mascle, G., & van Haver, T. 1986: Disparition des formations à l'Eocène inférieur en Himalaya. Nancy, Sciences de la Terre, Mém. 47, 103–111.

Bossart, P. 1986: Eine Neuinterpretation der Tektonik der Hazara-Kashmir Syntaxis (Pakistan). PhD. thesis, ETH Zürich.

Bossart, P., Dietrich, D., Greco, A., Ottiger, R., & Ramsay, J.G. 1988: The tectonic structure of the Hazara-Kashmir-Syntaxis, Southern Himalayas, Pakistan. Tectonics, 7/2, 273–297.

Bruguiere, J.G. 1972: Histoire naturelle des Vers. Encyclopédie méthodique Paris 1, 345–757.

Cavelier, C., & Pomerol, Ch. 1986: Stratigraphy of the Paleogene. Soc. géol. France, 8, II No. 2, 255–265.

CALKINS, J.A. 1966: The Geology of the Western limb of the Hazara-Kashmir Syntaxis, West Pakistan and Kashmir. PhD. thesis, Univ. Massachusets.

CALKINS, J.A., OFFIELD, T.W., ABDULLAH, S., & TAYYAB ALI, S. 1975: Geology of the Southern Himalaya in Hazara, Pakistan, and adjacent areas. Prof. Pap. U.S. geol. Surv. 716C.

CIZANCOURT, M. DE 1938: Contributions à l'étude des Faunes Tert. de l'Afghanistan. Mém. Soc. géol. France (NS) 39, 1–44.

COWARD, M.P., & BUTLER, R.W.H. 1985: Thrust tectonics and the deep structure of the Pakistan Himalaya. Geology 13, 417–420.

COWARD, M.P., JAN, M.Q., REX, O., TARNEY, J., THIRLWALL, M., & WINDLEY, B.F. 1982: Structural evolution of a crustal section in the Western Himalaya. Nature 295/5844, 22–24.

DAVIES, L.M., & PINFOLD, E.S. 1937: The eocene beds of the Punjab Salt Range. Mem. geol. Surv. India. Palaeontologica Indica (NS) 24.

DESHAYES, G.P. 1838: Description des coquilles fossiles recueillies en Crimée par M. de Verneuil. Mém. Soc. géol. France 1, 37–69.

FATMI, A.N. 1973: Lithostratigraphic units of the Kohat-Potwar Province, Indus Basin Pakistan. Mem. geol. Surv. Pakistan 10.

FEISTMANTEL, O. 1882: Note on remains of palm leaves. Rec. geol. Surv. India 15/1, 51–53.

GANSSER, A. 1964: Geology of the Himalayas. Interscience. New York, 189 pp.

GILE, L.H., PETERSON, F.F., & GROSSMAN, R.B. 1967: Morphological and genetic sequences of carbonate accumulation in desert soils. Soil Sci. 101, 347–360.

HARPE, P. DE LA 1880: Notes sur les Nummulites Partschi et Oosteri de la Harpe du Calcaire du Michelsberg, près Stockerau (Autriche) et du Gurnigel-Sandstein de Suisse. Bull. Soc. Yaud. Sci. nat. 18, 33–40.

— 1883: Monographie der in Ägypten und der libyschen Wüste vorkommenden Nummuliten. Palaeontographica (n.s.) 30, 155–216.

— 1926: Matériaux pour servir à une monographie des Nummulites et Assilines. Magyar áll. k. földt. Intéz. Evk. 27, 1–102.

HEER, O. 1855: Flora tert. Helvetiae 1.

HOMEWOOD, P., & ALLEN, P. 1981: Wave, tide and current controlled sandbodies of Miocene Molasse. Western Switzerland. Bull. amer. Assoc. Petroleum Geol. 65/12, 2534–2545.

HOTTINGER, L. 1960: Über paleocaene und eocaene Alveolinen. Eclogae geol. Helv. 53/1, 265–285.

HOTTINGER, L., & SCHAUB, H. 1960: Zur Stufeneinteilung des Paleocaens und des Eocaens. Einführung der Stufen Illerdien und Biarritzien. Bericht der Schweizerischen, Paläontologischen Gesellschaft. Eclogae Geol. Helv., 53, I, 453–479.

HOTTINGER, L., LEHMANN, R., & SCHAUB, H. 1964: Les grands foraminifères éocènes du bassins de Paris et leur importance pour la délimitation des étages du Paléogène. Mém. Bur. Rech. géol. min. 28, 629–651.

KLEIN, G. 1975: Tidalites in the Eureka Quarzite, Eastern California and Nevada. In: GINSBURG, N. (Ed.), Tidal Deposits (p. 145–151). Springer Verlag.

LATIF, M.A. 1970: Exlanatory notes on the geology of SE Hazara to accompany the revised geological map. Jb. geol. Bundesanst. (Wien), Sonderbd. 15, 5–19.

LEYMERIE, A. 1846: Mémoire sur le terrain à Nummulites (épicrétacé) des Corbières et de la Montagne Noire. Mém. Soc. géol. France 2, 5–41.

LYDEKKER, R. 1882: Geology of NW Kashmir and Kaghan. Rec. geol. Surv. India 15/1, 1–24.

MEISSNER, Ch.R. 1974: Stratigraphy of the Kohat Quadrangle Pakistan. Prof. Pap. U.S. geol. Surv. 716-D.

MEISSNER, Ch.R., MASTER, J.M., RASHID, M.A., & HUSSAIN, M. 1968: Stratigraphy of the Kohat Quadrangle. Proj. Rep. U.S. geol. Surv. PK 20.

NUTTALL, W.L. 1926: The larger foraminifera of the upper Ranikot Series of Sind (India). Geol. Mag. 63, 112–121.

— 1926: The zonal distribution of the larger foraminifera of the Eocene of Western India. Geol. Mag. 63, 495–504.

OTTIGER, R. 1986: Einige Aspekte der Geologie der Hazara-Kashmir Syntaxis (Pakistan). PhD. thesis, ETH Zürich.

PASCOE, E. 1920: Petroleum in the Punjab and NWFP. Mem. geol. Surv. India 40/3, 330–489.

PILGRIM, G.E. 1910: Preliminary note on a revised classification of tertiary freshwater deposits of India. Rec. geol. Surv. India 40/3, 187–196.

— 1919: Suggestions concerning the History of the Drainage of Northern India, arising out of the Study of the Siwalik Boulder Conglomerate. J. asiatic Soc. Bengal, NS 15, 81–99.

PINFOLD, E.S. 1918: Notes on structure and stratigraphy in the Punjab. Rec. geol. Surv. India 49, 138–161.

RASHID, M.A. 1965: Mineral deposits of eastern Kohat Region W. Pakistan. Rec. geol. Surv. Pakistan 13/2.

Reineck, H.E. 1972: Tidal flats Spec. Publ. Soc. Econ. Palaeont. Mineral. 16, 146–159.
Reineck, H.E., & Singh, I.B. 1967: Primary sedimentary structures in the recent sediments of the Jade, North Sea. Marine Geol. 5, 227–235.
Schaub, H. 1951: Stratigraphie und Paläontologie des Schlierenflysches mit besonderer Berücksichtigung der paleocänen und untereocänen Nummuliten und Assilinen. Schweiz. paläont. Abh. 68, 1–222.
— 1962: Über einige stratigraphisch wichtige Nummuliten-Arten. Eclogae geol. Helv. 55, 529–551.
— 1966: Über die Grossforaminiferen im Untereozän von Campo (Ober-Aragonien). Eclogae geol. Helv. 59, 335–377.
— 1981: Nummulites et Assilines de la Théthys paléogène. Schweiz. paläont. Abh. 104, 105, 106.
Shah, I. 1977: Stratigraphy of Pakistan. Mem. geol. Surv. Pakistan 12.
Steel, R.J. 1974: Cornstone (fossil Caliche) its origin, stratigraphic and sedimentological importance in the New Red Sandstone. J. Geol. 82, 351–369.
Tahirkheli Khan, R.A. 1982: Geology of the Himalaya, Karakoram and Hindukush in Pakistan. Geol. Bull. Univ. Peshawar, spec. Issue 15.
Tahirkheli Khan, R.A., & Qasim, J. 1979: Geology of Kohistan Karakoram Himalaya Northern Pakistan. Geol. Bull. Univ. Peshawar, spec. Issue 2/1.
Thompson, R.W. 1968: Tidal flat sedimentation on the Colorado River Delta (NW Gulf of California). Mem. geol. Soc. Amer. 107.
Wadia, D.N. 1926: The geology of Poonch State (Kashmir) and adjacent portions of the Punjab. Mem. geol. Surv. India 51, 185–370.
— 1931: The Syntaxis of the NW Himalaya. Rec. geol. Surv. India 65/2, 189–223.
Wynne, A.B. 1874: Notes on the Geology of the neighbourhood of Mari Hill Station in the Punjab. Rec. geol. Surv. India 7/2, 64–74.
— 1877: Note on the tertiary zone and underlying rocks of the NW Punjab. Rec. geol. Surv. India 10/3, 107–132.

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