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PERMIAN STRATIGRAPHY IN THE NORTHERN KARAKORUM, PAKISTAN

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Riassunto. Vengono trattati in modo complessivo i dati stratigrafici raccolti sul Permiano del Karakorum settentrionale, durante quattro spedizioni geologiche (1986, 1991, 1992a, b). La successione è definibile mediante 9 formazioni, suddivise in membri e litozone, qui definite formalmente per la prima volta. Alcune tavole illustrano le più significative specie di Fusulinidi, Brachiopodi e Conodonti, nonchè le principali lito- e microfacies, che hanno consentito gli inquadramenti cronostratigrafici.

La successione sedimentaria del Permiano può essere grosso modo divisa in tre parti. La parte inferiore è costituita da sedimenti terrigeni, pelitici e subordinatamente arenacei (quarzareniti, con potenti intervalli di arcose nell'Asseliano terminale-Sakmariano inferiore) testimonianti un ambiente continentale con limitate ingressioni marine. La seconda parte inizia nel Sakmariano, con la definitiva affermazione dell'ambiente marino, con barre di sabbie bioclastiche a Crinoidi e Brachiopodi seguite da ammassi di Fusulinidi. In Hunza si possono sviluppare in seguito anche barre oolitiche e cicli peritidali dolomitici. Verso ovest, la rampa carbonatica è frequentemente inquinata da terrigeni fini. Riprese di sedimentazione arenacea (quarzareniti) con possibili minori lacune si hanno sia ad occidente nella regione del passo Baroghil, che in Hunza-Shimshal, ad oriente. Al centro invece, nell'alto Karambar, si ha una possibile estesa lacuna di sedimentazione, con l'affermazione della sedimentazione carbonatica di piattaforma solo nel Permiano superiore. Questi episodi arenacei vengono posti in relazione con eventi di rifting legati alla apertura della Neotetide, in atto più a S della microplacca Karakorum, che portarono ad emersioni locali ed anche erosioni della successione carbonatica permiana. La terza parte della successione inizia con la fine del Murgabiano o l'inizio del Midiano, quando la regione si scompone in due comparti principali. Ad occidente, dopo un episodio trasgressivo con deposizione di livelli a ooidi ferriferi, si instaura una vasta piattaforma carbonatica peritidale, che si estende dalla regione del Baroghil sino alla zona di Chillinji in Karambar e nella zona di Pasu in valle Hunza. Questa situazione continuerà sino al Triassico. Verso nordest invece, si assiste ad un progressivo annegamento, con l'instaurarsi di ambienti più profondi ove si formeranno calcari con selce. L'attivazione di scarpate di faglia legate alla scomposizione in blocchi, è testimoniata da vistosi accumuli di brecce intercalate nei calcari con selce. Durante lo Dzhulfiano, importanti apporti di argilla diluiscono la deposizione dei fanghi carbonatici sino a divenire predominanti intorno al limite Permiano/Triassico. La sedimentazione carbonatica pelagica riprende gradualmente a partire dallo Smithiano.

Il Permiano del Karakorum rappresenta l'evidenza sedimentaria di un margine passivo di un blocco litosferico, che staccatosi dal Gondwana durante il Permiano, migrerà verso il centro della Paleotetide, unitamente ad altri blocchi continentali della placca di Mega Lhasa.

Abstract. The stratigraphical data collected during four geological expeditions to the Northern Karakorum (1986, 1991, 1992 a, 1992 b) are discussed. The sedimentary succession has been classified by 9 formations, here formalised, and subdivided into members and lithozones. The biochronology has been established on fusulinids, brachiopods, and conodonts. Several plates illustrate the most significant fossil species as well as the litho- and microfacies.

The sedimentary succession may be roughly subdivided into three parts. The lower part consists of terrigenous rocks, mostly pelitic and less frequently arenaceous (quartzarenites with thick arkose intervals during the latest Asselian-Early Sakmarian). They are evidence of a continental to coastal environment, with short term marine ingressions. The second part begins with the Sakmarian, when the marine environment spread over most of the studied area. Bioclastic sand bars with brachiopods and crinoids at the base are followed by huge fusulinid packages. In Hunza oolitic bars and dolostone peritidal cycles also follow. The carbonate ramp is often polluted by terrigenous sediments, especially westwards. Temporary arenaceous spillovers (quartzarenites), often linked to minor sedimentation gaps, occur both westwards in the Baroghil area, and eastwards in the Hunza-Shimshal area. In the centre, in the Upper Karambar valley, a large gap most probably occurs, with reappearance of the sedimentation only with the dolostones of the Upper Permian. These erosional episodes with arenaceous spillovers are interpreted as being linked to rifting events of the Neotethys opening, active southwards.

The third part of the succession concerns the Late Permian. Towards the end of the Murgabian or at the beginning of the Midian, the Northern Karakorum is subdivided into two major areas. To the west, after a transgressive episode with ironstone deposition, a wide peritidal carbonate platform spread over from Baroghil to Chillinji in Karambar and the Pasu area in Hunza. This palaeogeographic pattern extends up to the Triassic. However, biostratigraphic control is poor. Instead to the north-east, a progressive sinking of the slope is observed, with spreading of deeper environments and cherty limestone deposition. The down-warping is activated by block-faulting resulting in huge megabreccia bodies interbedded with the cherty limestones. During the Dzhulfian, significant clay inputs dilute the carbonate mud accumulation, and shales are dominant around the Permian-Triassic boundary. Pelagic carbonate sedimentation gradually recovers from the Smithian onward.

The Permian of the Karakorum is the sedimentary evidence of the passive margin of a lithospheric block, detached from the Gondwana continent during the Permian, that will later migrate towards the centre of the Paleo-Tethys, along with other lithospheric blocks of the Mega Lhasa plate.

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Introduction.

The remote areas of Northern Karakorum were always difficult to be reached for logistic and political reasons, due to their far and sensitive position. Thanks to the permits allowed us by the Government of Pakistan and with the opening of new roads to higher valleys, four geological expeditions have been carried out in 1986, 1991 and 1992 (a and b) in Karakorum. Additional data were obtained in two other expeditions in Shaksgam (1988) and Chitral (1990).

We shall illustrate here the Permian rocks cropping out from the Upper Yarkhun valley, in the west, to the Shimshal valley in the east (Fig. 1), mostly studied along 17 measured stratigraphic sections (Fig. 2). About 700 rock and fossil samples were examined. We shall deal with the Permian of the Northern Sedimentary Belt. However, the central Chitral will not be considered, since no new data can be added to the paper by Talent et al. (1981). Also the Permian rocks north-east of the Tirich Mir (Gaetani & Leven, 1993) and the possible Permian portion of the Wakhan Slates and Misgar Slates are not considered here. The Permian rocks cropping out to the south of the Axial Batholith in the area of Darkot (Ivanac et al., 1956; Matzushita & Hushita, 1965) were also not studied.

Previous knowledge.

Upper Yarkhun-Baroghil area. The first pioneer work was the Hayden (1915) reconnaissance in the Baroghil pass area, where he described a Lower Permian section, with several informal units. The fossils collected from Baroghil were subsequently illustrated by Reed (1925) and later reconsidered by Smith (1935). Tipper (in Pascoe, 1924) visited the area, but subsequently no papers were issued. Baroghil was briefly visited by J. A. Talent and R. A. K. Tahirkheli in 1973. First accounts were published in Talent & Mawson (1979) and Talent et al. (1981), later considered also by Tahirkheli et al. (1994).

Russian and Afghan Authors (Kafarskiy et al., 1974; Kafarskiy & Abdullah, 1976; Abdullah & Chmyriov, 1980) studied the area immediately north of Baroghil pass, in Wakhan. They identified a Tash Kupruk zone, thought to continue southwards in the Baroghil pass surroundings. We do not confirm this assumption, because the Tash Kupruk Unit is separated from the Baroghil area by a very important fault (Le Fort et al., 1994, fig. 2). Corals collected in our 1992 expedition from Baroghil are illustrated by Flügel (1995b).

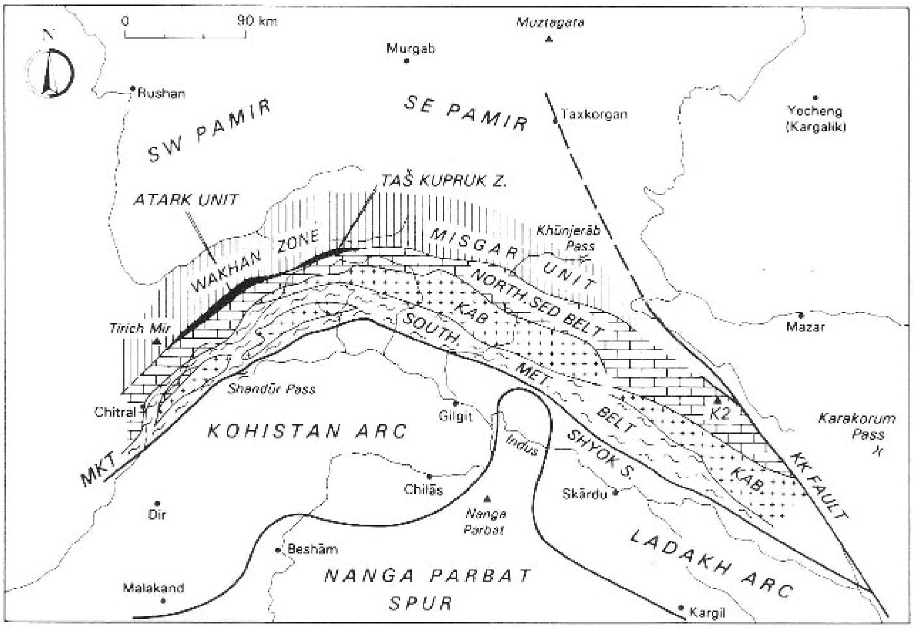


Fig. 1 - Tectonostratigraphic units of Karakorum and surrounding regions. MKT = Main Karakorum Thrust; KK Fault = Karakorum Fault; KAB = Karakorum Axial Batholith. The Permian rocks discussed in the present paper belong to the Northern Sedimentary Belt of the Karakorum.

Upper Karambar. No reports so far have been published on the Upper Karambar area. Casnedi (1980) only saw the area in distance.

Upper Hunza and Shimshal. The Hunza valley was firstly reported by McMahon (1900) and walked up by Hayden (1915) during his journey to Pamirs, but the real first data on the Permian were collected by the 1962 Desio expedition (Desio, 1963; Desio & Martina, 1972), who introduced the units Kilik and Gircha Fms. for the Permian rocks. Paleontological findings were illustrated by Fantini Sestini (1965) and Premoli Silva (1965). Casnedi & Nicora (1985) made a reconnaissance to Shimshal, collecting a few Permian brachiopods and conodonts. The first detailed exploration of Chapursan was made by our team in 1986 and the results were summarized in Gaetani et al. (1990). Data on Permian corals from Chapursan were pub-

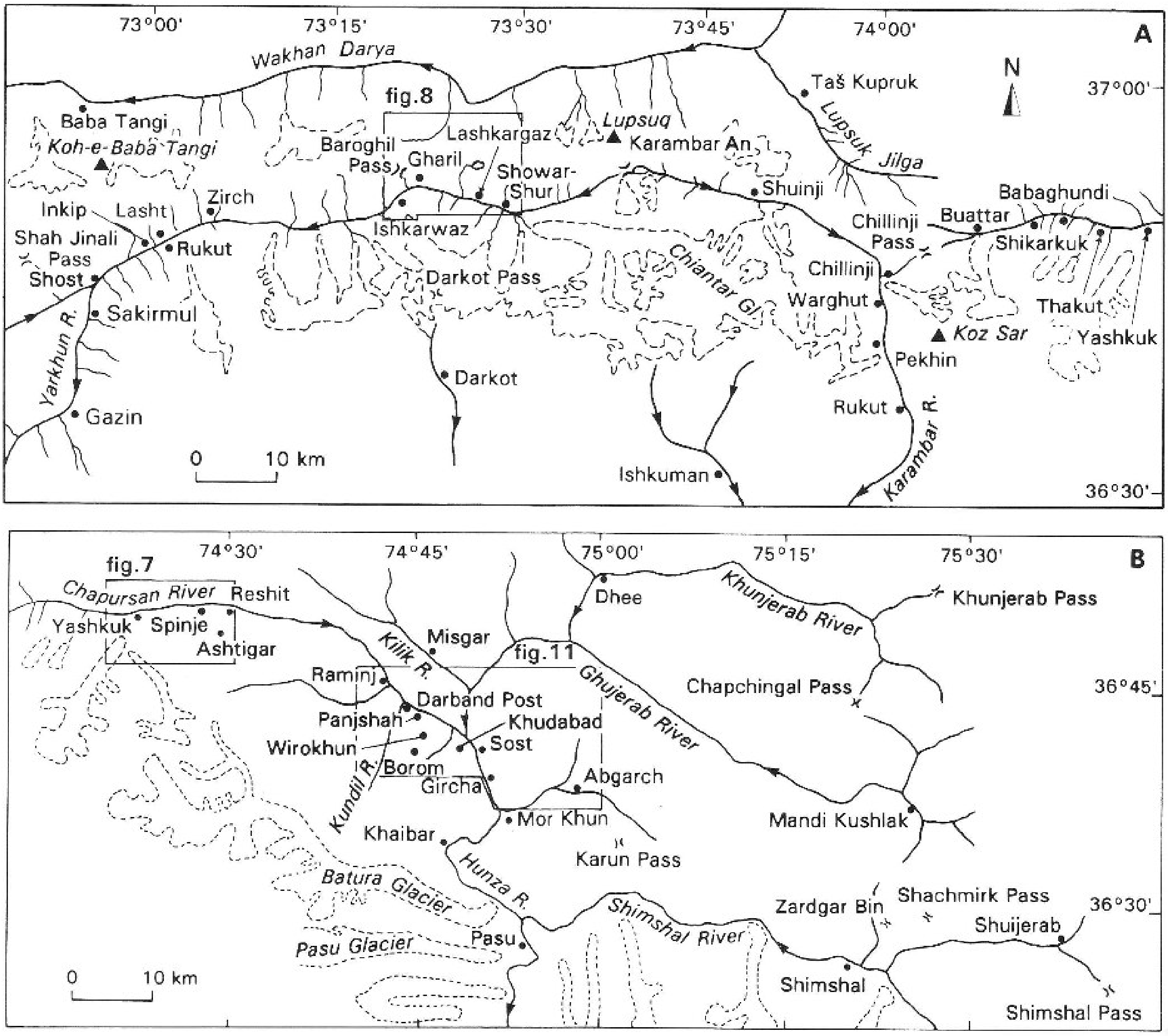


Fig. 2 - Index-map of the studied area with the localities quoted in the text. The position of the stratigraphic sections is reported on Fig. 7, 8 and 11. A - Upper Yarkhun to Karambar valleys. B - Chapursan valley to Shimshal pass.

lished by Flügel (1990, 1995a) and Flügel & Gaetani (1991). The main stratigraphic features were summarized with the explanation to the geological map of Zanchi & Gaetani (1994). Permian brachiopods have been studied by Angiolini (1994, 1995) and a new genus of foraminifers has been established by Angiolini & Rettori (1995). The stratigraphic vs. tectonic interpretations suggested by Tahirkheli et al. (1992, 1994) are not followed here.

Stratigraphy

We distinguish a number of lithostratigraphic units, most of them new. Due to significant lateral changes, only a few units may be traced through the whole range. They will be described in ascending order and their general stratigraphic scheme is depicted in Fig. 3.

The chronostratigraphic subdivisions of the Permian Period are still a matter of discussion. Due to the necessity to correlate with Central Asia, we shall use the Tethyan chronostratigraphic nomenclature, with geochronologic evaluation by Ross et al. (1994). This scale is preferred to the Odin's scale (1994), which seems too compacted for the Late Permian, being established on the Uralian succession (Fig. 3). Most of the stratigraphic sections are summarized in text-figures.

Gircha Formation.

Name. It was introduced by Desio (1963). The original description of the section near Gircha (Upper

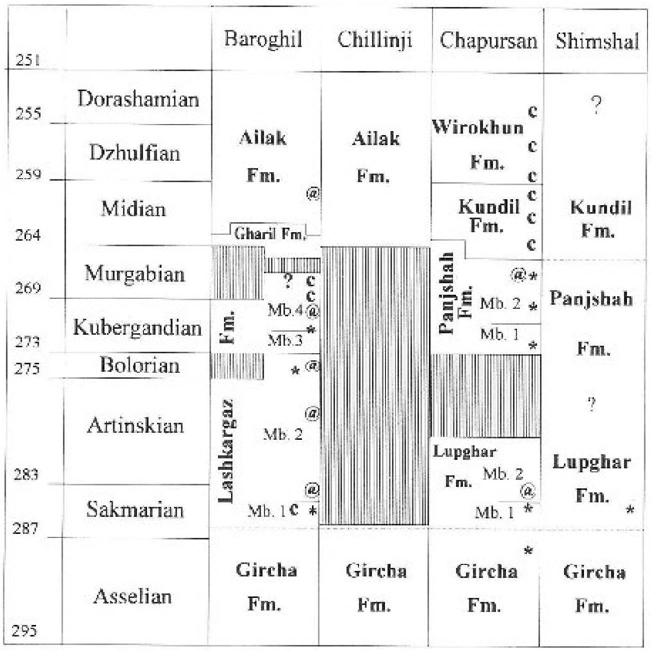


Fig. 3 - Stratigraphic scheme of the Permian formations of Northern Karakorum. Time scale after Ross et al. (1994). In this time scale the span attributed to the Sakmarian is possibly too short. * = brachiopod occurrence; @ = fusulinid or other foraminifer occurrence; c = conodont occurrence.

Hunza) is fairly vague and seems to incorporate part of the overlying unit. The original thickness of 6000 m given by Desio (1963) is largely overestimated because of faulting and folding. No type-section was described. The Ashtigar section could be a reference section. Nowhere in Hunza is the base of the section exposed.

Pasu Slates (Schneider, 1957) is here considered as a synonym of the Gircha Fm., being a local facies mostly shaly, with few sandstone intercalations in the upper part. Also Shimshal Slates (Casnedi & Nicora, 1985) is considered as a synonym, even though this name could be applied to the slates with spectacular ductile deformations exposed in the lower part of the valley. The name Kilik Formation (Desio, 1963) is instead to be rejected, because Permian and Jurassic tectonic slices including four formations are juxtaposed in the type locality at least.

Lithology. The Gircha Fm. is a terrigenous unit including shale to sandstone and very rare microconglomerate. Significant lateral changes occur in the studied region. In the Upper Yarkhun-Baroghil area, sandstones and shales are rather homogeneously interbedded throughout the section, with coarser-grained more lenticular beds showing festoon cross-lamination in the upper part. In Karambar and Hunza, the basal part is more shaly, and coarser-grained intervals become more common upwards. Fossiliferous arenaceous limestones occur in the lower-middle part in Hunza, where symmetric wave ripples with straight E/W-oriented crests occur (Fig. 4).

Thickness tends to increase eastwards from no more than 600 m in the Upper Yarkhun/Baroghil area to Karambar An, where detailed studies were prevented by falling snow. Around Chillinji all units above the Chilmarabad Fm. (Devonian or older) are terrigenous, and the lower boundary of the Gircha Fm. is hard to set. In Chapursan the unit exceeds 1000 m (the Ashtigar section alone, including only the central part of the unit is 650 m thick), but the base is never exposed; thickness seemingly increases further in Shimshal, where however a larger part of the Paleozoic section may be terrigenous and repeatedly folded.

Two reference sections have been measured in the Hunza (Ashtigar) and Yarkhun (East Baroghil) valleys; partial logs were studied at Chillinji and in the Sakirmul area (Fig. 5). The Ashtigar section at its base includes the topmost 81 m of the shaly lower part of the unit, where a few thin beds of upper fine-grained subarkose with bioclastic storm lags yielding Early Permian brachiopods are intercalated. The overlying middle part of the unit (about 530 m thick), beginning with a channelized lower fine-grained sandstone with basal lag of black mudclasts and NNW-ward cross-lamination, consists of monotonously alternating intervals of commonly burrowed dark grey siltstones and thickening-upward bodies of invariably very fine-grained grey arkoses displaying parallel to hummocky lamination and wave ripples to current ripples pointing to mainly NE-ward paleocurrents.

In-drift to in-phase climbing-ripple lamination is common, indicating high suspension/bedload ratio and high sedimentation rates (Reineck & Singh, 1975). Next, an abrupt transgression is marked by black shales (35 m), sharply followed by white, medium-grained quartz-cemented supermature quartzarenites (2.5 m), displaying NE-directed cross-lamination. Similar shale/quartzose sandstone sequences are repeated upward for well over a hundred metres. This upper part of the Gircha Fm., studied in the Gircha-Khudabad area, is characterized by 6 to 11 m thick fining-upward sandstone bodies with scoured base, mudclast lags, lateral accretion bedding and trough cross-lamination indicating NNW-ward to NE-ward paleocurrents. In the lower Lupghar valley at Raminji, 6 to 12 m thick lenticular intercalations of bioclastic quartzarenites with feldspars contain rounded quartz, arenaceous and bored silty lithoclasts, brachiopods, pelecypods, crinoids, bryozoans and phosphatic grains. Pedogenic structures and root casts occur at the base.

The East Baroghil section (about 174 m thick overall, including five decametric covered intervals)

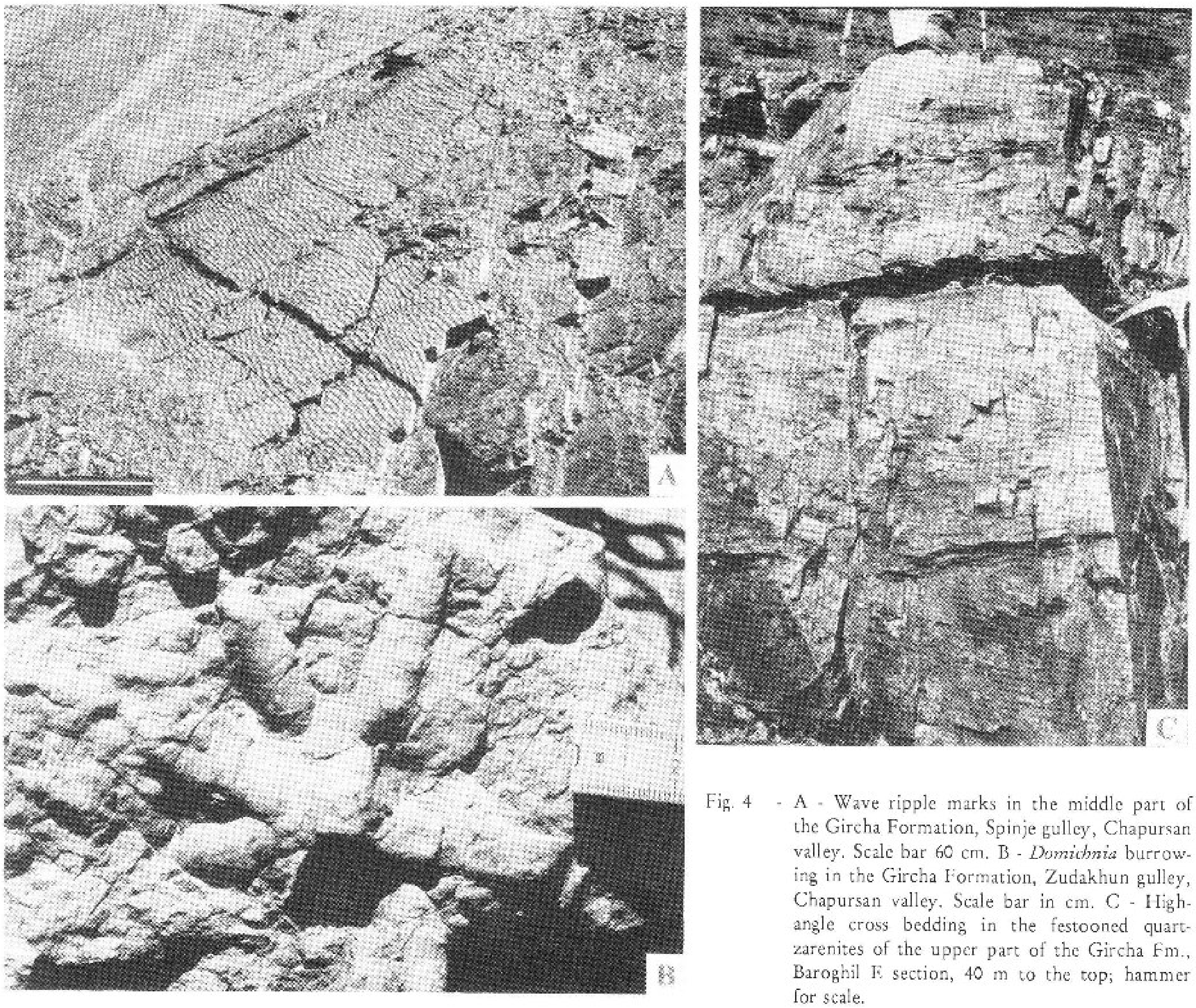


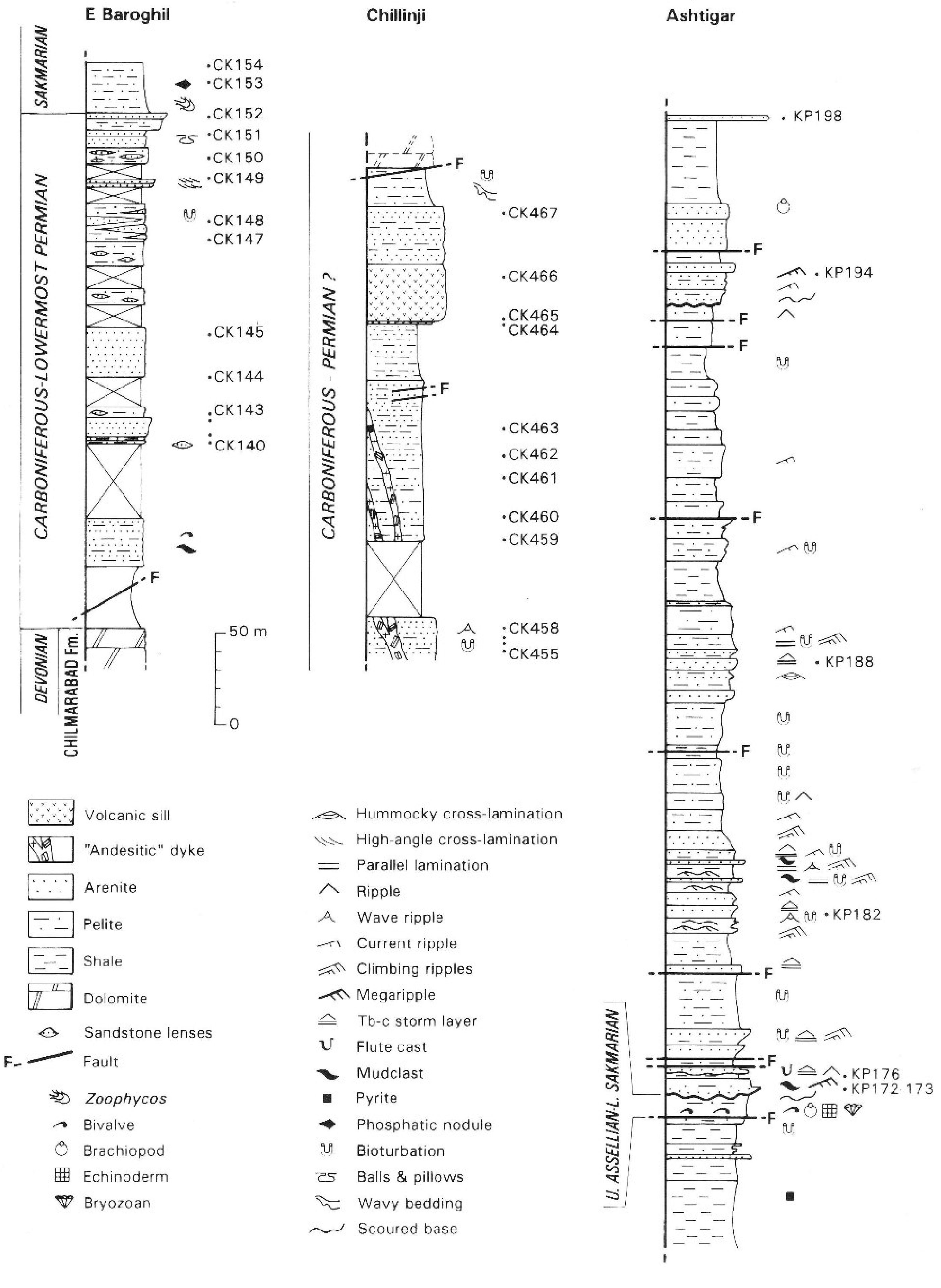
Fig. 4 - A - Wave ripple marks in the middle part of the Gircha Formation, Spinje gulley, Chapursan valley. Scale bar 60 cm. B - *Domichnia* burrowing in the Gircha Formation, Zudakhun gulley, Chapursan valley. Scale bar in cm. C - High-angle cross bedding in the festooned quartzarenites of the upper part of the Gircha Fm., Baroghil E section, 40 m to the top; hammer for scale.

begins with interbedded siltstones and thin lenses of up to coarse-grained quartzarenites with mudclasts, passing upward to medium-grained quartzarenites in lenticular metric intervals (about 20 m). Next, thin-bedded, medium-grained grey quartzarenites (between 25 and 50 m thick) are followed by a partly covered coarsening-upward sequence (about 60 m), represented by burrowed siltstones with intercalated fine to medium-grained quartzarenites becoming thicker and wider upwards. The top of the Gircha Fm. consists of medium-grained quartzarenites with high-angle cross-bedding (4 m), followed by three coarsening-upward sequences (about 30 m) of dark burrowed siltstones passing upward to very fine-grained feldspathic quartzarenites and medium-grained quartzarenites locally displaying soft-sediment deformations ("balls & pillows").

In the Chillinji section, mostly fine-grained quartzarenites, showing wave ripples with E/W-oriented straight crests near the base, alternate with burrowed siltstones in three decametric sandier-upward sequences (total thickness about 150 m). Next, a subvolcanic sill of unknown age is overlain by three bars of medium-grained quartzarenites (about 30 m) and in turn by burrowed or wavy-bedded siltstones (about 20 m).

Sandstone petrography. The lower-middle Gircha Fm. (Ashtigar section) mostly contains very fine to lower fine-grained arkoses (average detrital modes Q58±12 F39±11 L3±2 n=6; petrographic parameters after Dickinson, 1970), with negligible polycrystalline quartz (C/Q 3±2%), subequal amounts of plagioclase and K-feldspars (P/F 61±22%), and very few, mainly igneous rock fragments (myrmekite, micropegmatite, felsite) (Fig. 6).

The upper Gircha Fm. (Ashtigar-Khudabad-Gircha) is characterized by upper fine to medium-grained subarkoses or quartzarenites (average detrital modes Q90±8 F6±6 L4±4 n=8). Polycrystalline quartz is minor (C/Q 3±3%) even in coarser samples, suggesting low supply from metamorphic source rocks. Plagioclase prevails over K-feldspar and chessboard-albite (P/F 72±19%). Rock fragments tend to increase with grain size, and between Gircha and Sost coarse


E Baroghil
Chillinji
Ashtigar
SAKMARIAN
CARBONIFEROUS-LOWERMOST PERMIAN
DEVONIAN
CHILMARABAD Fm.
CARBONIFEROUS - PERMIAN ?
U. ASSELLIAN-L. SAKMARIAN
CK154
CK153
CK152
CK151
CK150
CK149
CK148
CK147
CK145
CK144
CK143
CK140
CK467
CK466
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CK464
CK463
CK462
CK461
CK460
CK459
CK458
CK455
KP198
KP194
KP188
KP182
KP176
KP172-173
F
50 m
0
Volcanic sill
"Andesitic" dyke
Arenite
Pelite
Shale
Dolomite
Sandstone lenses
Fault
Zoophycos
Bivalve
Brachiopod
Echinoderm
Bryozoan
Hummocky cross-lamination
High-angle cross-lamination
Parallel lamination
Ripple
Wave ripple
Current ripple
Climbing ripples
Megaripple
Tb-c storm layer
Flute cast
Mudclast
Pyrite
Phosphatic nodule
Bioturbation
Balls & pillows
Wavy bedding
Scoured base

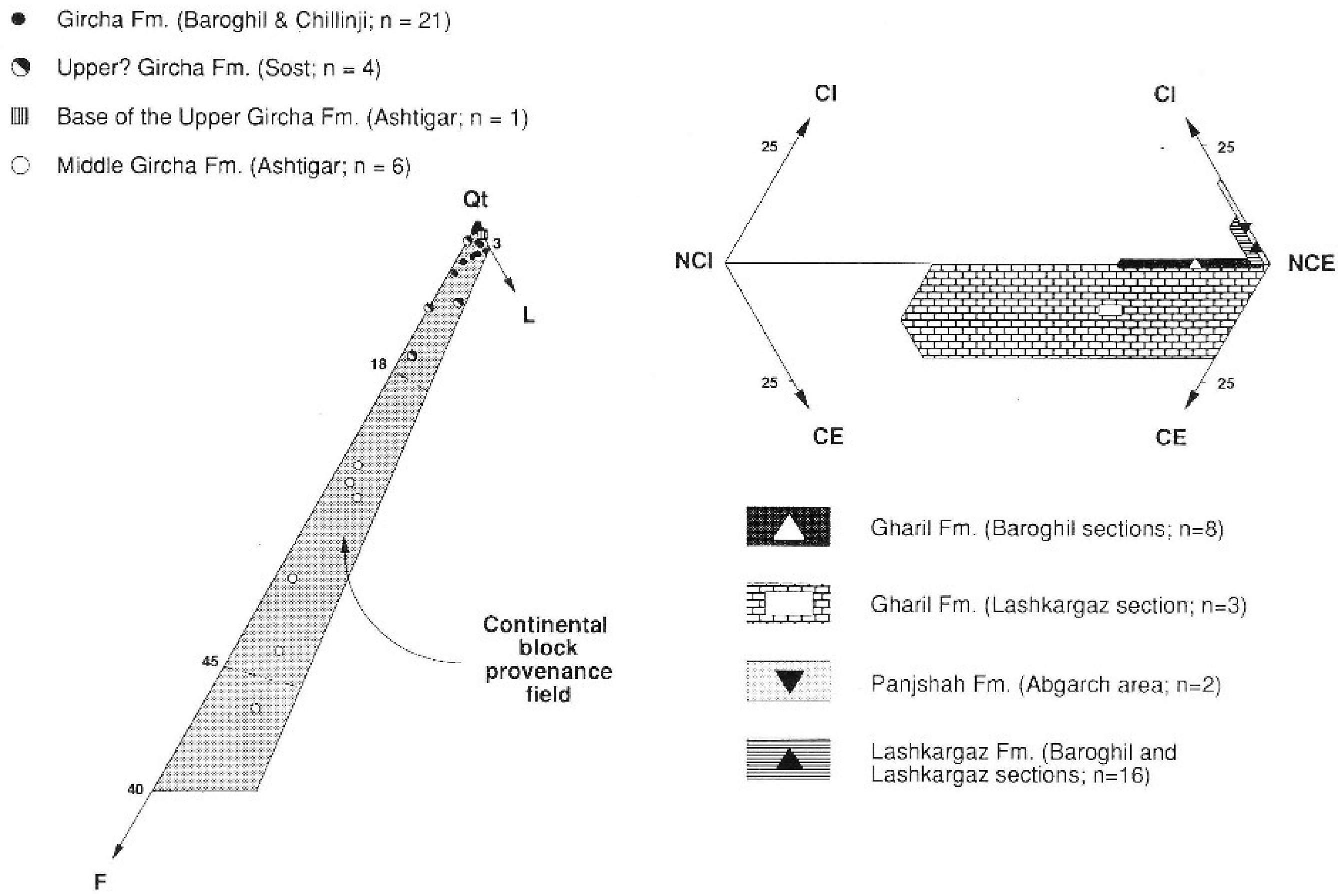


Fig. 6 - Petrography of Permian arenites (61 samples) from the investigated area. Detrital QtFL modes of the Gircha sandstones consistently cluster in the "continental block provenance field" of Dickinson (1985). The overlying units can be best discriminated according to their content in intrabasinal vs. extrabasinal grains (classification diagram modified after Zuffa, 1985; polygons are one standard deviation each side of the mean).

sublitharenites contain mainly igneous lithic grains (granitoid, hypabissal, felsitic and common microlitic types). A few conglomerate intercalations also including granitoid and gneissic pebbles occur further to the south in Shimshal.

The Gircha Fm. exposed at E Baroghil mostly consists of medium-grained quartzarenites (average detrital modes Q99±1 F1±1 L0±1 n=12); thus only the mid-Sakmarian upper part of the formation is likely to be represented. Detrital feldspars are concentrated in the very fine-grained sand fraction (corr. coeff. vs. grain size 0.82; sign. lev. 0.1%), but extremely fine-grained sandstones are still quartzarenites (F only up to 4).

Largely quartzarenitic compositions also characterize Late Paleozoic sandstones in the Chillinji area (F up to 6 in very fine-grained sandstones). Detrital feldspars are mostly albitized plagioclase (P/F >60% at Ashtigar, as documented by SEM-EDS analysis - courtesy of A. Rizzi, Milano), with sporadic occurrence of partly albitized K-feldspar. Lithic fragments are barely significant.

The Gircha Fm. thus displays a typical "Continental block provenance" with detrital modes passing upward from "basement uplift" to "stable craton" field of Dickinson (1985).

Upper boundary. In the Gircha-Chapursan area, the upper boundary has been set in correspondence of a rapid transition from a fining-upward well bedded sandstone-siltstone-shale sequence to dark grey hybrid recrystallized limestones, interbedded with siltstones-shales containing small phosphatic nodules. Upwards, the first bioclastic hybrid calcarenites with echinoids, crinoids and pelecypods appear.

Biostratigraphy. In Upper Yarkhun-Baroghil and Karambar no fossils have been found within this unit.

Fig. 5 - Stratigraphic sections of the Gircha Formation in the study area. The middle and the upper part of the Ashtigar section is not age constrained by fossils. Mineralogical compositional data have been quantitatively obtained for all of the indicated sandstone samples (CK, KP). Location of the Baroghil E section on Fig. 8 and of Ashtigar section on Fig. 7. The Chillinji section has been measured on the left bank of the Karambar river, some 400 m upwards from Chillinji.

Only a poorly preserved specimen of *Trigonotreta* was found in the debris, suggesting a possible correlation with the Asselian-Early Sakmarian fauna of the Gircha Fm. in Chapursan.

In Chapursan we found fossils in the Spinje gulley and near the Ashtigar meadows at the top of the lower part (Fig. 7). They are the brachiopods: *Lyonia* sp. ind., *Rhynchopora* sp. ind., *Trigonotreta stokesi* Koenig, *T. lyonsensis* Archbold & Thomas, *Spirelytha petaliformis* (Pavlova), *Punctospirifer afghanus* Termier, Termier, de Lapparent & Marin and *Tomiopsis* cf. *bazardarensis* (Grunt); bivalves: ? *Etheripecten* sp., *Deltopecten* sp., *Leiopteria* sp., *Eurydesma* sp. (Pl. 1). A similar assemblage, dominated by *S. petaliformis* was collected by A. Zanchi in 1991 in the Gircha Fm. cropping out at about 4000 m a.s.l. on the left side of the Yashkuk glacier. Angiolini (1994, 1995) identifies this as an assemblage zone, with *T. lyonsensis* and *P. afghanus* as index-species.

The Yashkuk glacier area needs further studies, because we found a big *Aphyllum* specimen in the debris on the slope near the trail along the Yashkuk left moraine. It was embedded in shales like Gircha shales, which has been considered not younger than Devonian by Flügel (1995a). The X-ray analysis of the clay inside the specimen corallites shows a significant difference to the embedding rock (Flügel, pers. comm., 1993). Upwards, F. Jadoul collected several compound corals, possibly of Devonian age, within a carbonate megabreccia embedded within splintery shales attributed to the Gircha Fm. The locality lies at the centre of fig. 8 of Zanchi (1993). We very tentatively interpret these findings as clasts within the Gircha.

Chronostratigraphy. The age of the Gircha Fm. is defined only for its middle-upper part. We attribute latest Asselian-Early Sakmarian age to the brachiopod assemblage of the middle part (Angiolini, 1994, 1995), as inferred by the presence of *P. afghanus* from the Asselian of the Wardak (Termier et al., 1974), *T. lyonsensis* from the Asselian-Early Sakmarian of the Carnarvon Basin (Archbold & Thomas, 1986), *T. stokesi* from the Tamarian (Asselian-Early Sakmarian) of Tasmania (Clarke 1979, 1990; Archbold & Dickins, 1989; Archbold, 1992), the genera *Lyonia* and *Rhynchopora* from the Asselian-Early Sakmarian of W Australia, Lyons Group (Archbold, 1983, 1992) and *T.*

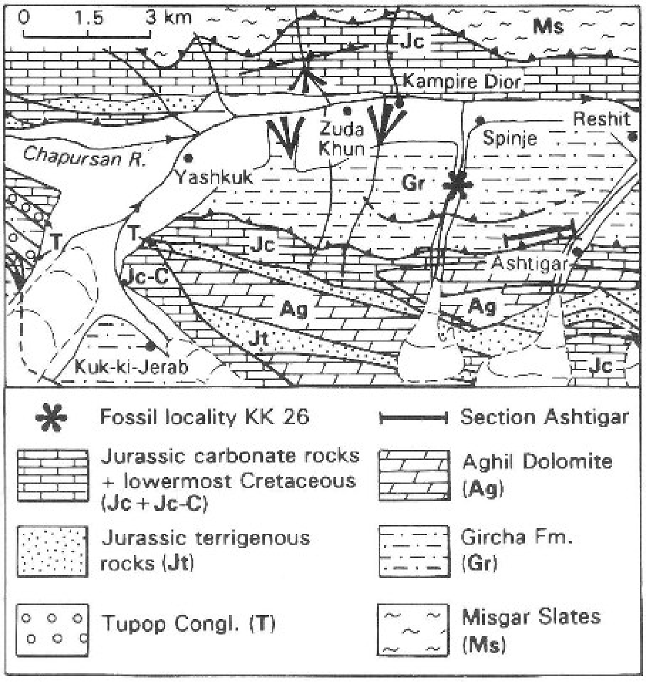
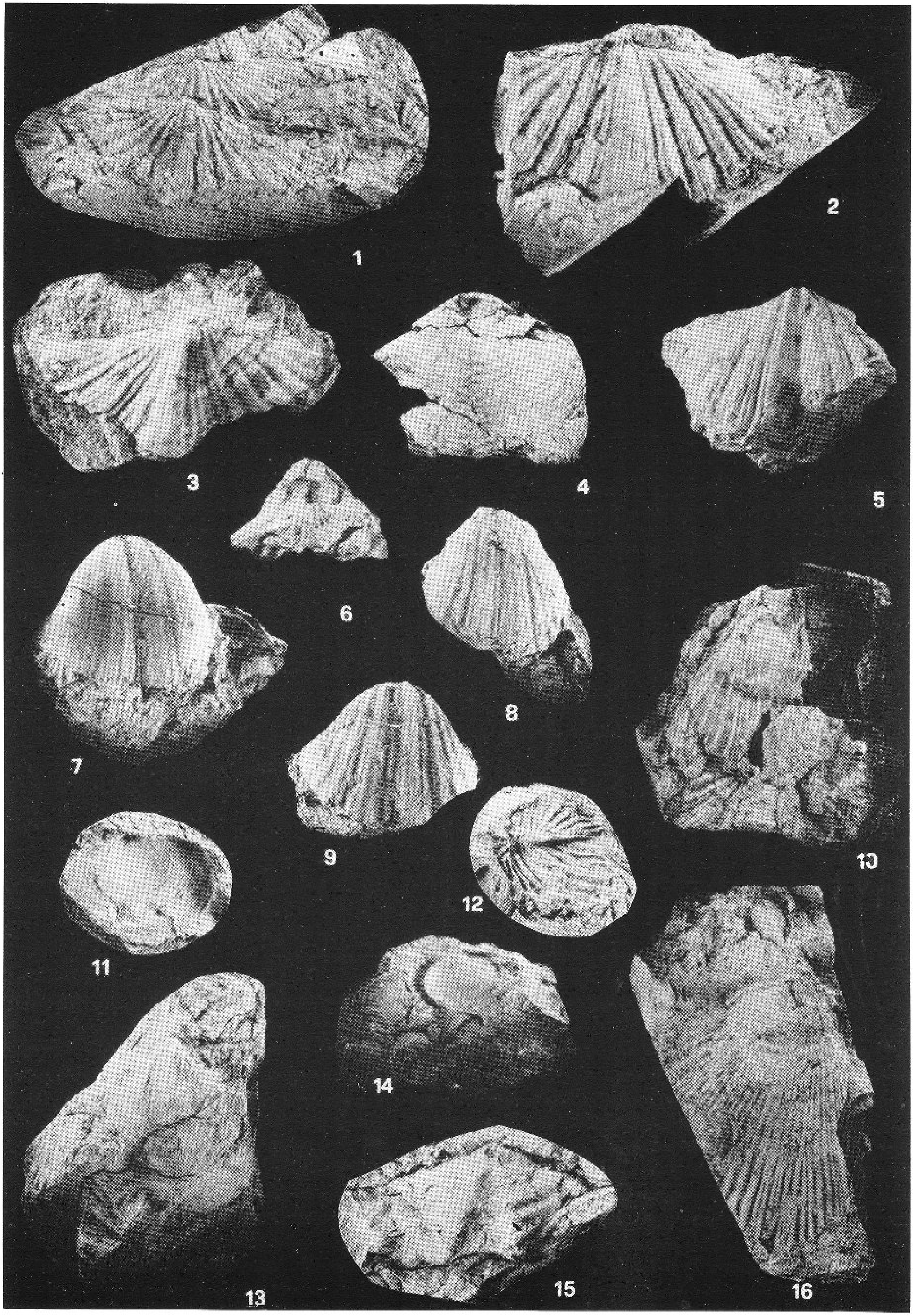


Fig. 7 - Location of the marine fossiliferous localities in Spinje - Ashtigar area. Geological map after Zanchi & Gaetani (1994).

PLATE 1

Fig. 1 - *Trigonotreta lyonsensis* Archbold & Thomas, 1986. Dorsal valves. Gircha Fm., Spinje, specimens KK 26-32,-33.
Fig. 2 - *Trigonotreta stokesi* Koenig, 1825. Dorsal valve. Gircha Fm., Spinje, specimen KK 26-35.
Fig. 3 - *Trigonotreta lyonsensis* Archbold & Thomas, 1986. Dorsal valve internal mould. Gircha Fm., Spinje, specimen KK 26-63.
Fig. 4 - *Spirelytha petaliformis* (Pavlova, 1973). Ventral valve. Gircha Fm., Yashkuk glacier, specimen KL 2-11.
Fig. 5 - *Trigonotreta paucicostulata* (Reed, 1925). Ventral valve. Lupghar Fm., Mb. 1, Shimshal section, specimen KL 19-49.
Fig. 6 - *Punctospirifer afghanus* Termier, Termier, de Lapparent & Marin, 1974. Anterior view of a complete specimen. Gircha Fm., Spinje, specimen KK 26-44.
Fig. 7 - *Hunzina electa* Angiolini, 1995. Ventral valve. Lashkargaz Fm., Baroghil E section, specimen CK 172-110.
Fig. 8 - *Hunzina tenuisulcata* (Merla, 1934). Ventral valve. Lupghar Fm., Mb. 1, Shimshal section, specimen KL 19-5.
Fig. 9 - *Hunzina electa* Angiolini, 1995. Ventral valve. Lashkargaz Fm., Baroghil E section, specimen CK 172-50.
Fig. 10 - *Etheripecten* sp. Gircha Fm., Spinje, specimen KK 26-7.
Fig. 11 - *Cleiothyridina ailakensis* Reed, 1925. Ventral valve external mould. Lashkargaz Fm., Baroghil E section, specimen CK 162-A.
Fig. 12 - *Gjelispinifera* aff. *cristata* (Schlotheim, 1828). External mould of conjoined valves. Lashkargaz Fm., Baroghil E section, specimen CK162-32.
Fig. 13 - *Lyonia* sp. ind. Ventral valve. Gircha Fm., Spinje, specimen KK 26-166.
Fig. 14 - *Permochonetes pamiricus* Afanaseva, 1977. Ventral valve internal mould. Lupghar Fm., Mb. 1, Yazghil glacier, specimen KL 21-40.
Fig. 15 - *Tomiopsis* cf. *bazardarensis* (Grunt, 1993). Ventral valve. Gircha Fm., Yashkuk glacier, specimen KL 2-18.
Fig. 16 - *Deltopecten* sp. Gircha Fm., Spinje, specimen KK 26-5.

(All x 1)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cf. *bazardarensis* from the lump-boulder member at the base of the Tashkazyk Fm. of the SE Pamir (Grunt & Dmitriev, 1973; Grunt & Novikov, 1994). We interpret this last occurrence as a mixed assemblage of Asselian - Early Sakmarian age (see Angiolini, 1995 for further discussion). The bivalve association (*Eurydesma* fauna) also testifies for this age. The occurrence of *S. petaliformis* which is known only from the Sakmarian of Western Australia and SE Pamir could suggest an age just near the Asselian-Sakmarian boundary. J.M. Dickins, Canberra (pers. comm., 1994) suggests that this association could be a deeper water equivalent of the *Eurydesma* fauna and prefers a Tastubian (i.e. Early Sakmarian) age for this fauna. N. Archbold, Melbourne (pers. comm., 1995) also prefers this age. If this assumption is correct, a very high accumulation rate for the Sakmarian is implied (>800 m, near half of the whole Permian of Karakorum). The high accumulation rate could also be an artifact produced by the Ross et al. (1994) geochronology, with a Sakmarian lasting only 4 Ma, possibly too short. We prefer to keep the possibility open for a latest Asselian age, keeping in mind also the warmer conditions of Northern Karakorum, where glacial deposits of Permo-Carboniferous age have never been found. Hence a climatic shifting in comparison to the cooler Australian reference sections.

The top of the unit should lie within the Sakmarian, because of the brachiopod and fusulinid assemblages occurring in the overlying units of the Chapursan Group. However, we have no data concerning its base. Is all the unit bracketed within the Asselian stage, as the high sedimentation rate could suggest? Or is the Gircha Fm. also representing part of the Carboniferous? To which extent? Are there discontinuities? At present we are not able to answer these questions.

Chapursan Group.

We introduce here this term, to include the mixed terrigenous/carbonate units, rich in shallow water fossils, like fusulinids, brachiopods, bryozoans, corals, bivalves and gastropods, which characterize the central part of the Permian in Northern Karakorum. Perhaps there are affinities with the Darkot Group (Ivanac et al., 1956). Having no direct knowledge of the Darkot area, we prefer to keep them distinct. We include in the Chapursan Group three formations: Lashkargaz, Lupghar and Panjshah. They are the most favourable for paleontological studies.

Lashkargaz Formation.

Name. Here introduced, with type-section the Lashkargaz section in the Upper Yarkhun area (Fig. 8, 9). However, the base is missing, because of the Yarkhun river braided plain. The lowest part has been measured in the Baroghil E section (Fig. 10).

Lithology. This unit consists of shales, with subordinate sandstones and limestones. Its total thickness should exceed 1000 m eastwards where the unit is thicker and more complete in its upper part. The formation is arranged in four main subunits, considered here as members. They will be described bottom to top.

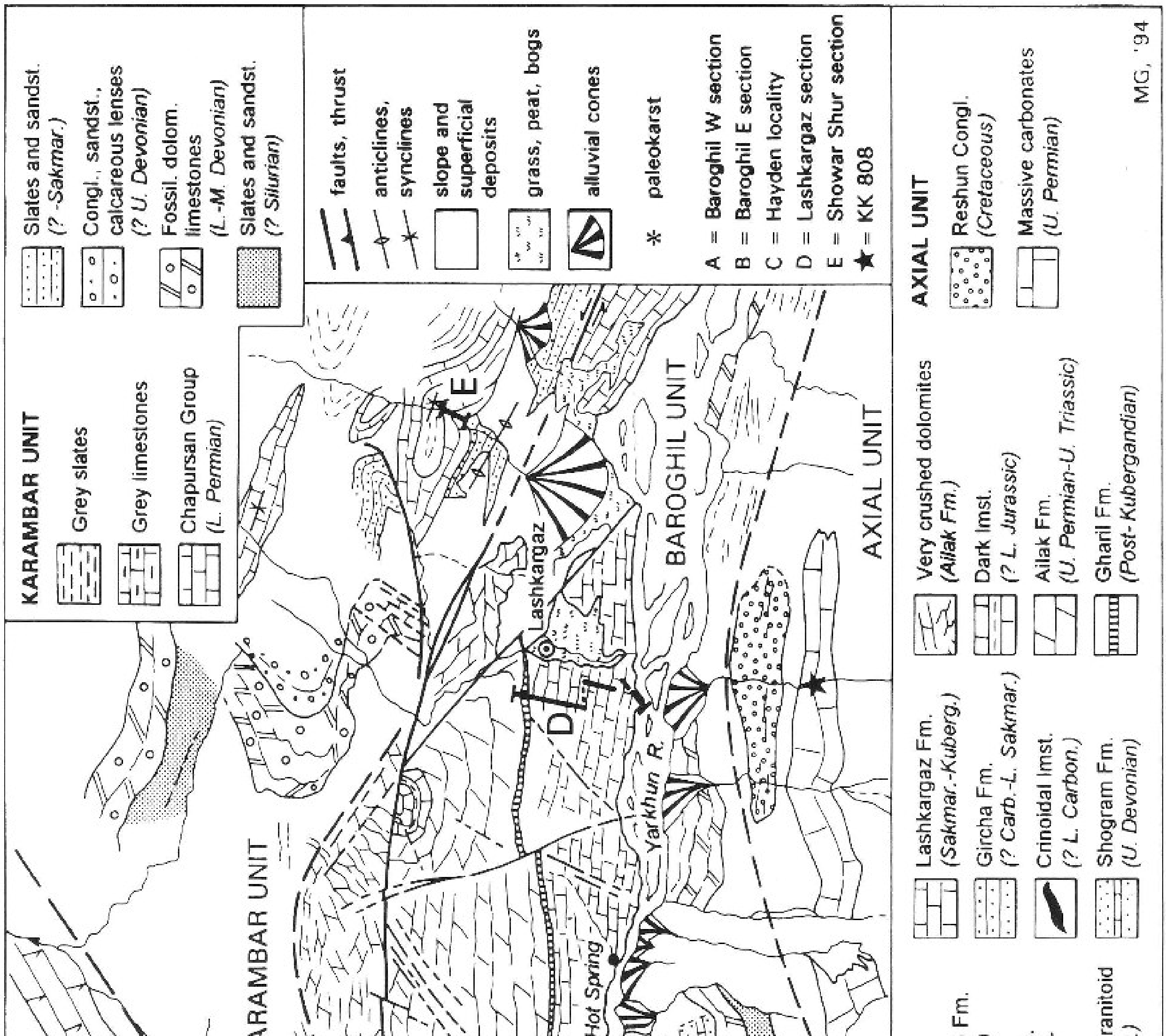
Member 1. In the Baroghil E section it is little less than 300 m thick. It starts with siltites with calcareous cements and small phosphatic nodules, and spread *Zoophycos*-like burrowings. Calcareous siltites and a few quartzarenites continue upwards, to give way in the upper part to calcareous siltites with well-washed crinoidal lenses and marls with calcareous nodules, containing fairly abundant brachiopods and bryozoans. Also rare conodonts were etched out. The quartzarenitic layers have mostly parallel laminations in contrast with the previously high-angle cross laminations of the Gircha Fm.

Member 2. This member is dominated by calcareous sediments, more washed and coarser westwards and richer in clay eastwards. It is only 108 m thick in the Baroghil East section, whilst it reaches 368 m in the Lashkargaz section. In the lower part packstones dominate with locally abundant in fusulinids. It is commonly dolomitized in the Baroghil area. This horizon was already noted by Hayden (1915, p. 291). At Baroghil dark grey wackestone/packstones with rare fusulinids and corals continue upwards (but a fault may reduce the section), at Lashkargaz there is an imposing continuous alternance of dark grey wackestone/packstones, locally very rich in oncoids up to 3 cm in size, also with abundant fossils. Marly layers commonly separate these wackestone/packstone horizons.

Member 3. This member is characterized by renewed terrigenous input. At Baroghil there are two major arenitic horizons separated by oncoidal packstones and marly limestones, for a total thickness of 144 m. At Lashkargaz sandstone intercalations are rarer and intermingled with the shaly and marly horizons. This member is less distinct eastwards, for a thickness of 80 m.

Member 4. The base of this member has been traced with the appearance of well-bedded grey wackstone/packstones, locally extremely rich in fusulinids

Fig. 8 - Geological map of the Upper Yarkhun valley and Baroghil pass area, with location of the stratigraphic sections and relevant fossiliferous localities. All the sections, but the section Showar Shur, have been measured in the Baroghil tectono-stratigraphic Unit.


TAŠ KUPRUK UNIT
Shales, dark green volcanics
Light dolomites
KARAMBAR UNIT
Grey slates
Grey limestones
Chapursan Group (L. Permian)
Slates and sandst. (? -Sakmar.)
Congl., sandst., calcareous lenses (? U. Devonian)
Fossil. dolom. limestones (L.-M. Devonian)
Slates and sandst. (? Silurian)
faults, thrust
anticlines, synclines
slope and superficial deposits
grass, peat, bogs
alluvial cones
paleokarst
A = Baroghil W section
B = Baroghil E section
C = Hayden locality
D = Lashkargaz section
E = Showar Shur section
★ = KK 808
BAROGHIL UNIT
Chilmarabad Fm. (? Devonian)
Yarkhun Fm. (L. Ordovic.- ? Silurian)
Ishkarwaz Granitoid (pre-Ordovic.)
Lashkargaz Fm. (Sakmar.-Kuberg.)
Gircha Fm. (? Carb.-L. Sakmar.)
Crinoidal lmst. (? L. Carbon.)
Shogram Fm. (U. Devonian)
Very crushed dolomites (Ailak Fm.)
Dark lmst. (? L. Jurassic)
Ailak Fm. (U. Permian-U. Triassic)
Gharil Fm. (Post- Kubergandian)
AXIAL UNIT
Reshun Congl. (Cretaceous)
Massive carbonates (U. Permian)
MG, '94
TAŠ KUPRUK UNIT
KARAMBAR UNIT
BAROGHIL UNIT
AXIAL UNIT
Baroghil Pass
Darya-i-Baroghil
Gharil
Hot Spring
Yarkhun R.
Lashkargaz
Chilmarabad
Baroghil Houses
Ishkarwaz
Yarkhun R.
A
B
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and with dark chert nodules. Corals and brachiopods, as well as crinoids and bivalves, may be locally abundant in the lower part. The topmost part is largely dolomitized in the Baroghil section, where this member is 224 m thick. Instead, wackestones with dark chert nodules are mainly developed at Lashkargaz, where the member reaches 450 m in thickness.

Upper boundary. The unit is channelized at the top in the Baroghil area, however to the east it seems to be covered without important erosion by shales and marls. But here the exposure is poor.

Sandstone petrography. Very fine to medium-grained sandstones contained in Member 1 and 3 are invariably quartzarenites (average detrital modes Q96±8 F3±7 L1±2 n=16), but for the basal sample in the Baroghil East section, which is a very fine-grained arkose including plagioclase, orthoclase, chess board-albite (F=27; P/F=88%) and mainly crystalline rock fragments (L=8). Detrital feldspars (mainly plagioclase) are notably enriched in the very fine-grained sandstones (F=1 to 5). Rock fragments are scarce. Bioclastic layers (CI up to 23) occur throughout the formation and are particularly common in Member 3.

Microfacies. (Pl. 2, 3). Silty or clayey mudstones are present through all the formation. Coarser microfacies are as follows. The most spread microfacies of the Member 1 are packstones with abundant crinoid ossicles, locally large-sized. Often they are still polluted by clay or quartz silt. In Member 2 grainstones with or without fusulinids occur, but packstones are dominant. Either with highly diverse, medium- to large-sized bioclasts, like crinoids, brachiopods, bryozoans, bivalves, rare fusulinids, and dasycladaceans, either with a very fine bioclastic sand in which small foraminifers may be abundant, like *Agathammina*, *Hemigordius* and *Globivalvulina*. Occasional are almost monobioclastic packstones with crinoids or bryozoans. Peculiar to the central part of the member are wackestone/packstone with large oncoids with multiple coatings. In the Member 3 of the Baroghil East section are dominating packstones with small sized bioclasts which support larger bioclasts like oncoids, coated fossils, *Tubiphytes* ex gr. *carinthiacus* Flügel. In the fine bioclastic matrix, small forams may be abundant. In the Member 3 of the section Lashkargaz, more washed microfacies may occur, with grainstones very rich in crinoids. In the lower part of the

PLATE 2

Microfacies of the Lashkargaz Formation. Lashkargaz section.

Member 4

Fig. 1 - Bioclastic packstone with frequent small specimens of *Tubiphytes obscurus* Maslov. Sample CK 346; x 23.2.

Fig. 2 - Bioclastic wackestone/packstone with small *Tubiphytes obscurus* Maslov. Sample CK 355; x 10.8.

Member 3

Fig. 3 - Well washed crinoidal packstone to grainstone, with few very fine quartz grains. Sample CK 364; x 5.9.

Member 2

Fig. 4 - Fine sized bioclastic packstone with small coated grains and small foraminifers with *Hemigordius* sp. Sample CK 313; x 28.3.

Fig. 5 - Large oncoid with polyphasic coating, envelopping fusulinid, gastropod and crinoid fragments. Sample CK 311; x 5.7.

Fig. 6 - Packstone/grainstone with abraded and partially coated fusulinids and crinoid ossicles. Sample CK 309; x 5.7.

Fig. 7 - Bioclastic medium-sized packstone/grainstone with crinoid, dasycladaceans, bryozoans, bivalves and a few micritized grains. CK 307; x 12.6.

Fig. 8 - Very fine bioclastic packstone, with endothyrids and coated grains. Largely microspatized. Sample CK 303; x 28.9.

Fig. 9 - Coarse bioclastic packstone with crinoids, dasycladaceans (? *Mizzia* sp.), fusulinids (? *Staffella* sp.), bryozoans and small bivalves. Sample CK 285; x 5.7.

Member 1

Fig. 10 - Hybrid wackestone with small quartz grains. Bioclasts consist of brachiopod and crinoids and small *Tubiphytes*-like problematics. Sample CK 273; x 7.0.

PLATE 3

Microfacies of the Lashkargaz Formation.

Baroghil E section. Member 4

Fig. 1 - Floatstone with frequent small foraminifers in the matrix, supporting partially worn and coated fusulinids. Sample CK 202; x 5.7.

Fig. 2 - Magnification of the matrix of fig. 1. *Climacammina* sp. and *Hemigordius* sp. Sample CK 202; x 20.8.

Fig. 3 - Bioclastic packstone with two mean grain sizes, with erosional contact supporting not reworked fusulinids. Sample CK 195; x 6.3.

Fig. 4 - Fine sized packstone with small *Tubiphytes* and coated small tubes. Largely recrystallized. Sample CK 196; x 28.9.

Fig. 5 - Floatstone with a large oncoid, possibly growned on a small *Tubiphytes*. Sample CK 183; x 10.8.

Fig. 6 - Fine sized packstone with problematica. Sample CK 182; x 8.6.

Fig. 7 - Grainstone, with partially worn fusulinids. Sample CK 91; x 5.7.

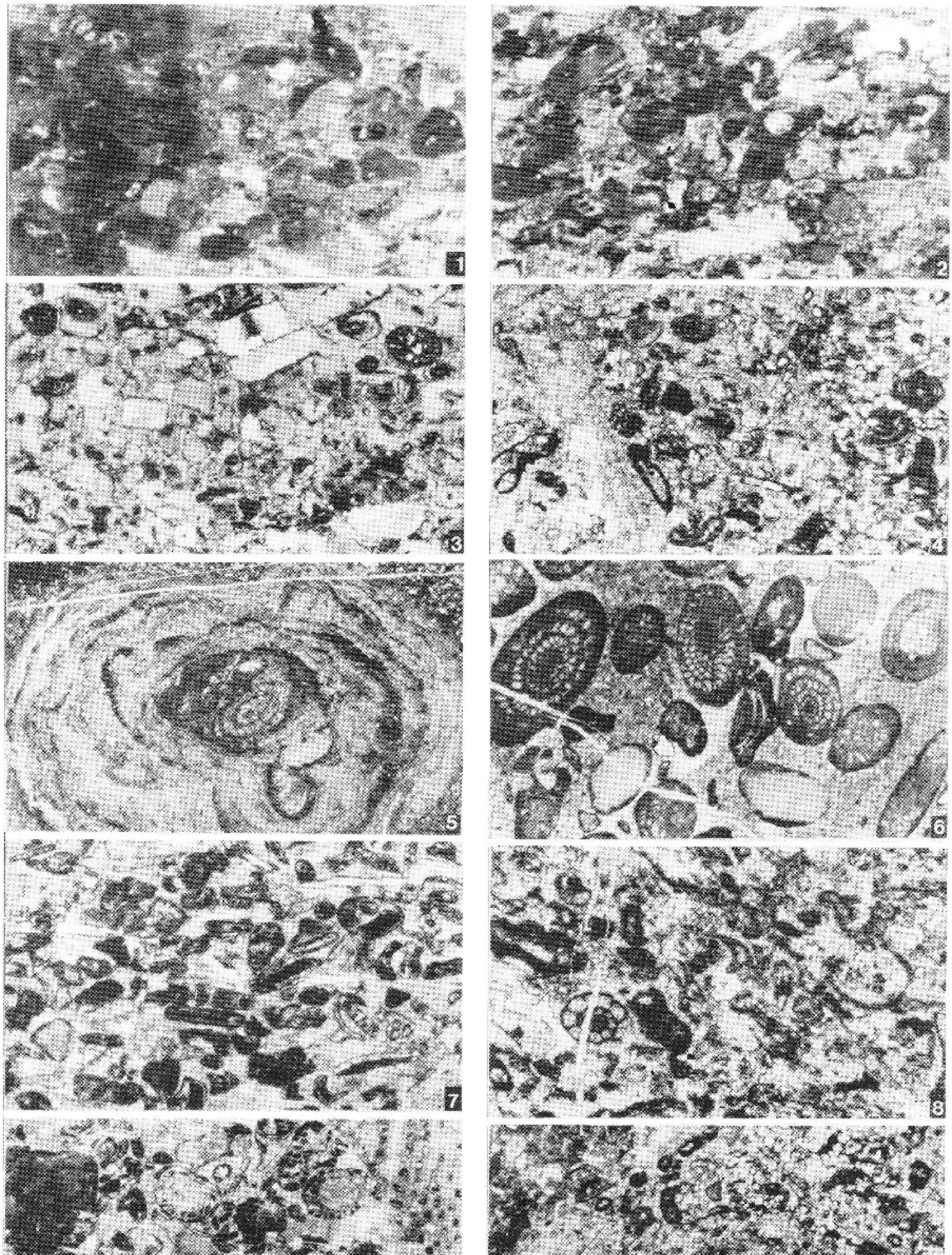
Member 2

Fig. 8 - Partly recrystallized wackestone/packstone with small tubes (sessil forams?). Sample CK 167; x 28.3.

Lashkargaz section. Member 4

Fig. 9 - Fragment of a bryozoan overgrowth by a *Tubiphytes* sp. Sample CK 339; x 10.7.

Fig. 10 - Boundstone with Sphinctozoan colony. Sample CK 353; x 5.7.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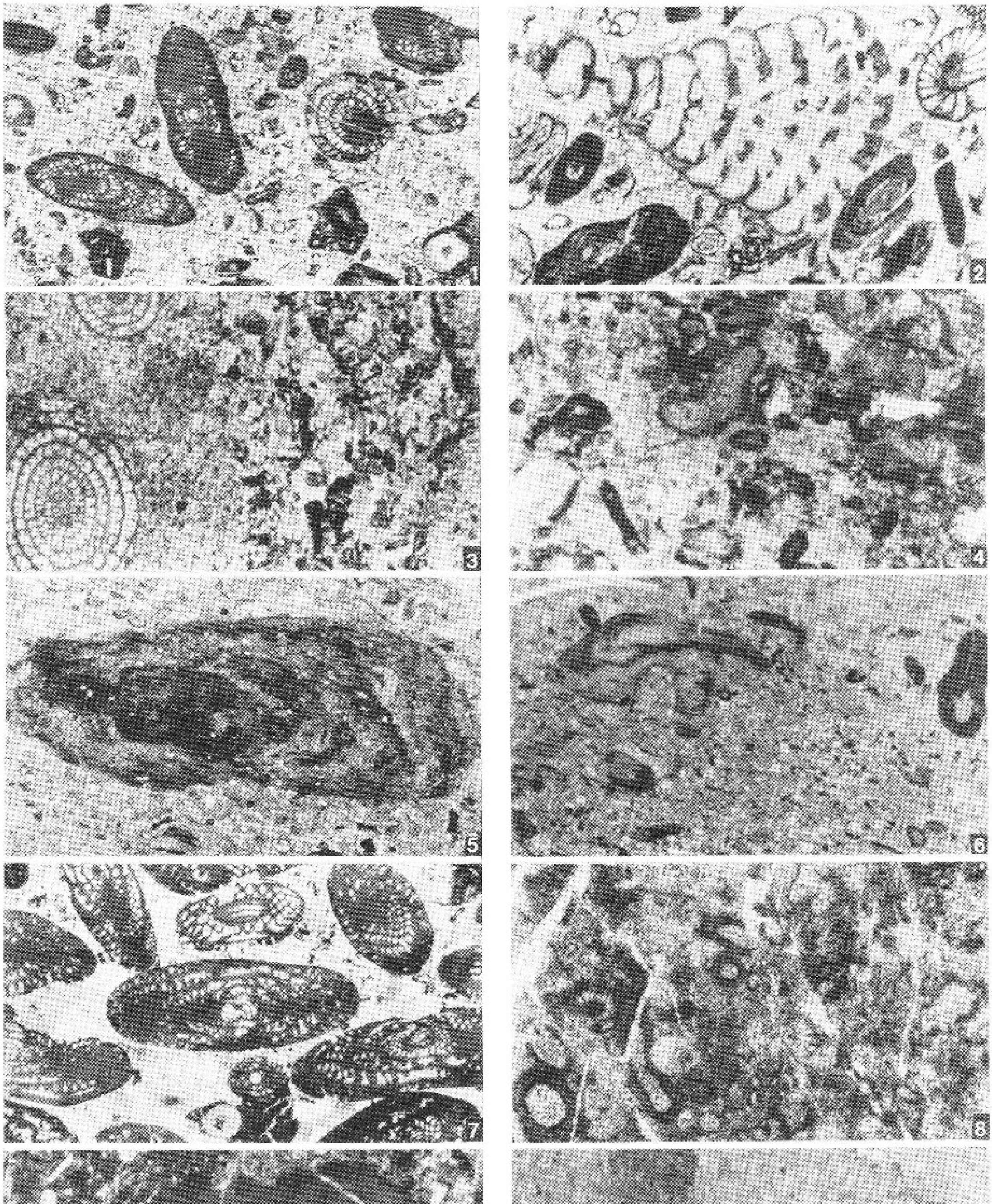
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Member 4 are repeated several microfacies of the Member 2. Particularly at Baroghil, packstones and more rarely grainstones with fusulinids are abundant. In the last 160 m of the Lashkargaz section are peculiar packstones or packstone/rudstones dominated by *Tubiphytes obscurus* Maslov. Only near the top a boundstone with several Porifera genera and algal crust has been detected. These two last microfacies are absent in Baroghil East (Fig. 10), possibly because of non deposition or erosion.

Biostratigraphy. The abundant fossil content of the Lashkargaz Formation may be described as follows, from bottom to top (Fig. 9, 10). Brachiopod zones after Angiolini (1994, 1995):

1. *Hunzina electa* range zone. It characterizes the topmost part of the Member 1. Besides the index-spe-

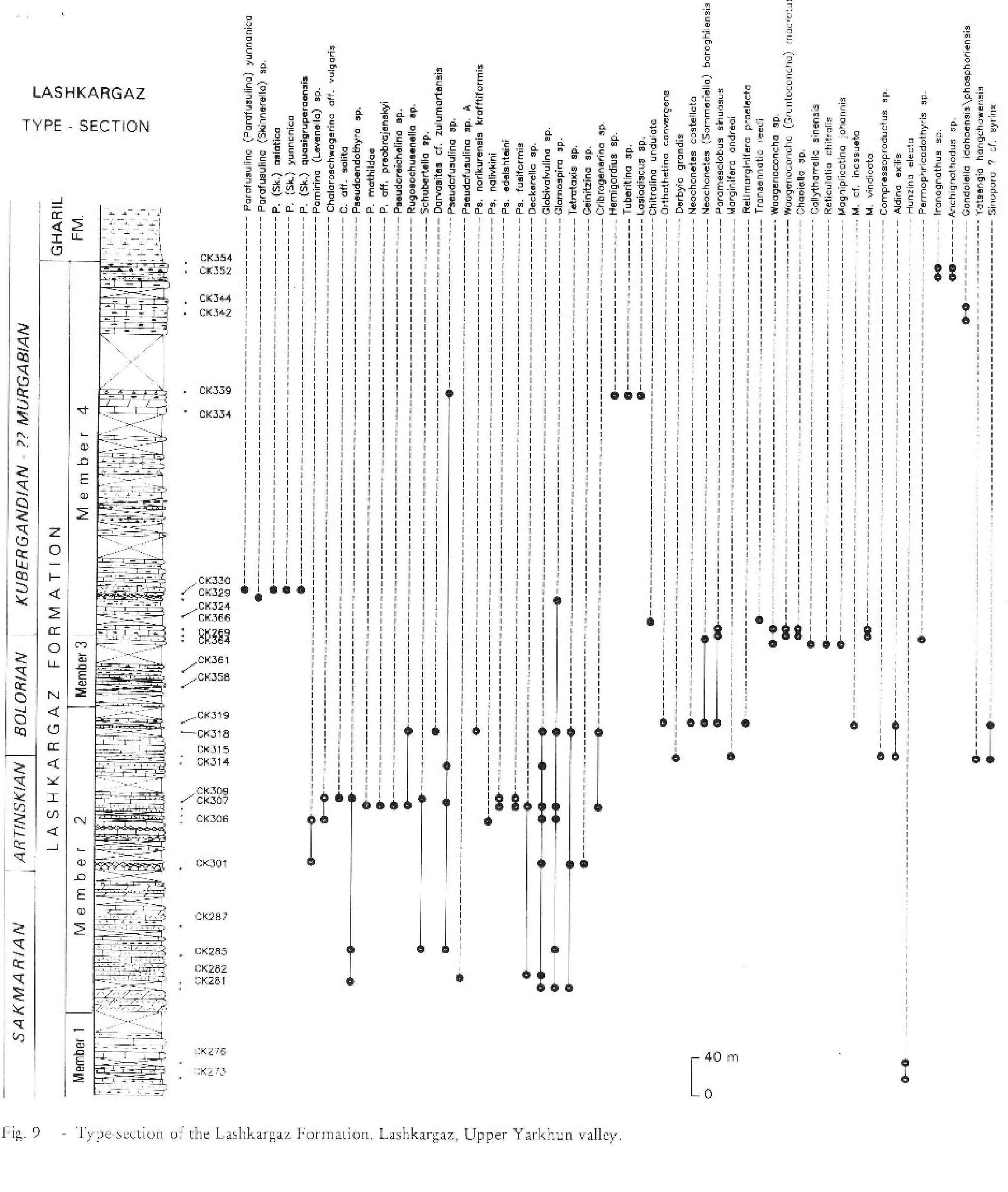

Fig. 9 - Type-section of the Lashkargaz Formation. Lashkargaz, Upper Yarkhun valley.

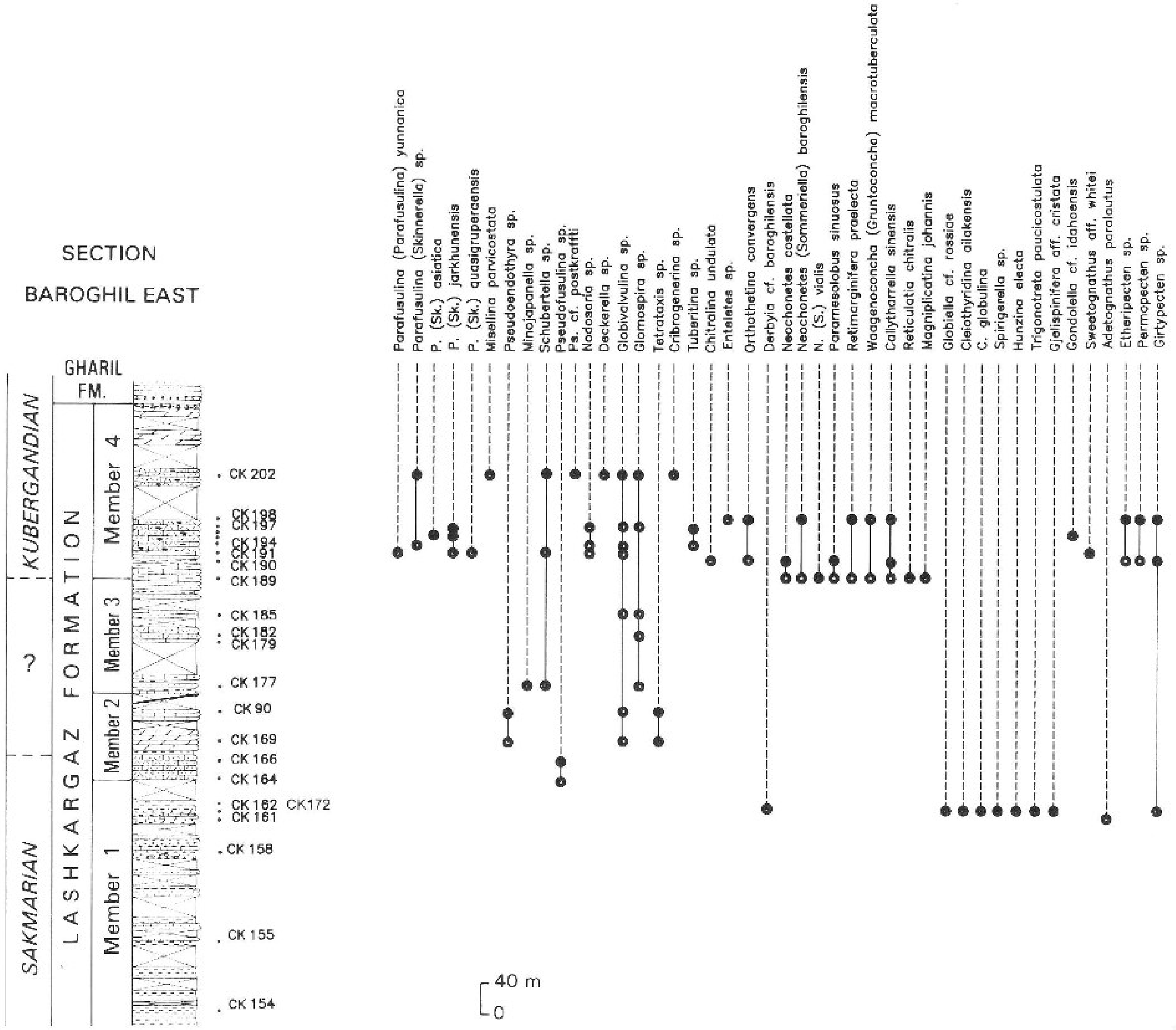

Fig. 10 - The Lashkargaz Fm. measured in the section Baroghil East. Upper Yarkhun valley.

cies, it contains *Derbyia* cf. *baroghilensis* Reed, *Globiella* cf. *rossiae* Fantini Sestini, *Cleiothyridina ailakensis* Reed, *Cleiothyridina globulina* (Waagen), *Spirigerella* sp. ind., *Trigonotreta paucicostulata* (Reed), *Gjelispinifera* aff. *cristata* (Schlotheim) (Pl. 1). The assemblage is dominated by the spiriferids. In the Baroghil East section the bivalve *Gyrtipecten* sp. has also been detected (det. J.M. Dickins, Canberra). Bryozoans have not yet been identified and the conodonts species *Adetognathus paralautus* Orchard has also been etched out (Baroghil East section). Details on finer zonation are discussed in Angiolini (1995). The thickness of this zone is 20 m.

PLATE 4

Fig. 1 - *Pseudofusulina norikurensis kraffiiformis* Leven, 1967. Axial section. Lashkargaz Fm., Lashkargaz section, sample CK 318; x 13.3.

Fig. 2-4 - *Pseudofusulina postkraffti* (Leven, 1967). All axial sections. Lashkargaz Fm., Baroghil E section, sample CK 91. All x 13.3.

Fig. 5, 6 - *Pseudofusulina edelshteini* Kalmykova, 1967. Lashkargaz Fm., Lashkargaz section. 5) Axial section, sample CK 309; 6) axial section, sample CK 307. All x 13.3.

Fig. 7 - *Pseudofusulina nalivkini* Leven, 1967. Axial section. Lashkargaz Fm., Lashkargaz section, sample CK 306; x 13.3.

Fig. 8 - *Parafusulina (Skinnerella)* aff. *quasigruperaensis* Sheng, 1963. Axial section. Lashkargaz Fm., Baroghil E section, sample CK 191; x 13.3.

Fig. 9, 10 - *Chalaroschwagerina vulgaris* (Schellwien, 1909). Lashkargaz Fm., Lashkargaz section, sample CK 309. 9) Subaxial section; 10) axial section. All x 13.3.

Fig. 11 - *Misellina* sp. ind. Oblique section. Lashkargaz Fm., Baroghil E section, sample CK 91; x 26.6.

Fig. 12 - *Pseudofusulina fusiformis* (Schellwien, 1909). Subaxial section. Lashkargaz Fm., Lashkargaz section, sample CK 309; x 13.3.


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2. The lowermost part of Member 2 contains a poorly preserved fusulinid assemblage dominated by the genera *Pseudofusulina* and *Pseudoendothyra*. They are associated with small foraminifers belonging to genera *Globivalvulina*, *Tetrataxis*, *Glomospira*, *Deckerella*. Thickness of this zone is about 40 m.

3. A second fusulinid assemblage, well developed in Lashkargaz (samples CK 301-309) is dominated by *Chalaroschwagerina*, *Pseudofusulina*, and *Pamirina*. The complete list is given in Fig. 9. The central part of the second member in the Baroghil E section, where Tabulata have also been found, is correlatable with this assemblage. *Protomichelinia multitabulata multitabulata* (Yabe & Hayasaka) and *Protomichelinia siyangensis* (Reed) are described by Flügel (1995b). The thickness of the zone is about 70 m.

4. Partly coincident with a third fusulinid assemblage (*Darvasites* cf. *zulumartensis* Leven, *Pseudofusulina norikurensis krafftiformis* Leven) is a brachiopod-coral assemblage, the *Orthothetina convergens/Aldina exilis* brachiopod assemblage zone, in which are also frequent large *Protomichelinia* in life position. The following brachiopod species are also present: *Derbyia grandis* Waagen, *Neochonetes (N.) costellata* Angiolini, *Neochonetes (Sommeriella) baroghilensis* (Reed), *Paramesolobus sinuosus* (Schellwien), *Marginifera andreai* Angiolini, *Retimarginifera praelecta* (Reed), *Magniplicatina* cf. *inassueta* (Reed), *Compressoproductus* sp. ind. (Pl. 6). Amongst the corals, besides fairly abundant *Protomichelinia* in life position (not collected), *Sinopora*? cf. *syrinx* (Etheridge) and *Yatsengia hangchowensis* Huang were found (Flügel, 1995b). The assemblage is dominated by chonetids and productids; rhynchonellids may locally form significant clusters. The thickness of this zone is about 45 m.

5. At the base of Member 4 another fusulinid assemblage is present together with the *Waagenoconcha (Gruntoconcha) macrotuberculata/Callytharrella sinensis* brachiopod assemblage zone. Foraminifers are represented by *Chitralina undulata* Angiolini & Rettori, *Globivalvulina* sp. and by the fusulinids *Parafusulina (Parafusulina) jarkhunensis* (Reed), *Parafusulina (Skinnerella) yunnanica* Sheng, *P. (Sk.) asiatica* Leven, *P. (Sk.) quasigruperaensis* (Sheng), *Misellina parvicostata* and *Pseudofusulina* cf. *postkraffti*. Among the brachiopods *Enteletes* sp., *Orthothetina convergens* Merla, *Neochonetes (N.) costellata*, *N. (S.) baroghilensis*, *N. (S.) vialis* (Reed), *Paramesolobus sinuosus*, *Retimarginifera praelecta*, *Transennatia reedi* Angiolini, *Reticulatia chitralis* Angiolini, *Chaoiella* sp., *Magniplicatina johannis* Angiolini, *M. vindicata* (Reed), *Permophrycodothyris* sp. are also present (Pl. 6). The bivalves *Girtypecten* sp., *Etheripecten* sp., *Permopecten* sp. and two new genera of pectinid together with gastropods of the subfamily Subulitinae and some bellerophontids have also been detected (det. J.M. Dickins). The conodont *Sweetognathus* aff. *whitei* and *Gondolella* cf. *idahoensis* have been detected in this zone in the Baroghil E section. The thickness of this assemblage zone is about 55 m.

6. Between 50 and 60 m from the top, in the Lashkargaz section, transitional forms between *Gondolella idaohensis* Youngquist, Hawley & Miller and *Gondolella phosphoriensis* Youngquist, Hawley & Miller have been etched out.

7. At 3 m from the top of the Member 4 in the Lashkargaz section, the conodonts *Anchignathodus* sp. and *Iranognathus* sp. have been detected.

Chronostratigraphy. The age of the Lashkargaz Fm. spans from the Sakmarian to the Kubergandian, with a suggestion for the Murgabian at the top in the Lashkargaz area. The *H. electa* range zone is Sakmarian as testified by the occurrence of *C. ailakensis* known from the Sakmarian of the SE Pamir (Grunt & Dmitriev, 1973), *G. rossiae* from the Sakmarian of the Elburz (Fantini Sestini, 1966), *T. paucicostulata* present in the Sakmarian of Elburz (Fantini Sestini, 1966) and in the Sakmarian of the SE Pamir (Grunt & Dmitriev, 1973). The presence of the conodont *A. paralautus* also suggests a Sakmarian age (Orchard, 1984; Orchard & Forster, 1988).

The second fusulinid assemblage (Member 2) is characterized by *Pamirina (Levenella)* sp., *Pseudoendothyra mathildae*, *Chalaroschwagerina* aff. *solita*, *C.* aff. *vulgaris* which may suggest an Artinskian age. *Ps. mathildae* was found in the Artiskian by Rauser-Chernousova (1935).

The *O. convergens/A. exilis* assemblage zone (Member 2) seems to be Bolorian as testified by the occurrence of the fusulinids *Darvasites* cf. *zulumartensis* and *P. norikurensis krafftiformis*. It could be still Artinskian, but it is standing higher than the previuos Artinskian assemblage.

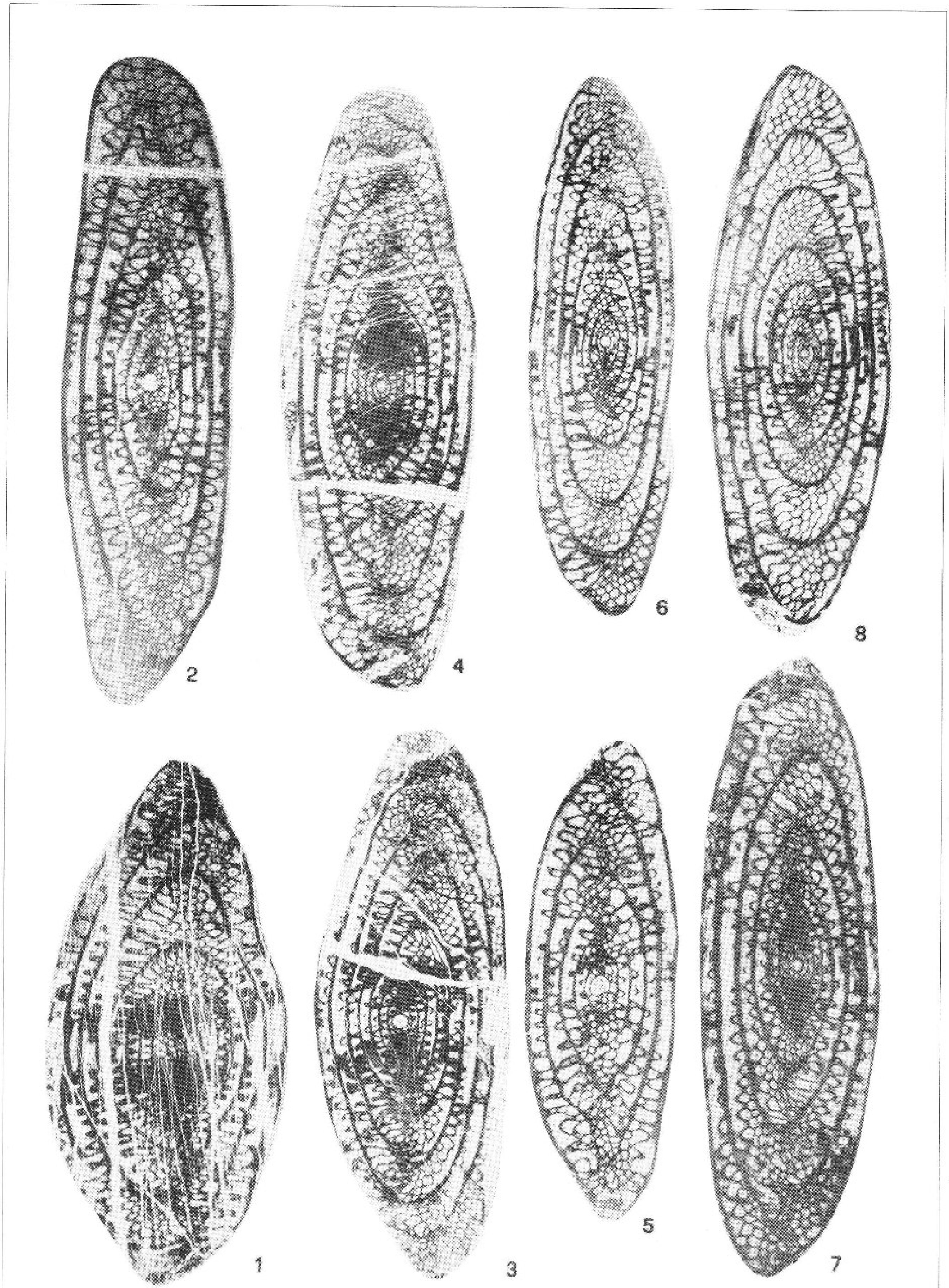
The fusulinid-brachiopod assemblage in the lower part of of Member 4 is Kubergandian as sug-

PLATE 5

Fig. 1 - *Parafusulina (Skinnerella) asiatica* Leven, 1967. Axial section. Lashkargaz Fm., Lashkargaz section, sample CK 330; x 10.

Fig. 2, 5-8 -*Parafusulina (Parafusulina) jarkhunensis* (Reed, 1925). All axial sections. Lashkargaz Fm., Baroghil E section. 2) Sample CK 191; x 13.3; 5) sample CK 191; x 13.3; 6) sample CK 197; x 10; 7) sample CK 195; x 10; 8) sample CK 197; x 10.

Fig. 3, 4 - *Parafusulina (Skinnerella) yunnanica* Sheng, 1963. Axial sections. Lashkargaz Fm., Lashkargaz section, sample CK 330; x 10. Panjshah Fm., Mb. 1, Panjshah section, sample KK 93-65.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gested by the presence of *Parafusulina (Skinnerella) yunnanica*, *P. (Sk.) asiatica*, *P. (Sk.) quasigruperaensis*. The presence of *Misellina parvicostata* would instead suggest still a Bolorian age, but the other components of the assemblage are Kubergandian. This same age is suggested by the conodont assemblage, where *Sweetognathus* aff. *whitei* and *Gondolella* cf. *idahoensis* are considered of Leonardian age (Orchard & Forster, 1988). The correlation to the Tethyan scale are made according to Ross et al. (1994). The occurrence of the brachiopod *C. sinensis*, originally described from the Tunlonggongba Fm., NW Tibet (Sun Te, 1983) is also evidence for a Kubergandian age, as suggested by the pectinids (J.M. Dickins, pers. comm., 1994).

Finally the conodonts in the upper part of the Member 4 in the Lashkargaz Fm., namely the transitional forms *G. idahoensis/G. phosphoriensis* (Beyers & Orchard, 1991) and the *Iranognathus* sp. and *Anchignathodus* sp. suggest an age spanning from the Kubergandian to the Murgabian.

Lupghar Formation.

Name. Here proposed. In a previous paper (Gaetani et al., 1990), we informally proposed the term Panjshah fm. with 3 members for the Upper Hunza area. Because of a possible hiatus between members 2 and 3, we prefer to keep the lower part of the former Panjshah fm. separate as the Lupghar Fm. The type section is a composite one measured along both sides of Lupghar valley, near Raminji (Fig. 11, 12, 13).

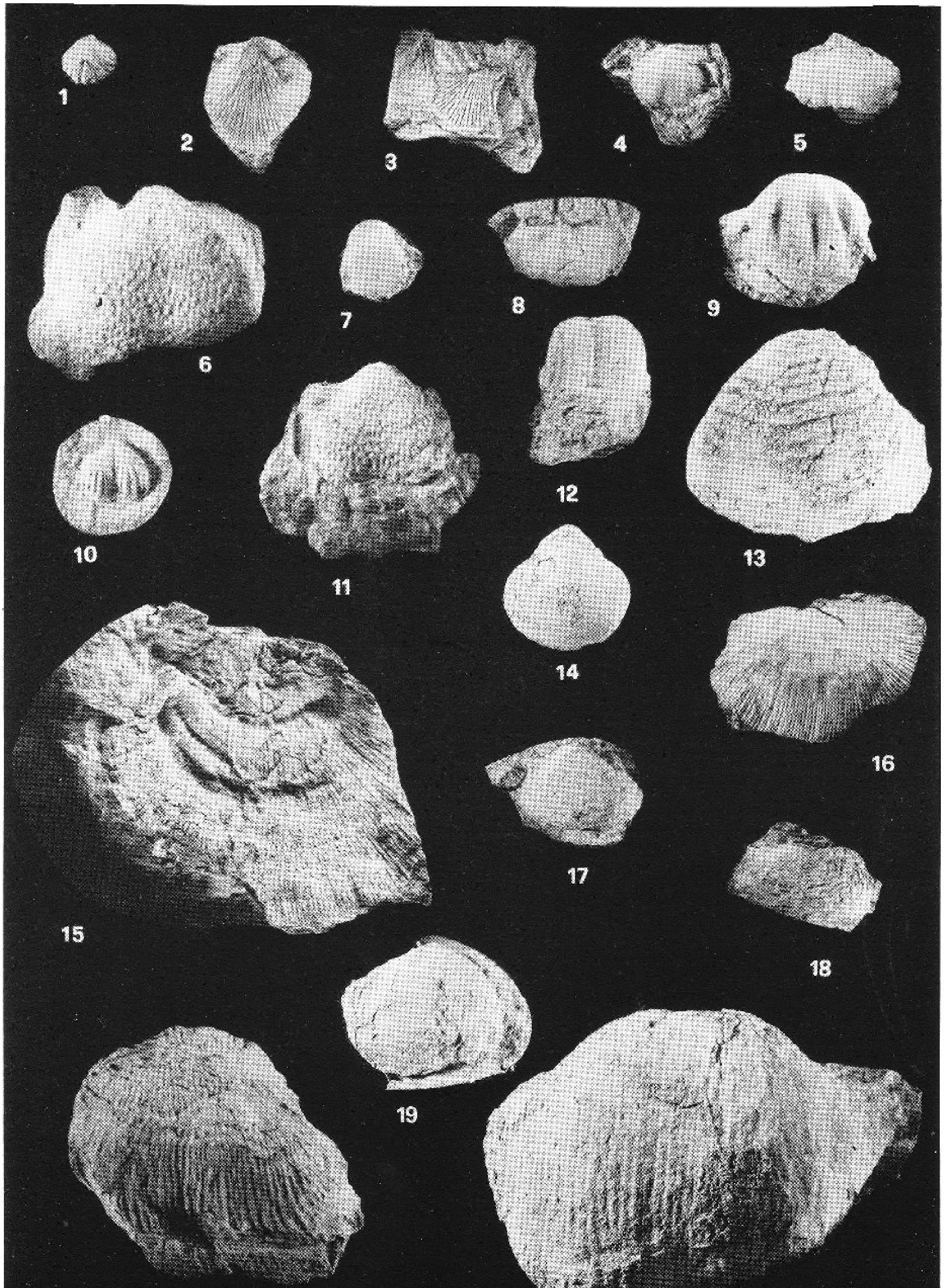
Lithology. The Lupghar Fm. may be easily subdivided into two parts, a lower one with alternance of shales/sandy shales with well-bedded mudstones/wackestones and a second one mostly or exclusively calcareous, with a massive occurrence of fusulinids at the base. Nine partial or complete sections have been measured (Fig. 12). The first member could be equivalent to Member 1 of the Lashkargaz Fm. Member 2 of the Lupghar Fm. is typically calcareous and dolomitic, whilst the Lashkargaz Fm. continues with an alternance of limestones (mudstone to grainstone) and shales. Because of the different subsequent development, we kept the two similar members 1 of the two formations separate in two different formations. The total thickness of the Lupghar Fm. varies between 300 and 380 m (Fig. 14).

Member 1. In Chapursan it is possible to recognize three lithozones. At the base, grey-green clayey siltites with phosphatic and ferruginous nodules are followed by dark grey bioclastic or hybrid calcarenites and by marly-silty mudstones. Bedding is mostly thin and poorly defined. Parallel, hummocky and cross laminations characterise these lithofacies. The central part of the member has locally evident cyclothemes, 7

PLATE 6

Fig. 1 - *Aldina exilis* Angiolini, 1995. Dorsal valve. Lashkargaz Fm., Mb. 2, Lashkargaz section, specimen CK 315-21.
Fig. 2 - *Orthothetina convergens* Merla, 1934. Ventral valve. Panjshah Fm., Mb. 1, Panjshah section, specimen KK 93-23.
Fig. 3 - *Neochonetes (N.) costellata* Angiolini, 1995. Ventral valve. Lashkargaz Fm., Mb. 4, Baroghil E section, specimen CK 189-1.
Fig. 4 - *Neochonetes (Sommeriella) baroghilensis* (Reed, 1925). Ventral valve internal mould. Lashkargaz Fm., Mb. 4, Baroghil E section, specimen CK 189-6.
Fig. 5 - *Paramesolobus sinuosus* (Schellwien, 1900). Ventral valve internal mould. Lashkargaz Fm., Mb. 4, Lashkargaz section, specimen CK 365bis-18.
Fig. 6 - *Waagenoconcha (Gruntoconcha) macrotuberculata* Angiolini, 1995. Ventral valve. Lashkargaz Fm., Mb. 4, Yarkhun river, specimen CAL 4-83.
Fig. 7 - *Marginifera andreai* Angiolini, 1995. Ventral valve. Lashkargaz Fm., Mb. 2, Lashkargaz section, specimen CK 315-108.
Fig. 8 - *Neochonetes (Sommeriella) baroghilensis* (Reed, 1925). Partially decorticated ventral valve. Lashkargaz Fm., Mb. 4, Baroghil E section, specimen CK 189-9.
Fig. 9 - *Enteletes* sp. Ventral valve. Lashkargaz Fm., Mb. 4, Baroghil E section, specimen CK 198-17.
Fig. 10 - *Retimarginifera praelecta* (Reed, 1925). Ventral valve. Lashkargaz Fm., Mb. 2, Lashkargaz section, specimen CK 319-14.
Fig. 11 - *Waagenoconcha (Gruntoconcha) macrotuberculata* Angiolini, 1995. Ventral valve. Lashkargaz Fm., Mb. 4, Lashkargaz section, specimen CK 365bis-12.
Fig. 12 - *Transennatia reedi* Angiolini, 1995. Ventral valve. Lashkargaz Fm., Mb. 4, Lashkargaz section, specimen CK 324-31.
Fig. 13 - *Echinoconchus* sp. Ventral valve. Lashkargaz Fm., Mb. 4, Yarkhun river, specimen CAL 4-64.
Fig. 14 - *Permophricodothyris* sp. Ventral valve. Lashkargaz Fm., Mb. 4, Lashkargaz section, specimen CK 365-5.
Fig. 15 - *Derbyia grandis* Waagen, 1884. Interior of a ventral valve. Panjshah Fm., Mb. 1, Panjshah section, specimen KK 93-65.
Fig. 16 - *Derbyia grandis* Waagen, 1884. Dorsal valve internal mould. Panjshah Fm., Mb. 1, Panjshah section, specimen KK 93-27.
Fig. 17 - *Magniplicatina johannis* Angiolini, 1995. Ventral valve. Lashkargaz Fm., Mb. 4, Yarkhun river, specimen CAL 4-60.
Fig. 18 - *Magniplicatina johannis* Angiolini, 1995. Dorsal valve external mould. Lashkargaz Fm., Mb. 4, Lashkargaz section, specimen CK 365-12.
Fig. 19 - *Magniplicatina vindicata* (Reed, 1925). Ventral valve. Lashkargaz Fm., Mb. 4, Lashkargaz section, specimen CK 365bis-11.
Fig. 20 - *Callytharrella sinensis* (Sun, 1983). Dorsal valve external mould. Panjshah Fm., Mb. 1, Panjshah section, specimen KK 93-9.
Fig. 21 - *Reticulatia chitralis* Angiolini, 1995. Ventral valve. Lashkargaz Fm., Mb. 4, Lashkargaz section, specimen CK 269-10.

(All x 1)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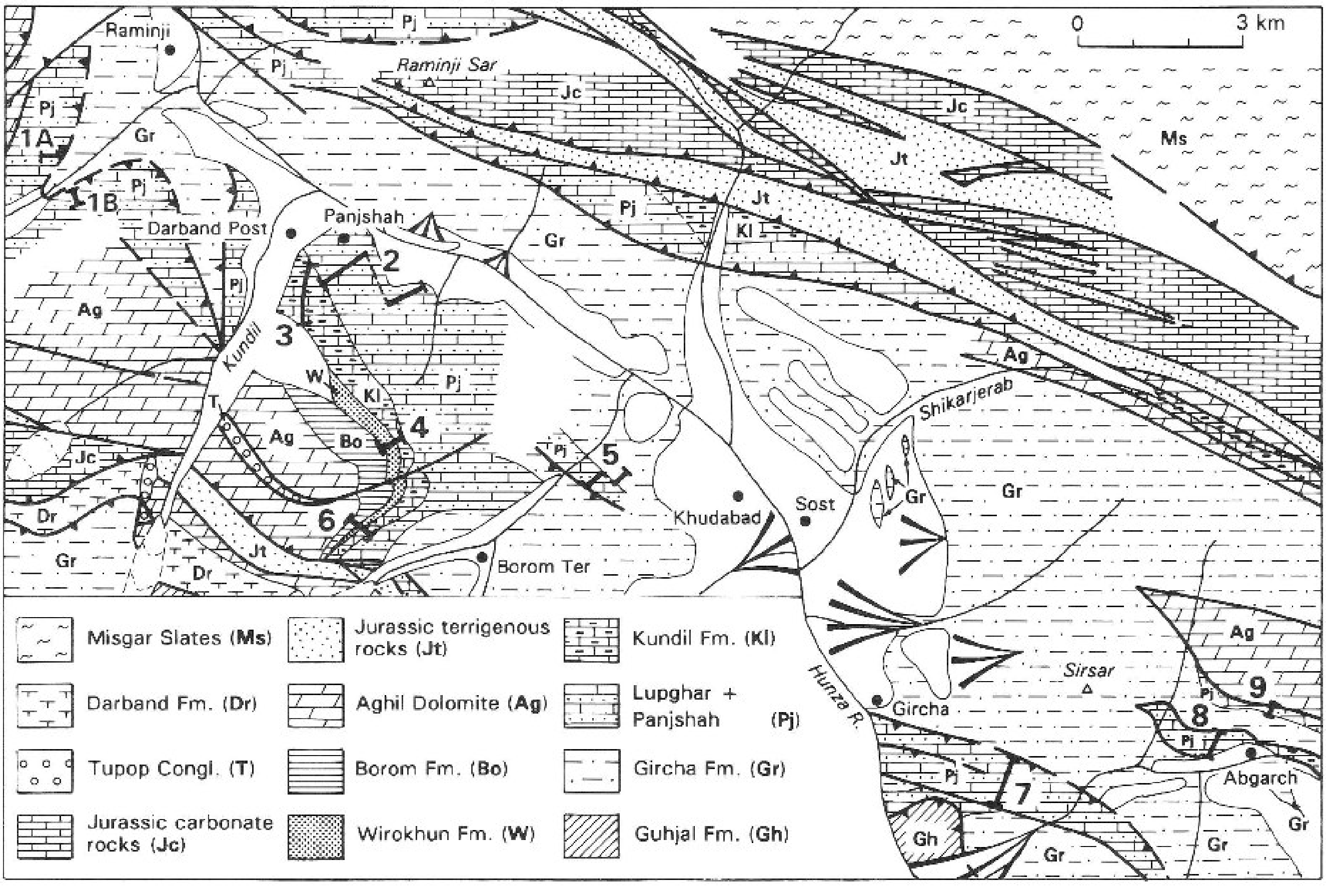


Fig. 11 - Index map of the relevant stratigraphic sections in the lower Chapursan valley. Geological map after Zanchi & Gaetani (1994). 1A = Lupghar NW; 1B = Lupghar SE; 2 = Panjshah; 3 = Kundil; 4 = Wirokhun; 5 = Khudabad E; 6 = Khudabad W and, slightly to the south, Tupop; 7 = Gircha NE; 8 = Abgarch W; 9 = Abgarch NE.

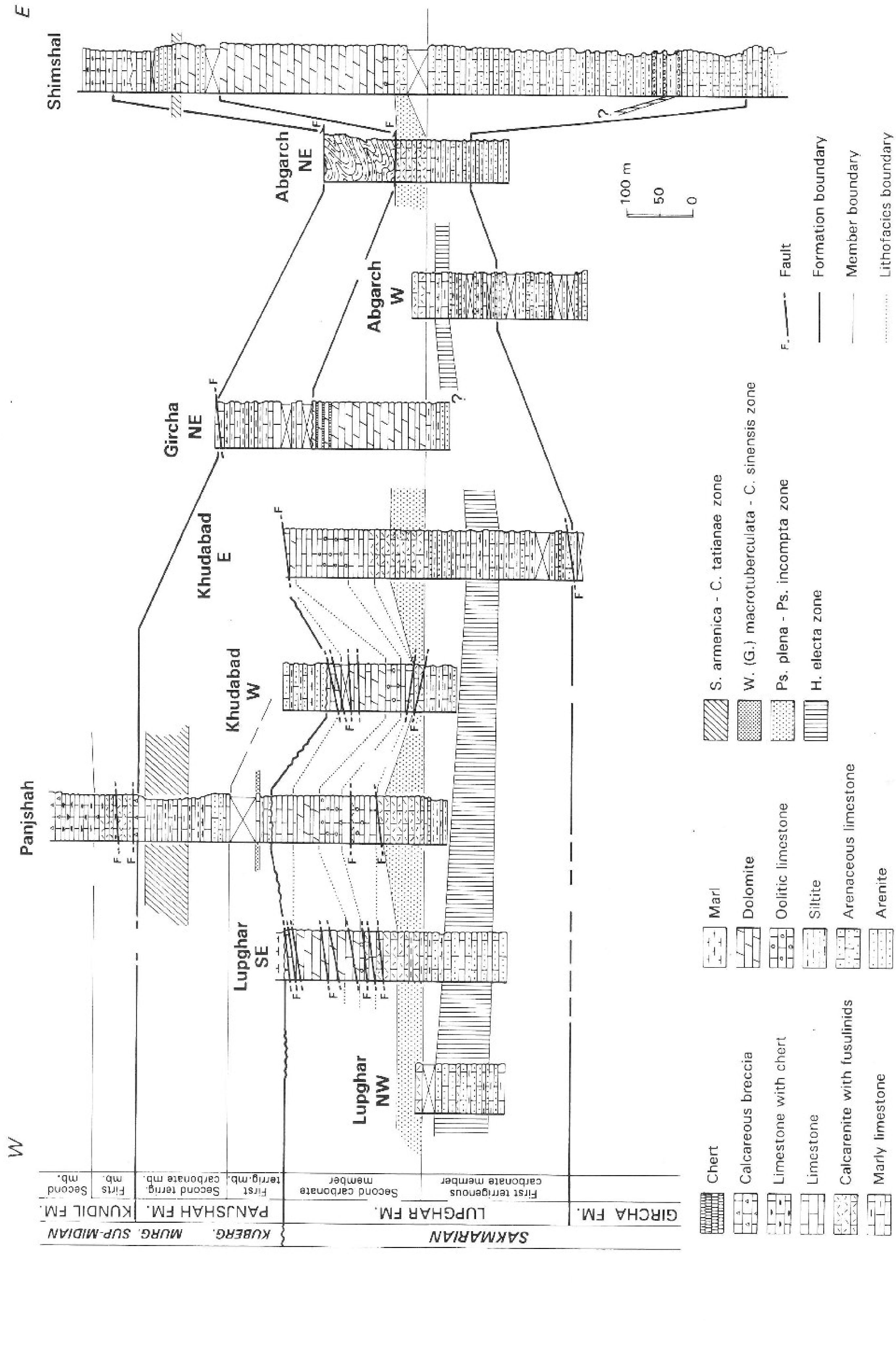
to 20 m thick, from fine terrigenous up to carbonates. In the upper part, a 10 m-thick bioclastic intercalation is rich in brachiopods, molluscs, and crinoids. Fragments of corals and oncoids have been also observed. The maximum thickness is about 210 m.

Member 2. In the Chapursan-Khudabad area it is a carbonate dominated succession. Four lithozones have been recognized: a) basal bioclastic, thick-bedded calcarenites with local cyclothemes (1-2 m thick) with a basal crinoidal layer and at the top prevailing fusulinid and bryozoan calcarenite bars; b) oolitic limestones passing upward and laterally to (c) peritidal dolostones and at the top (d) to subtidal grey dark-grey limestones. The thickness varies between 150 and 280 m.

Upper boundary. The sudden appearance of shales and siltites, and locally quartzarenites, resting on massive dark grey limestones and dolostones marks the upper boundary of this unit.

Microfacies. *Member 1* (Pl. 7). Hybrid lithofacies are dominant with carbonate siltstones and very fine quartz-rich arenites interbedded with bioclastic rudstone-floatstones. Bioclasts consist of crinoids, bryozoans, gastropods, brachiopods and very rare fragmentary fusulinids. Several species of bryozoans are present, often sessile on bivalve fragments. Boring, bioturbation and bioclast micritization are also common. A few benthic foraminifers (*Globivalvulina* sp.) have been detected. *Member 2*. In the lower lithozone bioclastic rudstones to floatstones dominate, rich with fusulinids, bryozoans, crinoids, brachiopods, ostracods and subordinate pelecypods. Small foraminifers occur with *Climacammina* sp., *Tetrataxis* sp., and nodosariids. Fusulinids are often packed and deformed by loading, with Fe-rich dark organic matter partially filling the internal voids. At the top of the lithozone, bioclastic recrystallized rudstones-floatstones alternate with bioturbated packstones. Both are rich in crinoids, oncoids, scattered fusulinids and rare small foraminifers (*Globivalvulina* sp.). The matrix of calcarenites consists of fine hybrid siltstones. Calcitic syntaxial cements are common. The oolitical and peritidal carbonates of the upper part of Member 2 are characteri-

Fig. 12 - Correlation chart of measured stratigraphic section from Chapursan valley to Shimshal valley. The Shimshal section was sampled and cursorly measured along the gulley from the Shimshal bridge up towards the meadows of Zardgar Bin.


W
E
Shimshal
Abgarch NE
Abgarch W
Gircha NE
Khudabad E
Khudabad W
Panjshah
Lupghar SE
Lupghar NW
SAKMARIAN
KUBERG.
MURG. SUP-MIDIAN
GIRCHA FM.
LUPGHAR FM.
PANJSHAH FM.
KUNDIL FM.
First terrigenous carbonate member
Second carbonate member
First terrig.mb.
Second terrig. carbonate mb.
First mb.
Second mb.
100 m
50
0
Chert
Calcareous breccia
Limestone with chert
Limestone
Calcarenite with fusulinids
Marly limestone
Marl
Dolomite
Oolitic limestone
Siltite
Arenaceous limestone
Arenite
S. armenica - C. tatianae zone
W. (G.) macrotuberculata - C. sinensis zone
Ps. plena - Ps. incompta zone
H. electa zone
Fault
Formation boundary
Member boundary
Lithofacies boundary

zed by bioclastic packstones with peloids, oncoids, crinoids, and small fragmentary foraminifers. The oolitic grainstone may be partially dolomitized with authigenic quartz. The peritidal dolostones are dominated by packstones to litho-intraclastic floatstones, passing to fine stromatolitic boundstones with Spongiostromata, crinoids and coated grains, with rare dasycladaceans. To the top, a more open microfacies is present in the subtidal carbonates, with bioclastic floatstones and rudstones. Authigenic quartz is always present.

Biostratigraphy (Fig. 13, 14). The first member of the Lupghar Fm. is characterized by the occurrence of *H. electa* range zone in its middle-upper part (Angiolini, 1995). This unit has its equivalent in Member 1 of the Lashkargaz Fm. Beside the index-species, the brachiopods *Permochonetes pamiricus* Afanaseva, *Reticulatia* sp. ind., *Globiella* cf. *rossiae*, *Costatumulus irwinensis* Archbold, *Cleiothyridina ailakensis* Reed, *Cleiothyridina* sp., *C.* aff. *semiconcava* (Waagen), *Spirigerella* sp., *Trigonotreta paucicostulata*, *Cyrtella* cf. *nagmargensis* Bion have been collected. In the Shimshal section *Hunzina tenuisulcata* (Merla) and *Trigonotreta paucicostulata* characterise the brachiopod assemblage. The thickness of this zone is about 65 m.

The second member is characterised at the base by a fusulinid assemblage with *Pseudofusulina plena* Leven, *P.* cf. *psharti* Leven, *P.* cf. *karapetovi* Leven, *P.* cf. *tumidiscula* Leven, *P. incompta* Leven, *P.* cf. *sedujachensis* Konovalova & Baryshnikov, *P.* cf. *callosa* Rauser-Chernousova, *P.* cf. *granuliformis* Leven, *P.* aff. *syniensis* Konovalova, *Eoparafusulina* sp., *E.* aff. *pamiriensis* Leven. This assemblage is fully expanded here and may correspond to assemblage 2 of the Lashkargaz Fm. where it is not so well preserved. Furthermore this assemblage is very similar to the *Pseudofusulina* assemblage of the Rosh Gol, East Hindu Kush (Gaetani & Leven, 1993). The same assemblage is spread from Central Afghanistan to Central Pamir and possibly also in the Domar area in W Tibet (Leven, 1993a). The thickness of this zone is about 35 m.

Chronostratigraphy. The Lupghar Fm. is mostly Sakmarian in age. The brachiopod assemblage of Member 1 contains *P. pamiricus* and *C. ailakensis* which occur in the Sakmarian-? Early Artinskian of SE Pamir (Grunt & Dmitriev, 1973; Afanaseva, 1977; Grunt & Novikov, 1994), *G. rossiae* and *T. paucicostulata* from the Sakmarian of the Central Elburz (Fantini Sestini, 1966). The last species is present also in the Sakmarian of the SE Pamir (Grunt & Dmitriev, 1973). *C. irwinensis* is known from the Late Sakmarian of W Australia (Archbold, 1983). Three genera (*Hunzina*, *Costatumulus* and *Cyrtella*) are in common with the Sakmarian Callytharra Fm. (W Australia, Carnarvon Basin) and J.M. Dickins (pers. comm., 1994) suggests it can be a deeper water equivalent of the *Oriocrassatella* Fauna of Tibet.

The fusulinid assemblage in the lower part of Member 2 seems to characterise the Sakmarian of a wide area from Central Afghanistan (Helmand Block and Koh-i Baba) to East Hindu Kush, North Karakorum, Central Pamir and possibly the westernmost part of the Domar area, Qiantang microplate (Leven, 1993b). There are no significant fossils in the upper part of Member 2 and we do not exclude an early Artinskian age for it.

PLATE 7

Macro- and microfacies of the Lupghar Fm. Lower Chapursan-Khudabad area.

Fig. 1 - Burrowing in subtidal dark grey limestones of Lupghar Fm., Member 2; transition between oolitic and dolomitic-peritidal lithozones. Photo high is 14 cm, Khudabad section.

Fig. 2 - Dolomitic lithofacies of Lupghar Fm., Member 2. The basal subtidal cross-laminated calcarenites are followed by fine intraformational paraconglomerates. Lithofacies association within the "peritidal dolomites" of the Khudabad section.

Fig. 3 - Well sorted oolitic grainstones of the Lupghar Fm., Member 2. Oolitic lithozone of Panjshah section.

Fig. 4 - Bioclastic packstone with foraminifers (Paleotextulariidae). Lupghar Fm., Member 2, subtidal uppermost lithozone, above the peritidal dolomites. Khudabad section. Sample KJ 288; x 8.5.

Fig. 5 - Siltites rich in quartz with bioclastic bryozoan. Uppermost part of the Lupghar Fm., Member 1. NW Lupgar section, sample KK 202; x 21.

Fig. 6 - Bioclastic rudstone with a slightly worn fossil assemblage. It consists mainly of fusulinid and subordinated of crinoids, sessil forams, bryozoans. Lupghar Fm., Member 2, basal fusulinid lithozone. Panjshah section, sample KJ 296; x 8.5.

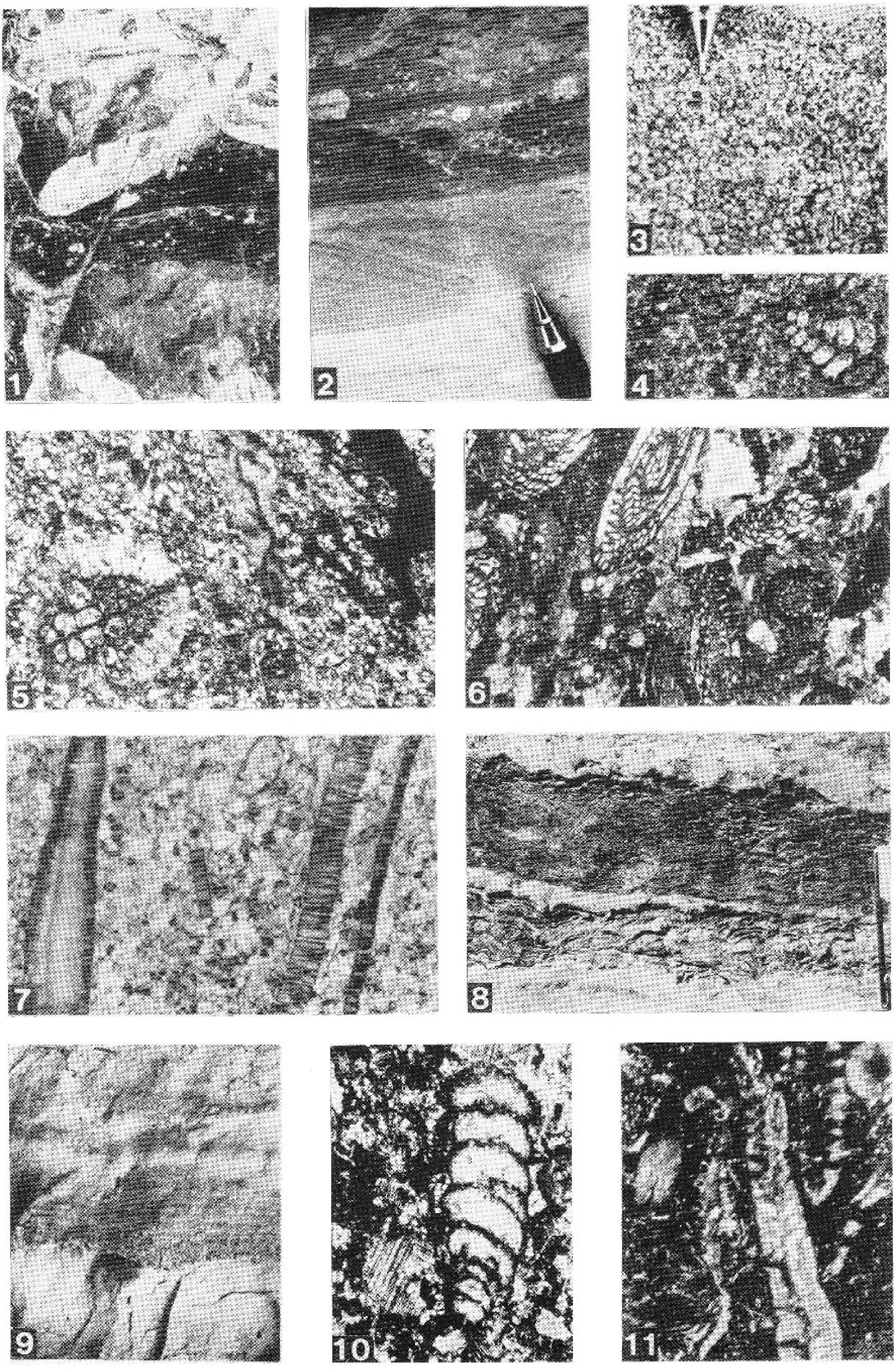
Fig. 7 - Hybrid bioclastic fine arenite containing pelecypod and algal fragments. They are associated with echinoderms, brachiopods, and bryozoans. Lupghar Fm., Member 1, upper portion in the Lupghar NW section. Sample KK 199; x 21.

Fig. 8 - Tempestite in a dm-thick bioclastic pelecypod layer. Lupghar Fm., Member 1, Panjshah section.

Fig. 9 - Dm-thick siltstone-fine arenite with erosional surface and parallel lamination at the base. Lower Lupghar Fm., Member 1, Panjshah section. Photo high is 12 cm.

Fig. 10 - Bioclastic floatstone with bryozoans, crinoids, sessil and benthonic foraminifers (*Climacammina* sp.). Uppermost subtidal lithofacies interbedded within the fusulinids packstone-rudstones of the lower lithozone of Lupghar Fm., Member 2, Khudabad section, sample KJ 300; x 21.

Fig. 11 - Bioclastic packstone with dasycladacean algae and crinoid. Subtidal lithofacies interbedded within the fusulinids packstone-rudstones of the lower lithozone of Lupghar Fm., Member 2, Khudabad section, sample KJ 303; x 8.5.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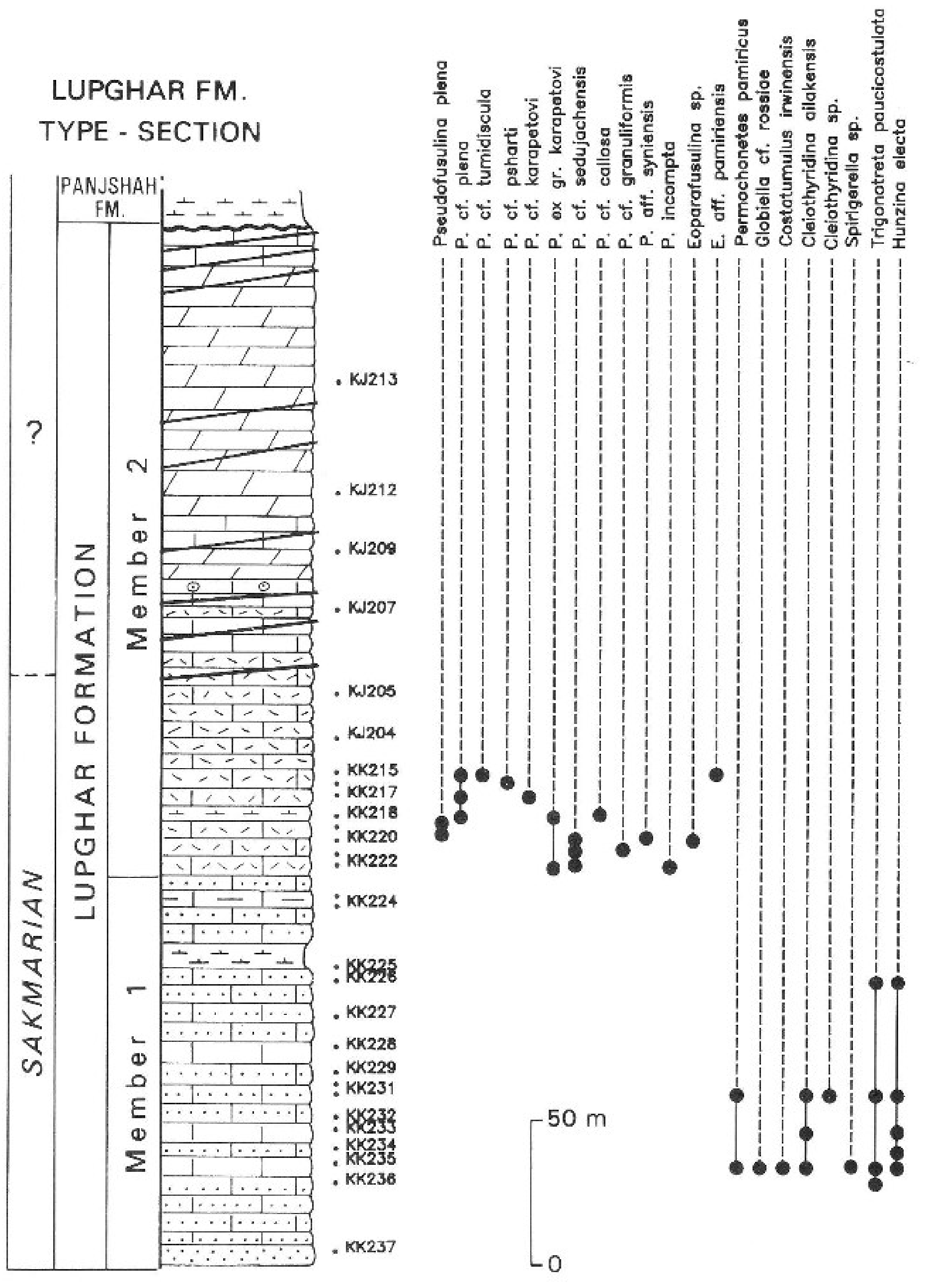


Fig. 13 - Type-section of the Lupghar Formation. Section 1B of Fig. 11. The Member 1, however, may be more easily sampled on the opposite side of the valley, along the section 1A.

Panjshah Formation.

Name. The name was informally proposed by Gaetani et al. (1990). It is emended here to include only the member 3, which is now subdivided into two members. The type-section has been measured above the Panjshah Shrine, in the lower Chapursan valley (Fig. 11, 12, 15).

Lithology. *Member 1.* Grey-green calcareous siltites and splintery marls with rare biocalcarenitic horizons increasing at the top. In the lower part there also dark shales, thin-bedded siltites, lenticular, coarsening-upward, mature feldspathic quartzarenites with festoons and erosional base. Wave ripples and hummocky cross-laminations are also present. Sandstone layers are more abundant in the upper section of the Borom valley. Upwards, the unit is mostly covered because of the prevailing shaly lithology. The thickness varies from 70 to 100 m.

Member 2. Composite terrigenous-carbonate unit, characterized by 3 main calcareous horizons separated by marls and shales. The lower carbonate horizon is characterized by prevalent subtidal, fossiliferous dark gray limestones with Porostromata, bryozoans, crinoids, brachiopods, locally with corals and oncoids. The central portion is made of marls and marly limestone alternances. The more calcareous horizons consist of grey bioclastic packstone to wackestones in m-thick beds, making transition to marls, by increasing mud pollution. The bioclastic lags may preserve asymmetric ripples. These levels are rich in brachiopods, crinoids and bryozoans. The marl and shale horizons are commonly thicker than the calcareous horizons and contain a few more thin discontinuous calcareous

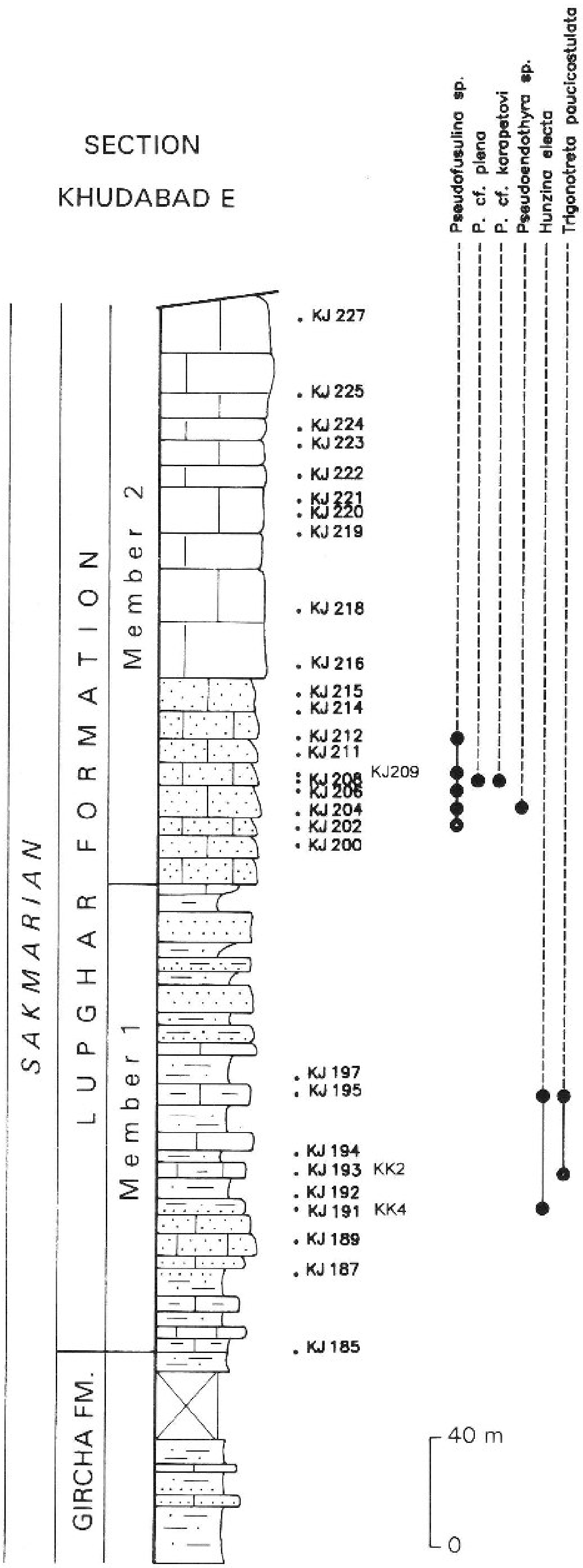


Fig. 14 - The Lupghar Fm. in the section Khudabad E (= Section 5 in Fig. 11).

layers. The upper part of the member is mostly terrigenous in the Gircha area, whilst it contains mixed lithofacies in Chapursan valley, whith frequent bioclastic bioturbated carbonate intercalations (oncoids, crinoids, bryozoans, brachiopods). The topmost portion of the member consists of 10 m of dark marls and dark gray limestones in thin beds, with rare brachiopods and nautiloids.

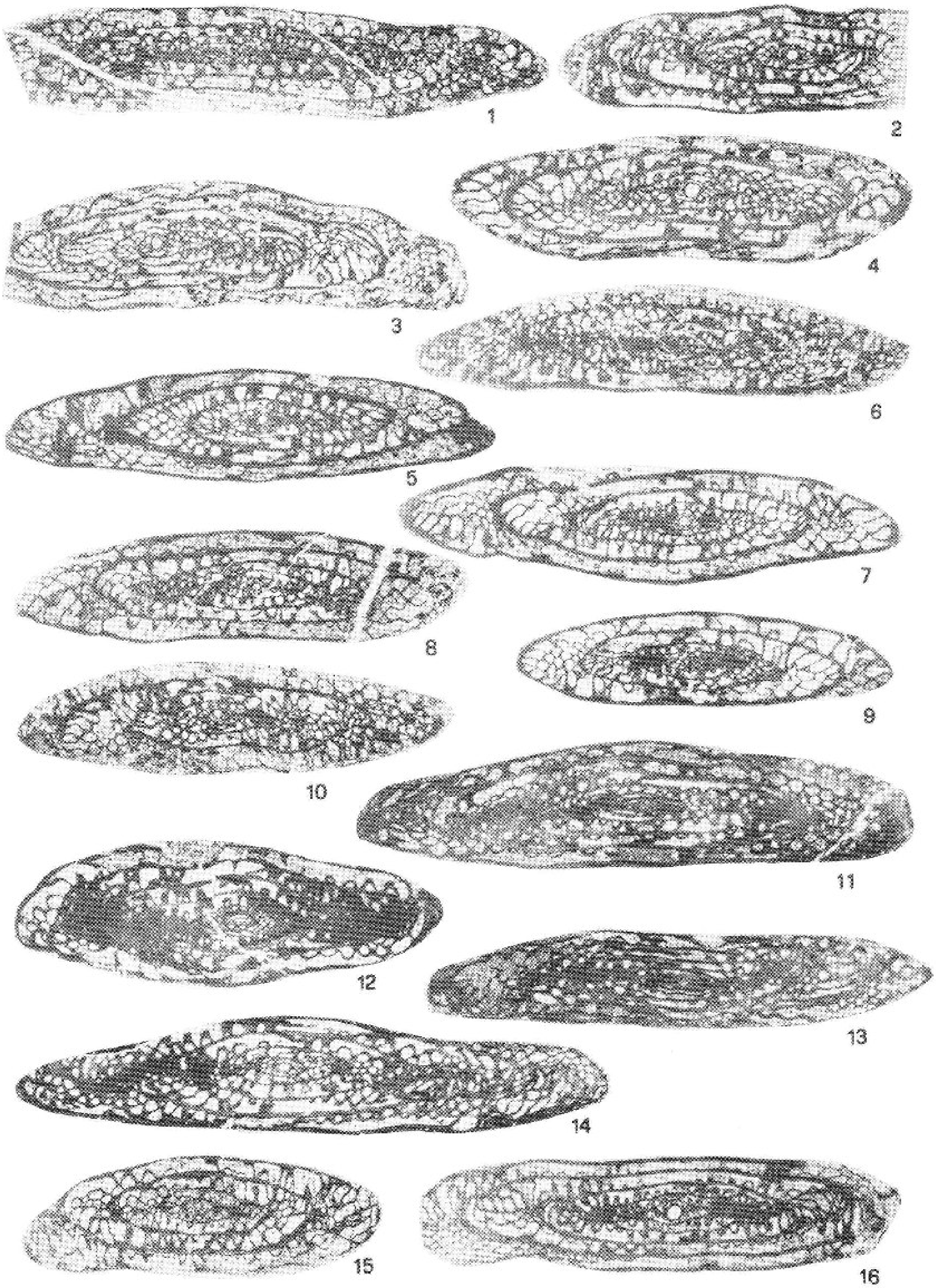
The thickness is up to 160 m in the lower Chapursan valley, decreasing eastward and westward (Lupghar, Gircha); in the Shimshal valley it is about 130 m.

Upper boundary. It is sharp, corresponding to the rapid desappearance of the thick marl/limestone intercalations and the first appearance of channelized, lenticular litho-bioclastic calcarenites-rudites with crinoids and reworked fusulinids in rounded carbonate lithoclasts and mud chips.

Sandstone petrography. Locally bioclastic fine-grained sandstones at Abgarch have a subarkosic composition (Q81-91 F6-9 L3-9 n=2). Plagioclase dominates over chessboard-albite (P/F 90±6%); microlitic volcanic, granophyric and siltstone lithic fragments occur. At Khudabad W, medium-grained subarkoses (Q89 F6-9 L2-5 n=2) contain abundant plagioclase, alkali feldspars (including chessboard-albite) and silty rock fragments along with hypabissal and felsitic to microlitic volcanic grains. Fine- to medium-grained subarkoses (Q85-91 F4-8 L3-5 n=2) with P/F = 100%, yielding silty and possibly volcanic lithic grains, are found again along the gulley from Shimshal bridge up to Zardgarb.

Microfacies. *Member 1* (Pl. 9). Bioturbated, locally fossiliferous quartz-rich siltstones are prevalent in the Lupghar area. The subordinate carbonate lithofacies contains prevalent bioclastic rudstone/floatstones with brachiopods, bryozoans (large branched forms), and sessil foraminifers. Bioturbated mudstone/wackestones with thin laminations and locally lithoclasts are also present. A fine quartz-rich matrix is common in all microfacies.

Member 2. The lower carbonate horizon is characterised by packstone/wackstones with Porostromata, bryozoans, corals, and packstones with crinoids, brachiopods, coated grains and oncoids. Locally there are intercalated rudstones with micritized fusulinids, crinoids, borings on bioclasts and phreatic, isopachous calcitic cement. Upwards pseudosparites with bryozoans and floatstones with bryozoans, crinoids, foraminifers (*Geinitzina* sp., *Tetrataxis* sp.), brachiopods, oncoids and thin laminations constitute the dominant microfacies. Abundant Fe in the matrix and inter- granular porosity is present. The topmost lithofacies are bioturbated bioclastic floatstones with brachiopods, oncoids, sessil bryozoans and crinoids.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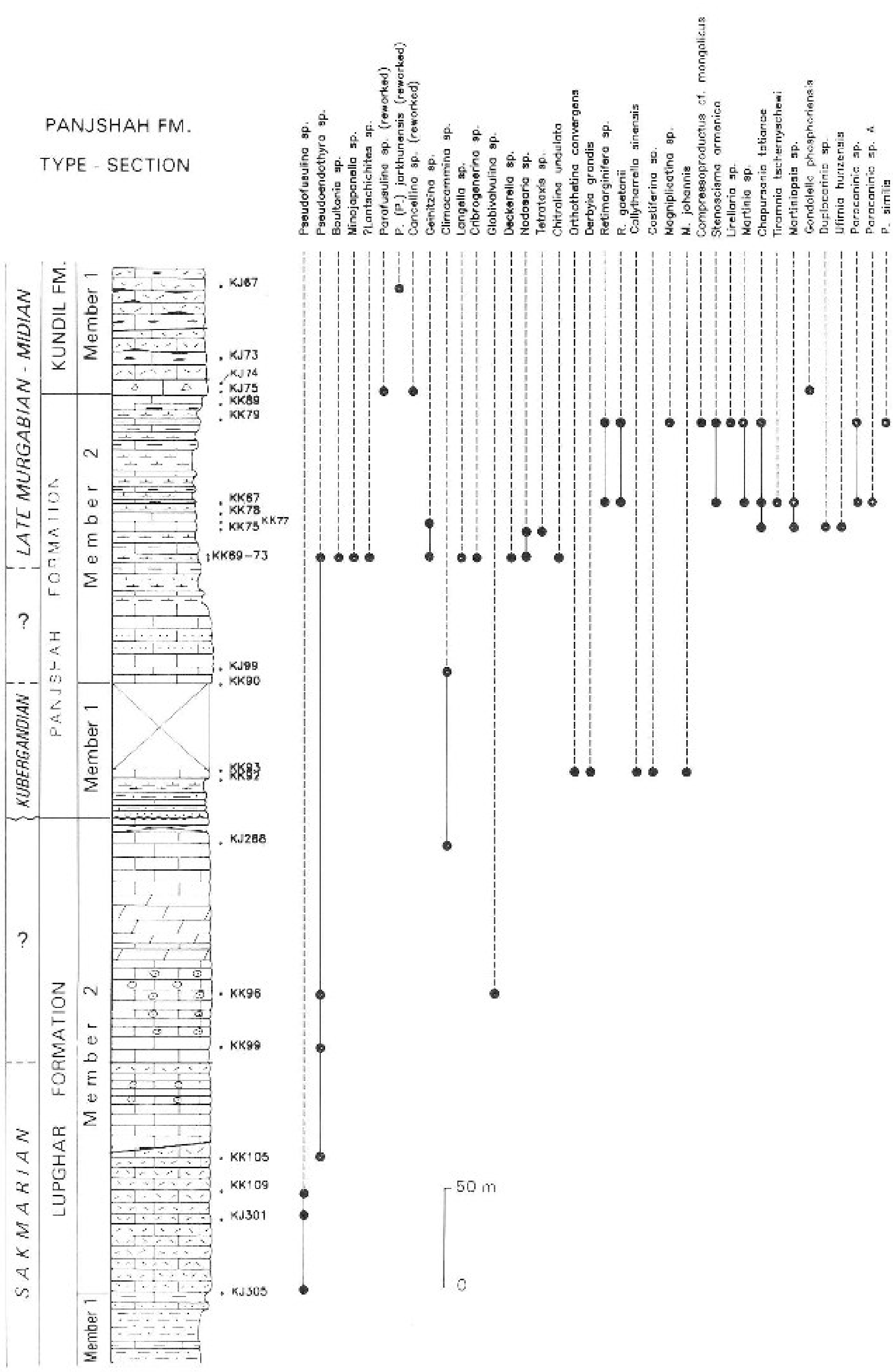


Fig. 15 - Type-section of the Panjshah Formation, Chapursan valley. (= Section 2 in Fig. 11). Almost all the section was measured immediately above the Panjshah Shrine. Only the base of the unit it is better exposed farther south. The fusulinids at the base of the overlying Kundil Fm. (samples KJ 75 and KJ 67) are reworked.

PLATE 8

Fig. 1 - *Pseudofusulina* aff. *sedujachensis* Konovalova & Baryshnikov, 1980. Subaxial section. Lupghar Fm., Lupghar section, sample KK 222.

Fig. 2, 4 - *Pseudofusulina* aff. *syniensis* Konovalova, in Konovalova & Baryshnikov, 1980. Axial sections. Lupghar Fm., Lupghar section, sample KK 220.

Fig. 3 - *Pseudofusulina plena* Leven, 1993b. Subaxial section. Lupghar Fm., Lupghar section, sample KK 220.

Fig. 5-10 - *Pseudofusulina* ex gr. *karapetovi* Leven, 1993b. Lupghar Fm., Lupghar section. 5) Subaxial section, sample KK 218; 6) axial section, sample KK 222; 7) subaxial section, sample KK 218; 8) axial section, sample KK 222; 9) subaxial section, sample KK 218; 10) subaxial section, sample KK 222.

Fig. 11, 13 -*Eoparafusulina* aff. *pamirensis* Leven, 1993b. Lupghar Fm., Lupghar section. 11) Axial section, sample KK 215; 13) axial section, sample KK 215.

Fig. 12 - *Pseudofusulina* cf. *callosa* Rauser-Chernousova, 1940. Tangential section. Lupghar Fm., Lupghar section, sample KK 218.

Fig. 14 - *Pseudofusulina* sp. A. Axial section. Lashkargaz Fm., Lashkargaz section, sample CK 282.

Fig. 15 - *Pseudofusulina incompta* Leven, 1993b. Subaxial section. Lupghar Fm., Lupghar section, sample KK 222.

Fig. 16 - *Eoparafusulina* ? sp. ind. Axial section. Lupghar Fm., Lupghar section, sample KK 220.

(All x 13.3)

Biostratigraphy. The first member of the Panjshah Fm. is characterized by abundant *Callytharrella sinensis* (Sun) which crops out 18 m above its base. This is an index for the *Waagenoconcha (Gruntoconcha) macrotuberculata/Callytharrella sinensis* assemblage zone. Besides the index-species, *Derbyia grandis*, *Ortothetina convergens*, *Costiferina* sp. ind., *Magniplicatina johannis* are also present (Pl. 10). This assemblage corresponds to assemblage 5 of the Lashkargaz Fm.

The second member is rich in echinoderms, bryozoans, corals, fusulinids (?*Lantschichites* sp., *Boultonia* sp., *Minojapanella* sp., *Neofusulinella* sp.), small foraminifers (*Chitralina undulata*, *Globivalvulina* sp., *Deckerella* sp., *Langella* sp., *Climacammina* sp., *Geinitzina* sp.) and brachiopods (*Stenoscisma armenica/Chapursania tatianae* assemblage zone). Besides the index-species the brachiopods *Retimarginifera* sp., *R. gaetanii* Angiolini, *Magniplicatina* sp. ind., *Compressoproductus* cf. *mongolicus* (Diener), *Lirellaria* sp. ind., *Martinia* sp. ind., *Tiramnia tschernyschewi* (Grunt) and *Martiniopsis* sp. ind. have been collected. Amongst the corals, Flügel (1990) identified *Duplocaninia* sp., *Ufimia hunzensis* Flügel, *Paracaninia similis* (Schindewolf), *Paracaninia* sp. A, *Paracaninia* sp.

Chronostratigraphy. The age of the Panjshah Fm. should span from the Kubergandian to the Murgabian and possibly also to the Midian. However, the increase of endemic species makes more difficult to establish firm correlations and the ages assigned here to this unit are modified with respect to the Murgabian age proposed by Gaetani et al. (1990) for the upper part of the unit. The presence of *C. sinensis* in the first member testifies to a Kubergandian age (Sun, 1983) for the base of the unit. Whereas the second member and the top of the unit are much more in dispute. The fusulinid *Lantschichites* sp. (identification with a question mark) and the brachiopods *S. armenica* and *C.* cf. *mongolicus* suggest a Midian or even younger age for the second member of the Panjshah Fm. However, the conodonts recovered in the basal part of the overlying Kundil Fm. seem to indicate still a Late Murgabian/Early Midian age (see later).

Sparse outcrops of the Chapursan Group in the Yarkhun valley.

The Permian successions so far described in western Karakorum belong to the Baroghil tectonic Unit (Gaetani et al., submitted). Other partial sections or isolated outcrops were found in different tectonic units, that are assigned to the Chapursan Group, but not to a specific formation. They belong to:

Axial Unit in the Lasht area. Grey massive dolomitic limestones and dolomites. They form a fairly continuous belt across the Yarkhun between Sakirmul to the south of Aliabad, with a thickness of up to 150 m. They lie on terrigenous rocks attributed to the Gircha Fm. and are channelized and unconformably covered by a polymictic conglomerate referred to as the Reshun Conglomerate (? Cretaceous). Evidence for a Permian age consists of a few badly preserved foraminifers (*Paradagmarita* aff. *monodi* Lys, *Hemigordius* sp.), found in the first limestone outcrop along the trail, north of Sakirmul.

Axial Unit in the Baroghil area. A massive dark grey limestone, forming a strip a few km in length on the southern bank of the Upper Yarkhun river (Fig. 8) was sampled by P. Le Fort (sample KK 808). It yielded the following foraminifers *Luisettita elegantissima* Altiner & Brönnimann, *Paraglobivalvulina mira* Reitlinger, *Hemigordius* sp., *Paradagmarita* sp., *Pachyphloia* sp., *Agathammina* sp. This assemblage suggests a Late Permian age (identifications by R. Rettori, Perugia, pers. comm., 1995).

PLATE 9

Panjshah and Kundil Fms. macro- and microfacies.

Fig. 1 - Bioclastic packstone with dasycladacean algae (? *Mizzia* sp.), fusulinids, echinoids, foraminifers (? *Neodiscus* sp.). Panjshah Fm., Member 2, Zardgar Bin gulley, Shimshal valley. Sample KK 307; x 21.

Fig. 2 - Bioclastic packstone with bryozoans, dasycladacean algae in coated grains, and echinoderms. Panjshah Fm., Member 2, transition to the carbonate platform lithofacies of lower Lupghar valley. Sample KKJ 227; x 8.5.

Fig. 3 - Cross-laminated fine calcarenites. Lower Panjshah Fm., Member 1, Panjshah section. The coin for scale is 1 cm in diametre.

Fig. 4 - Carbonate siltstone rich in quartz with fusulinids. Panjshah Fm., Member 1, lower Lupghar valley. Sample KKJ 216; x 8.5.

Fig. 5 - Bioclastic rudstone with reworked fusulinids and crinoids. Kundil Fm., Member 1, Panjshah section. Sample KJ 75; x 21.

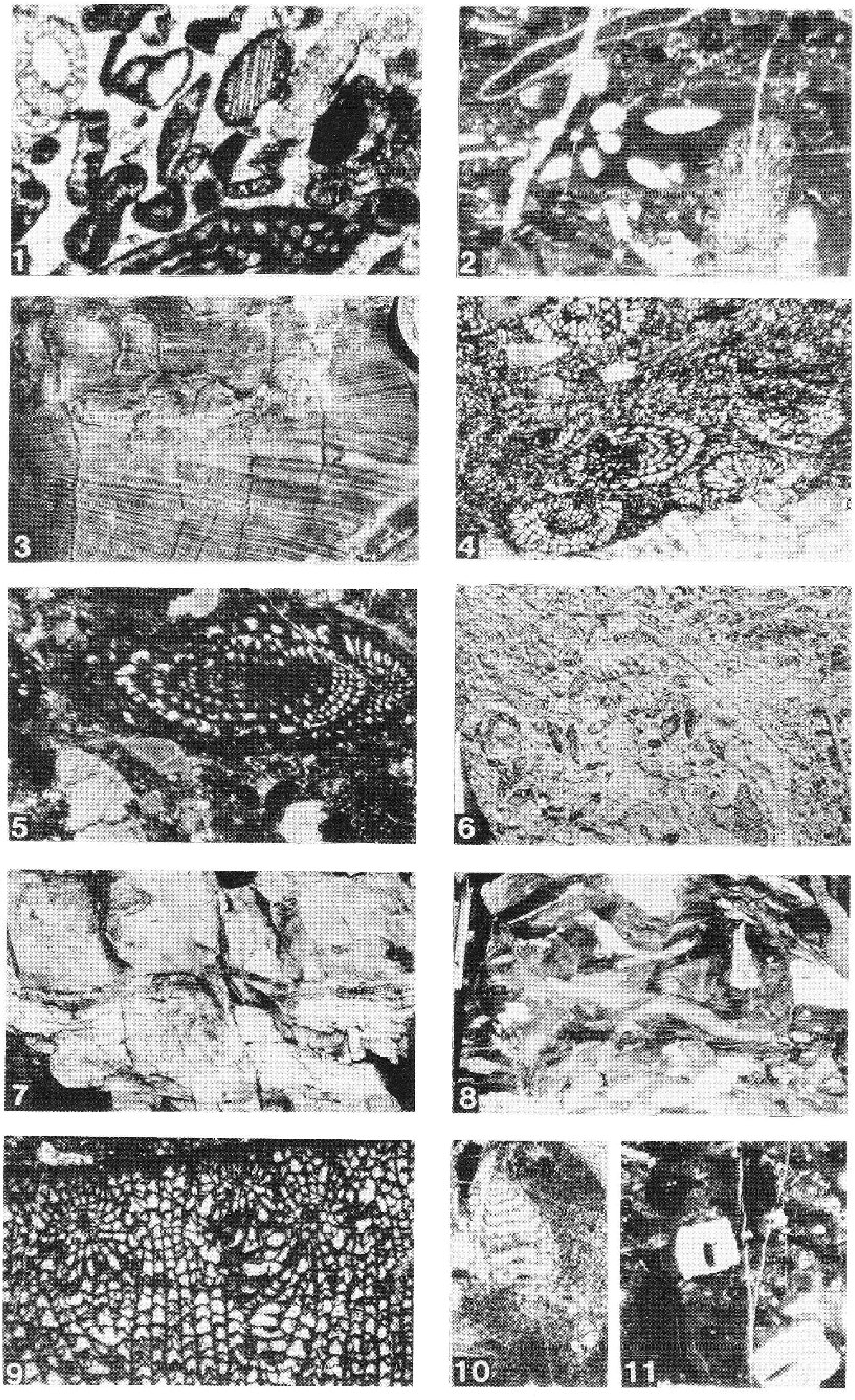
Fig. 6 - Macrofacies of fig. 5. Bioclastic calcarenites-rudites with bryozoans, fusulinids, intraclasts and lithoclasts. Some clasts are intraformational, others derive from the Lupghar Fm., Member 2. Kundil Fm., Member 1, Panjshah section.

Fig. 7 - Bedded fine laminated pelagic limestones with white chert lenses. Kundil Fm., Member 2, Kundil section. High of photo is 60 cm.

Fig. 8 - Polygenic breccias with deformed, recrystallized and tectonized white to grey dm-thick clasts in dark grey pelagic carbonate matrix. Megabreccia body between Member 2 and 3 of the Kundil Fm., Kundil section; hammer for scale.

Fig. 9 - Bioclastic rudstone with a large clast of a colonial coral. Panjshah Fm., Member 2, transitional lithofacies to a carbonate platform. Lower Lupghar valley. Sample KKJ 230; x 8.5.

Fig. 10, 11 -Bioclastic rudstone with foraminifers (fig. 10, *Geinitzina* sp.), oncolithes, *Tubiphytes* sp. and crinoids (fig. 11). Carbonate platform possibly following the Panjshah Fm. in the lower Lupghar valley. Sample KKJ 227; x 21.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Lasht Unit. A few isolated outcrops of marls and shales, with crinoidal biocalcarenite intercalations in m-thick layers yieldeld a few distorted fusulinids. This outcrops could be correlated with the lower part of the Lashkargaz Fm.

Karambar Unit in the Baroghil area. In the largely folded succession that crops out to the north of Showar Shur, a partial section was measured in terrigenous rocks referred to the Gircha Fm. and in the following calcareous unit. The Gircha Fm. forms the core of the complex anticline at the base of the gulley. It consists mainly of dark grey-brown splintery siltstones with rare arenaceous intercalations. A sample yielded a moderately sorted arkose (Q=50 F=49 L=1). Upwards, about 30 m of marls and siltstones with subordinate marly limestones with fragments of *Hunzina electa*, are followed by several cliff-forming ledges, tens of m-thick, of crinoidal calcarenites locally with fusulinid fragments. The total thickness of this part is more than 100 m. The microfacies consists of a bioclastic packstone, dominated by crinoids and fusulinid fragments. The clasts are commonly bimodal in size with fine bioclastic sands, supporting large crinoid ossicles or other bioclasts. This succession is somewhat intermediate between the Lashkargaz Fm., which is richer in terrigenous detritus and the Lupghar Fm., with which it shares the thick bioclastic layers.

Guhjal Formation.

McMahon (1900) introduced this term (with the unusual spelling Gujhal) to identify a huge mass of massive carbonates, mostly dolostones, which crops out south of the Upper Hunza Fault. The presence of megalodontids and colonial scleractinians points to a Late Triassic age, but the following findings indicate that the unit starts in the Permian.

On the northern flank of the Pasu syncline (Zanchi & Gaetani, 1994), the slightly metamorphic slates of the Gircha Fm. (Pasu Slate of Desio, 1963) pass gradually into the peritidal dolomites of the Gujhal Fm. The transitional lithofacies consists of slates alternating with 20-50 cm-thick marly limestones, increasing upward with respect to the slates. The thickness of this lithofacies is about 20-30 m. Along the path leading from Pasu to the right side of the Batura glacier, a fusulinid assemblage dominated by *Parafusulina* sp. (sample ZZ139) has been found in the marly limestones of the transitional facies between the Gircha and Gujhal Fms., suggesting a mid-to late Permian age.

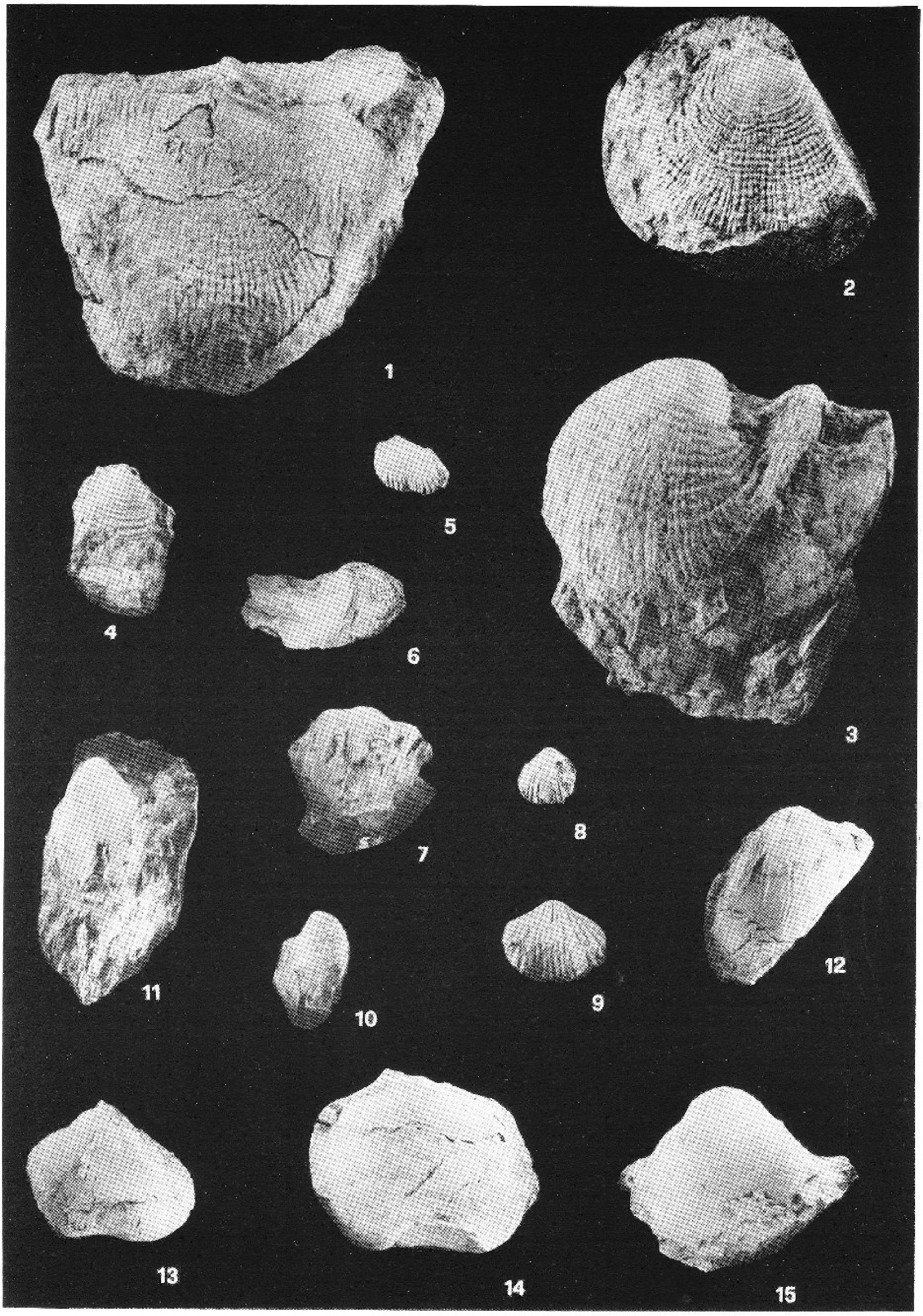
Gharil Formation.

Name. The term is introduced here to identify a thin but very continuous and significant terrigenous horizon in the Baroghil Unit. The name derives from the houses of Gharil, in the Upper Yarkhun valley (Fig. 8). It corresponds to the ironstone horizon quoted by Hayden (1915, p. 292).

Lithology. The unit is fairly different from west (Baroghil) to east (Lashkargaz). In the west it consists of two fining-upward sequences 12 to 17 m thick. The basal sequence scours deeply (up to 7 m) into the underlying Lashkargaz Fm. and is overlain by moderately to poorly-sorted microconglomerates followed in turn by dark red hematitic sandstones with cross-lamination and mudclasts. The occurrence of a major ironstone is very significant. In the east, a lower lithozone (up to 80 m thick) consists of extensively burrowed grey siltstones to very fine-grained sandstones and marls locally bearing brachiopods. The upper lithozone is represented by 4.7 m of pebbly conglomerates to microconglomerates with scoured base and yielding very angular carbonate and more rounded silty lithoclasts, passing upward to sparsely bioclastic hybrid arenites and quartz-bearing dolostones (1.2 m). These two lithozones may correspond with the two sequences recognized around the Baroghil pass.

PLATE 10

Fig. 1 - *Reticulatia chitralis* Angiolini, 1995. Interior of a dorsal valve. Lashkargaz Fm., Mb. 4, Yarkhun river, specimen CAL 4-17.
Fig. 2 - *Callytharrella sinensis* (Sun, 1983). Dorsal valve external mould. Lashkargaz Fm., Mb. 4, Baroghil E section, specimen CK198-27.
Fig. 3 - *Callytharrella sinensis* (Sun, 1983). Ventral valve. Lashkargaz Fm., Mb. 4, Lashkargaz section, specimen CK 269-18.
Fig. 4 - *Compressoproductus* cf. *mongolicus* (Diener, 1897). Ventral valve. Panjshah Fm., Mb. 2, Panjshah section, specimen KK 88-8.
Fig. 5 - *Retimarginifera* sp. ind. Ventral valve. Panjshah Fm., Mb. 2, Panjshah section, specimen KK 79-4.
Fig. 6 - *Retimarginifera gaetanii* Angiolini, 1995. Ventral valve. Panjshah Fm., Mb. 2, Panjshah section, specimen KK 88-10.
Fig. 7 - *Retimarginifera gaetanii* Angiolini, 1995. Ventral valve. Panjshah Fm., Mb. 2, Panjshah section, specimen KK 79-31.
Fig. 8 - *Lirellaria* sp. ind. Dorsal valve. Panjshah Fm., Mb. 2, Panjshah section, specimen KK 79-22.
Fig. 9 - *Stenoscisma armenica* (Sokolskaya, 1965). Ventral valve. Panjshah Fm., Mb. 2, Panjshah section, specimen KK 67-29.
Fig. 10 - *Magniplicatina* sp. ind. Ventral valve. Panjshah Fm., Mb. 2, Panjshah section, specimen KK 79-6.
Fig. 11 - *Martiniopsis* sp. ind. Ventral valve. Panjshah Fm., Mb. 2, Panjshah section, specimen KK 67-35.
Fig. 12 - *Chapursania tatianae* Angiolini, 1995. Ventral valve internal mould. Panjshah Fm., Mb. 2, Panjshah section, specimen KK 67-28.
Fig. 13 - *Chapursania tatianae* Angiolini, 1995. Ventral valve. Panjshah Fm., Mb. 2, Panjshah section, specimen KK 76-25.
Fig. 14 - *Chapursania tatianae* Angiolini, 1995. Dorsal valve. Panjshah Fm., Mb. 2, Panjshah section, specimen KK 67-63.
Fig. 15 - *Tiramnia tschernyschewi* (Grunt, 1973). Ventral valve. Panjshah Fm., Mb. 2, Panjshah section, specimen KK 67-3.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Sandstone petrography. The non-carbonate extrabasinal fraction (NCE of Zuffa, 1985) mostly consists of monocrystalline to subordinately polycrystalline detrital quartz (C/Q up to 15%), and sandstones within the Gharil Fm. are thus mostly quartzarenites (average detrital modes Q97±3 F2±2 L1±2 n=11). Detrital feldspars (mainly microcline with subordinate plagioclase and chessboard-albite) are significant only in peloidal and sparsely bioclastic, lower fine-grained, quartz-rich dolomitic subarkoses at the top of the unit at Lashkargaz. The ultrastable heavy mineral fraction includes a variety of blue, green and colourless tourmaline in grains up to 1-2 mm in size, along with zircon and rutile. Volcanic lithoclasts containing plagioclase laths interspersed within a phyllosilicate groundmass, found sporadically at Baroghil and locally in abundance at Lashkargaz, are interpreted as pyroclastic debris (resedimented crystal-fall tephra) erupted from fairly distant active volcanic sources (reworked V3 neovolcanic grains of Zuffa, 1985).

Granule to pebble-sized sedimentary lithoclasts (siltstone prevailing over carbonate particles: bioclastic wackestones, quartzose peloidal grainstones, stromatolitic bindstones, reworked bivalves, bryozoans, brachiopods and echinoderms with ferruginous rims) are dominant at the base of the upper lithozone at Lashkargaz. Since these are markedly angular, oversized and very irregular in shape, they are interpreted as grains derived intrabasinally from the underlying indurated sedimentary succession.

The carbonate intrabasinal fraction (CI of Zuffa, 1985) is invariably lacking. Instead, the non-carbonate intrabasinal fraction (NCI of Zuffa, 1985; Garzanti, 1991) consists of common blackened ferriclasts and phyllosilicate clasts. The upper sequence is characterized at NW Baroghil by an abundance of bauxite to laterite ooids and pisoids. At Baroghil East this major ironstone horizon contains chamositic ferruginous pisoids instead. Several lines of evidence indicate that these ooids and pisoids were pedogenetic in origin and were derived from erosion of deeply-weathered lateritic profiles. Redeposition in paralic environments is indicated for the East Baroghil chamositic layer. Ferriclasts were also derived locally from scouring of extensively hematitized sandstones and siltstones capping the underlying sequence. The unconformities both at the base and within the unit document prolonged (up to a few Ma?) exposure and pedogenization in warm and humid equatorial climates.

Bio- and chronostratigraphy. Age-diagnostic fossils have not been found in this formation, which is bracketed between the Kubergandian and the Midian? according to stratigraphic position.

Ailak Formation.

Name. The term is introduced here to designate a huge pile of massive dolostones, at least 1000 m thick, which forms the continental divide ridge to the north of Baroghil Ailak (hence the name) and Lashkargaz. Unfortunately its top is exposed on the Afghan side of the ridge and consequently we didn't study it, except for a small outcrop above Lashkargaz (Fig. 8).

Lithology. A section was measured on the eastern slope of the peak dominating to the west of the Baroghil pass, at an average altitute of 4350 m a.s.l. Other cursory sections have been made along the ridge between the Baroghil pass and the Gharil area, and NW of Lashkargaz. The Ailak Formation consists chiefly of thick bedded dolostones. Stromatolitic dolomites, with planar to wavy stromatolites (Fig. 16) or grey, as well as dark grey dolomitized wackestones. Some of the darker wackestones are less dolomitized and may be considered as dolomitic limestones. More rarely there are dolomitized packstone with high angle cross-lamination. Small breccia lenses, made by dolomitic clasts are also rare. Distribution of facies seems to be fairly random, with a prevailance of darker wackestones to the east, especially in the middle and upper part, whilst stromatolitic layers seem to be more abundant to the west.

Most probably there are internal discontinuities within this unit, but we were unable to trace them, because we would probably need to observe the Afghan side. As a matter of fact, on the east side of the Chitral/Wakhan boundary area to the Baroghil pass, there is striking evidence of a huge paleokarst. Cavities, up to 100 m deep and 70-80 m wide, with polyphasic infillings were observed.

The extension towards the east of this unit is still problematic. It is possible that, together with the Permian part of the Gujhal Dolomite and sparse out-

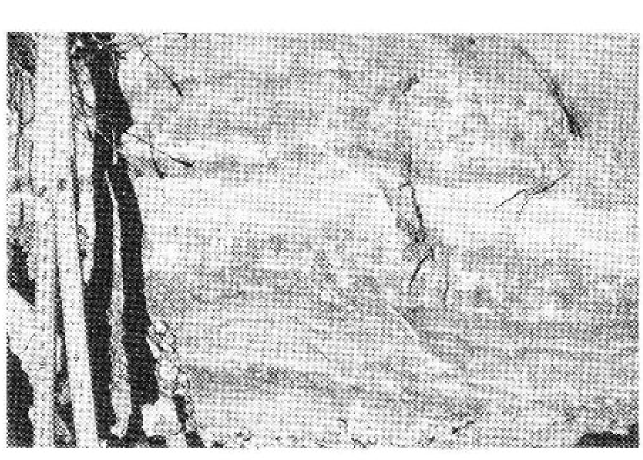


Fig. 16 - Stromatolitic layers in the middle part of the Ailak Formation (Baroghil W section).

crops of massive dolostone resting on the Panjshah Fm. in the upper Lupghar valley they may constitute a continuous Upper Permian platform. At present it is too early to state a definite position.

Bio- and chronostratigraphy. The strong dolomitization destroyed most of the microfacies. 160 m above the base, in the Baroghil West section, we found a small foraminifer assemblage with *Paraglobivalvulina* ? sp., *Dagmarita chanakiensis* Reitlinger, *Langella* sp., which characterizes the Late Permian, more frequently the Midian or the Dzhulfian (Fig. 17). Higher up we have no data for several hundred meters. Only towards the top, some ghosts of foraminifers could suggest a Late Triassic age (I. Premoli Silva, Milano, pers. comm., 1994). The emersions producing the karst should be already in the Mesozoic.

Kundil Formation.

Name. It was proposed in Gaetani et al. (1990) to designate the cherty limestone succession, that crops out from Chapursan to the Shimshal valleys. It is absent in Chillinji and in the Axial and Baroghil Units of the Upper Yarkhun valley. We have no information about the time-equivalent evolution of the Karambar Unit. The type section has been measured following the base of the buttress which closes the entrance of the Kundil valley on its right side (Fig. 11, 18).

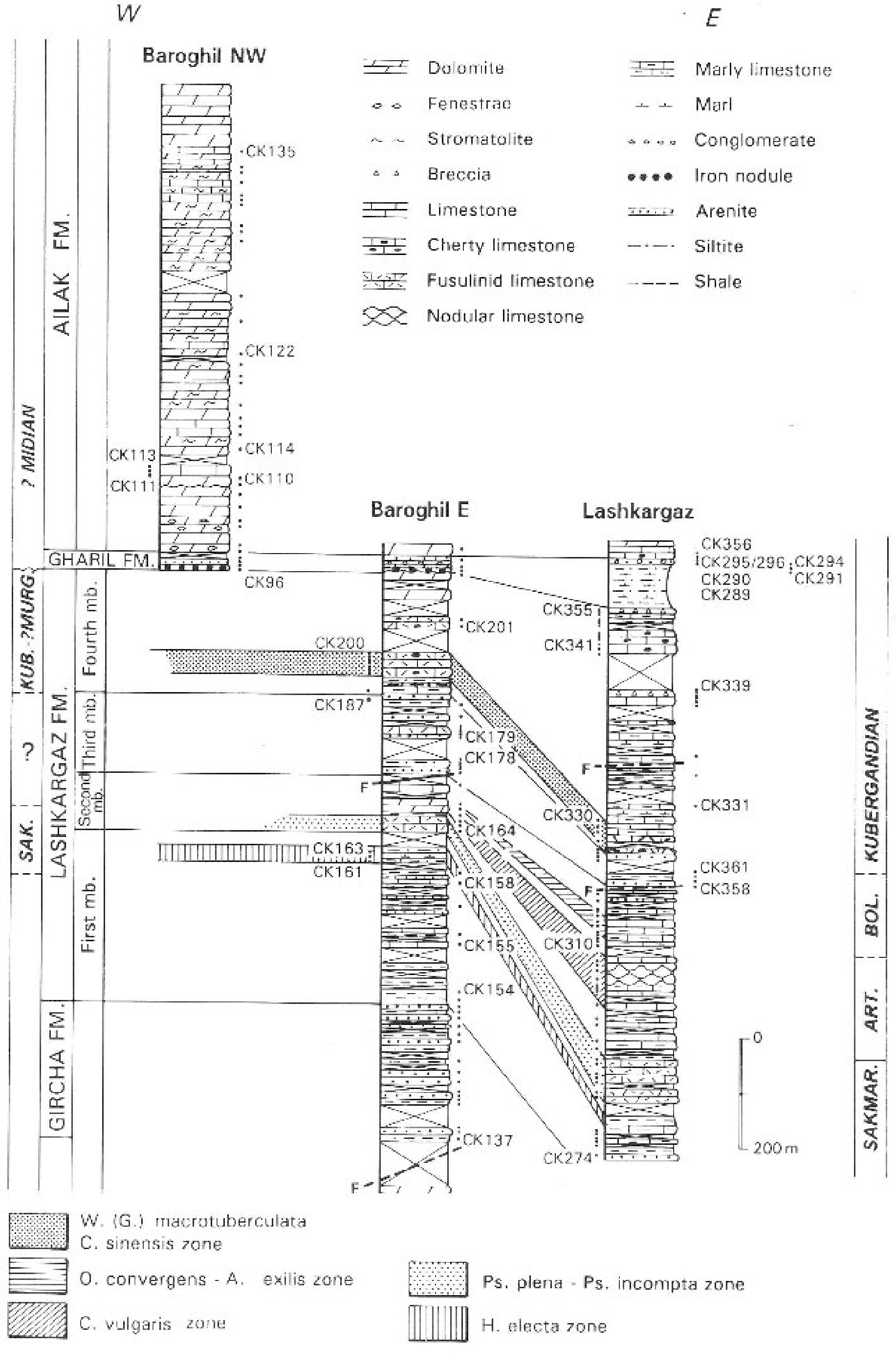


Fig. 17 - Correlation chart of the main sections measured in the Permian of Baroghil area, Upper Yarkhun valley. The brachiopod and/or fusulinid biozones are indicated.

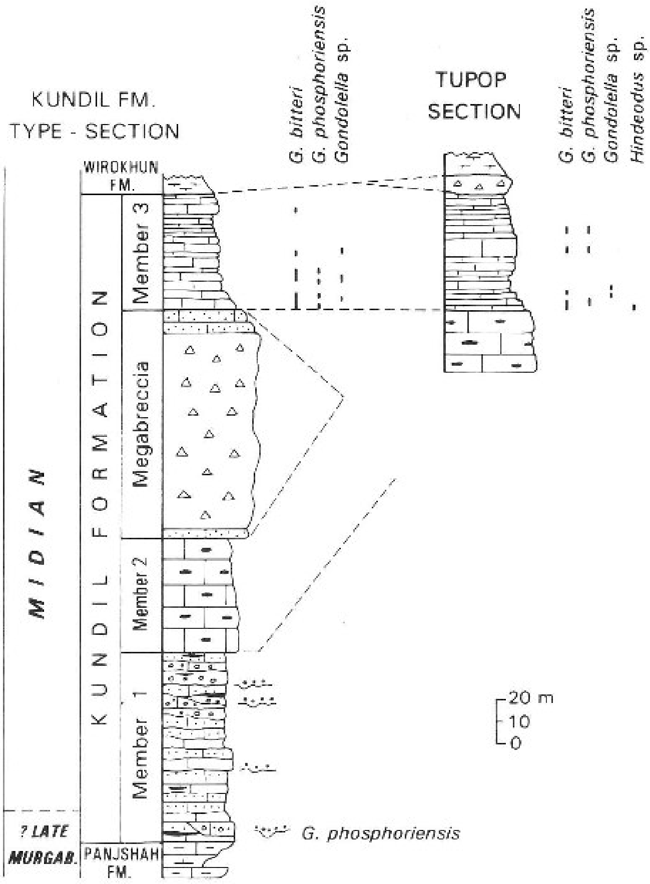


Fig. 18 - Type-section of the Kundil Formation, lower Kundil valley, Upper Hunza. To be noted that *G. phosphoriensis* is present since the base of the unit in the type section. The Member 3 of the Kundil Fm. was sampled also in the Borom valley, section Tupop.

Lithology. The unit is chiefly characterized by stratified cherty limestones. It may be subdivided into three members, and locally huge piles of megabreccias may also be interbedded. The total thickness may reach 190 m.

Member 1. Dark grey, locally nodular limestones with a few thin marl interbeds. In this lithofacies, there are intercalated frequently litho-bioclastic calcarenites and rudites, up to 4 m thick, with erosional base and reverse grading. Rounded lithoclasts contain fusulinids and crinoids; white chert nodules and silicification processes are common. Upwards grey cherty crinoidal calcarenites prevail, with reworked fusulinids, and dark grey limestones. The top of the member is characterized by top coarse grained calcarenites with white chert nodules, fining upwards and a few fine megabreccia with scour base and reverse grading (10-20 cm blocks with crinoids, fusulinids). Thickness up to 76 m.

Member 2. Well bedded (10-60 m thick), locally squeezed, with thin marl interbeds and abundant white intrastratal cherts. Grey limestones in 20-40 cm-thick beds, locally nodular, sometimes amalgamated to form thicker layers. Coarsely recrystallized, they contain fairly abundant nodules of withish chert, brown when altered. Occasionally recrystallized dark grey calcarenites with crinoids and small fusulinids with parallel and cross laminations (current ripples) are present. Thickness about 65 m.

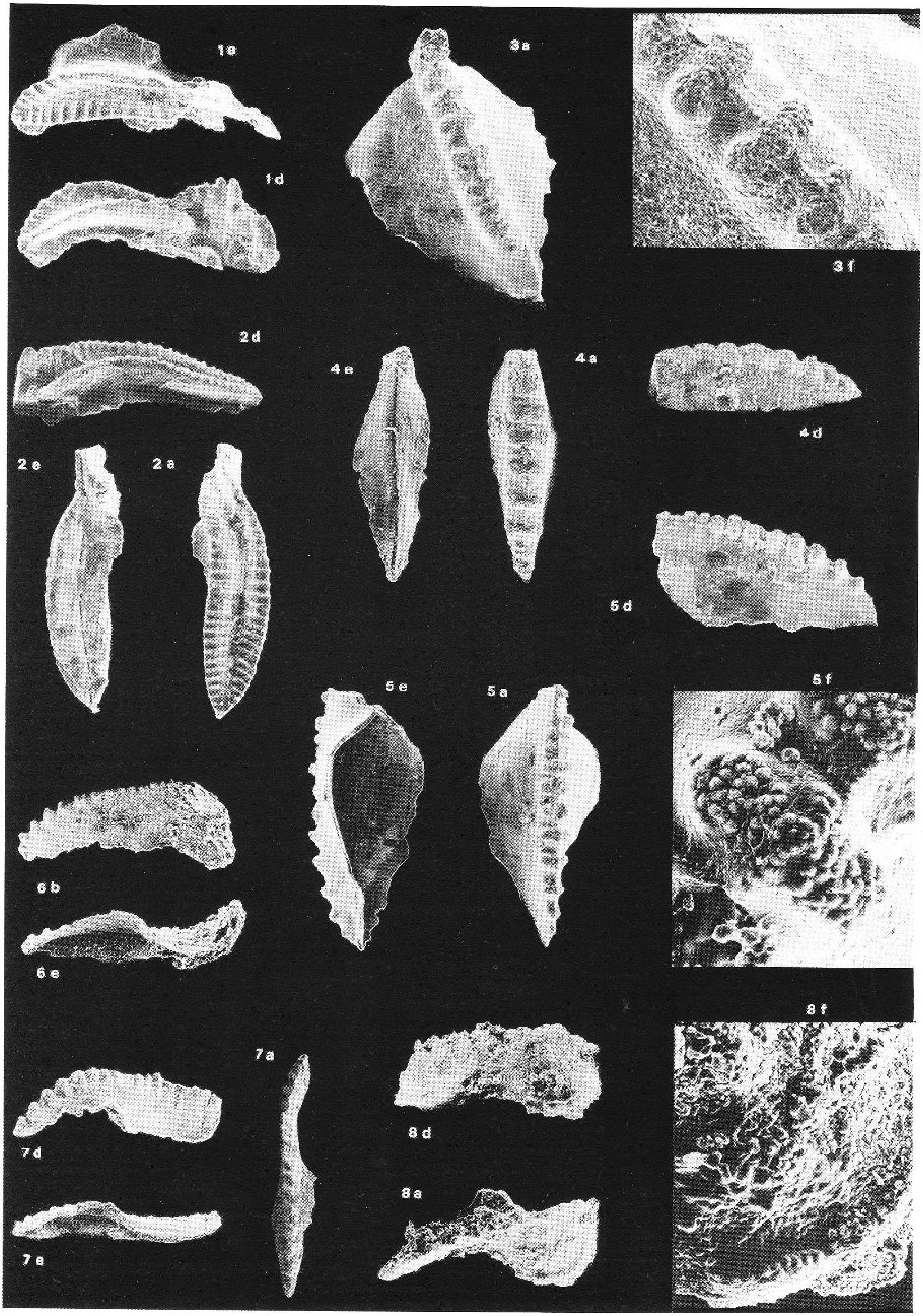
Member 3. Thin bedded grey limestones, with grey or whit chert nodules rarely elongated to form lenses. In the middle and upper part thicker beds may be occasionally intercalated. The matrix of the nodular limestones may consists of pale green very fine-grained tuffs. Thickness 40-50 m.

Megabreccias. Megabreccias bodies may be intercalated in the middle or upper part of the Kundil Fm. The thickest (about 100 m-thick) forms the buttress closing the entrance of the Kundil valley on the right side. It consists of polymictic angular cobbles, 15-30 cm in size, forming megabreccia bodies up to 10 m in thickness. The most abundant are cherty limestone from lower members of the Kundil Fm., but also clasts with fusulinids from the Lupghar Fm. have been collected. The abundance of the matrix is highly variable. In the Kundil-Chapursan area, the topmost part may be calcarenitic/ruditic with carbonate platform clasts, and paraconglomerates (1-10 cm clasts). In the Borom section a single calciruditic body, about 5 m thick, is present at the top of the Kundil Fm. These megabreccia intercalations are considered as subaqueous gravity debris flow.

PLATE 11

Fig. 1 - *Adetognathus paralautus* Orchard. Lashkargaz Formation, Member 1, Baroghil E section, sample CK 161 a,d; x 100.
Fig. 2 - *Adetognathus paralautus* Orchard. Lashkargaz Formation, Member 1, Baroghil E section, sample CK 161 a,d,e; x 100.
Fig. 3 - *Sweetognathus* aff. *whitei* (Rhodes). Lashkargaz Formation, Member 4, Baroghil E section, sample CK 191 a; x 100; f, enlargement of fig. 3 a; x 250.
Fig. 4 - *Sweetognathus* aff. *whitei* (Rhodes). Lashkargaz Formation, Member 4, Baroghil E section, sample CK 191 a,e,d; x 100.
Fig. 5 - *Sweetognathus* sp. Lashkargaz Formation, Member 4, Lashkargaz section, sample CK 352 a,e,d; x 100; f, enlargement of fig. 5a; x 500.
Fig. 6 - *Sweetognathus* cf. *hanzongensis* (Wang). Kundil Formation, Member 2. Locality Khunjerab Road, sample KP 43 b,e; x 50.
Fig. 7 - *Sweetognathus* cf. *hanzongensis* (Wang). Kundil Formation, Member 2. Locality Khunjerab Road, sample KP 43 a, d, e; x 50.
Fig. 8 - *Iranognathus* cf. *unicostatus* Kozur, Mostler & Rahimi-Yazd. Wirokhun Formation, Wirokhun section, sample KK 158 a,d; x 100; f, enlargement of fig. 8 a; x 500.

a=upper view; b=lateral view; d=oblique/ lateral view; e=lower view; f=enlargement.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Microfacies. At the base lithoclastic rudstones with bryozoans, crinoids, pelecypods, coated grains, oncoids, radiolarians prevail; microspatic fine wacke-packstones. Lithoclastic rudstones-floatstones and fine packstones with partially silicified bioclasts crinoids, brachiopods, rare bryozoans and dasycladaceans characterize the upper part of the unit in the Kundil/Chapursan valley. Authigenic quartz is common in all the lithofacies.

Upper boundary. It is fairly sharp, defined by the significant appearance of black marls and splintery shales, alternated with grey dark mudstones without chert nodules.

Biostratigraphy. Only conodonts have rarely been found (1:10 positive samples). The first member of the Kundil Fm. is characterized at its base by the presence of reworked fusulinids (*Pseudofusulina* sp., *Cancellina* sp.) originating from the underlying formations. The conodont *Gondolella phosphoriensis* Youngquist, Hawley & Miller (=*G. rosenkrantzi* in Gaetani et al., 1990) has also been identified. In the second member the conodont *Sweetognathus* cf. *hanzhongensis* is present, associated with *Gondolella bitteri* Kozur and *Gondolella phosphoriensis*. At the base of the third member the conodonts *Gondolella bitteri* and *G. phosphoriensis* are fairly continuous, while higher up conodonts are extremely rare (Pl. 11; Tab. 1 & 2). The samples collected near the top of the unit are barren of conodonts.

	G. phosphoriensis	G. bitteri	Gondolella sp.	ramiformes
KN 46 + 42.60 m		*		
KN 39 + 24.40 m		*	*	
KN 35 + 15.30 m		*		
KN 33 + 13.60 m	*	*		*
KN 32 + 12.00 m		*	*	
KN 27 + 6.50 m	*	*		
KN 25 + 4.90 m	*	*		*
KN 24 + 4.05 m		*		
KN 23 + 3.80 m	*	*		*
KN 22 + 3.50 m		*		
KN 21 + 2.70 m		*	*	
KN 19 + 2.05 m		*	*	
KN 15 + 1.15 m		*		
KN 14 + 0.90 m	*	*		
KN 13 + 0.50 m	*	*		*
KN 12 + 0.15 m	*	*		*

Tab. 1 - Conodont range in the Kundil Fm., Member 3, Kundil section.

Chronostratigraphy. The age of the Kundil Fm. should be ? Late Murgabian to Midian, according to the conodont associations occurring in the three members.

Gondolella phosphoriensis Youngquist, Hawley & Miller (=*G. rosenkrantzi* Youngquist, Hawley & Miller in Wardlaw & Collinson, 1979) according to Wardlaw & Collinson (1984) spans an age Late Wordian-Early Capitanian. Sweet (1988b) refers *G. phosphoriensis* from the late Early up to the early Late Guadalupian. Beyers & Orchard (1991) refer to the Guadalupian the species and report *G. phosphoriensis* from Clinton (British Columbia, Canada) together with *Lepidolina* (formerly *Yabeina*; Goto et al., 1986). This fusulinid has a Midian range, then the occurrence of *G. phosphoriensis* from the Late Murgabian up to the Midian seems to be confirmed.

Sweetognathus hanzongensis (Wang Z.), according to Wang Z. (1978), Bando et al. (1980) and Wang C. et al. (1987), is present in the middle and upper Maokou Formation and then it spans from the middle Early Wordian up to the Late Capitanian. The species reported here as *Sweetognathus* cf. *hanzongensis* occurs along with *G. phosphoriensis* and *G. bitteri*, so a Late Murgabian-Midian age can be inferred for the second member of the Kundil Fm. Finally the association *Gondolella bitteri*-*G. phosphoriensis* points to an early Late Guadalupian or Midian age (Sweet, 1988b; Kozur et al., 1975; Beyers & Orchard, 1991) for the last conodont association found in the Kundil Fm.

Wirokhun Formation.

Name. Here proposed, by the name of the first steep gulley on the right side, when entering in the Kundil valley (Fig. 11, 19). It corresponds to the un-

	G. phosphoriensis	G. bitteri	Gondolella sp.	Hindeodus sp.	ramiformes
KG 135 + 38.80 m	*	*			*
KG 132 + 25.15 m	*	*			
KG 130 + 21.75 m		* ?			
KG 127 + 12.75 m			*		
KG 126 + 8.70 m		*			*
KG 125 + 6.80 m			*		
KG 124 + 4.30 m	*	*			*
KG 123 + 3.00 m	*	*			
KG 122 + 2.65 m	*	*			
KG 121 + 1.70 m	*				*
KG 120 + 1.25 m		*			
KG 119 + 0.65 m		*		*	*

Tab. 2 - Conodont range in the Kundil Fm., Member 3, Tupop section.

named unit in Gaetani et al. (1990). This unit was recognized only on the high ridges between the Borom and Kundil valleys, often being squeezed out between the more rigid hanging units.

Lithology. The units may be subdvided in three lithozones. The lower one, 26.5 m-thick, consists of dark shales and marls, rythmically alternated (3:1 ratio) with grey, dark mudstones in 20-40 cm thick beds. The middle lithozone is characterized by 6.4 m of thin bedded cherty limestones with a few shaley partings, followed by about 21 m of grey-green recrystallized, sometimes tuffitic, limestones alternated with cherty limestones (total 27.4 m). The upper part is characterized by the reappraisal of black splintery shales and marls, squeezed by faults, followed by intercalations of individual mudstone beds (20 to 70 cm-thick) every 2-5 m within the shales and marls (42 m). The total thickness of the units is not less than 96 m.

Upper boundary. The boundary to the overlying Borom Fm. is inferred by with the appearance of more persistent calcareous beds, with gently nodular or parallel laminations, forming thicker packages.

Biostratigraphy. The fossil content of the Wirokhun Fm. is represented by four conodont associations in the Wirokhun section (Fig. 19). The first conodont assemblage (*Gondolella orientalis* (Barskov & Koroleva), *Hindeodus minutus* (Ellison) (=*H. typicalis* (Sweet)), and representatives of the *Gondolella subcarinata* (Sweet) group occurs at the base of the formation. *Gondolella subcarinata subcarinata*, *Gondolella subcarinata changxingensis* (Wang & Wang) and locally *Hindeodus minutus* are present from samples KK 149 up to KK 153 (Wirokhun Pass section, cherty limestone beds). The third conodont assemblage occurs in the calcareous lithozone and it is characterized by *Iranognathus* cf. *unicostatus* Kozur, Mostler & Rahimi-Yazd, *Gondolella orientalis* and representatives of the *G. subcarinata* group. The fourth assemblage occurs at the top of the formation and it consists of *Neospathodus dieneri* Sweet, *Gondolella carinata* Clark, and *Hindeodus* sp.

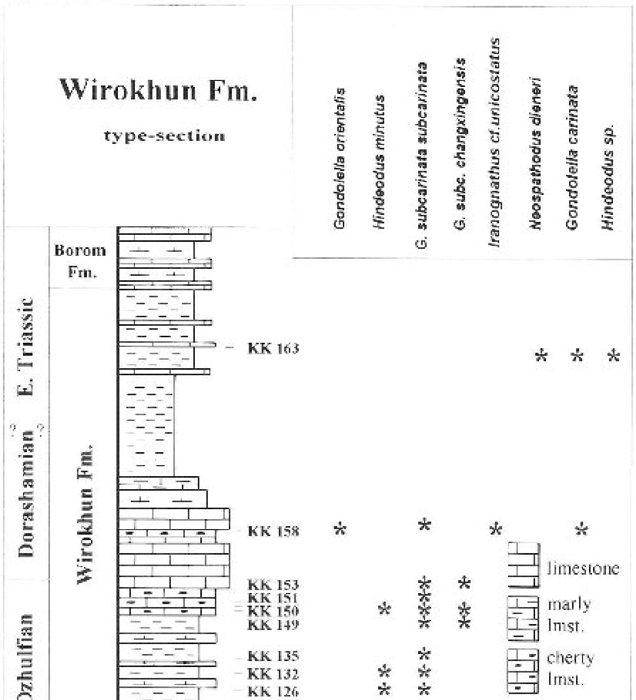

Fig. 19 - Type-section of the Wirokhun Formation, Wirokhun gulley, Kundil valley. The section has been measured near the ridge at the top of the gulley, on the Kundil side.

Chronostratigraphy. The age of the Wirokhun Fm. spans from the Dzhulfian to the Dienerian (Early Triassic). In fact, according to Kozur et al. (1975), Wang (1978), Bando et al. (1980), Sweet (1988a,b) and Beyers & Orchard (1991), conodont assemblages 1 to 3 suggest a Dzhulfian-Dorashamian age, whereas the conodont assemblage at the top confirms an early Dienerian age (Sweet & Bergstrom, 1986; Sweet, 1988a,b). Since up to 2/3 of the underlying Kundil Fm., Member 3, the *phosphoriensis/bitteri* conodont fauna has been collected, a gap between Kundil and Wirokhun Fms. cannot be excluded.

Sedimentary evolution

Gircha Formation.

The Permian succession of the Karakorum starts everywhere with a huge terrigenous prism increasing in thickness from southwest to the northeast. The lower and middle parts of the unit to the west consist of fine-grained sandstones, with a lower accumulation rate and an absence of shell lags. It suggests a proximal position within the dispersal systems of the terrigenous detritus. To the east, abundant shales and sporadic shell lags indicate deposition in a prodelta to storm-dominated neritic environment. Transgressive episodes are recorded by coarse open marine bioclastic sandstones overlying rooted surfaces in the central? part of the unit. The occurrence of point bar deposits in the upper part of the unit, at Baroghil, Gircha and Shimshal, suggests fluvio-deltaic settings, prograding on the previous marginal marine areas. Paleocurrent directions indicate north-eastward sediment transport. Coarser proximal deposits in the Shimshal-Hunza valleys passed north-westward to finer grained more distal deposits in the Chapursan valley, with consistent provenance of detritus from uplifted granitoid basement blocks in the south.

Chapursan Group.

Lashkargaz Formation.

The occurrence of arkose in the basal silty interval at E Baroghil (Member 1) suggests to a tectonically-enhanced rather then purely eustatic transgression, marked by an abrupt transition from coastal sands to siltstones with open shelf *Zoophycos*-type burrows and phosphatic nodules. Gradually, bioclastic sands in lenticular bodies tend to substitute for the more laterally continuous quartzarenite layers indicating an open shelf depositional environment. Member 2 is characterised by bioclastic packstones in the higher energy area of Baroghil, whilst the more depressed Lashkargaz area received finer sediments. Metre-thick coarsening-upwards cycles are capped by oncoid - or more washed bioclastic packstones. Abundance of fusulinids, Rugosa, Tabulata (either turned or in life position), brachiopods and gastropods, indicates a carbonate ramp environment occasionally polluted by clay input, deepening towards the east, but everywhere still in the photic zone.

Member 3 is characterised by two decametric sequences with renewed quartzarenitic input in the west, with a decrease in grain-size eastwards, where sandstones are replaced by well-washed bioclastic layers. An eustatic low-standing could be hypothesised.

Member 4 testifies to a renewed deepening. The carbonate ramp persisted to the west in an open shelf under photic conditions, reaching deeper conditions with higher accumulation rates in the east. Mudstone/wackestones with sparse chert nodules, the occurrence of conodont and disappearance of megafauna suggest more pelagic conditions. However, abundance of *Tubiphytes* suggests still photic conditions. The positive movement leading to the pre-Gharil unconformity is also recorded in the boundstone microfacies at the top of the Lashkargaz section.

Lupghar Formation.

The first member is very similar to the first member ot the Lashkargaz Fm., and testifies to the gradual transgression onto the sedimentary prism of the Gircha Fm. The second member consists instead of four well defined lithozones. At the base the 20 m-thick fusulinid accumulation testifies to the upper part of the carbonate ramp, swept by currents to keep clean the bottom from the mud, thus fostering the climax of the *Pseudofusulina* community. The major fusulinid accumulations are in the Khudabad-Lupghar area. The oolitic and bioclastic layers of the second lithozone suggests a shallowing episode, which continues to peritidal conditions inferred by the fenestral and/or stromatolitic dolostones of the third lithozone. After these internal platform facies, the area returned to subtidal conditions, testified by the crinoidal and oncoidal packstone/wackestones of the fourth lithozone.

Panjshah Formation.

Also the Chapursan area records the reappearance of the terrigenous input during the mid-Permian, with mostly very fine-grained hybrid arenites displaying parallel to hummocky cross-lamination and wave-ripples, indicating storm deposition on a shallow-water shelf. These are infrequent episodes on a prevailing muddy shelf. Upwards, brachiopod/bryozoan communities dwell on the more swept parts of the shelf. These are intermingled with muddier ponds, where only mud-tolerant, especially spiriferid brachiopod and crinoid communities are present. Solitary Rugosa, like *Paracaninia*, usually spread in the lower Permian cold water of the Gondwanian margins (Flügel, 1990), suggest a cooler and deeper environment. The absence of compound Rugosa and Tabulata is notable. They are present instead in the Lashkargaz-Baroghil area.

Gharil Formation.

The Gharil Fm. overlies a major tectonically-enhanced? disconformity associated with prolonged emersion, development of lateritic soil profiles and dolomitization at the top of the underlying Lashkargaz Fm. Initially, depositional environments were largely continental in the western part of the Baroghil Unit, where fining-upward fluviatile redbed sequences were deposited, and shallow-marine in the eastern part, as indicated by much thicker, burrowed and sparsely bioclastic mid-shelf muds. Another unconformity associated with emergence, pedogenesis and strong local erosion is documented in the middle-upper part of the unit, and it was finally followed by a widespread marine transgression testified by oolitic ironstones sharply overlain by the dolomitic carbonates of the Ailak Fm. Petrographic features suggest a pedogenetic origin for the ironstones (Siehl & Thein, 1989), which were reworked by fluviatile currents and deposited in continental to paralic environments. Further reworking and chemical alteration of pedogenetic concretions occurred locally during rapid marine transgression (Garzanti, 1991). Time involved in these layers was of several hundred thousand years at least. Unique features of ferriclasts and of in situ to redeposited aluminum and iron hydroxide concretions indicate that the Gharil Fm. was deposited at equatorial latitudes.

Ailak Formation.

The rapid transgression of the carbonate shelf in the southern and western domain is testified by the dolostones of the Ailak Fm. Two kinds of sequences are recorded. Peritidal cyclothems, 2 to 10 m thick, with fenestral and stromatolitic layers (Fig. 16), channel lags with cross-laminated fine carbonate breccias, and residual breccia linked to emersions. Alternated in an irregular way are coarsely to finely crystallized dolostones, with fragments of bivalves, solitary corals and gastropods testifying to a mostly subtidal flat. The darker colour suggests a better preservation of the organic matter. The absence of fusulinids is interpreted as being due to a too shallow, not sufficiently agitated and possibly hypersaline environment. However, no traces of gypsum have been found. The chronostratigraphic control is poor, consequently we cannot place the imposing paleokarst phenomena cropping out immediately to the east of the Baroghil pass in the Permian or in the Triassic. However, such a huge dissolution testifies to a warm, humid, subequatorial climate.

Kundil Formation.

The Kundil Fm. testifies to a fairly rapid deepening of the depositional environment. Slope deposits with ruditic and calcarenitic resedimentation, intermingled with cherty limestones characterize the basal member of the unit. Pelagic conditions are indicated by the following two members of the Kundil Fm. consisting of well stratified mudstone/wackestones with rare radiolarians and conodonts, possibly deposited in upper bathyal settings. The presence of block-faulting and high scarp slopes are suggested by the huge debris flows and megabreccias intercalated within Members 2 and 3 of the Kundil Fm., in which also fusulinids deriving from the second Member of the Lupghar Fm. have been collected.

Wirokhun Formation.

The pelagic bathyal setting continued through the whole Wirokhun Fm., thus crossing the Permian/Triassic boundary. The cyclic marl to marly limestone sedimentation in the lower 25 m of the unit (first lithozone) is to be noted. A decrease of clay input in the second lithozone resulted either in a recovering of cherty thin bedded mudstone, or in thicker volcanoclastic layers. The third lithozone, in which the P/T boundary occurs, is mostly shaly, possibly linked to a largely anoxic stratified oceanic event occurring in the eastern Tethys (Kajiwara et al., 1995).

Geodynamic evolution

The Permian of northern Karakorum records the evolution of a passive margin (Fig. 20). This evolution may be subdivided into three steps. In the lowest part of the succession, terrigenous shelfal to paralic sediments spread everywhere, with occasional fully marine ingressions. The second step records a generalized marine transgression during the (Late ?) Sakmarian, except the area of Chillinji and perhaps to the south of Babaghundi (Chapursan valley), where emersions linked to rifting occurred. During this step, several tectonic uplift and block rotation episodes occurred in a time which encompasses most of the mid-Permian. The third step, from Midian onward, records a significant facies differentiation. The paleogeographic map suggests that in the south-west, shallow-water conditions were persistent throughout most, if not all, of the Permian. Although very poorly dated, also in the Darkot area dolomites seem to follow the basal terrigenous unit of the Permian (Matzushita & Hushita, 1965; Tahirkheli et al., 1994). The dolostones of the Ailak Fm. in Chitral and Karambar, and the Gujhal Dolomite in Hunza sealed a previously more irregular horst and graben setting. This major Murgabian-Midian transgression, recorded in a vast region from the Pamirs (Leven, 1993a) and the Central Afghanistan (Blaise et al., 1977; Vachard, 1980) to the Tethys Himalayan succession of northern India and central Nepal (Garzanti et al., 1992, 1994), is thought to mark a turning point in the initial opening of Neo-Tethys. Instead, to the north-east, during the Late Permian, an important sinking of the shelf occurred, with bathyal pelagic conditions. Intense block-faulting provided huge debris flows during the Midian-Dzhulfian. Outside the studied area, we interpret the very thick Misgar-Wakhan Slate lithosome, as far as the Permian part is concerned, as being deposited in the deeper, distal part of the passive margin. Not only black shales and siltites, but also condensed, thin nodular limestone layers have been recorded (Kafarskiy & Abdullah, 1976).

Additional evidence is given by sandstone petrography. The quartzo-feldspathic Permian sandstones of the Karakorum fall in the continental block provenance field of Dickinson (1985), and are thus consistent with deposition in subsiding rift-troughs, with provenance from granitoid rocks exposed on the shoulders of the rift to the south. The Lower Permian (latest Asselian - earliest Sakmarian) arkoses of the Gircha Fm. in Hunza document rapid erosion of uplifted basement blocks. Mineralogical stability of detritus increases in the mid-Permian (Artinskian-Murgabian), possibly documenting more extensive

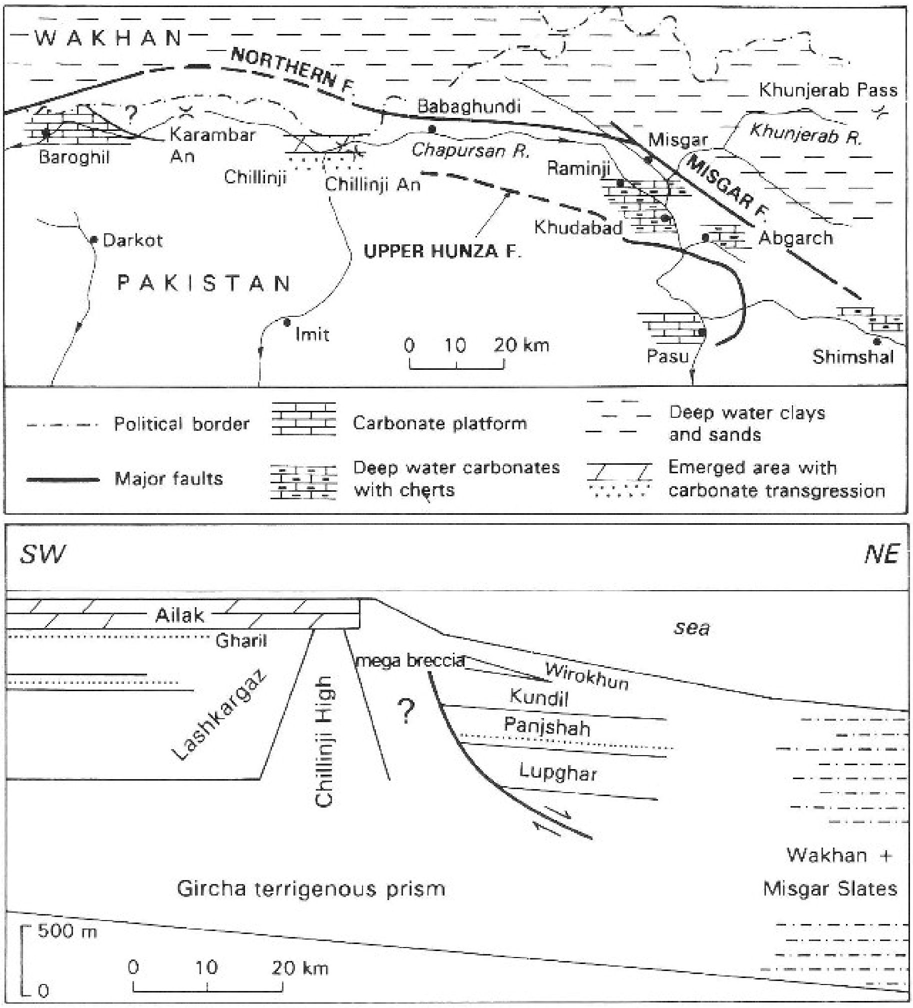

Fig. 20 - Paleogeographic map of the Permian in Karakorum and ideal cross-section of the continental margin.

chemical alteration in warmer climates or decreasing rift-shoulder relief. Mainly microlitic and possible felsitic volcanic grains are recorded locally at several stages (Gircha, Panjshah and Gharil Fms.), suggesting a prolonged phase of mafic to bimodal volcanism in nearby areas. However, not a single lava flow has been detected in the field. Only very fine green tuffs have been found in the third member of the Kundil Fm. and in the Wirokhun Fm., both of Dzhulfian age.

A tentative subsidence curve (Fig. 21) suggests that the tectonic vs. thermal subsidence was reactivated during the mid-Permian and that the Northern Karakorum passive margin had a multicyclic history during the Permian. The volcanic evidence, fairly poor in the studied area, is instead recorded as important in the Karakorum pass area (Dainelli, 1934; Ak Tash Fm.; Gergan & Pant, 1983). Intense volcanic activity is also recorded in the Pshart Block, between SE and Central Pamir (Pashkov & Shvol'man, 1979; Leven, 1995). This activity may also correlate with the coeval Panjal Trap effusions of northern India (Honegger et al., 1982; Gaetani & Garzanti, 1991), all being evidence of the rifting and initial spreading of branches of Neo-Tethys and disintegration of the Perigondwanian fringe (Megalhasa Plate; Baud et al., 1993).

Conclusions

The stratigraphy of the Permian successions of Northern Karakorum has been comprehensively studied for the first time. Obviously, in such a rugged mountain area, a lot of details remain to be discovered. However, for some valleys at least, it was previously "blank on the map" (Shipton, 1938). 17 stratigraphic sections and about 700 samples were studied, allowing us to build up a lithostratigraphy based on 9 formations subdivided into members and lithozones. The biostratigraphic control is mainly through fusulinids, conodonts and brachiopods; accessory are bivalves and corals.

The history of the Permian may be subdivided into three parts. A thick clastic wedge at the base, represented by the Gircha Fm., deposited under shelfal to paralic conditions, in which no evidence of glacigene sediments has been found. The sediment dispersal was northward in present direction. During the Sakmarian a general transgression brought a shallow sea onto most of the area, except for a few horsts. From the Artinskian to the Murgabian a complex rift shoulder and trough topography developed, linked to

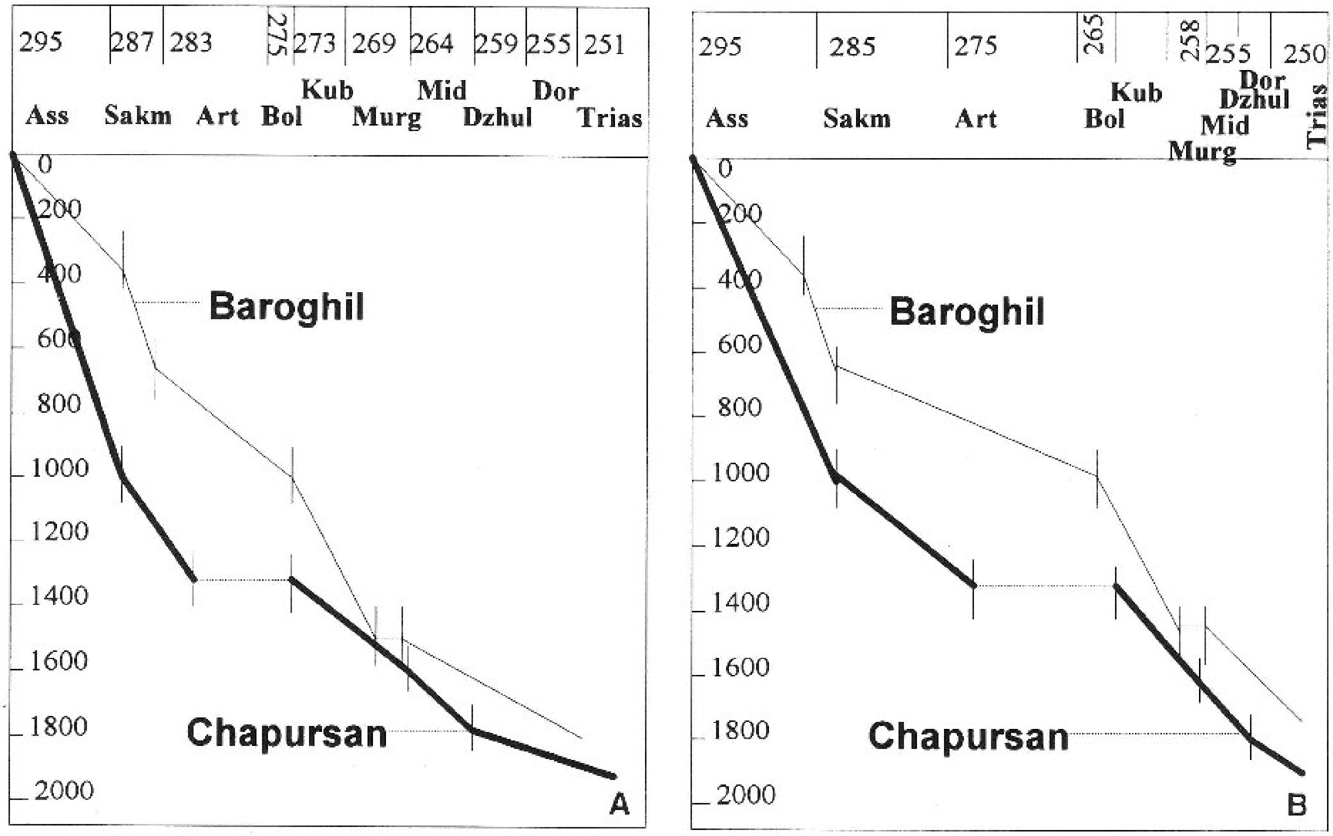

Fig. 21 - Tentative subsidence curve for Baroghil area (thin line) and Chapursan area (bold line). A) Geochronology after Ross et al. (1994); B) Geochronology after Odin (1994). The very high accumulation rate for Sakmarian is to be noted, resulting either from the possible attribution to the Sakmarian of the *Trigonotreta* assemblage in the Gircha Fm. and the short time attributed to the Sakmarian in the Ross et al. scale.

the extension movements of the Megalhasa Plate. Temporary emersions and local deeper troughs are recorded. The evidence for a tropical/equatorial climate in the Gharil and in the Ailak Fms. indicates a significant northward drift of the Northern Karakorum during the Permian. Since the Late Murgabian or the Early Midian, the northeastern part sunk to bathyal and pelagic conditions, which persisted until the Middle Triassic. Cold water is testified by a solitary coral fauna, usually found in the Lower Permian sediments of the Tethys Himalaya and the Lhasa Plate (Smith & Xu, 1988). To the south and west, peritidal carbonate flats developed up to the Triassic. The subsidence reactivated during the Late Permian, as a result of a further step of the Neo-Tethys opening in this part of the Perigondwanian fringe.

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