Rivista Italiana di Paleontologia e Stratigrafia	volume 106	numero 1	tavole 1-3	pagine 3-18	Aprile 2000

LOWER TO MIDDLE ORDOVICIAN ACRITARCHS AND CHITINOZOANS FROM NORTHERN KARAKORUM MOUNTAINS, PAKISTAN

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Received September 1, 1999; accepted November 20, 1999

Keywords: Acritarchs, Stratigraphy, Ordovician, Arenig, Karakorum, Pakistan.

Riassunto. La parte inferiore della sezione di Vidiakot (Chitral, Pakistan) comprende la parte bassa (Formazione di Yarkhun e base della Formazione di Vidiakot) del complesso terrigeno che sormonta in trasgressione il basamento cristallino del Nord Karakorum. In questa sezione, si sono ottenuti 8 campioni paliniferi su 15 trattati; essi contengono moderatamente abbondanti (anche se relativamente mal conservati) acritarchi e rari e mal conservati chitinozoi. Sono stati distinte tre associazioni palinologiche, riferibili all'intervallo cronologico Arenig inferiore-Llanvirn basale. La presenza di *Arbusculidium*, *Coryphidium* e *Striatotheca* nella maggior parte dei campioni conferma l'attribuzione paleogeografica della Terrana del Nord Karakorum al margine settentrionale di Gondwana (Paleoprovincia Mediterrannea ad acritarchi dell'Ordoviciano Inferiore-Medio). Dettagliate correlazioni con altre aree e con la sezione di Ishkarwaz (alta valle dello Yarkhun, Chitral), già studiata in precedenza, permettono agli autori di assegnare alla Formazione di Yarkhun un'età arenigiana, corrispondente ad un intervallo esteso dalla parte inferiore della Zona inglese a graptoliti *nitidus*, fino alla parte superiore della Zona a graptoliti *hirundo*. La base della sovrastante Formazione di Vidiakot viene qui correlata con l'intervallo a graptoliti *hirundo* alto-*artus* basale (Arenig terminale-inizio Llanvirn).

Abstract. The lower Vidiakot section (Chitral, Pakistan) comprises the lower part (Yarkhun Formation and base of the Vidiakot Formation) of the terrigenous complex transgressively overlying the crystalline basement of Northern Karakorum. From this section, 8 of 15 samples contain moderately abundant and poorly preserved acritarchs and rare, badly preserved chitinozoans. Three different palynological assemblages have been distinguished which are referable to the chronological interval early Arenig-earliest Llanvirn.

The presence of *Arbusculidium*, *Coryphidium*, and *Striatotheca* in most samples confirms the palaeogeographic attribution of the Northern Karakorum Terrane to the northern Gondwana margin (Lower to Middle Ordovician Mediterranean acritarch Palaeoprovince). Refined correlation with other areas and with the previously studied Ishkarwaz section (upper Yarkhun Valley, Chitral) enables the authors the Yarkhun Formation to be dated as early Arenig (British lower *nitidus* graptolite Zone) to latest Arenig (uppermost graptolite *hirundo* Zone). The base of the overlying Vidiakot Formation is here correlated with the uppermost *hirundo*-lowermost *artus* graptolite Zones (latest Arenig-earliest Llanvirn).

Introduction.

The granitoid pluton and its country rocks near Ishkarwaz, north of the Karakorum Axial Batholith, were discovered by P. Le Fort and M. Gaetani in 1992 (Le Fort et al., 1994; Gaetani et al., 1996). The Ishkarwaz Pluton intrudes low grade metasediments (quartzites) and migmatites and is covered by a transgressive sequence which was analyzed for acritarchs (Tongiorgi et al., 1994). The terrigenous complex forming the base of this sedimentary succession is fairly widespread in Northern Karakorum. However, good sections with little or no metamorphic imprint are almost absent.

Following the discovery of Arenig acritarchs and chitinozoans from the Ishkarwaz section in the Baroghil area during the 1996 expedition, one of us (M. G.) measured a further section (here labelled "Vidiakot section") along the mountain ridge between the Vidiakot Gully and the Baroghil Pass depression (Fig. 1). This ridge comprises the best outcrops in the Chitral area, though the succession is truncated and partially repeated by regional faults. The Vidiakot section was thoroughly sampled for acritarchs. From the same area Ordovician conodonts have been collected (Talent et al., 1981, 1999, sample JAT1).

The present paper deals with the lower part of the Vidiakot section (Fig. 2); its aim is to provide more information about the lower part of the sedimentary sequence overlying the crystalline basement of Northern Karakorum Terrane (Searle, 1991).

Stratigraphic nomenclature.

Below the dolomitic Chilmarabad Formation, the lower part of the sedimentary succession of Northern

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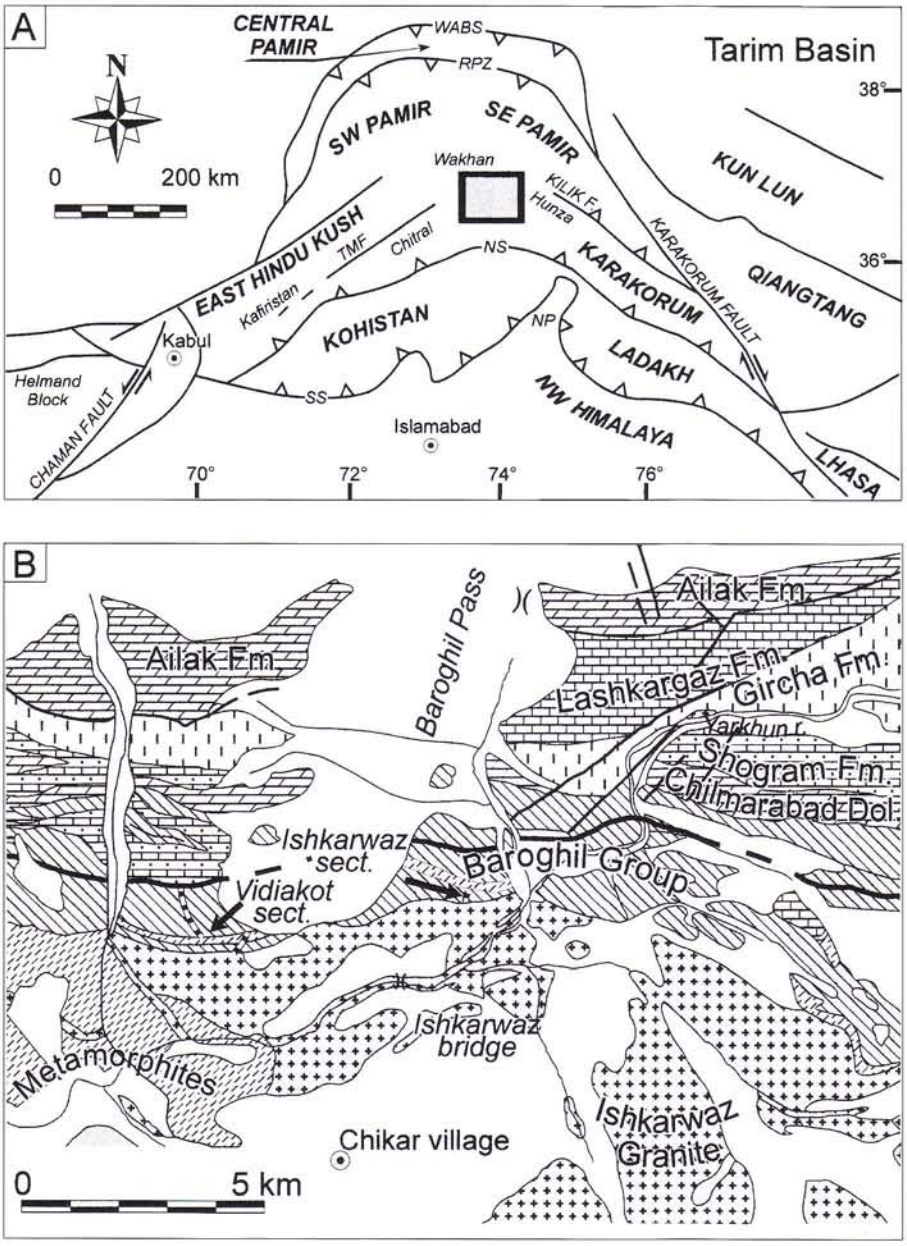

Fig. 1 - Geographic location and geological setting of the Vidiakot section, Northern Karakorum, Pakistan. A) The main tectonostratigraphic units of the Karakorum and surroundings ranges (redrawn from Gaetani et al., 1996). B) Geological map of the Baroghil pass area with location of the Vidiakot and Ishkarwaz sections (simplified from A. Zanchi' geological map, in progress).

Karakorum is almost entirely terrigenous, mostly shaly. Because all sections are influenced by folds (often isoclinal and difficult to detect) or faults, a detailed stratigraphic sequence cannot be established. However, two units may be fairly easily identified; the lower being of mixed shaly/arenaceous composition, the upper dominated by black shales.

For part of these rocks Tahirkheli (1982) introduced the term Broghil (*sic*) Formation. As the precise lithostratigraphic interval defined by this term is unclear, the whole complex was informally designated by Gaetani et al. (1996) as "Yarkhun formation". However, this use has been called in question for priority reasons by Kazmi & Qasim (1997), who prefer the term Baroghil Formation. Actually, Tahirkheli (1982, p. 48, text-fig. 20) seemingly designated with his term Broghil Formation most of the lower Palaeozoic succession.

Therefore, to settle this problem, and in agreement with Talent et al. (1999), we designate Baroghil as a "group", comprising two formations. The word "Broghil" is here considered a simple misprint for Baroghil; accordingly, it is here corrected, though the priority for designation of the Baroghil unit still remains with Tahirkheli (1982).

The Yarkhun Formation designates the mixed quartz-arenitic/slaty lower part of the Baroghil Group and the Vidiakot Formation covers its mostly slaty upper part. The section described herein is designated as the type-section of the Yarkhun Formation.

As regards the stratigraphical nomenclature, we use herein the tripartite subdivision of the Ordivician System into Lower, Middle, and Upper Ordovician which was established in 1996 by vote of Titular Members of the Ordovician Subcommission of the IUGS/ICS (Mitchell et al., 1997; Webby, 1998). However, there is no international agreement on the scope, rank, and correlation of the various proposed series/epochs and stages/ages, including the Arenig. Thus, we will here adopt the informal two-fold subdivisions of the Arenig proposed by Harland et al. (1989); e.g., lower/early and upper/late Arenig, where the latter only comprises the British *Didymograptus hirundo* graptolite Zone.

The Vidiakot section.

The lower part (230 m) of this section (Fig. 1) is composed of the weakly metamorphosed (low grade)

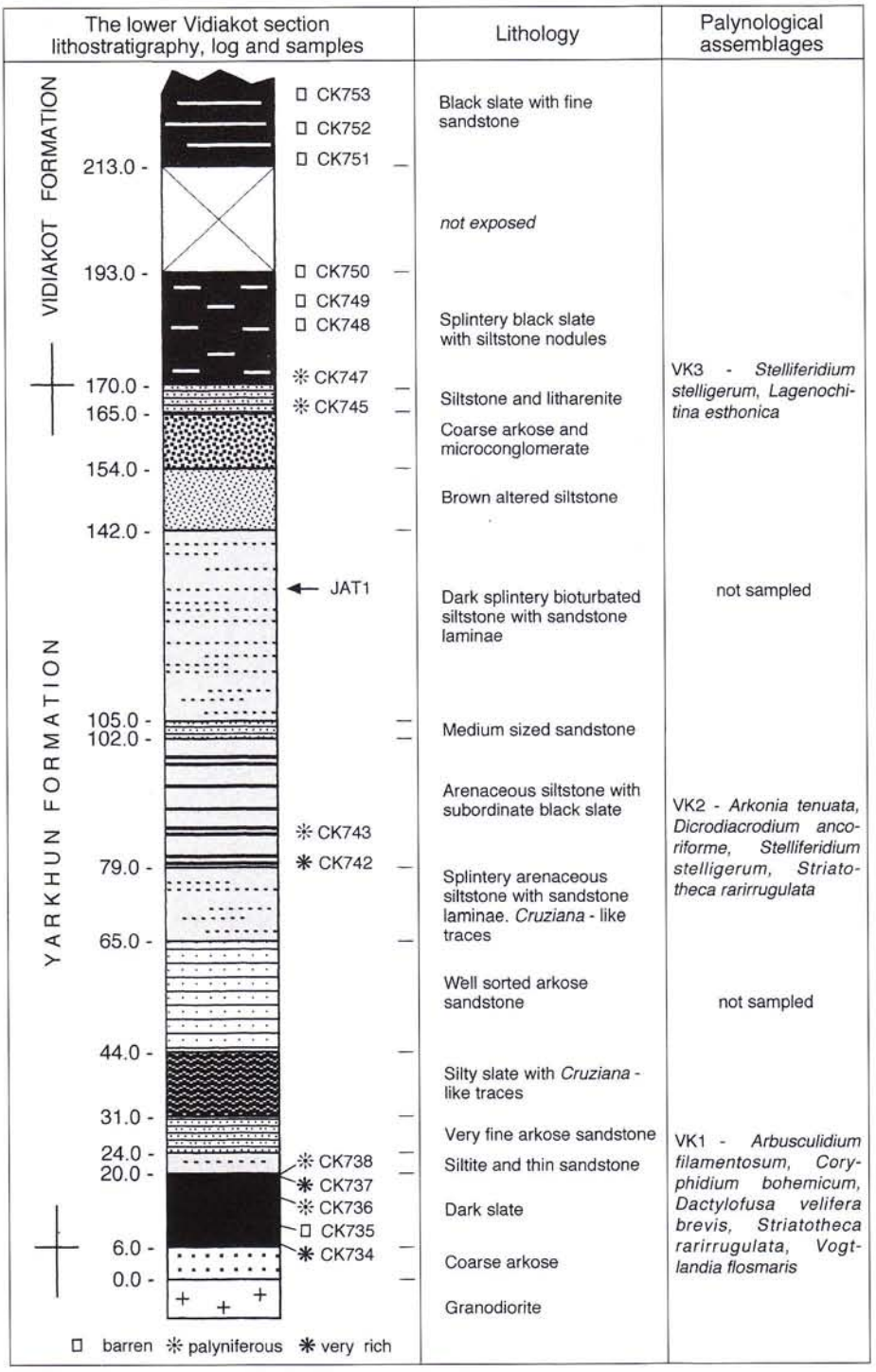

Fig. 2 - The lower part of the Vidiakot section (Yarkhun Formation and basal layers of the Vidiakot Formation, Baroghil Group). The approximate location of a previous conodont finding (sample JAT1, Talent et al., 1981, 1999) is showed. For each fossil assemblage, some representative species have been listed (including chitinozoans); the limits of the inferred stratigraphical ranges (dotted) are somewhat uncertain, as discussed in the text.

terrigenous sediments of the lower Baroghil Group (Yarkhun Formation and basal part of the Vidiakot Formation). This stratigraphic interval was first measured by one of us (M. G.) along the eastern slope of the ridge located between the Vidiakot Gully and the Baroghil depression, starting from 4050 m a.s.l.; thickness of each distinctive bed, lithology and sample location are incorporated in Fig. 2 and Appendix 1. A prominent bed (light coarse sandstone and microconglomerates) enables correlation of the section up to the crest at 4300 m a.s.l. The upper limit of the Yarkhun Formation is located along the crest, at 4305 m a.s.l. (top of bed 13; see Appendix 1).

About 100 m above the base of the section, dark splintery bioturbated siltstones alternating with very fine sandstones (37 m thick) form a prominent wall; this easy recognizable, stratigraphic interval (bed 10; Appendix 1) may comprise the arenaceous limestones, 3.6 m thick, in which Talent et al. (1981, 1999) found Ordovician conodonts.

The uppermost 16 m of the Yarkhun Formation (beds 12 and 13; Appendix 1) should correspond to the level 4 of Talent et al. (1981, p. 79).

Immediately succeeding the Yarkhun Formation are splintery black slates with siltstones nodules or with very fine sandstone intercalations. The intense cleavage in the upper part of these strata and some faulting prevent detailed thickness measurement. For this unit the term Vidiakot Formation is here proposed.

Materials, methods and repository.

Fifteen shale samples for acritarchs were collected from the lower Vidiakot section (Fig. 2; Appendix 1).

All samples were collected from shales to silty shales. Seventy grams of each sample were processed using the standard palynological method of the Palynological Laboratory of Pisa (Bagnoli et al., 1988; Albani, 1989). Organic residues, after recognition of the acritarch content, underwent a gentle oxidation using standard Schulze solution; when necessary, HNO3 proportion was slightly increased (Gray, 1965). The aim of

this procedure was to decolourize the palynomorphs for enhanced microphotography.

The palynological slides, prefixed CPT, are deposited in the collections of the "Museo di Storia Naturale e del Territorio", University of Pisa, Calci (Pisa), Italy.

In order to avoid untimely new combinations, the generic attribution of the acritarch species reported in the text is the same reported in the protologue or in the last, validly published re-combination, regardless of the taxonomic interpretation shared by the authors of the present paper. Similarly, names of subspecific acritarch taxa retain the same formal rank below the species level (ICBN art. 4) as reported in the protologue or in the last validly published new combination. Unformal or not typified taxa below the species rank are cited with the notation "*sensu*" before author's name.

Results.

Of the Yarkhun Formation samples (CK734, CK735, CK736, CK737, CK738, CK742, CK743, and CK745), only CK735 proved to be palynologically barren. Seven samples from the basal Vidiakot Formation (CK747, CK748, CK749, CK750, CK751, CK752, and CK753) proved barren with the excepture of CK747.

All palyniferous samples yielded rather abundant, dark-brown to almost opaque acritarchs.

The state of preservation varies from sample to sample. An appreciable percentage of acritarchs are strongly affected by metamorphism and pyritization, producing corrosion, deformation, and fragmentation of the vesicle. Samples CK734 and CK737 have better preserved specimens, albeit somewhat damaged. Samples CK736 and CK738-CK747 contain badly preserved acritarch specimens whose specific identification is sometimes quite difficult. The presence of a few fragments of chitinozoans is a noteworthy feature of samples CK742, CK743, and CK747.

The vertical distribution of acritarch and chitinozoan species through the sampled Vidiakot section (Fig. 3) enables definition of three distinct, stratigraphically successive, palynological assemblages (Fig. 4), as follows.

Assemblage VK1.

Description - This assemblage is characterized by the following acritarchs: *Arbusculidium filamentosum* (Vavrdová, 1965) Vavrdová, 1972, *Coryphidium bohemicum* Vavrdová, 1972, *Dactylofusa velifera* Cocchio, 1982 forma *brevis sensu* Albani, 1989, *Striatotheca rarirrugulata* (Cramer, Kanes, Díez & Christopher, 1974) Eisenack, Cramer & Díez, 1976, and *Vogtlandia flosmaris* (Deunff, 1977) Molyneux, 1987. Characteristic attributes of this assemblage include numerous diacrodians (principally referable to the *Acanthodiacrodium costatum* group), as well as the common presence of *Polygonium* spp. In addition, accompanying taxa include:

Acanthodiacrodium costatum group *sensu* Cramer, 1977
Acanthodiacrodium tasselii Martin, 1969
Adorfia firma Burmann, 1970
Ampullula erchunensis (Fang, 1986) Brocke, 1998
Arbusculidium spp.
Baltisphaeridium spp.
Barakella sp.
Buedingiisphaeridium tremadocum Rasul, 1979
Coryphidium baraka Cramer & Díez, 1976
Coryphidium elegans Cramer, Allam, Kanes & Díez, 1974
Coryphidium tadla Cramer & Díez, 1976
Cristallinium dentatum (Vavrdová, 1976) Fensome, Graham, Barss, Freeman & Hill, 1990
Cymatiogalea granulata Vavrdová, 1966
Kladothecidium eligmosum (Vavrdová, 1973) Vavrdová, 1986
Micrhystridium spp.
Multiplicisphaeridium irregulare Staplin, Jansonius & Pocock, 1965
Multiplicisphaeridium spp.
Petaloferidium bulliferum Yin, Di Milia & Tongiorgi, 1998
Petaloferidium florigerum (Vavrdová, 1977) Fensome, Graham, Barss, Freeman & Hill, 1990
Peteinosphaeridium spp.
Picostella turgida Yin, Di Milia & Tongiorgi, 1998

PLATE 1

All figures x1000.

Fig. 1, 2 - *Arbusculidium filamentosum* (Vavrdová, 1965) Vavrdová, 1972. Fig. 1) sample CK734, CPT702021-02, E.F. F43-3; Fig. 2) sample CK734, CPT702021-01, E.F. L42.
Fig. 3, 4 - *Arkonia tenuata* Burmann, 1970. Fig. 3) sample CK742, CPT702026-07, E.F. L23-3/M23-1; Fig. 4) sample CK742, CPT702026-06, E.F. M27-4/N27-2.
Fig. 5 - *Ampullula erchunensis* (Fang, 1986) Brocke, 1998. Sample CK736, CPT702023-04, E.F. N23-3.
Fig. 6 - Gen. et sp. ind. Sample CK745, CPT702028-01, E.F. Q47-4.
Fig. 7 - *Coryphidium tadla* Cramer & Díez, 1976. Sample CK734, CPT702021-01, E.F. O43-4.
Fig. 8 - *Coryphidium bohemicum* Vavrdová, 1972. Sample CK734, CPT702021-01, SEM, E.F. L38.
Fig. 9, 10, 14 - *Cristallinium dentatum* (Vavrdová, 1976) Fensome, Graham, Barss, Freeman & Hill, 1990. Fig. 9) sample CK734, CPT702021-02, SEM, E.F. L38-3; Fig. 10), sample CK734, CPT702021-01, E.F. M29-2; Fig. 14) sample CK734, CPT702021-01, E.F. G28-1.
Fig. 11 - *Coryphidium elegans* Cramer, Allam, Kanes & Díez, 1974. Sample CK734, CPT702021-01, E.F. P44-4.
Fig. 12 - *Cymatiogalea granulata* Vavrdová, 1966. Sample CK734, CPT702021-01, E.F. V40-4.
Fig. 14 - *Dactylofusa velifera* Cocchio, 1982 forma *brevis sensu* Albani, 1989. Sample CK734, CPT702021-01, E.F. T45-4/T46-3.


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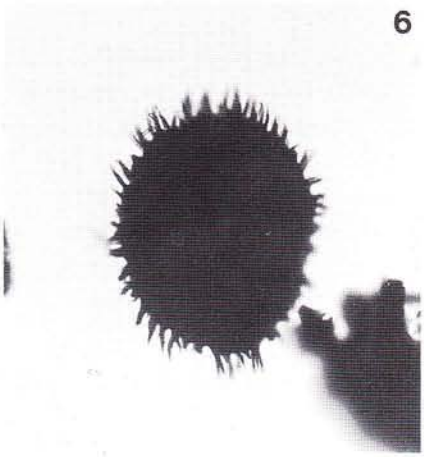
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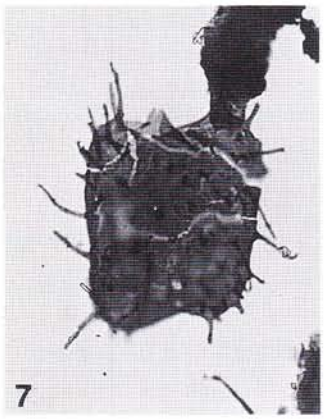
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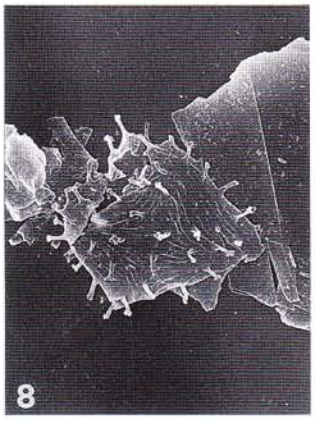
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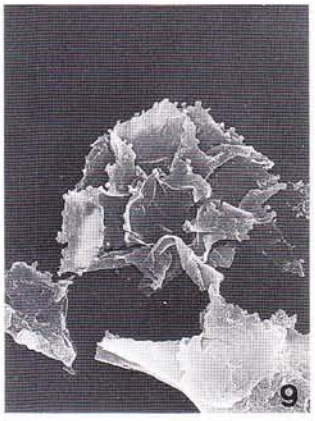
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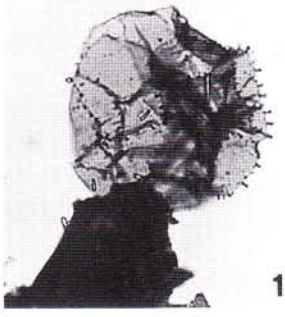
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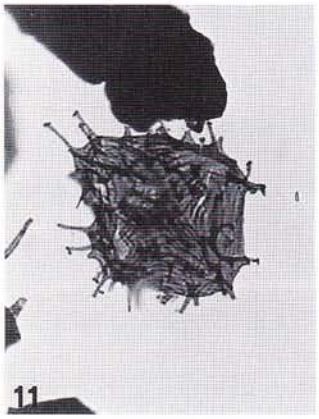
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Polygonium dentatum (Timofeev, 1959 ex Konzalová-Mazanková, 1969) Albani, 1989
Polygonium gracile Vavrdová, 1966
Polygonium radiatusum Yin, 1986
Schizodiacrodium sp. cf. *S. ramiferum* Burmann, 1968
Schizodiacrodium sp.
Stellechinatum uncinatum (Downie, 1958) Molyneux, 1987
Stelliferidium stelligerum (Górka, 1967 emend. Martin, 1972) emend. Deunff, Górka & Rauscher, 1974
Striatotheca microrugulata (Vavrdová, 1972) Martin, 1977
Striatotheca monorugulata Yin, Di Milia & Tongiorgi, 1998
Striatotheca principalis Burmann, 1970 subsp. *parva* (Burmann, 1970) Martin, 1977
Striatotheca rugosa Tongiorgi, Yin & Di Milia, 1995
Tongzia meitana Li, 1987
Tongzia vavrdovae Yin, Di Milia & Tongiorgi, 1998
Vavrdovella areniga (Vavrdová, 1973) Loeblich & Tappan, 1976
Veryhachium trispinosum (Eisenack, 1938) Stockmans & Willière, 1962
Veryhachium spp.
Villosacapsula ? sp.

Occurrence - Samples yielding assemblage VK1 come from the lowermost part of the Yarkhun Formation, transgressively overlying the Ishkarwaz Granodiorite, as follows: sample CK734 (6.30 m above section base); sample CK736 (16 m); sample CK737 (about 20 m); sample CK738 (from the same bed of sample CK737, laterally and roughly at the same level).

Assemblage VK2.

Description - Assemblage VK2 is characterized by the first occurrence of the acritarchs *Arkonia tenuata* Burmann, 1970, *Aureotesta clathrata* Vavrdová, 1972 var. *simplex* (Cramer, Kanes, Díez & Christopher, 1974) Brocke, Fatka & Servais, 1997, *Dicrodiacrodium ancoriforme* Burmann, 1968 emend. Servais, Brocke & Fatka, 1996, and *Orthosphaeridium* sp. [possibly referable to *O. ternatum* (Burmann, 1970) Eisenack, Cramer & Díez, 1976].

In addition, the following taxa also appear in assemblage VK2: *Cymatiogalea deunffii* Jardiné, Combaz, Magloire, Peniguel & Vachey, 1974, *Multiplicisphaeridium* sp. cf. *M. delicatum* Cramer & Diez, 1977, *M.* sp. cf. *M. inconstans* Cramer & Díez, 1977, *Poikilofusa spinata* Staplin, Jansonius & Pocock, 1965, and *Striatotheca* sp. cf. *S. prolixa* Molyneux in Molyneux & Rushton, 1988. Further characteristic attributes of this assemblage include abundant diacrodians of the *Acanthodiacrodium costatum* group, together with common *Stelliferidium stelligerum*, *Striatotheca* spp., and *Veryhachium trispinosum*. Twenty-two taxa are shared with the previous assemblage (Fig. 3).

Assemblage VK2 also yielded the following chitinozoans:

Conochitina sp. cf. *C. chydaea* Jenkins, 1967
Conochitina sp. cf. *C. decipiens* Taugourdeau & de Jekhowsky, 1960
Belonechitina sp.
Conochitina sp.
Lagenochitina sp. cf. *L. esthonica* Eisenack, 1955
Laufeldochitina sp.

Occurrence - This assemblage characterizes sample CK742 and CK743, both from the middle part of the Yarkhun Formation, 79.40 m and 86.10 m above the section base, respectively.

Assemblage VK3.

Description - This assemblage is very poor in both taxonomic diversity and preservation state. Owing to the poor state of preservation and the small number of specimens recorded, a specific attribution is precluded in most cases. The most significant fossils are the acritarch *Arkonia tenuata* and the chitinozoan *Lagenochitina esthonica* Eisenack, 1955. In addition, VK3 contains abundant *Stelliferidium stelligerum* (together with the unidentified taxon illustrated in Pl. 1, fig. 6) and is characterized by the absence of many Arenigian acritarchs, in particular diacromorphs, while veryhachiids are extremely rare. Few specimens of *Pachysphaeridium* sp. occur. All species which have been fully identified (4 out of 13) are shared with previous assemblages (Fig. 3). Accompanying taxa are:

Baltisphaeridium spp.
Multiplicisphaeridium spp.
Peteinosphaeridium spp.
Polygonium sp.
Veryhachium spp.
Villosacapsula ? sp.

Occurrence - Assemblage VK3 characterizes sample CK745, close to the top of the Yarkhun Formation (ca. 166.50 m above the section base) and sample CK747, 2 m above the base of the Vidiakot Formation (ca. 172 m above the section base).

Age of the acritarch assemblages.

Assemblage VK1.

The age attribution of assemblage VK1 may be attempted by considering the palaeontologically ascertained, restricted ranges (i.e., the ranges independently confirmed by the co-occurence of other fossils) of the following taxa.

The range of *Cristallinium dentatum* extends from the Chinese *Azygograptus suecicus* graptolite Zone (Li, 1987) - equivalent to the British *Didymograptus nitidus* and lower *Isograptus gibberulus* graptolite Zones (Wang, X.f. et al., 1992; Wang, Z.-h. et al., 1996; Wang, X.f. et al., 1996; Chen et al., 1997) - up to the Bohemian (Vavrdová, 1976) *Tetragraptus* cf. *pseudobigsbyi* graptolite Zone of Kraft (1977). The latter corresponds to the *T. reclinatus abbreviatus* graptolite Zone of Boucek (1973; revised by Kraft & Kraft, 1995) which embraces the

ACRITARCH / CHITINOZOAN SPECIES	SAMPLES							
	CK 734	CK 736	CK 737	CK 738	CK 742	CK 743	CK 745	CK 747
Acanthodiacrodium costatum group	A		F		A	R		
Acanthodiacrodium tasselii	R		RR		R			
Arbusculidium filamentosum	A	R	R	RR				
Arbusculidium spp.	C	R		R	RR			
Barakella sp.	RR							
Buedingiisphaeridium tremadocum	C	F	F	R	R	R		
Coryphidium bohemicum	A	F	A	RR	RR	?		
Coryphidium elegans	C	F	R					
Cristallinium dentatum	A	R	R					
Cymatiogalea granulata	A	R	R			R		
Dactylofusa velifera forma *brevis*	A	R	R	F	F	RR		
Petaloferidium florigerum	C	R	R	C				
Peteinosphaeridium spp.	RR	RR	R	R	R		F	R
Picostella turgida	A	R	R	F	R			
Polygonium dentatum	A					F		
Polygonium gracile	A		F			R		
Polygonium radiatusum	C					F		
Schizodiacrodium sp.	RR		R					
Stellechinatum uncinatum	R	RR	RR	RR			R	
Stelliferidium stelligerum	A			F	F	A	A	A
Striatotheca microrugulata	F	R	F		RR			
Striatotheca principalis subsp. *parva*	R	R	F	R	RR			
Striatotheca rarirrugulata	R	A	A	A	A	R		
Tongzia meitana	R			F				
Tongzia vavrdovae	F			RR				
Vavrdovella areniga	F	RR	R					
Veryhachium spp.	C							A
Vogtlandia flosmaris	C	F	R					
Ampullula erchunensis		RR						
Coryphidium baraka		RR						
Kladothecidium eligmosum		RR						
Petaloferidium bulliferum		R		F	RR			
Micrhystridium spp.		C	C	F	C			R
Multiplicisphaeridium spp.		R	R				F	
Schizodiacrodium sp. cf. *S. ramiferum*		R	R					
Striatotheca monorugulata		RR	F	C	F	R		
Striatotheca rugosa		C	C	RR	R			
Adorfia firma			R					
Baltisphaeridium spp.			F	R			A	A
Coryphidium tadla			RR					
Multiplicisphaeridium irregulare				F			C	
Veryhachium trispinosum				A	R	F		
Villosacapsula ? sp.				C	R	R	R	
Arkonia tenuata					A		R	
Aurotesta clathrata var. *simplex*					R	R		
Cymatiogalea deunffii					R			
Dicrodiacrodium ancoriforme					F			
Multiplicisphaeridium sp. cf. *M. delicatum*					A			
Orthosphaeridium sp.					R			
Poikilofusa spinata					F			
Multiplicisphaeridium sp. cf. *M. inconstans*						R		
Petaloferidium sp. cf. *P. florigerum*						RR		
Striatotheca sp. cf. *S. prolixa*						RR		
Striatotheca spp.						F		
Gen. et sp. ind.							A	
Pachysphaeridium sp.							F	
Polygonium sp.								R
Conochitina sp. cf. *C. chydaea*					R			
Conochitina sp. cf. *C. decipiens*					R			
Conochitina sp.					R	R		
Lagenochitina sp. cf. *L. esthonica*					R			
Laufeldochitina sp.					R			
Belonechitina sp.						R		
Lagenochitina esthonica								R
PALYNOLOGICAL ASSEMBLAGES	VK 1				VK 2		VK 3	

Fig. 3 - Acritarch and chitinozoan occurrence (by first appearance) and relative abundance throughout the lower Vidiakot section. RR: very rare (1-2 specimens in each slide); R: rare (3-5 specimens); F: few (6-10 specimens); C: common (11-20 specimens); A: abundant (more than 20 specimens); ?: questionably present.

British *gibberulus*- plus almost the entire *hirundo* graptolite Zone of the British standard (Paris & Mergl, 1984; Kraft & Kraft, 1995). Thus, the actual LAD of *C. dentatum* still remains largely undefined.

Kladothecidium eligmosum has the same range, because it has been reported as extending in Bohemia (Vavrdová, 1993) from the early Arenig *Hologratpus tardibrachiatus* graptolite Zone - corresponding to the British *nitidus* graptolite Zone (Paris & Mergl, 1984; Kraft & Kraft, 1995) - to the *T. reclinatus abbreviatus* graptolite Zone.

A wider range has been ascertained for *Petaloferidium florigerum* which is known from the *A. suecicus* graptolite Zone (British *nitidus* and lower *gibberulus* graptolite Zones) of South China (Li, 1987) up to the upper *Didymograptus artus* graptolite Zone of Germany (Maletz & Servais, 1993).

Striatotheca rarirrugulata is positively known from the *A. suecicus* graptolite Zone of South China (Tongiorgi et al., 1995) up to the *D. hirundo* graptolite Zone of Great Britain (Rushton & Molyneux, 1989; Cooper et al., 1995).

Similarly, the range of *Striatotheca monorugulata* is between the *A. suecicus* and the lower *Undulograptus austrodentatus* graptolite Zone (i.e., up to the British upper *hirundo* graptolite Zone, according to Chen et al., 1997, among others) of South China (Yin et al., 1998; Tongiorgi et al., 1998).

According to Yin et al. (1998), *T. vavrdovae* has been reported in Central Bohemia from the early Arenig *H. tardibrachiatus* graptolite Zone; its upper chronological limit is considered to be latest early Arenig-early late Arenig (probably younger than the *Eremochitina brevis* chitinozoan Zone) based on occurrence of Karakorum (Tongiorgi et al., 1994). *T. meitana* has a more restricted

range, which is bracketed between the Chinese *Didymograptus deflexus* graptolite Zone (Li, 1987) and the *A. suecicus* graptolite Zone (Li, 1987), not younger than the British middle *gibberulus* graptolite Zone. Nevertheless, both these latter species are rather rare and not very well known outside China.

In summary, therefore, the palynological available evidence dates the assemblage VK1 as Arenig, within an interval extending from the British nitidus to the middle-upper *hirundo* graptolite Zones. The occurrence of Tongzia species might suggest a more restricted range, correlative within the *D. nitidus* and the middle *I. gibberulus* zonal interval (Fig. 4). The palynological age of the succeeding assemblage supports this chronological attribution.

Assemblage VK2.

Dating of sample CK742 is facilitated by the restricted ranges of *Arkonia tenuata*, *Dicrodiacrodium ancoriforme*, and *Striatotheca rarirrugulata*.

According to Servais (1997), the first occurrence of *Arkonia* Burmann, 1970 approximately corresponds to the British *D. hirundo* graptolite Zone (Brocke et al., 1995); this is confirmed by the co-occurrence of chitinozoans referred to the *Desmochitina bulla* chitinozoan Zone (Soufiane & Achab, 1993; Fatka et al., 1994).

Dicrodiacrodium Burmann, 1968 first occurs in the upper *Undulograptus sinodentatus/Didymograptus nexus* graptolite Zone of South China (Brocke et al., 1995) which is considered (Servais et al., 1996) roughly equivalent to the British middle-upper *gibberulus* graptolite Zone. However, taking into account the graptolite biostratigraphy of the South Chinese upper Arenig (GSSP of Darriwilian) as revised by Chen et al. (1997), the top of the *U. sinodentatus-D. nexus* graptolite Zone (*U. sinodentatus* Zone in Brocke et al., 1995, fig. 2) - corresponding to the base of the *U. austrodentatus* graptolite Zone - falls within the British lower *hirundo* graptolite Zone. Therefore, the FAD of *Dicrodiacrodium* is probably early late Arenig.

Striatotheca rarirrugulata, as previously discussed in assemblage VK1, disappears before the end of the *D. hirundo* graptolite Zone of Great Britain (Rushton & Molyneux, 1989; Cooper et al., 1995).

The presence of rare specimens of *Cymatiogalea deunffii*, previously known from the Tremadoc-Arenig boundary interval (Servais & Molyneux, 1997), is possibly due to reworking. The same significance may have the (questionable) presence of *Striatotheca* sp. cf. *S. prolixa* in sample CK743.

Compared with CK742, sample CK743 shows lower diversity and no significant new taxa inception. For example, *Aureotesta clathrata* var. *simplex* appears in Great Britain in the upper *Tetragraptus phyllograptoides* graptolite Zone (Cooper et al., 1995) and continues to the early Llanvirn *D. artus* graptolite Zone of Belgium (Servais & Maletz, 1992); *Striatotheca monorugulata* has a shorter range which extends up to the lower *U. austrodentatus* graptolite Zone of South China (Yin et al., 1998; Tongiorgi et al., 1998). The presence of the chitinozoans *Conochitina* sp. and *Belonechitina* sp. does not provide any further chronological evidence.

In summary, therefore, the age of assemblage VK2 probably falls entirely within the early late Arenig *hirundo* graptolite Zone (Fig. 4).

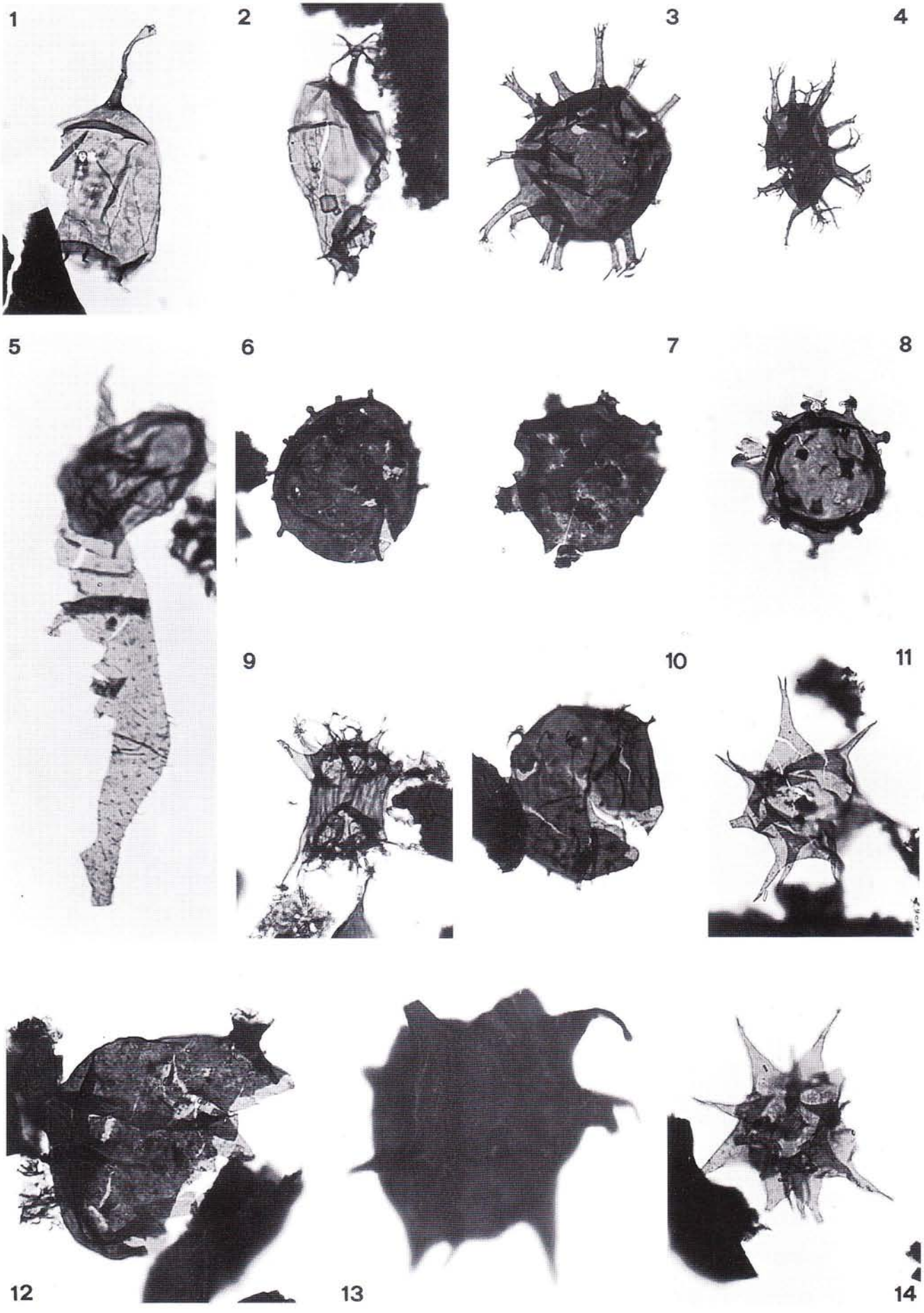
Assemblage VK3.

Chronologically, the most significant elements of assemblage VK3 are the acritarch *Arkonia tenuata* and the chitinozoan *Lagenochitina esthonica*. The first appears during the late Arenig and also extends into the early Llanvirn; the second, has been recorded worldwide from the lower Arenig to the lowermost Llanvirn (Paris, 1996).

PLATE 2

All figures x1000.

Fig. 1, 2 - *Dicrodiacrodium ancoriforme* Burmann 1968 emend Servais, Brocke & Fatka 1996. Fig. 1) sample CK742, CPT702026-06, E.F. Y29-2; Fig. 2) sample CK742, CPT702026-01, E.F. R39-3.
Fig. 3 - *Multiplicisphaeridium* sp. cf. *M. delicatum* Cramer & Díez, 1977. Sample CK742, CPT702026-02, E.F. L48-1.
Fig. 4 - *Multiplicisphaeridium irregulare* Staplin, Jansonius & Pocock, 1965. Sample CK738, CPT702025-02, E.F. Q54.
Fig. 5 - *Poikilofusa spinata* Staplin, Jansonius & Pocock, 1965. Sample CK742, CPT702026-01, E.F. N39-1.
Fig. 6 - *Petaloferidium bulliferum* Yin, Di Milia & Tongiorgi, 1998. Sample CK738, CPT702025, E.F. P44.
Fig. 7 - *Petaloferidium* sp. cf. *P. florigerum* (Vavrdová, 1977) Fensome, Graham, Barss, Freeman & Hill, 1990. Sample CK743, CPT702027, E.F. O33-3/P33-1.
Fig. 8 - *Petaloferidium florigerum* (Vavrdová, 1977) Fensome, Graham, Barss, Freeman & Hill, 1990. Sample CK737, CPT702024-03, E.F. R33.
Fig. 9 - *Schizodiacrodium* sp. cf. *S. ramiferum* Burmann, 1968. Sample CK737, CPT702024-03, E.F. K43.
Fig. 10 - *Schizodiacrodium* sp. Sample CK734, CPT702021-02, E.F. Y42-2.
Fig. 11, 14 - *Picostella turgida* Yin, Di Milia & Tongiorgi, 1998. Fig. 11) sample CK734, CPT702021-01, E.F. J34-4; Fig. 14) sample CK734, CPT702021-01, E.F. O42.
Fig. 12 - *Orthosphaeridium* sp. Sample CK742, CPT702026-02, E.F. M38.
Fig. 13 - *Pachysphaeridium* sp. Sample CK745, CPT702028-01, E.F. J31-4.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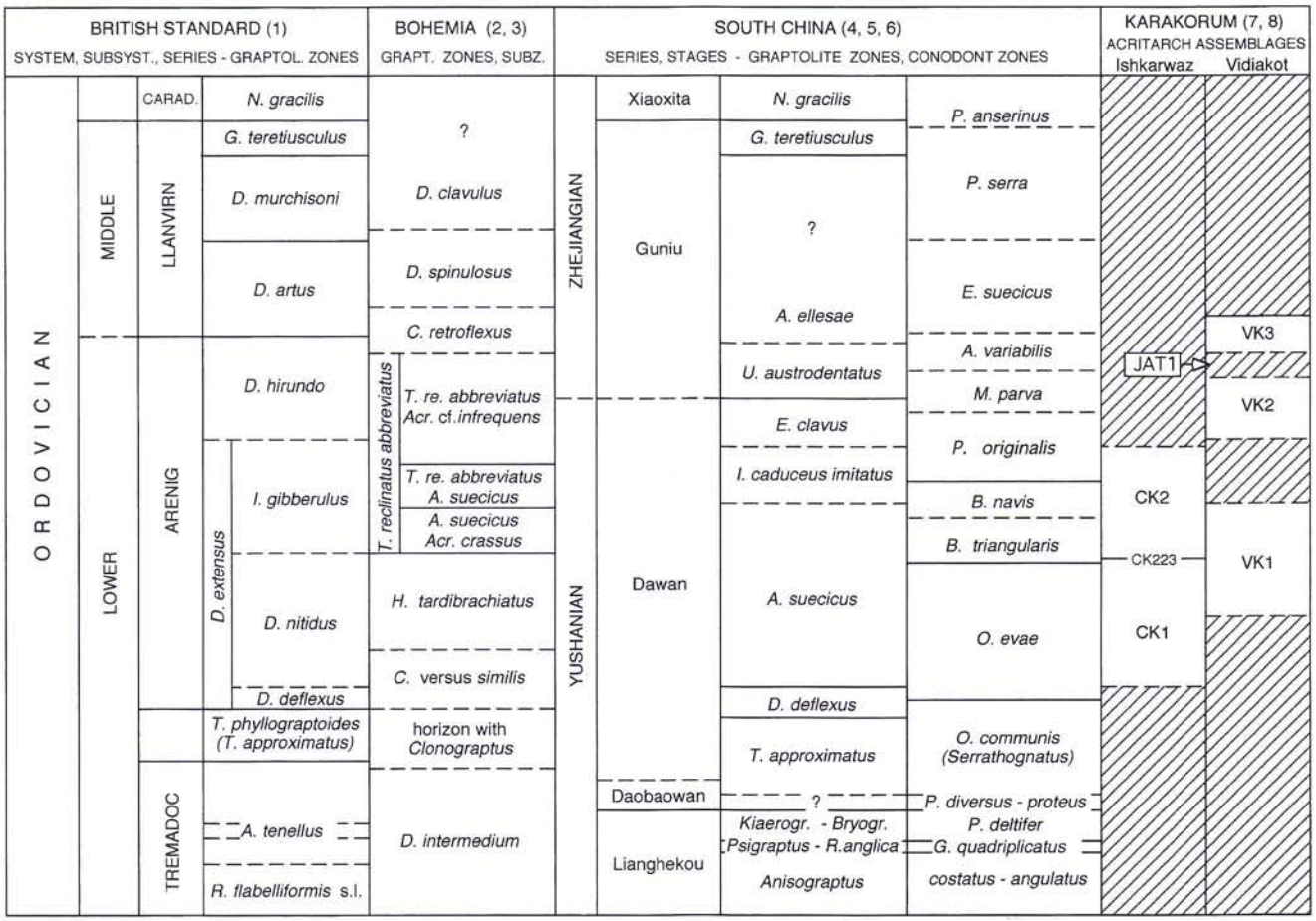

Fig. 4 - Comparison of the Ishkarwaz and Vidiakot sections, (Northern Karakorum, Chitral) and Lower Ordovician, interregional, chronostratigraphic and biostratigraphic correlations. Main bibliographic sources: a) Great Britain: 1) Fortey et al., 1995; b) Bohemia: 2) Paris & Mergl, 1984, 3) Kraft & Kraft, 1995; c) South China: 4) Wang, X.f. et al., 1992, 5) Chen et al., 1997, 6) Wang, X.f. et al., 1996. JAT1 indicates the probable location of a sample bearing Ordovician conodonts (Talent et al., 1981, 1999); CK1, CK223, CK2 are the palynological assemblages from the Iskarwarz section, Karakorum (Tongiorgi et al., 1994); VK1 to VK3 are the assemblages described herein.

PLATE 3

All figures x1000, except Fig. 14 (x200) and Fig. 5 (x2000).

Fig. 1 - *Schizodiacrodium* sp. cf. *S. ramiferum* Burmann, 1968. Sample CK737, CPT702024-02, E.F. O43-2.
Fig. 2 - *Stelliferidium stelligerum* (Górka, 1967 emend. Martin, 1972) emend. Deunff, Górka & Rauscher, 1974. Sample CK734, CPT702021-01, E.F. V40-4.
Fig. 3 - *Striatotheca monorugulata* Yin, Di Milia & Tongiorgi, 1998. Sample CK742, CPT702026-01, E.F. U36.
Figs. 4, 7- *Striatotheca principalis* Burmann, 1970 subsp. *parva* (Burmann, 1970) Martin, 1977. Fig. 4) sample CK738, CPT702025-02, E.F. K45; Fig. 7) sample CK737, CPT702024, E.F. G50-2.
Fig. 5 - *Striatotheca rarirrugulata* (Cramer, Kanes, Díez & Christopher, 1974) Eisenack, Cramer & Díez, 1976. Sample CK742, CPT702026, SEM, E.F. S37.
Fig. 6 - *Striatotheca rugosa* Tongiorgi, Yin & Di Milia, 1995. Sample CK736, CPT702023, E.F. R44.
Fig. 8 - *Striatotheca microrugulata* (Vavrdová, 1972) Martin, 1977. Sample CK742, CPT702026-06, E.F. R38-1.
Fig. 9 - *Vogtlandia flosmaris* (Deunff, 1977) Molyneux, 1987. Sample CK734, CPT702021, E.F. F34.
Fig. 10 - *Vavrdovella areniga* (Vavrdová, 1973) Loeblich & Tappan, 1976. Sample CK734, CPT702021-01, E.F. N47-2.
Fig. 11 - *Tongzia vavrdovae* Yin, Di Milia & Tongiorgi, 1998. Sample CK734, CPT702021-01, E.F. N53.
Fig. 12 - *Tongzia meitana* Li, 1987. Sample CK738, CPT702025-01, E.F. T42-4.
Fig. 13 - *Villosacapsula* ? sp. Sample CK738, CPT702025, E.F. K24-1.
Fig. 14 - *Lagenochitina esthonica* Eisenack, 1955. Sample CK747, CPT702028-01, E.F. Y52.


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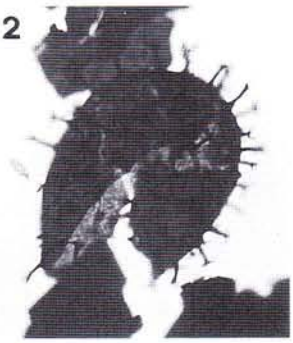
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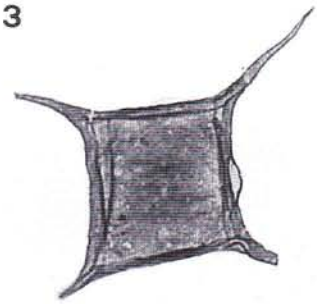
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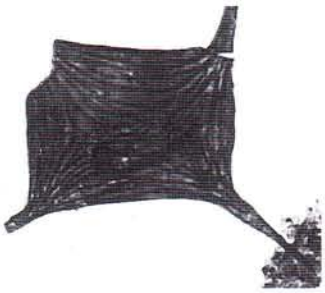
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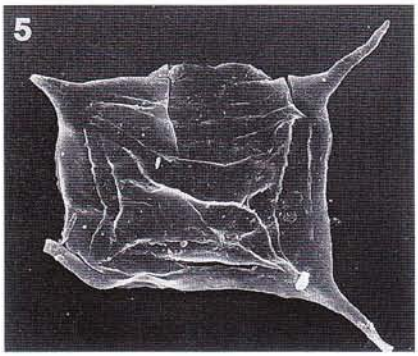
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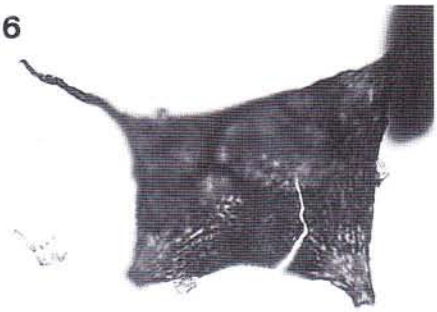
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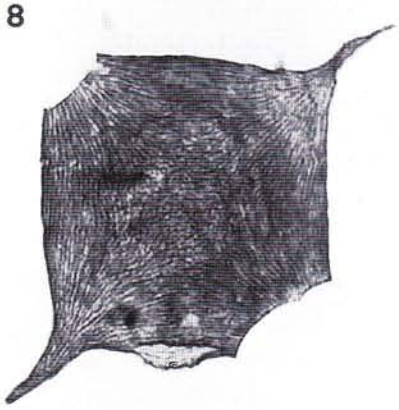
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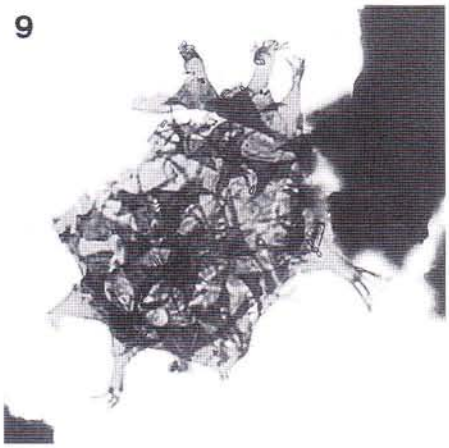
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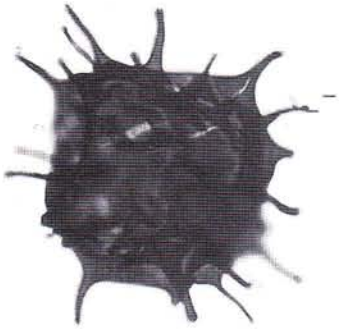
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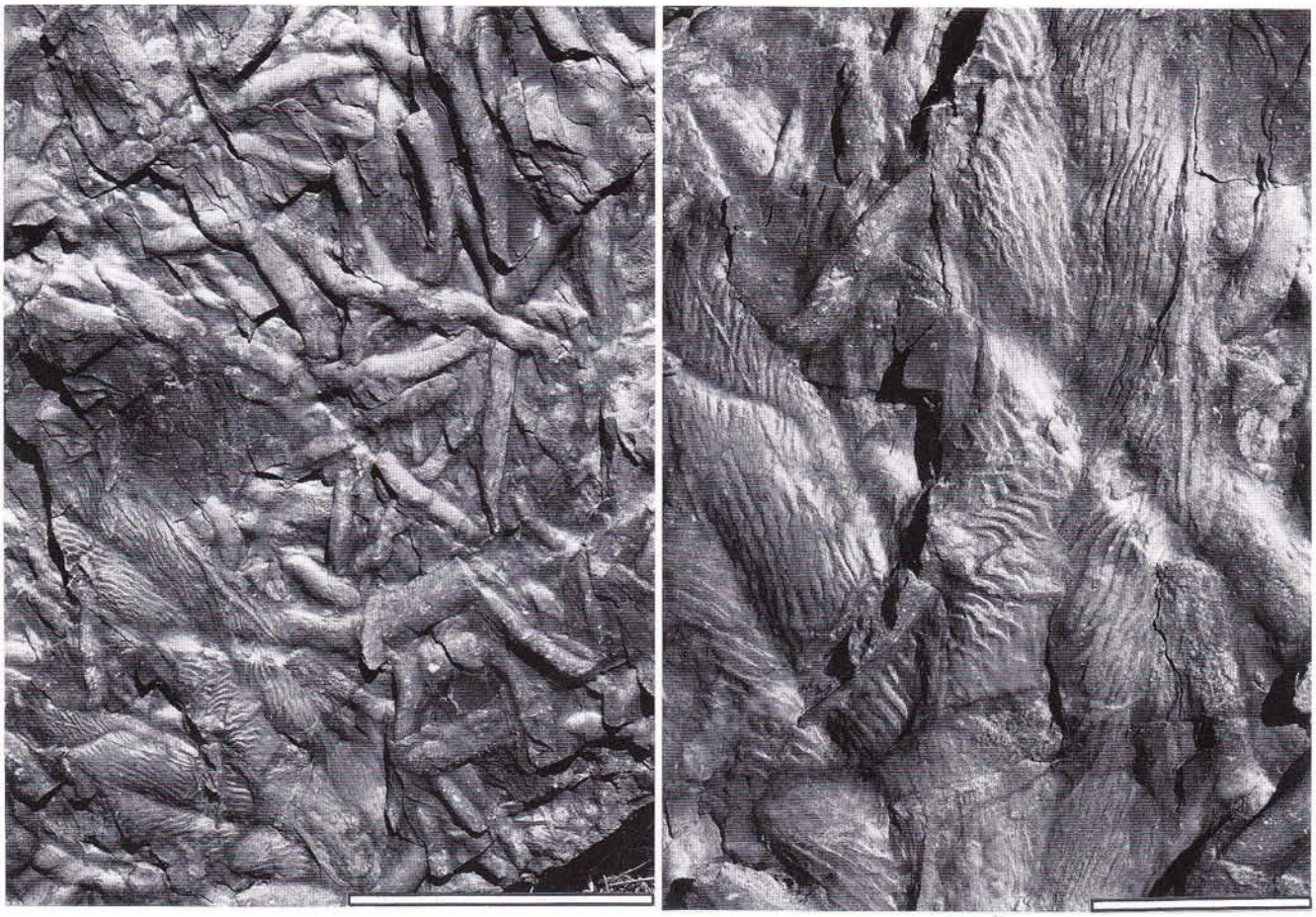

Fig. 5 - *Cruziana* and *Planolites*-like burrows from the bed 7. To the left, view of the entire slab; the scale bar is equivalent to 10 cm. To the right, details of the *Cruziana* trails, scale bar equivalent to 5 cm. The entire slab is preserved in the Geoscience Laboratory of the Geological Survey of Pakistan, Islamabad. (Collector M. Gaetani).

As noted by several authors (Paris, 1984, 1996), at least two morphotypes (possibly two species) of *L. esthonica* s.l. can be distinguished. The "short-necked "specimens seem to be restricted to the lower-"middle" Arenig; "long-necked" specimens, such as the one in sample CK747, are reported only from the upper Arenig to lower Llanvirn (Paris, 1996, p. 531). Accordingly, sample CK747 is probably referable to an interval between the British late Arenig *D. hirundo* graptolite Zone and the lowermost Llanvirn, basal *D. artus* graptolite Zone (Paris, 1996, text-fig.2).

No direct palynological evidence support separation of VK3 from the previous assemblage. Nevertheless, the assemblage VK3 is separated from the previous one by more than 80 m. This unsampled interval comprises the bed JAT1 where Talent (Talent et al., 1981, 1999) collected Ordovician conodonts (within our bed 10). According to Talent et al. (1999), the most significant taxon of their conodont fauna [*Baltoniodus* sp. cf. *B. medius* (Dzik, 1976)] possibly indicates an interval ranging from Lindström's (1971) *variabilis* to upper *suecicus* conodont Zones (latest Arenig - lower Llanvirn).

Because the age of the overlying beds which yielded assemblage VK3 does not postdate the lowermost *artus* graptolite Zone (LAD of the chitinozoan *Lagenochitina esthonica*), VK3 is probably assignable just within the Arenig-Llanvirn boundary interval.

Correlation with the Ishkarwaz Section.

It is now possible to further refine the stratigraphic ranges of the Ishkarwaz assemblages CK1 and CK2 (Tongiorgi et al., 1994). According to Tongiorgi et al. (1994), the base of CK1 is marked by the concomitant occurrence of *C. dentatum* and *C. deunffii*. The South China inception of *C. dentatum* is within the *A. suecicus* graptolite Zone (Li, 1987); according to recent biostratigraphical correlations (see Fig. 4), the *A. suecicus* graptolite Zone corresponds to the entire nitidus and to a part of the *gibberulus* graptolite Zones of Great Britain. Thus, with respect to Tongiorgi et al.'s (1994) correlation, the lower limit of CK1 could now be shifted downwards, to the base of the nitidus graptolite Zone. On the other hand, *C. deunffii* is considered to be not younger than the lowermost Arenig (Servais &

Molyneux, 1997). The three lowermost samples from Ishkarwaz (CK219, CK220, CK221) fall within the total range of *C. deunffii*; therefore, it could be justified to tentatively locate the lower limit of the Ishkarwaz sequence at the base of the British *nitidus* graptolite Zone.

Sample CK223 contains *Eremochitina brevis* Benoit & Tougourdeau, 1961 whose FAD (not older than the upper part of the *nitidus* graptolite Zone; Paris, 1990) places CK223 close to or at the top of the British *nitidus* graptolite Zone.

The CK2 assemblage comprises only long-ranging species which do not enable identification of the assemblage's upper limit. The absence of typical late Arenigian markers, like *Arkonia* and *Dicrodiacrodium*, suggests a pre-*hirundo* age (Tongiorgi et al., 1994).

The resulting tentative correlation is shown in Fig. 4.

Palaeoprovincial affinity.

The occurrence of acritarch species belonging to *Arbusculidium*, *Coryphidium* and *Striatotheca* unambiguously supports the attribution of assemblages VK1 and VK2 to the Mediterranean Palaeoprovince as first defined in 1974 by Vavrdová (discussion and bibliography in Tongiorgi & Di Milia, 1999). The composition of VK3 does not contrast with a Mediterranean pertinence.

Conclusions.

This study of the lower part of the Vidiakot section enhances our knowledge regarding the age of the sedimentary sequence overlying the crystalline basement of the Karakorum Mountains. Correlation with other areas and with the previously studied Ishkarwaz section (upper Yarkhun Valley, Chitral) enables the authors the Yarkhun Formation to be approximately dated as early Arenig (British lower *nitidus* graptolite Zone) to latest Arenig, uppermost graptolite *hirundo* Zone; accordingly, the base of the overlying Vidiakot Formation is here correlated with the uppermost *hirundo*-lowermost *artus* graptolite Zones (latest Arenig - earliest Llanvirn boundary interval).

Compared with the Ishkarwaz section and based on the older fossiliferous levels, the Vidiakot section apparently begins stratigraphically higher. The apparent diachroneity of the transgressive base of the sedimentary cover may be explicated by the coarser lithology in the lowermost part of the Vidiakot section (6 m of coarse arkosic sandstone at Vidiakot, against only 1.1 m of polygenic microconglomerates in the Ishkarwaz section). A study of the *Cruziana*-like ichnofossils from beds 5 and 7 (Fig. 5) could hopingly provide further elements for a more refined palaeoecological interpretation of this part of the Vidiakot section (Yarkhun Formation).

Acknowledgements

Grateful acknowledgement is expressed to G. Playford (Queensland University, Australia) and T. Servais (Lille University, France) for accurate refereeing and profitable suggestions. Particular thanks are also expressed to the following members of the Department of Earth Sciences, Pisa University: Dr. Roberto Albani for identification of the chitinozoans and for assistance and advice with SEM; prof. Adolf Seilacher, Tübingen, for trace fossil identification; Mr. Giorgio Misuri for palynological preparations and Mr. Marcello Gini for photographic printing. This research was supported by the MURST grant "Biodiversificazione e provincialismo di acritarchi e conodonti dell'Arenigiano-Llanvirniano in relazione a variazioni climatiche e paleogeografiche" ("Cofinanziato" 1997, Local Coordinator M. Tongiorgi; National Leader A. Farinacci, Roma University).

REFERENCES

Albani R. (1989) - Ordovician (Arenigian) acritarchs from the Solanas Sandstone Formation, Central Sardinia, Italy. *Boll. Soc. paleontol. Ital.*, v. 28, n. 1, pp. 3-37, Modena.

Bagnoli G., Stouge S. & Tongiorgi M. (1988) - Acritarchs and conodonts from the Cambro-Ordovician Furuhäll (Köpingsklint) section (Öland, Sweden). *Riv. ital. Paleontol. Stratigr.*, v. 94, pp. 163-248, Milano.

Boucec B. (1973) - Lower Ordovician graptolites of Bohemia. V. of 185 pp., Czech. Acad. Sci., Praha.

Brocke R., Fatka O., Molyneux S.G. & Servais T. (1995) - First appearance of selected Early Ordovician acritarch taxa from peri-Gondwana. In Cooper J.D., Droser M.L. & Finney S.C. (eds.) - Ordovician Odyssey: short papers for the Seventh International Symposium on the Ordovician System. Pacific Sect. Soc. sediment. Geol. (SEPM), pp. 473-476, Fullerton, Californa, U.S.A.

Chen X., Mitchell C.E., Zhang Y.-D., Wang Z.-H., Bergström S.M., Winston D. & Paris F. (1997) - GSSP of Darriwilian (Middle Ordovician) in China. *Acta Palaeontol. sinica*, v. 36, pp. 423-431, Beijing.

Cooper A.H., Rushton A.W.A., Molyneux S.G., Hughes R.A., Moore R.A. & Webb B.C. (1995) - The stratigraphy, correlation provenance and palaeogeography of the Skiddaw Group (Ordovician) in the English Lake District. *Geol. Mag.*, v. 132, pp. 185-211, Cambridge.

Fatka O., Kraft J. & Kraft P. (1994) - Paleontological-stratigraphical relations on the Arenig-Llanvirn boundary in the Prague Basin (Ordovician, Bohemia). 2nd International Meeting IGCP n. 351, pp. 35-36 (cited in Brocke R., Fatka O., Molyneux S.G. & Servais T., 1995).

Fortey R.A., Harper D.A.T., Ingham J.K., Owen A.W. & Rushton A.W.A. (1995) - A revision of Ordovician series and stages from the historical type area. *Geol. Mag.*, v. 132, pp. 15-30, Cambridge.

Gaetani M., Le Fort P., Tanoli S., Angiolini L., Nicora A., Sciunnach D. & Asif K. (1996) - Reconnaissance geology in Upper Chitral, Baroghil and Karambar districts (Northern Karakorum, Pakistan). *Geol. Rdsch.*, v. 85, pp. 683-704, Stuttgart.

Gray J. (1965) - Extraction techniques. In Kummel B. & Raup D. (eds.) - Handbook of Paleontological Techniques, 852 pp., Freeman & Co., San Francisco.

Harland W.B., Armstrong R.L., Cox A.V., Smith A.G. & Smith D.G. (1989) - A geologic time scale, 263 pp., Cambridge Univ. Press, Cambridge.

Kazmi A.H. & Qasim J.M. (1997) - Geology and tectonics of Pakistan, 544 pp., Graphic Publishers, Karachi.

Kraft J. (1977) - Graptolites from the Klabava Formation (Arenigian) of the Ordovician of Bohemia. *Folia Mus. Rerum nat. Bohemiae Occident., Geol.*, v. 6, pp.1-31, Plzen.

Kraft J. & Kraft P. (1995) - Biostratigraphy of the Klabava and Sarka Formations (Bohemia, Lower Ordovician). A brief overwiew of new investigations. *Acta Univ. Carolinae*, v. 1-2, pp. 23-29, Praha.

Le Fort P., Tongiorgi M. & Gaetani M. (1994) - Discovery of crystalline basement and Early Ordovician marine transgression in the Karakorum Mountain Range. *Geology*, v. 28, pp. 941-944, Boulder, Colorado.

Li J. (1987) - Ordovician acritarchs from the Meitan Formation of Guizhou Province, South-West China. *Palaeontology*, v. 30, pp. 613-634.

Lindström M. (1971) - Lower Ordovician conodonts of Europe. *Geol. Soc. Amer., Mem.*, v. 127, pp. 21-61, Boulder, Colorado.

Maletz J. & Servais T. (1993) - Acritarchs and graptolites from the Early Llanvirn (Ordovician) of the Herscheider Schichten (Rheinisches Schiefergebirge, Germany). *N. Jb. Geol. Paläont., Abh.*, v. 190, n. 1, pp. 125-142, Stuttgart.

Mitchell C.E., Xu C., Bergström S.M., Yuan-dong Z., Zhi-hao W., Webby B.D. & Finney S.C. (1997) - Definition of a global boundary stratotype for the Darriwilian stage of the Ordovician system. *Episodes*, v. 30, pp. 158-166, Antwerpen.

Paris F. (1990) - The Ordovician chitinozoan biozones of the northern Gondwana Domain. *Rev. Palaeobot. Palynol.*, v. 166, pp. 181-209, Amsterdam.

Paris F. (1996) - Chitinozoan biostratigraphy and palaeoecology. In Jansonius J. & McGregor D.C. (eds.) - Palynology: Principles and applications, v. 2., n. 17, pp. 531-552. Amer. Assoc. stratigr. Palynolsts. Found., Publ. Press, Salt Lake City, Utah.

Paris F. & Mergl M. (1984) - Arenigian chitinozoans from the Klabava Formation, Bohemia. *Rev. Palaeobot. Palynol.*, v. 43, pp. 33-65, Amsterdam.

Rushton A.W.A. & Molyneux S.G. (1989) - The biostratigraphic age of the Ordovician Skiddaw Group in the Black Combe Inlier, English Lake District. *Proc. Yorkshire geol. Soc.*, v. 47, pp. 267-276, Leeds.

Searle M.P. (1991) - Geology and Tectonics of the Karakoram Mountains, 358 pp., J. Wileys & Sons, London.

Servais T. (1997) - The Ordovician *Arkonia-Striatotheca* acritarch plexus. *Rev. Palaeobot. Palynol.*, v. 98, pp. 47-79, Amsterdam.

Servais T., Brocke R. & Fatka O. (1996) - Variability in the Ordovician acritarch *Dicrodiacrodium*. *Palaeontology*, v. 39, pp. 389-405, London.

Servais T. & Maletz J. (1992) - Lower Llanvirn (Ordovician) graptolites and acritarchs from the "assise de Huy", Bande de Sambre-et-Meuse, Belgium. *Ann. Soc. géol. Belgique*, v. 115, pp. 265-285, Liège.

Servais T. & Molyneux S.G. (1997) - The messaoudensis-trifidum acritarch assemblage (Ordovician: late Tremadoc - early Arenig) from subsurface of Rügen (Baltic Sea, NE Germany). *Palaeontographia Italica*, v. 84, pp. 113-161, Pisa.

Soufiane A. & Achab A. (1993) - Quelques assemblages de Chitinozoaires de l'Ordovicien du Maroc, Bassin de Tadla. *Geobios*, v. 26, pp. 119-143, Villeurbanne.

Tahirkheli R.A.K. (1982) - Geology of the Himalaya, Karakoram and Hindu Kush in Pakistan. *Geol. Bull. Univ. Peshawar*, v. 15, pp.1-51, Peshawar.

Talent J.A., Conaghan P.J., Mawson R., Molloy P.D. & Pickett J.W. (1981) - Intricacy of tectonics in Chitral (Hindu Kush): faunal evidence and some regional implications. In Himalayan Seminar (1976), Section IIA. *Geol. Surv. India, Misc. Pub.*, v. 41, n. 3, pp. 77-101, Calcutta.

Talent J.A., Gaetani M., Mawson R., Molloy P.D. & Conaghoan P.J. (1999) - Early Ordovician and Devonian conodonts from the Western Karakorum and Hindu Kush, Northernmost Pakistan. *Riv. ital. Paleontol. Stratigr.*, v. 105, pp. 1-29, Milano.

Tongiorgi M., Di Milia A., Le Fort P. & Gaetani M. (1994) - Palynological dating (Arenig) of the sedimentary sequence overlying the Ishkarwaz Granite (Upper Yarkhun valley, Chitral, Pakistan). *Terra Nova*, v. 6, pp. 595-607, Oxford.

Tongiorgi M., Yin L.M. & Di Milia A. (1995) - Arenigian acritarchs from the Daping Section (Yangtze Gorges area, Hubei province, Southern China) and their palaeogeographic significance. *Rev. Palaeobot. Palynol.*, v. 86, pp. 13-48, Amsterdam.

Tongiorgi M. & Di Milia A. (1999) - Differentiation and spread of the Baltic acritarch Province (Arenig-Llanvirn). In Tongiorgi M. & Playford G. (eds.) - Studies in Palaeozoic palynology. Selected papers from the CIMP Symposium at Pisa, 1998. *Boll. Soc. paleont. ital.*, v. 38, n. 2-3, pp. 297-312, Modena.

Tongiorgi M., Yin L.M., Di Milia A. & Ribecai C. (1998) - Changing palaeogeographical affinities of the acritarch assemblages throughout the Dawan Formation (Arenig, Yichang area, South China). *Palynol.*, v. 22, pp. 181-196, Dallas, Texas.

Vavrdová M. (1972) - Acritarchs from Klabava Shales (Arenig). *Vestn. ústred. Ustavu geol.*, v. 47, pp. 79-86, Praha.

Vavrdová M. (1974) - Geographical differentiation of Ordovician acritarch assemblages in Europe. *Rev. Palaeobot. Palynol.*, v. 18, pp. 171-175, Amsterdam.

Vavrdová M. (1976) - Excystment mechanism of Early Paleozoic acritarchs [Mechanismus excystace u rane paleo-

zoickych akritarch]. *Cas. Mineral. Geol.*, v. 21, n. 1, pp. 55-64, Praha.

Vavrdová M. (1993) - Acritarch assemblages in the Arenig Series of the Prague Basin, Czech Republic. In Molyneux S.G. & Dorning K.G. (eds.) - Contributions to acritarch and chitinozoans research. *Spec. Pap. Palaeontol.*, v. 48, pp. 125-139, London.

Wang X.F., Erdtmann B.D. & Chen X.H. (1992) - Ordovician chronostratigraphy - A Chinese approach. In Webby B.D. & Laurie J.R. (eds.) - Global perspectives on Ordovician geology. Proceedings of the 6th International Symposium on the Ordovician System, (University of Sydney), pp. 35-55, Rotterdam.

Wang X.F., Li Z.M., Chen J.Q., Chen X.H. & Shu W.B. (1996) - Early Ordovician sea level events in South China and its worldwide correlation. *J. Geol. Miner. Res. South China*, v. 3, pp. 1-11, Wuhan.

Wang Z.-H., Bergström S.M. & Lane H.R. (1996) - Conodont provinces and biostratigraphy in Ordovician of China. *Acta Palaeontol. sinica*, v. 35, pp. 26-59, Beijing.

Webby B.D. (1998) - Steps toward a global standard for Ordovician stratigraphy. *Newsl. Stratigr.*, v. 36, n. 1, pp. 1-33, Leiden.

Yin L.m., Di Milia A. & Tongiorgi M. (1998) - New and emended acritarch taxa from the lower Dawan Formation (Lower Arenig, Huanghuachang section, South China). *Rev. Palaeobot. Palynol.*, v. 102, pp. 223-248, Amsterdam.

APPENDIX 1

The Vidiakot section: bed number, bed thickness, lithology, and samples

15	17 m	Black slate with very fine sandstone intercalations.	CK751 (+0.5), CK752 (+5.5), CK753 (+11.5)
	20 m	not exposed	
14	23 m	Splintery black slate with flattened siltstone nodules.	CK747 (+2.0), CK748, (+12.0), CK749 (+17.0), CK750 (+23.0)
13	5 m	Alternating shale, siltstone, and litharenite in 10 cm thick beds. Shale largely subordinate.	CK745 (+1.5)
12	11 m	Light coarse arkose and microconglomerate in m-thick cross-laminated beds.	
11	12 m	Brown altered siltstone, poorly exposed.	
10	37 m	Dark splintery bioturbated siltstone alternating with very fine sandstone.	JAT1 (Talent et al., 1981, 1999)
9	3 m	Medium grained sandstone	
8	23 m	Arenaceous siltstone with subordinate black splintery slates and occasional sandstone beds.	CK742 (+0.4), CK743 (+7.1)
7	14 m	Light grey, splintery arenaceous bioturbated siltstone with frequent intercalations of very fine sandstone. *Cruziana* - like traces.	
6	21 m	Fine light arkose and sublitharenite in amalgamated beds 50-70 cm-thick, with faint parallel lamination.	
5	13 m	Silty slate poorly exposed, locally deeply bioturbated, with *Cruziana* - like traces.	
4	7 m	Very fine arkose sandstone in 20-40 cm thick beds.	
3	4 m	Splintery siltite and very thin sandstone	
2	14 m	Black splintery slate, steeply dipping to the north.	CK734 (+0.3), CK735 (+5.0), CK736 (+10.0), CK737 and CK738 (about +14.0)
1	6 m	Coarse arkose in thick, poorly defined beds.	
0	0 m	Deeply altered Ishkarwaz Granodiorite.	