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Acritarch biostratigraphy of the upper Tremadoc-Arenig of the Eastern Cordillera, northwestern Argentina: relationships with graptolite and trilobite faunas

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ABSTRACT – *Biostratigraphic results and palaeogeographic inferences have been obtained from an integrated study of acritarchs, graptolites, and trilobites of late Tremadoc to middle Arenig age, from the Eastern Cordillera, northwestern Argentina. One new acritarch species Eisenackidium orientalis Rubinstein is proposed, together with two new combinations Polygonium akrochordum (Rasul) Rubinstein, and Ammonidium multipugiunculatum (Cramer & Diez) Rubinstein. A biostratigraphic scheme, based on acritarchs and graptolites, is established for the interval upper Tremadoc-middle Arenig in the studied sections. Acritarch assemblages appear to relate to the cold-water to temperate Peri-Gondwana Province, based on the occurrence of Striatotheca, Coryphidium, and Arbusculidium.*

RIASSUNTO – [Biostratigrafia ad acritarchi del Tremadoc superiore-Arenig della Cordigliera Orientale, Argentina nord occidentale: relazioni con le faune a graptoliti e trilobiti] – *Risultati biostratigrafici e implicazioni palaeogeografiche sono stati ottenuti da uno studio integrato su acritarchi, graptoliti e trilobiti di età compresa tra il Tremadoc superiore e l'Arenig medio, provenienti dalla Cordigliera Orientale dell'Argentina nord-occidentale. Vengono proposte una nuova specie di acritarchi, Eisenackidium orientalis Rubinstein, e due nuove combinazioni, Polygonium akrochordum (Rasul) Rubinstein e Ammonidium multipugiunculatum (Cramer & Diez) Rubinstein. Viene inoltre presentato uno schema biostratigrafico, basato su acritarchi e graptoliti, per l'intervallo Tremadoc superiore-Arenig medio delle sezioni studiate. In base alla presenza di Striatotheca, Coryphidium e Arbusculidium, le associazioni ad acritarchi appaiono riferibili alla Provincia Perigondwaniana, di acque fredde fino a temperate.*

INTRODUCTION

The Eastern Cordillera constitutes a geological province extending northwards from northwestern Argentina through Bolivia and Peru (Text-fig. 1). Widespread lower Ordovician sedimentary rocks are represented by the Santa Rosita Formation (locally called the Saladillo Formation) of Tremadoc age, and the Acoite Formation (early to middle Arenig). These two units comprise the Santa Victoria Group, consisting of a considerable thickness of dominantly clastic sediments. The lower Ordovician deposits have provided an abundant macrofauna, mainly composed of trilobites and graptolites (Harrington & Leanza, 1957; Turner, 1960).

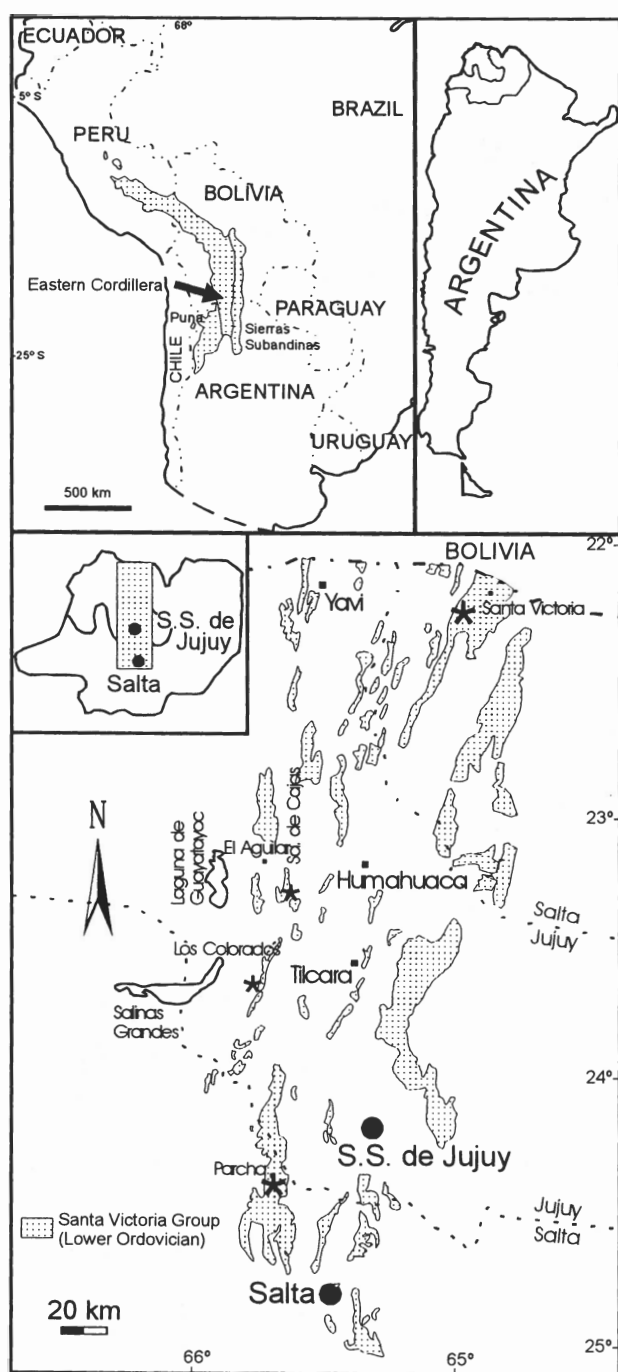
Moya (1988) recognized two different sedimentation areas in the lower Ordovician of the Eastern Cordillera; i.e., a western lagoonal area and an eastern open platform area, separated by a swell or barrier island.

Most of the recent research on the macrofauna has focused on the western side of the Eastern Cordillera, where a graptolite zonation scheme has been proposed, based on extensive collections from several regions (Toro, 1994a, b; 1997). On the eastern side

of the Eastern Cordillera, studies have been recently concentrated on the type section of the Acoite Formation (Santa Victoria area); preliminary correlation between both sides of the Eastern Cordillera has thus been established on graptolite evidence. Abundant and widespread trilobite assemblages have also been recently described from the Arenig of this region (Waisfeld, 1995, 1997), and a preliminary attempt has been made to integrate these assemblages with the graptolite zonal scheme of the Eastern Cordillera (Toro & Waisfeld, 1998).

Only a few lower Ordovician palynological assemblages have been previously recorded from this region. Tremadoc assemblages come from the San Jose Shales and Caldera Sandstone (Bultynck & Martin, 1982), and from the Nazareno area (Rubinstein, 1997), both from the Salta Province, on the eastern side of the Eastern Cordillera. Arenig assemblages were found at the Los Colorados Creek and Río Cajas Creek localities (Ottone *et al.*, 1992), on the western side of the Eastern Cordillera. In the same area, at the Chalala Creek locality (Ottone *et al.*, 1995), acritarchs were tentatively assigned to the Arenig.

In order to further biostratigraphic studies, the



Text-fig. 1 - Geographic location of sampling localities in the Eastern Cordillera. Santa Victoria and Parcha: areas studied in this paper; Los Colorados and Río Cajas: sections studied by Ottone *et al.* (1992) and here correlated with study localities.

present paper is focused on uppermost Tremadoc to middle Arenig palynofloras from two new areas: Santa Victoria, in the north, corresponding to the eastern side of the Eastern Cordillera basin; and Parcha, in the south, belonging to the western side of the same basin.

The aim of this paper is to establish an integrated biostratigraphic scheme based on independent chronostratigraphic data provided by palynomorphs, graptolites, and trilobites. This new approach could contribute to resolution of the still open question as to whether, during the early Ordovician, there was open connection or physical restriction (isolation) between the eastern and western sides of the Eastern Cordillera. On this basis, the previously inferred early Ordovician palaeogeographic location of the Eastern Cordillera could be re-evaluated (Waisfeld, 1995; Toro, 1996).

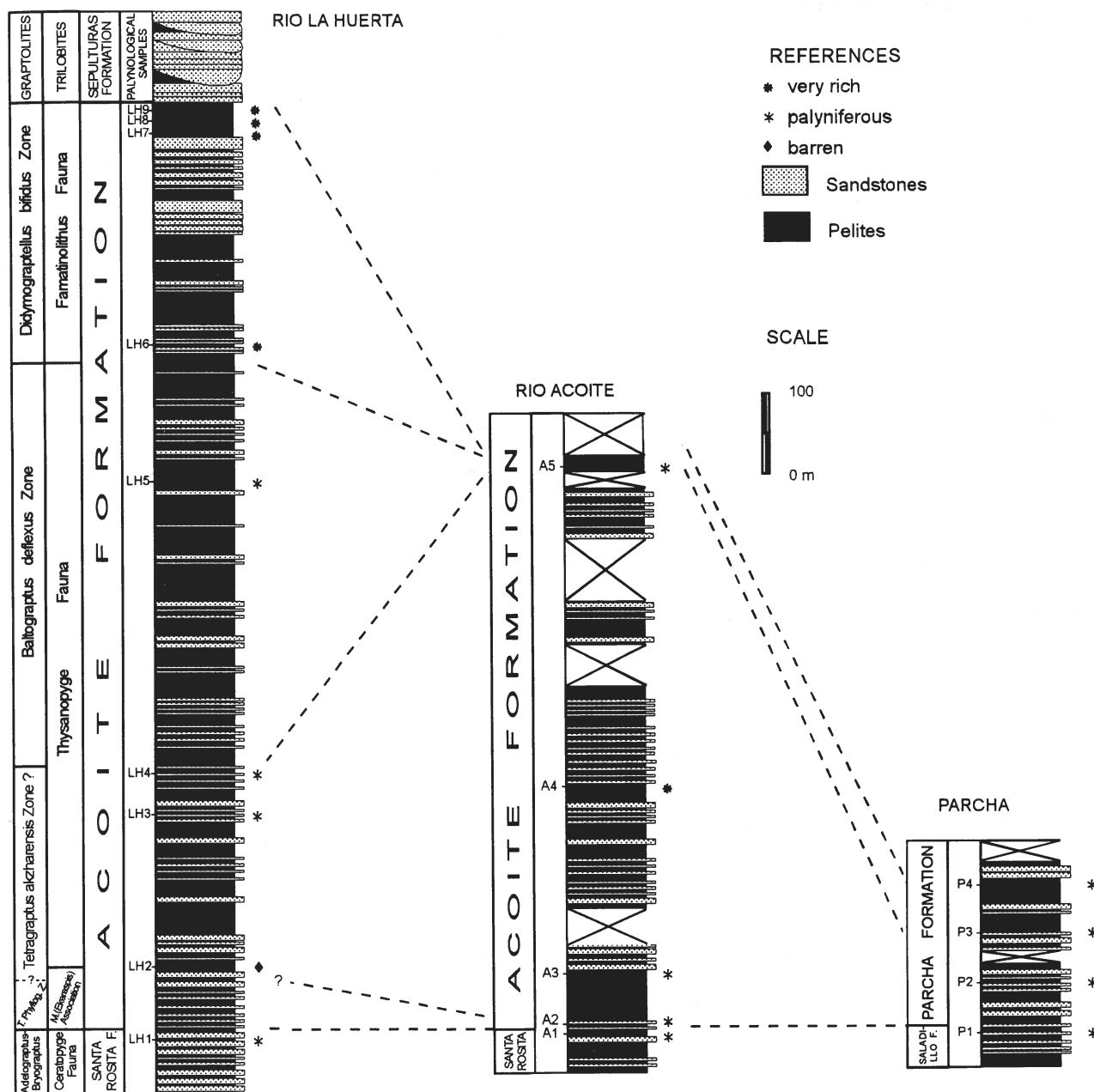
GEOLOGICAL SETTING

The uppermost Tremadoc (Santa Rosita and Saladillo Formations) and the lower-middle Arenig (Acoite Formation) are represented in the Argentine Eastern Cordillera by thick, shallowing-upward, inner-shelf successions, related to a storm-dominated deltaic system (Astini & Waisfeld, 1993). These units, with a maximum total thickness of almost 1300 m, are mainly represented by greenish-grey shales and fine-sandstones, often alternating with dark grey to black shales and siltstones. Toward the top of the sequence, extensively bioturbated sandstones bodies occur. The Acoite Formation rests conformably on the Tremadoc Santa Rosita (or Saladillo) Formation and it is conformably overlain by the coarse-grained sandstones of the upper Arenig-lower Llanvirn? Sepulturas Formation. Erosional unconformities separate the Ordovician from Cambrian and Cretaceous units respectively.

RESULTS

Acritarchs and prasinophytes were recovered from the La Huerta and Río Acoite sections, both in the Santa Victoria area, and in the Parcha section (Text-fig. 2). Eighteen samples were analyzed and only one was found to be barren; the latter was collected from the lower Acoite Formation (LH2), close to the probable *Tetraraptus phyllograptoides*-*Tetraraptus akzharensis* zonal boundary.

The La Huerta Section represents the most complete lower Ordovician sequence, from the upper Tremadoc (equivalent to the *Adelograptus-Bryograptus* association) to the middle Arenig (*Didymograptellus bifidus* Zone). Palynomorphs from the upper Tremadoc are varied and moderately well preserved. By contrast, only a few, poorly preserved acritarchs, without stratigraphic value, were recovered from the *T. phyllograptoides* graptolite Zone. There is a notable increase in diversity and preservation-quality from the upper *Tetraraptus akzharensis* Zone to the *Didymograptellus bifidus* Zone. The latter graptolite zone contains rich palynomorph assemblages, in terms of both abundance and diversity, and contains relatively well preserved acritarch and prasinophyte taxa (Text-fig. 3).



Text-fig. 2 - Lithostratigraphy, biostratigraphy (palynomorphs, graptolites, trilobites), and correlation of sections studied. Location and identification numbers of samples are indicated for each section.

The Acoite section has, on the whole, moderately varied and well preserved acritarch assemblages, from the upper Tremadoc to the lower Arenig (Text-fig. 3). The *T. akzharensis* graptolite Zone is extensively represented in this section and one level yielded a remarkably rich acritarch assemblage.

In the Parcha section, the palynofloras are poor in abundance, diversity, and preservation; their identification at specific level is mostly tentative and correlation with other sections is based on graptolites.

Most of the samples studied herein were collected

from beds in which graptolites and trilobites co-occur. The graptolite biozonation adopted here is that established for the Eastern Cordillera and correlated with biozones recognized elsewhere in the world (Toro, 1997).

Samples have been treated using standard palynological techniques. Palynological slides are deposited in the Palynoteque of the Palaeopalynology Unit, IANIGLA, CRICYT, Mendoza, Argentina. Slides in the repository are prefixed LPPM (Laboratorio de Palaeopalynología Mendoza). England Finder coordi-

nates of all illustrated specimens are provided in the plate captions.

PALYNOLOGICAL ASSEMBLAGES

Because of poor preservation, only a few acritarch taxa have been identified from the Parcha section. Therefore, age and correlations are based on graptolites. The Tremadoc (sample P1) contains *Polygonium dentatum* (Timofeev, 1959 *ex* Konzalová-Mazanková, 1969) Albani, 1989 and *Baltisphaeridium* sp. cf. *B. multipilosum* (Eisenack, 1931) Eisenack, 1958. In the same section, the *T. akzharensis* graptolite Zone (sample P2) yielded *Stelliferidium* sp. and *Actinodissus*? sp., while the *B. deflexus* graptolite Zone (samples P3, P4) provided *Cymatiogalea* sp., *Cymatiosphaera* sp., *Coryphidium* sp., *Micrhystridium stellatum* Deflandre, 1945, *Peteinosphaeridium* sp., *Stellechinatum* sp. cf. *S. uncinatum* (Downie, 1958) Molyneux, 1987, and *Stelliferidium* sp. *Leiosphaeridia* sp., *Acanthodiacrodium* spp., and *Polygonium* spp. occur throughout the entire lower Arenig sequence.

Five palynological assemblages have been recognized (Text-fig. 4) in the more richly palyniferous upper Tremadoc-middle Arenig sediments of the Santa Victoria area. In ascending order, these comprise the following.

Assemblage 1

This assemblage has been recognized in the upper Tremadoc from the la Huerta and Río Acoite sections (samples LH1 and A1), and is stratigraphically equivalent to the *Adelograptus-Bryograptus* graptolite association, which corresponds to the *Hunnegraptus copiosus* Zone of the Baltoscandian zonation and to La2 of the Australian biostratigraphic scheme.

Assemblage 1 comprises: *Acanthodiacrodium* sp. cf. *A. spinum* Rasul, 1979, *Acanthodiacrodium* sp., *Actinodissus* sp. cf. *A. achraisi* (Martin, 1972) Yin, 1986, *Athabascaella*? sp., *Cymatiogalea cristata* (Downie, 1958) Rauscher, 1973, *C. cuvillieri* (Deunff, 1961) Deunff, 1964, *C. multarea* (Deunff, 1961) Eisenack, Cramer & Díez, 1973, *C. velifera* (Downie, 1958) Martin, 1969, *Cymatiosphaera* sp., *Micrhystridium stellatum* Deflandre, 1945, *Polygonium dentatum*, *P. gracile* Vavrdová, 1966, *Polygonium* sp. cf. *P. akrochordum* (Rasul, 1979) Rubinstein comb. nov., *Stellechinatum uncinatum*, *Stelliferidium*? *simplex* (Deunff, 1961) Deunff, Górká & Rauscher, 1974, and *Vulcanisphaera* sp.

Assemblage 2

This suite is represented in samples A3, A4, and LH3; sample A4 is particularly rich in species. This assemblage comes from the lower Arenig, equivalent to the *Tetragraptus akzharensis* Zone *sensu* Toro, 1997, which corresponds to Be1 and to part of Be2 of the

Australian zonation, *sensu* Cooper & Lindholm (1990).

Assemblage 2 is distinguished by the first appearance of *Coryphidium* Vavrdová, 1972, *Dactylofusa velifera* forma *brevis* Albani, 1989, and *Eisenackidium orientalis* Rubinstein sp. nov. *Veryhachium* sp. cf. *V. rhomboidium* Downie, 1959 also appears in this assemblage. *Rhopaliophora palmata* (Combaz & Peniguel, 1972) Playford & Martin, 1984 and *R. sp.* cf. *R. pilata* (Combaz & Peniguel, 1972) Playford & Martin, 1984 are restricted to this assemblage in the Río Acoite section. Other species which are exclusive to this assemblage are: *Acanthodiacrodium* sp. cf. *A. tassellii* Martin, 1969, *Buedingiisphaeridium tremadocum* Rasul, 1979, *Cymatiogalea* sp. cf. *C. membranispina* Deunff, 1961, *Micrhystridium henryi* Paris & Deunff, 1970, *Ordovicidium* sp. cf. *O. yangtzeense* Tongiorgi, Yin & Di Milia, 1995, *Stelliferidium* sp. cf. *S. brevipalmatum* Albani, 1989, and *Vavrdovella areniga* (Vavrdová, 1973) Loeblich & Tappan, 1976.

Assemblage 3

Samples LH4 and A5 contain this association, which corresponds to the lower part of the *Baltograptus deflexus* graptolite Zone (lower Arenig) and to part of Be2-Be4 from Australia. The only species which appears in this assemblage is *Cymatiogalea granulata* Vavrdová, 1966.

Assemblage 4

This assemblage is represented by sample LH5. It comes from the upper part of the *B. deflexus* graptolite Zone (lower Arenig), which is equivalent to part of the Australian Be2-Be4. A noteworthy feature is the first appearance of *Striatotheca* Burmann, 1970, represented by the species *Striatotheca* sp. cf. *S. principalis parva* Burmann, 1970. *Ammonidium multipugiunculatum* (Cramer & Díez, 1977) Rubinstein comb. nov. also makes its debut in this assemblage.

Assemblage 5

This association was recovered from samples LH6, LH7, LH8, and LH9. These are representative of the *Didymograptellus bifidus* graptolite Zone (middle Arenig), which corresponds to Ch1-Ch2 from Australia.

Increased acritarch abundance and diversity are characteristic of this assemblage, which is notable also for the first occurrence of the following taxa: *Acanthodiacrodium costatum* Burmann, 1968 *sensu* Cramer & Díez, 1977, *Adorfia hoffmanensis* (Cramer, Allam, Kanes & Díez, 1974) Ottone, 1992, *Arbusculidium filamentosum* (Vavrdová, 1965) Vavrdová, 1972, *Aureotesta clathrata* var. *simplex* Brocke, Fatka & Servais, 1997, and *Coryphidium miladae*-*C. tadla* group *sensu* Rubinstein herein.

Acritarch distribution	D. bifidus				B. deflexus			T. akzharensis			T. phyllogra ptoides	Adelograptus - Bryograptus		
La Huerta and Rio Acoite sections Santa Victoria area	middle Arenig				lower Arenig								upper Tremadoc	
	LH9	LH8	LH7	LH6	LH5	A5	LH4	LH3	A4	A3	A2	LH1	A1	
Veryhachium trispinosum	X													
Striatotheca transformata	X													
Veryhachium lairdii	X	X												
Striatotheca microrugulata	X	X												
Adorfia hoffmanensis	X	X												
Striatotheca spp.	X	X												
Arbusculidium filamentosum	X	X	X	X										
Acanthodiacrodium costatum	X	X		X										
Aureotesta clathrata var. simplex	X	X		X										
Striatotheca principalis parva	X	X			cf.									
Ammonidium multipugiunculatum	X	X			X									
Cymatogalea granulata	X	X	X	X	X	X	X							
Eisenackidium orientalis	X	X	X	X			X		X					
Polygonium gracile	X	X	X	X	X	X	X	X	X			X	X	
Coryphidium miladae-tadla group		X	X	X										
Dactylofusa velifera forma brevis		X				X	X		X					
Micrhystridium stellatum		X						X		X		X		
Stellechinatum sp. cf. brachyscolum			X											
Actinodissus sp. 1			X											
Cymatogalea sp.			X							X				
Polygonium dentatum			X	X		X				X		X		
Coryphidium australe				X										
Acanthodiacrodium spp.				X										
Barakella sp. cf. rara				X										
Polygonium sp. cf. delicatum				X										
Polygonium sp. cf. symbolum				X										
Petaloferidium sp. cf. florigerum				X										
Striatotheca sp. cf. rarirugulata				X										
Veryhachium sp. cf. rhomboidium				X				X						
Polygonium sp. cf. akrochordum				X								X		
Stellechinatum uncinatum				X								X		
Tectitheca sp. cf. additionalis					X									
Cymatogalea sp.						X								
Cymatiosphaera spp.						X								
Actinodissus sp. 2								X						
Ordovicium sp. cf. yangtzeense								X						
Rhopaliophora palmata									X					
Rhopaliophora sp. cf. pilata									X					
Buedingiisphaeridium tremadocum									X					
Cymatogalea sp. cf. membranispina									X					
Micrhystridium henryi									X					
Stelliferidium sp. cf. brevipalmatum									X					
Peteinosphaeridium ? sp.									X					
Dictyotidium sp.									X					
Coryphidium sp.									X					
Vavrdovella areniga										X				
Acanthodiacrodium sp. cf. tassellii										X				
Acanthodiacrodium spp.										X				
Polygonium sp.										X				
Stelliferidium ? sp.											X			
Lophosphaeridium sp.											X			
Cymatogalea cristata												X		
Cymatogalea multarea												X		
Cymatogalea velifera												X		
Acanthodiacrodium sp. cf. spinum												X		
Actinodissus sp. cf. achrasi												X		
Vulcanisphaera sp.												X		
Athabascaella ? sp.												X		
Acanthodiacrodium sp.												X		
Cymatiosphaera sp.												X		
Cymatogalea cuvillieri												X	X	
Stelliferidium ? simplex													X	
Lophosphaeridium sp.													X	

Text-fig. 3 - Check list of acritarch occurrences, by samples, stratal sections, and graptolite biozones.

AGE	EASTERN CORDILLERA Graptolite Zones					ACRITARCH ASSEMBLAGES						STRATIGRAPHIC DISTRIBUTION OF SELECTED ACRITARCH TAXA
						A5	A4	A3	A2	?	A1	
MIDDLE ARENIG	Didymograptellus bifidus											Stelliferidium? simplex
LOWER	Baltograptus deflexus											Cymatogalea cuvillieri
	Tetragraptus elzharensis											Athabascaella? sp.
ARENIG	Tetragraptus phylograptoides											Vulcanisphaera sp.
	Adelograptus - Briograptus											Actinodissus sp. cf. achrasi
UPPER TREMADOC												Acanthodiacrodium sp. cf. spinum
												Cymatogalea velifera
												Cymatogalea multarea
												Cymatogalea cristata
												Acanthodiacrodium sp. cf. tassellii
												Vavrdovella arenig
												Coryphidium sp.
												Stelliferidium sp. cf. brevipalmatum
												Michrystidium henryi
												Cymatogalea sp. cf. membranispina
												Buedingisphaeridium tremadocum
												Rhopaliophora sp. cf. pilata
												Rhopaliophora palmata
												Ordovicium sp. cf. yangtzeense
												Dactylofusa velifera forma brevis
												Eisenackidium orientalis
												Cymatogalea granulata
												Tectitheca sp. cf. additionalis
												Ammonidium multipugiunculatum
												Striatotheca principalis parva
												Striatotheca sp. cf. rarirugulata
												Petaloferidium sp. cf. florigerum
												Barakella sp. cf. rara
												Coryphidium australe
												Stellechinatum sp. cf. brachysolum
												Coryphidium miladae-tadla group
												Aureotesta cithrata var. simplex
												Acanthodiacrodium costatum
												Arbusculidium filamentosum
												Adorfia hoffmanensis
												Striatotheca microrugulata
												Striatotheca transformata

Text-fig. 4 - Stratigraphic distribution of the five acritarch assemblages (A1-A5; upper Tremadoc-middle Arenig) based on occurrences of selected acritarch taxa; and correlation between acritarch and graptolite biostratigraphy.

The following taxa also appear in this assemblage, but are restricted to its lower part (lower *D. bifidus* graptolite Zone): *Barakella* sp. cf. *B. rara* (Lu, 1987) Tongiorgi, Yin & Di Milia, 1995, *Coryphidium australe* Cramer & Díez, 1976, *Petaloferidium* sp. cf. *P. florigerum* (Vavrdová, 1977) Fensome *et al.*, 1990, *Polygonium* sp. cf. *P. delicatum* Rasul, 1979, *P.* sp. cf. *P. symbolum* Rasul, 1979, *P.* spp., *Striatotheca microrugulata* (Vavrdová, 1972) Martin, 1977, *S.* sp. cf. *S. rarirugulata*, *S. transformata* Burmann, 1970 (Cramer, Kanes, Díez & Christopher, 1974) Eisenack, Cramer & Díez, 1976, and *Tectitheca* sp. cf. *T. additionalis* Burmann, 1968.

Stellechinatum sp. cf. *S. brachysolum* Turner, 1984, *Veryhachium lairdii* Deflandre, 1946 *ex* Loeblich, 1970, and *V. trispinosum* (Eisenack, 1938) Stockmans & Willièrè, 1962 are other components of this assemblage.

DISCUSSION

STRATIGRAPHIC SIGNIFICANCE OF SELECTED ACRITARCH TAXA

From the upper Tremadoc-lowest Arenig of the Eastern Cordillera, taxa diagnostic of the *messauoudensis-trifidum* assemblage (Cooper *et al.*, 1995) were not recorded, despite the presence of many elements of Gondwanan or peri-Gondwanan affinity, such as *Cymatogalea cristata*, *C. cuvillieri*, *C. velifera*, and *Vulcanisphaera* sp. The *messauoudensis-trifidum* assemblage, subdivided in England into five sub-assemblages (Cooper *et al.*, 1995), ranges from the *A. murrayi* graptolite Zone (upper Tremadoc) to the upper *T. phylograptoides* graptolite Zone (basal Arenig) and is widely distributed in peri-Gondwanan successions (Servais & Molyneux, 1997).

In the Eastern Cordillera, only two samples (A1, LH1) of the uppermost Tremadoc (*Adelograptus-Bryograptus* graptolite association equivalent to the *H. copiosus* graptolite Zone) have been presently studied. Moreover, acritarchs from the *T. phylograptoides* graptolite Zone are poor in number and preservational quality, and no stratigraphically diagnostic taxa were recognized. Finally, the analyzed sections did not provide enough data to rule out the presence of the *messauoudensis-trifidum* assemblage in the Eastern Cordillera.

The *Coryphidium-Vavrdovella* group (Brocke *et al.*, 1995), *Striatotheca*, *Aureotesta* Vavrdová, 1972, and *Arbusculidium filamentosum* are typical of the early Ordovician Perigondwanan assemblages. After revision of these important taxa Brocke *et al.* (1995) proposed a first appearance datum (FAD) for each of them.

The *Coryphidium-Vavrdovella* group appears initially in the *messauoudensis-trifidum* assemblage; i.e., *Vavrdovella* first appears in England (Brocke *et al.*, 1995) in the late Tremadoc (*A. murrayi* graptolite

Zone), while bona fide *Coryphidium* spp. appear near the base of the Arenig (Molyneux & Leader, 1997). In the Eastern Cordillera, *Vavrdovella areniga* occurs near the base of the *T. akzharensis* graptolite Zone (Assemblage 2) and the first appearance of *Coryphidium* is in the middle part of the same zone. Note that the *Coryphium-Vavrdovella* group has not been recorded from the *B. deflexus* graptolite Zone. *Coryphidium* reappears, and is represented abundantly by many different species, in the middle Arenig Assemblage 5 (*D. bifidus* graptolite Zone). As noted in the systematic section, all of the Eastern Cordilleran species of *Coryphidium* have non-striate vesicles.

The FAD of *Striatotheca* was dated by Brocke *et al.* (1995) as latest Tremadoc (*A. murrayi* or *H. copiosus* graptolite Zone). Nevertheless, in the studied region this genus first appears in the upper part of the *B. deflexus* graptolite Zone (Assemblage 4) and increases in abundance and diversity and preservation during the middle Arenig (Assemblage 5).

The FADs of *Aureotesta* (as emended by Brocke, Fatka & Servais, 1997) and *Arbusculidium filamentosum* fall within the South Chinese *B. deflexus* graptolite Zone, equivalent to the British *D. nitidus* graptolite Zone. In accord with these occurrences, *Arbusculidium filamentosum* and *Aureotesta clathrata* var. *simplex* first appear in the middle Arenig (Assemblage 5) of the Eastern Cordillera.

Other species with supposedly high stratigraphic potential are *Rhopaliophora palmata* and *R. pilata*. Both were originally described from the Arenig to probable Llanvirn of Australia (Combaz & Peniguel, 1972; Playford & Martin, 1984). They were subsequently considered as widely distributed species of latest Tremadoc-earliest Arenig to Llanvirn-Llandeilo? age (Playford & Wicander, 1988). The two species have been recorded from Canada (Martin, 1992), England (Cooper *et al.*, 1995), Czech Republic (Fatka, 1993), Estonia (Uutela & Tynni, 1991), North China (Martin & Yin, 1988), and South China (Tongiorgi *et al.*, 1995; Brocke *et al.*, 1997). In the Eastern Cordillera, *Rhopaliophora palmata* and *R. cf. R. pilata* occur exclusively in the richly acritarchous sample A4 of the Acoite section (Assemblage 2), which has been assigned to the lower Arenig (*T. akzharensis* graptolite Zone).

Dactylofusa velifera forma *brevis* occurs in strata dated as latest early Arenig-early late Arenig, in central Sardinia (Albani, 1989; Di Milia *et al.*, 1993), Pakistan (Tongiorgi *et al.*, 1994), and western Turkey (Martin in Tongiorgi *et al.*, 1994). These records are from Perigondwanan regions in strata devoid of macrofossil control. In the Eastern Cordillera, this forma first occurs and is very abundant in strata assigned to the *T. akzharensis* graptolite Zone (Assemblage 2). It has also been recovered from the lower part of the *B. deflexus* graptolite Zone (Assemblage 4) and from the *D. bifidus* graptolite

Zone (Assemblage 5). Thus, the known range of *Dactylofusa velifera* forma *brevis* is lower (but not lowermost) to middle Arenig.

The new species *Eisenackidium orientalis* has the same range as *Dactylofusa velifera* forma *brevis* (*T. akzharensis* to *D. bifidus* graptolite Zone) but is more common in Assemblage 5. This species has also been recovered from the lower and middle Arenig of Los Colorado Creek and Río Cajas Creek (Ottone *et al.*, 1992). Therefore, *E. orientalis* could be considered as a good stratigraphic marker for the lower to middle Arenig of the Eastern Cordillera.

PALAEOGEOGRAPHIC AFFINITIES

a) Acritarchs

Five acritarch assemblages have been defined in the study sections. Assemblages 1-3 are recognizable in the La Huerta and Acoite sections and assemblages 4 and 5 in the La Huerta section. In both sections, the age of the acritarch assemblages has been verified from co-occurring age-diagnostic graptolites (Text-fig. 4). The Parcha section yielded poorly preserved, often indeterminable acritarch and prasinophyte specimens, so that correlation with the La Huerta and Acoite sections is based necessarily on graptolite evidence (Text-fig. 2). From a biostratigraphic viewpoint, acritarch and graptolite-based age-determinations agree in the studied sections. Consequently, a precise biostratigraphic scheme, based on both groups can be established for the upper Tremadoc-middle Arenig interval of the Eastern Cordillera.

The former Mediterranean Province (Vavrdová, 1974) has been redefined and extended by different authors, and is referred to as the Perigondwana Province. The Perigondwana Province, as defined by Playford *et al.* (1995), comprises "a broad, latitudinally extensive, circumpolar, cold to temperate palaeogeographical belt along the northern Gondwana border, from Argentina through eastern Newfoundland, north Africa, central and southern Europe, and southern Turkey to South China".

Based on the occurrence of *Arbusculidium*, *Striatotheca*, and *Coryphidium*, the Argentine acritarch assemblages belong to the Perigondwana Province (Tongiorgi *et al.*, 1994), or Perigondwana Realm (climatically controlled unit) as suggested by Servais & Fatka (1997). However, more species are shared with South China, Pakistan, the Czech Republic, and Sardinia than with other Perigondwanan areas (Text-fig. 5). Argentine acritarch assemblages have strong affinities with those of South China and Pakistan. This would indicate a temperate palaeolatitudinal location of northwestern Argentina (transitional, near the limit of the cold water Perigondwana Realm) during early to middle Arenig.

The presence of *Rhopaliophora palmata* and *R. pilata*, first recovered from Australia, does not indicate a

PERI-GONDWANA DISTRIBUTION OF SELECTED ACRITACHS	S.W. China	Pakistan	Czech Rep.	Sardinia (Italy)	England	Newfoundland	N. Africa	NW Argentina	Belgium	France	Spain	Iran
<i>Striatotheca transformata</i>												
<i>Striatotheca microrugulata</i>												
<i>Adorfia hoffmanensis</i>												
<i>Arbusculidium filamentosum</i>												
<i>Acanthodiacrodium costatum</i>												
<i>Aureotesta clathrata</i> var. <i>simplex</i>												
<i>Striatotheca principalis parva</i>												
<i>Ammonidium multipugiunculatum</i>												
<i>Cymatiogalea granulata</i>												
<i>Eisenackidium orientalis</i>												
<i>Polygonium gracile</i>												
<i>Coryphidium miladae-tadla</i> group												
<i>Dactylofusa velifera</i> forma <i>brevis</i>												
<i>Polygonium dentatum</i>												
<i>Coryphidium australe</i>												
<i>Barakella rara</i>												
<i>Petalofleridium florigerum</i>												
<i>Striatotheca rarirugulata</i>												
<i>Stellechinatum uncinatum</i>												
<i>Tectitheca additionalis</i>												
<i>Ordovicium yangtzeense</i>												
<i>Rhopaliophora palmata</i>												
<i>Rhopaliophora pilata</i>												
<i>Buedingiisphaeridium tremadocum</i>												
<i>Micrhystridium henryi</i>												
<i>Stelliferidium brevipalmatum</i>												
<i>Vavrdovella areniga</i>												
<i>Acanthodiacrodium tassellii</i>												

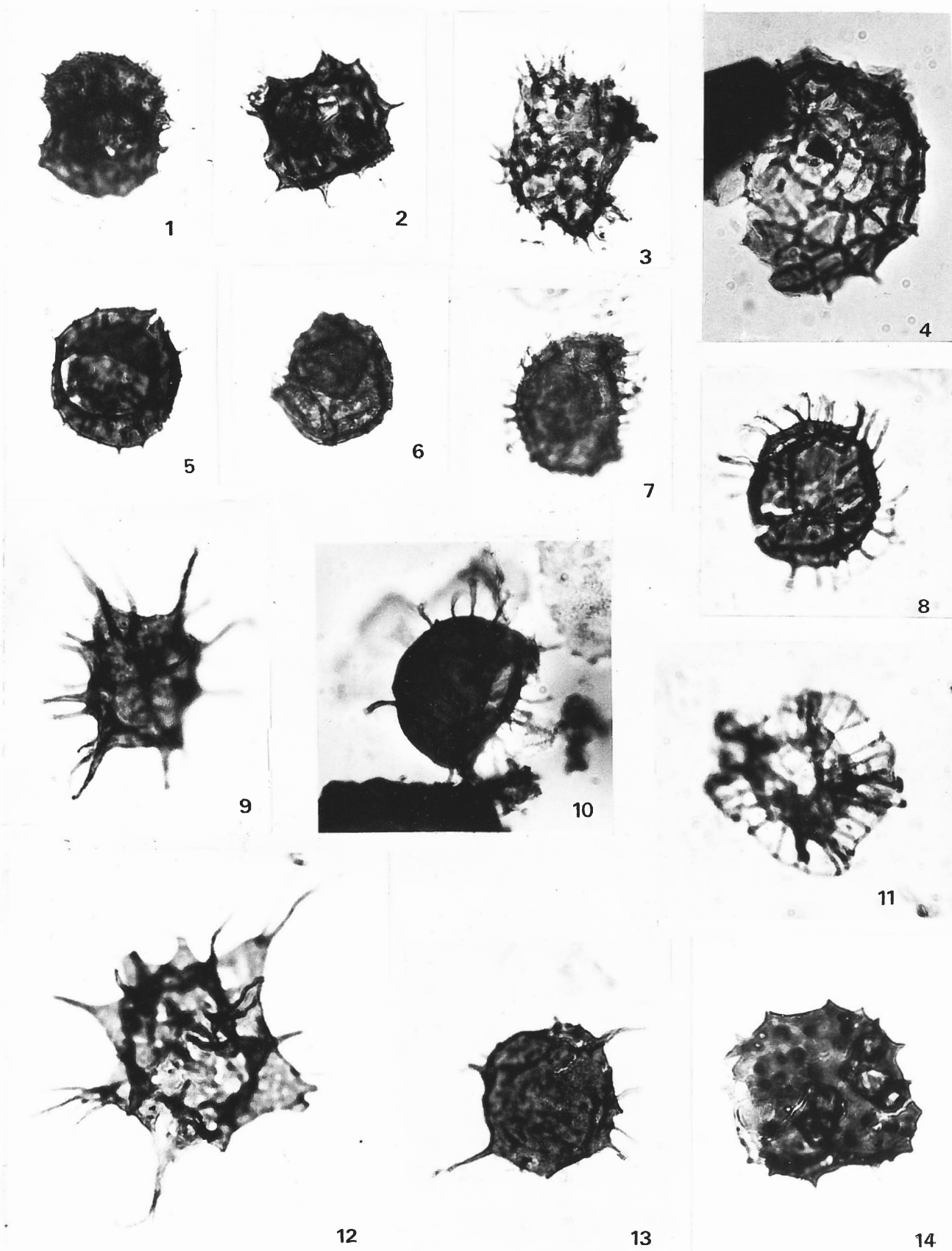
Text-fig. 5 - Geographic distribution of selected Arenig acritarchs in Perigondwana.

Southwest China: Li, 1987; Tongiorgi *et al.*, 1995; Brocke, 1997. Pakistan: Tongiorgi *et al.*, 1994. Czech Republic: Vavrdová, 1966, 1968, 1997; Fatka, 1993. Sardinia: Albani, 1989. England: Rasul, 1979; Rasul & Downie, 1974; Molyneux, 1987; Molyneux & Rushton, 1988; Cooper *et al.*, 1995. Newfoundland (Canada): Dean & Martin, 1978; Martin & Dean, 1981; Martin, 1982. North Africa: Deunff, 1961; Combaz 1967; Cramer *et al.*, 1974a, 1974b; Jardine *et al.*, 1974; Deunff & Massa, 1975; Cramer & Díez, 1977. Northwestern Argentina: Ottone *et al.*, 1992; Ottone *et al.*, 1995. Belgium: Martin, 1969; Martin, 1977; Vanguestaine, 1974. France: Martin, 1973; Rauscher, 1974. Spain: Mette, 1989. Iran: Ghavidel-Syooki, 1997.

EXPLANATION OF PLATE 1

- Fig. 1 - *Acanthodiacrodium* sp. cf. *A. spinum* Rasul, 1979: LH1, LPPM 6281d, E35/0.
 Fig. 2 - *Vavrdovella areniga* (Vavrdová) Loeblich & Tappan, 1976: A3, LPPM 6205b, C21/1.
 Fig. 3 - *Acanthodiacrodium* sp. cf. *A. tassellii* Martin, 1969: A3, LPPM 6205b, K37/3.
 Fig. 4 - *Dictyotidium* sp.: A4, LPPM 6203b, F20/0.
 Fig. 5 - *Stelliferidium?* *simplex* (Deunff, 1961) Deunff, Górká & Rauscher, 1974: A1, LPPM 6202b, O30/0.
 Fig. 6 - *Cymatiogalea cuvillieri* (Deunff, 1961) Deunff, 1964: A1, LPPM 6202b, F39/3.
 Fig. 7 - *Cymatiogalea cristata* (Downie, 1958) Rauscher, 1973: LH1, LPPM 6281d.
 Fig. 8 - *Athabascaella?* sp.: LH1, LPPM 6281d, J27/0.
 Fig. 9 - *Actinodissus* sp. cf. *A. achnasi* ((Martin, 1972) Martin *in* Martin & Dean, 1988: LH1, LPPM 6281d, E35/0.
 Fig. 10 - *Cymatiogalea multarea* (Deunff, 1961) Eisenack *et al.*, 1973: LH1, LPPM 6281d, E33/0.
 Fig. 11 - *Cymatiogalea velifera* (Downie, 1958) Martin, 1969: LH1, LPPM 6281d, C25/0.
 Fig. 12 - *Vulcanisphaera* sp.: LH1, LPPM 6281d, P24/4.
 Fig. 13 - *Polygonium* sp. cf. *P. akrochordum* (Rasul, 1979) Rubinstein comb. nov.: LH1, LPPM 6281d, R40/0.
 Fig. 14 - *Coryphidium* sp.: A4, LPPM 6203b, X17/4.

All figures $\times 1000$.



particular relationship with that warm province, because these species are also known from Perigondwana localities, including South China and Pakistan.

The Perigondwanan *messauoudensis-trifidum* assemblage (latest Tremadoc-earliest Arenig) is as yet unrecorded in the Eastern Cordillera sedimentary sequence.

b) Graptolites

The graptolite faunas evince a mixture of Atlantic (high latitude) and Pacific (low latitude) taxa in the Arenig. Species of the *Tetraraptus phyllograptoides* graptolite Zone (basal Arenig) have Baltoscandian affinities; while those of the *Tetraraptus akzharensis* graptolite Zone (lower Arenig) exhibit Pacific affinities. Components of the *Baltograptus deflexus* graptolite Zone (lower Arenig) have Atlantic affinities; whereas those of the *Didymograptellus bifidus* graptolite Zone (middle Arenig) are indicative of Pacific affinities. These observations, and the record of southwest Chinese graptolite species with geographically restricted distributions, suggest a close palaeogeographic relationship with other mixed provinces located at intermediate latitudes (Toro, 1996). Accordingly, such a latitudinal situation is implied for the Eastern Cordillera during Arenig time.

c) Trilobites

Trilobite faunas are abundant and widespread in the studied area but are mostly endemic. The *Megistaspis (Ekeraspis)* association connotes some Baltic influence, while the *Thysanopyge* and *Famatinolithus* faunas contain a considerable number of endemic taxa associated with Perigondwanan elements.

COMPARISON BETWEEN OPPOSITE SIDES OF THE EASTERN CORDILLERA

Acritarchs, graptolites, and trilobites are closely similar on the eastern and western sides of the Eastern

Cordillera. Acritarch assemblages from Los Colorados and Río Cajas Creeks (Ottone *et al.*, 1996), on the west, show similarities with those on the east (La Huerta and Acoite sections). In the two creek sections (Los Colorados and Río Cajas), two distinct palynomorph assemblages have been distinguished; i.e., the Lower Acoite Palynological Assemblage (early Arenig) and the Upper Acoite Palynological Assemblage (middle Arenig).

Though acritarch assemblages from the western side are of lesser abundance, diversity, and preservational quality than those from the east, some species are common to both: *Eisenackidium orientalis* and *Michrhystridium henryi* (in the lower to middle Arenig), *Adorfia hoffmanensis*, *Ammonidium multipugiunculatum*, *Cymatiogalea granulata*, *Striatotheca principalis parva*, *S. transformata*, *Veryhachium lairdii*, and *Veryhachium trispinosum* (in the middle Arenig).

CONCLUSIONS

Biostratigraphic information and palaeogeographic inferences are forthcoming from an integrated study of acritarchs, graptolites, and trilobites from late Tremadoc-middle Arenig strata exposed in the Eastern Cordillera of northwestern Argentina.

The Perigondwanan *messauoudensis-trifidum* assemblage (latest Tremadoc-earliest Arenig) has not yet been recorded in the Eastern Cordilleran sedimentary sequence.

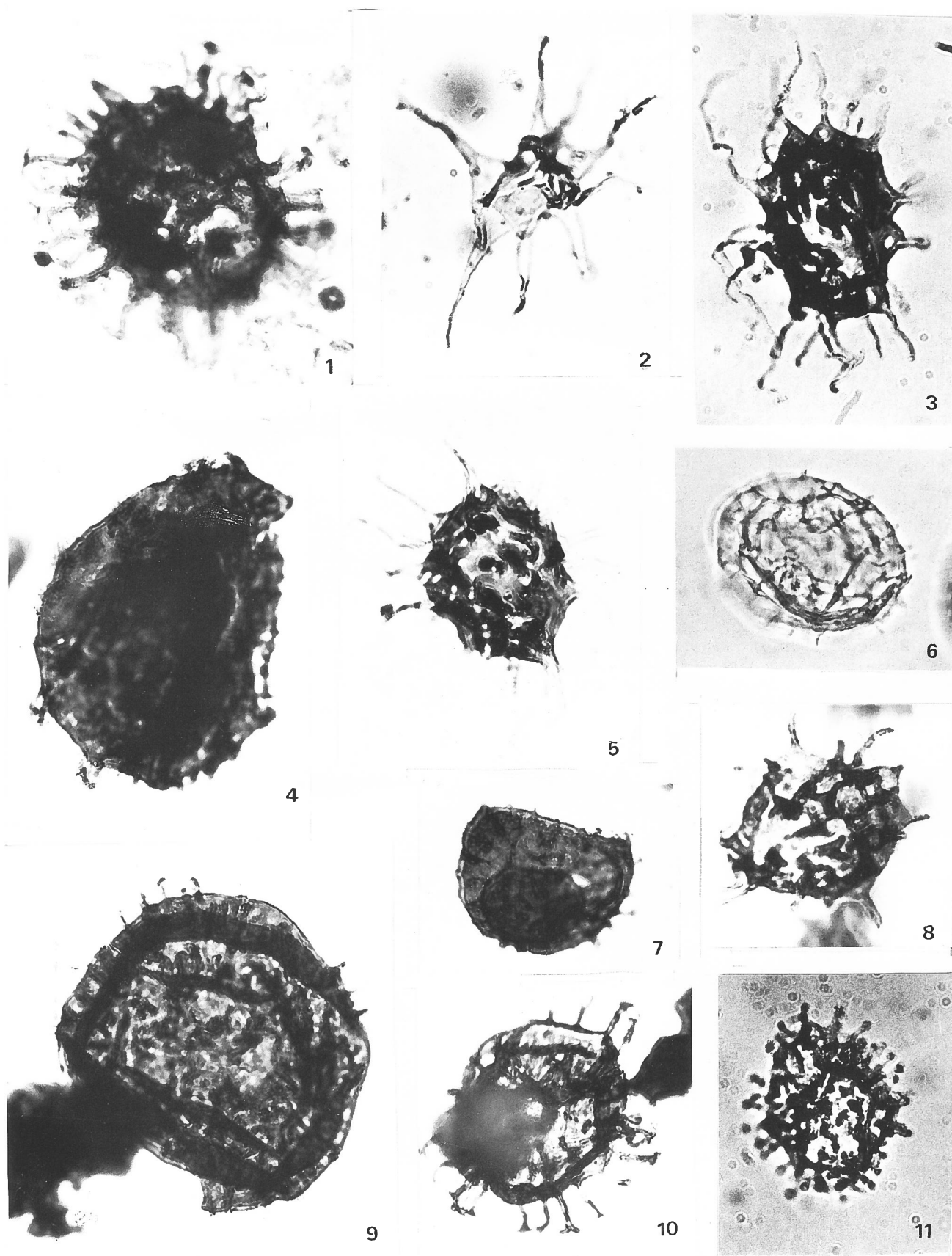
A detailed biozonation, based on acritarchs and graptolites, has been established for the upper Tremadoc-middle Arenig interval from sections of the Santa Victoria area. The acritarch assemblages are characterized by the presence of *Arbusculidium*, *Coryphidium*, and *Striatotheca*, which together indicate palaeogeographic affinity with the cold to temperate Perigondwana Province.

Based on acritarchs, graptolites, and trilobites, it is postulated that unrestricted communication existed between both sides of the Argentine Eastern Cordillera during Arenig time.

EXPLANATION OF PLATE 2

- Fig. 1 - *Ordoviciidium* sp. cf. *O. yangtzeense* Tongiorgi, Yin & Di Milia, 1995: LH3, LPPM6283a, T28/1.
- Fig. 2 - *Tectitheca* sp. cf. *T. additionalis* Burmann, 1968: LH5, LPPM 6285a, Y24/0.
- Fig. 3 - *Polygonium* sp. cf. *P. delicatum* Rasul, 1979: LH6, LPPM 6286b: Z24/0.
- Fig. 4 - *Rhopaliophora palmata* (Combaz & Peniguel, 1972) Playford & Martin, 1984: A4, LPPM 6203b, W31/2.
- Fig. 5 - *Polygonium* sp. cf. *P. symbolum* Rasul, 1979: LH6, LPPM 6286b, T35/0.
- Fig. 6 - *Cymatiosphaera* sp.: A5, LPPM 6204b, R20/1.
- Fig. 7 - *Stelliferidium* sp. cf. *S. brevipalmatum* Albani, 1989: A4, LPPM 6203b, G35/0.
- Fig. 8 - *Polygonium dentatum* (Timofeev ex Konzalová-Mazancová, 1969) Albani, 1989: LH6, LPPM 6286b, Q34/2.
- Fig. 9 - *Rhopaliophora* sp. cf. *R. pilata* (Combaz & Peniguel, 1972) Playford & Martin, 1984: A4, LPPM 6203b, N36/3.
- Fig. 10 - *Cymatiogalea* sp. cf. *C. membranispina* Deunff, 1961: A4, LPPM 6203b, B25/0.
- Fig. 11 - *Petaloferridium* sp. cf. *P. florigerum* (Vavrdová, 1977) Fensome *et al.*, 1990: LH6, LPPM 6286b, P24/1.

All figures ×1000.



SYSTEMATIC PALAEONTOLOGY

Incertae sedis "group" ACRITARCHA Evitt, 1963

Genus AMMONIDIUM Lister, 1970

Type species (by original designation) – *Ammonidium microcladum* (Downie, 1963) Lister, 1970.

Remarks – Lister pointed out that homomorphic processes are highly typical of *Ammonidium* Lister, 1970, in marked contrast to, for instance, the heteromorphic processes borne by *Multiplicisphaeridium* Staplin emend. Staplin, Jansonius & Pocock, 1965. In *Ammonidium*, each process is distally subdivided into branches of equal length which arise from a common point.

AMMONIDIUM MULTIPUGIUNCULATUM

(Cramer & Díez, 1977) Rubinstein comb. nov.
Pl. 5, fig. 9; pl. 6, fig. 7.

1977 *Multiplicisphaeridium multipugiunculatum* CRAMER & DíEZ, p. 348; pl. 3, figs. 14–16, 18; text-fig. 3:7.

Description – Vesicle circular to subcircular in outline, originally spherical. Processes clearly differentiated from vesicle, numerous, hollow, homomorphic, freely communicating with vesicle cavity, fairly regularly distributed over the vesicle. Processes truncated at their distal extremity, distally bearing 3–6 simple, spine-like, rarely bifurcated, second-order projections.

Dimensions – Vesicle diameter 26.5 (28) 35 µm; process length 6 (8) 10 µm; basal diameter of processes 2–2.5 µm (20 specimens measured).

Remarks – *Multiplicisphaeridium multipugiunculatum* (Cramer & Díez, 1977) Rubinstein comb. nov. is characterized by a spherical vesicle with numerous, short, homomorphic, truncate processes, each bear-

ing at its distal terminus palmate (rarely bifurcated) pinnae. The equifurcate process termini justify the assignment to *Ammonidium* rather than to *Multiplicisphaeridium*.

Occurrence – Río La Huerta section, Santa Victoria area: LH5, Acoite Formation, lower Arenig (*Baltograptus deflexus* graptolite Zone); LH8, LH9, Acoite Formation, middle Arenig (*Didymograptellus bifidus* graptolite Zone).

Genus CORYPHIDIUM Vavrdová, 1972

Type species (by original designation) – *Coryphidium bohemicum* Vavrdová, 1972.

CORYPHIDIUM MILADAE-CORYPHIDIUM TADLA group
Pl. 3, figs. 3, 7; pl. 5, fig. 4

1976 *Coryphidium milada* CRAMER & DíEZ, p. 205; pl. 23, figs. 9, 14, 22–23; text-fig. 2:6.

1976 *Coryphidium tadla* CRAMER & DíEZ, p. 206; pl. 23; figs. 3–4, 15, 18–19; text-fig. 2:9.

1984 *Coryphidium milada* Cramer & Díez - TONGIORGI, ALBANI & DI MILIA, pl. 2, fig. 16.

1984 *Coryphidium tadla* Cramer & Díez - TONGIORGI, ALBANI & DI MILIA, pl. 2, fig. 17.

1990 *Coryphidium miladum* Cramer & Díez - FENSOME *et al.*, p. 155.

1990 *Coryphidium tadlum* Cramer & Díez - FENSOME *et al.*, p. 156.

Description – Vesicle smooth, square, with rounded corners. Processes irregularly distributed on vesicle surface or tending to be concentrated at vesicle corners. Processes heteromorphic, filose; sharp-tipped, capitate or bifurcant distally.

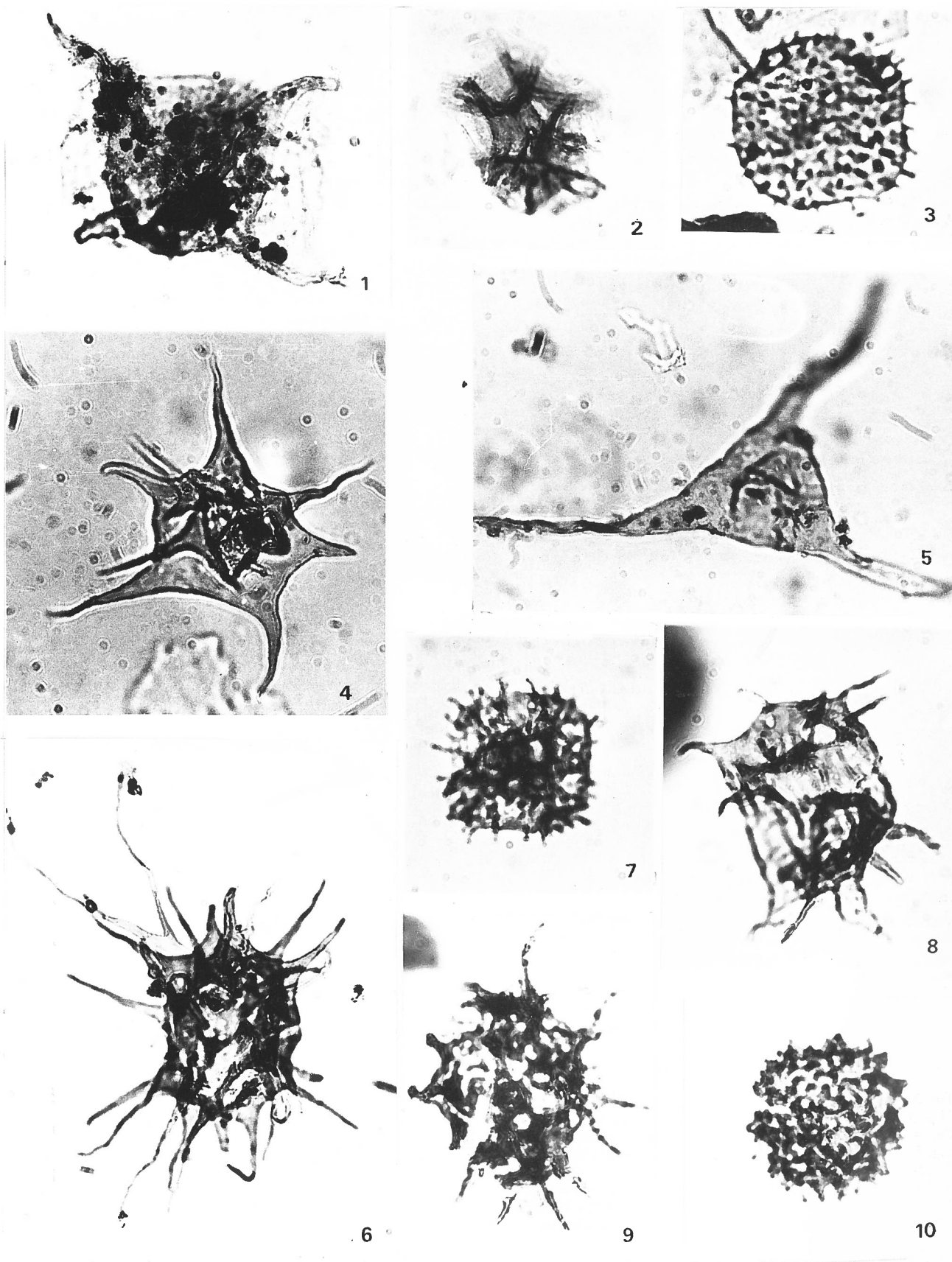
Dimensions – Length of vesicle sides 24 (28) 32 µm; process length 2 (3) 3.5 µm (10 specimens measured).

Remarks – Based on the descriptions provided by Cramer & Díez (1976), no essential difference can be detected between their species *Coryphidium miladae*

EXPLANATION OF PLATE 3

- Fig. 1 - *Aureotesta clathrata* var. *simplex* (Cramer, Kanes, Díez & Christopher, 1974) Brocke, Fatka & Servais, 1997: LH9, LPPM 6289b, K38/3.
Fig. 2 - *Cymatiosphaera* sp.: A5, LPPM 6204b, J18/2.
Figs. 3, 7 - *Coryphidium miladae*-*C. tadla* group. 3) LH8, LPPM 6288a, P42/0. 7) LH6, LPPM 6286b, K33/2.
Fig. 4 - *Polygonium gracile* Vavrdová, 1966: LH8, LPPM 6288a, Q20/1.
Fig. 5 - *Veryhachium trispinosum* (Eisenack, 1938) Stockmans & Willière, 1962: LH9, LPPM 6289b, P29/4.
Fig. 6 - *Actinodissus* sp. 1: LH7, LPPM 6287b, X34/1.
Fig. 8 - *Barakella* sp. cf. *B. rara* (Lu, 1987) Tongiorgi, Yin & Di Milia, 1995: LH6, LPPM 6286b, F43/4.
Fig. 9 - *Stellechinatum uncinatum* (Downie, 1958) Molyneux, 1987: LH6, LPPM 6286b, G39/4.
Fig. 10 - *Buedingiisphaeridium tremadocum* Rasul, 1979: A4, LPPM 6203b, C22/1.

All figures ×1000.



and *C. tadla*, which, furthermore, have the same stratigraphic range.

According to Cramer & Díez (1976), *Coryphidium miladae* is distinguishable by featuring a smooth vesicle bearing a few widely spaced processes. These latter are in the form of thin bacula or are distally club-shaped, sharp-tipped, or even bifurcated. Length of a vesicle side is ca. 25 µm; the processes may reach 3 µm in length. The same authors described *C. tadla* as having a smooth vesicle (sides 20-35 µm long) with filose, capitate (spoon-shaped), rarely bifurcant processes (up to 4 µm long).

Specimens recovered from the La Huerta section may be assigned to either *C. miladae* or to *C. tadla*, according to their predominant morphological characters and dimensions; however, the two species are really intergradational. Accordingly, these species are here considered together to comprise an informal *Coryphidium miladae*-*C. tadla* group.

Occurrence – Río La Huerta section, Santa Victoria area: LH6, LH7, LH8, Acoite Formation, middle Arenig (*Didymograptellus bifidus* graptolite Zone).

Genus EISENACKIDIUM Cramer & Díez, 1968
emend. Eisenack, Cramer & Díez, 1973

Type species (by original designation) – *Eisenackidium triplodermum* (Cramer, 1967) Cramer & Díez, 1968.

EISENACKIDIUM ORIENTALIS Rubinstein sp. nov.
Pl. 4, figs. 1, 8-10; pl. 5,
figs. 7, 10; pl. 6, figs. 1-3

1992 *Eisenackidium* sp. A OTTONE in Ottone, Toro & Waisfeld, p. 104; pl.3, figs. 6, 11.

Diagnosis – Vesicle variable in shape, roughly circular to subcircular in outline, wall two-layered. Inner layer relatively thick, fairly rigid and apparently smooth, comprising an inner body surrounded by outer wall. The latter thin, diaphanous, profusely

wrinkled, locally extending outwards to form the processes. Processes 4-6 in number, simple, homomorphic, often longitudinally folded; tapering distally to a pointed, blunt, or rounded termination. A few, smaller, second-order, spine- or hair-like processes (1-4 in number) may also occur. Excystment mode not observed.

Dimensions – Vesicle diameter 23 (31) 36 µm; process length 5 (19) 31 µm; basal diameter of processes 2 (8.5) 20 µm (40 specimens measured).

Holotype – Upper part of Acoite Formation. Sample LH7: LPPM 6287b, H38/3. Dimensions: vesicle diameter 35 µm; process length 20-23 µm; basal diameter of processes 10-12 µm; process number 4. Pl. 4, fig. 8; pl. 5, fig. 10.

Paratype – Upper part of Acoite Formation. Sample LH9: LPPM 6289b, S31/3. Dimensions: vesicle diameter 30 x 37 µm; process length 31 µm; basal diameter of processes 15-20 µm; 4 main processes, plus second-order processes ca. 10 µm long, 1.5 µm broad at base. Pl. 5, fig. 7.

Type locality and stratum – Eastern Cordillera, Salta Province, Argentina, upper Acoite Formation, La Huerta section (Santa Victoria area), sample LH7, middle Arenig (*Didymograptellus bifidus* graptolite Zone), 1100 m above base of Acoite Formation.

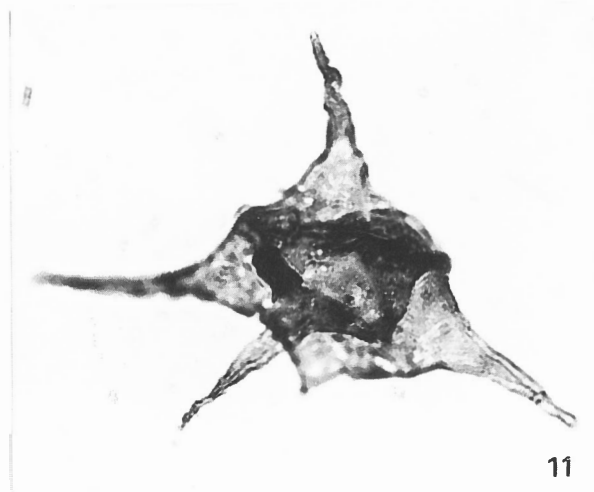
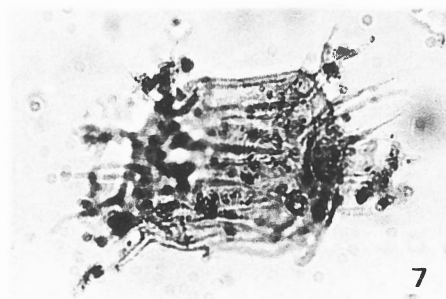
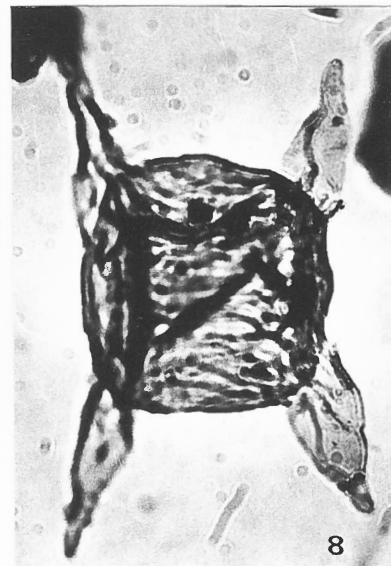
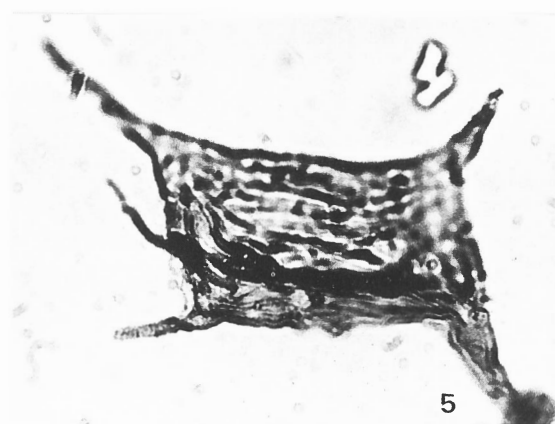
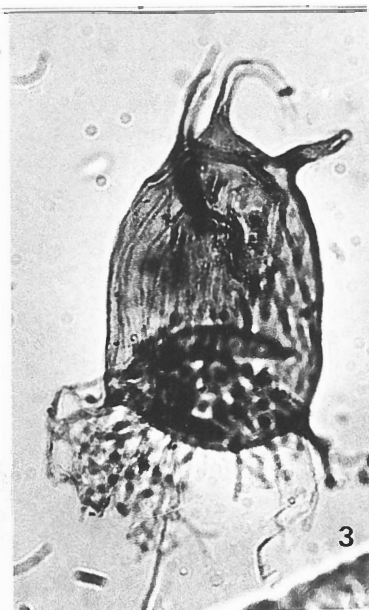
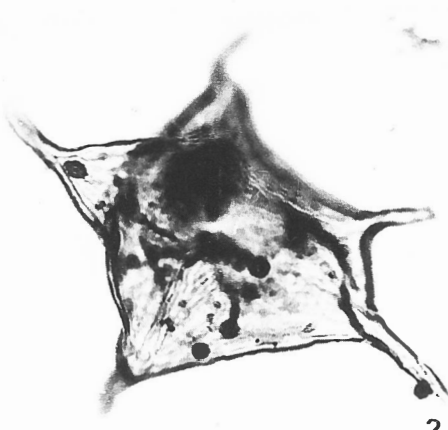
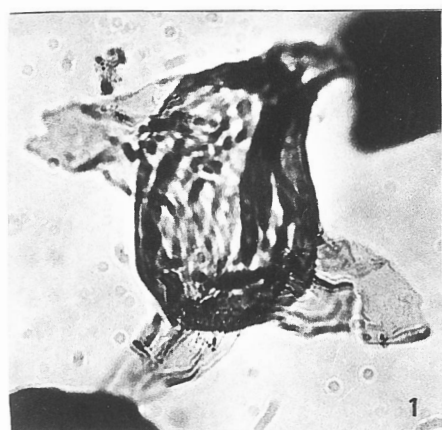
Name derivation – In reference to the Cordillera Oriental (Eastern Cordillera).

Remarks – This species shows considerable stratigraphic variation from the lower through middle Arenig. Specimens from the *D. bifidus* graptolite Zone (LH6, LH7, LH8, LH9) have four, mostly long, broad-based processes [length 7 (21.5) 31 µm, basal diameter 5 (12) 20 µm]. On the contrary, most of the specimens from the *B. deflexus* graptolite Zone have shorter, more narrowly based processes [length 5 (17.5) 20 µm, basal diameter 2 (4) 7 µm]. However, a few specimens from the lower Arenig display tran-

EXPLANATION OF PLATE 4

- Figs. 1, 8-10 - *Eisenackidium orientalis* Rubinstein sp. nov. 1) LH7, LPPM 6287b, N33/3. 8) LH7, LPPM6287b, H38/3. 9) LH6, LPPM 6286b, P28/0. 10) A4, LPPM6203b, U22/1.
Fig. 2 - *Striatotheca* sp.: LH9, LPPM 6289b, N14/4.
Fig. 3 - *Arbusculidium filamentosum* (Vavrdová, 1965) Vavrdová, 1972: LH8, LPPM 6288a, V30/1.
Fig. 4 - *Dactylofusa velifera* Cocchio forma *brevis* Albani, 1989: LH8, LPPM 6288a, N26/3.
Fig. 5 - *Striatotheca* sp. cf. *S. rarirrugulata* (Cramer, Kanes, Díez & Christopher, 1974) Eisenack, Cramer & Díez, 1976: LH6, LPPM 6286b, T31/0.
Fig. 6 - *Dactylofusa velifera* Cocchio forma *brevis* Albani, 1989: A4, LPPM 6203b, C31/2.
Fig. 7 - *Acanthodiacrodium costatum* Burmann 1968 *sensu* Cramer & Díez, 1977: LH9, LPPM 6289b, O27/4.
Fig. 11 - *Verhachium* sp. cf. *V. rhomboidium* Downie, 1959: LH6, LPPM 6286b, N41/0.

All figures ×1000.



sitional features, thus resembling the specimens from younger levels.

Comparison – *Eisenackidium orientalis* differs from other species of the same genus in having the outer wall profusely wrinkled.

Occurrence – Río La Huerta Section, Santa Victoria area: LH4: Acoite Formation, lower Arenig (*Baltograptus deflexus* Zone), only one specimen assigned with doubt (similar to specimens from A4 in Río Acoite Section); L H6, LH7, LH8, LH9: Acoite Formation, middle Arenig (*Didymograptellus bifidus* Zone). Río Acoite Section, Santa Victoria area: A4, Acoite Formation, lower Arenig (*Tetragraptus akzharensis* Zone).

Genus POLYGONIUM Vavrdová, 1966

Type species (by original designation) – *Polygonium gracile* Vavrdová, 1966.

POLYGONIUM sp. cf. P. AKROCHORDUM
(Rasul, 1979) Rubinstein comb. nov.
Pl. 1, fig. 13

cf. 1979 *Baltisphaeridium akrochordum* RASUL, p. 56; pl. 1, fig. 6.
1982 *Goniosphaeridium* aff. *G. akrochordum* MARTIN in
Dean & Martin, p. 138; pl. 1, figs. 8, 12, 14.

Remarks – Following Turner (1984), Albani (1989) and Le Hérisse (1989), *Goniosphaeridium* is here considered to be a junior synonym of *Polygonium*.

Occurrence – Río La Huerta section, Santa Victoria area: LH1, Santa Rosita Formation, upper Tremadoc (*Adelograptus-Bryograptus* graptolite association); LH6, Acoite Formation, middle Arenig (*Didymograptellus bifidus* graptolite Zone).

POLYGONIUM DENTATUM (Timofeev *ex* Konzalová-Mazancová, 1969) Albani, 1989
Pl. 2, fig. 8

1996 *Polygonium dentatum* (Timofeev *ex* Konzalová-Mazancová) Albani, 1989 - VECOLI, p. 39; pl. 7, fig. 5 (*cum syn.*).

Remarks – Welsch (1986) considered that *Polygonium dentatum* (Timofeev, 1959 *ex* Konzalová-Mazancová, 1969) Albani, 1989 and *P. pungens* (Timofeev, 1959 *ex* Martin, 1969) Albani, 1989 are synonyms. This is accepted herein (see also discussion in Vecoli, 1996, p. 39).

Occurrence – Río La Huerta section, Santa Victoria area: LH1, Santa Rosita Formation, upper Tremadoc (*Adelograptus-Bryograptus* graptolite association); LH6, LH7, Acoite Formation, middle Arenig (*Didymograptellus bifidus* Zone). Río Acoite section, Santa Victoria area: A3, Acoite Formation, lower Arenig (*Tetragraptus akzharensis* Zone); A5, Acoite Formation, lower Arenig (*Baltograptus deflexus* Zone).

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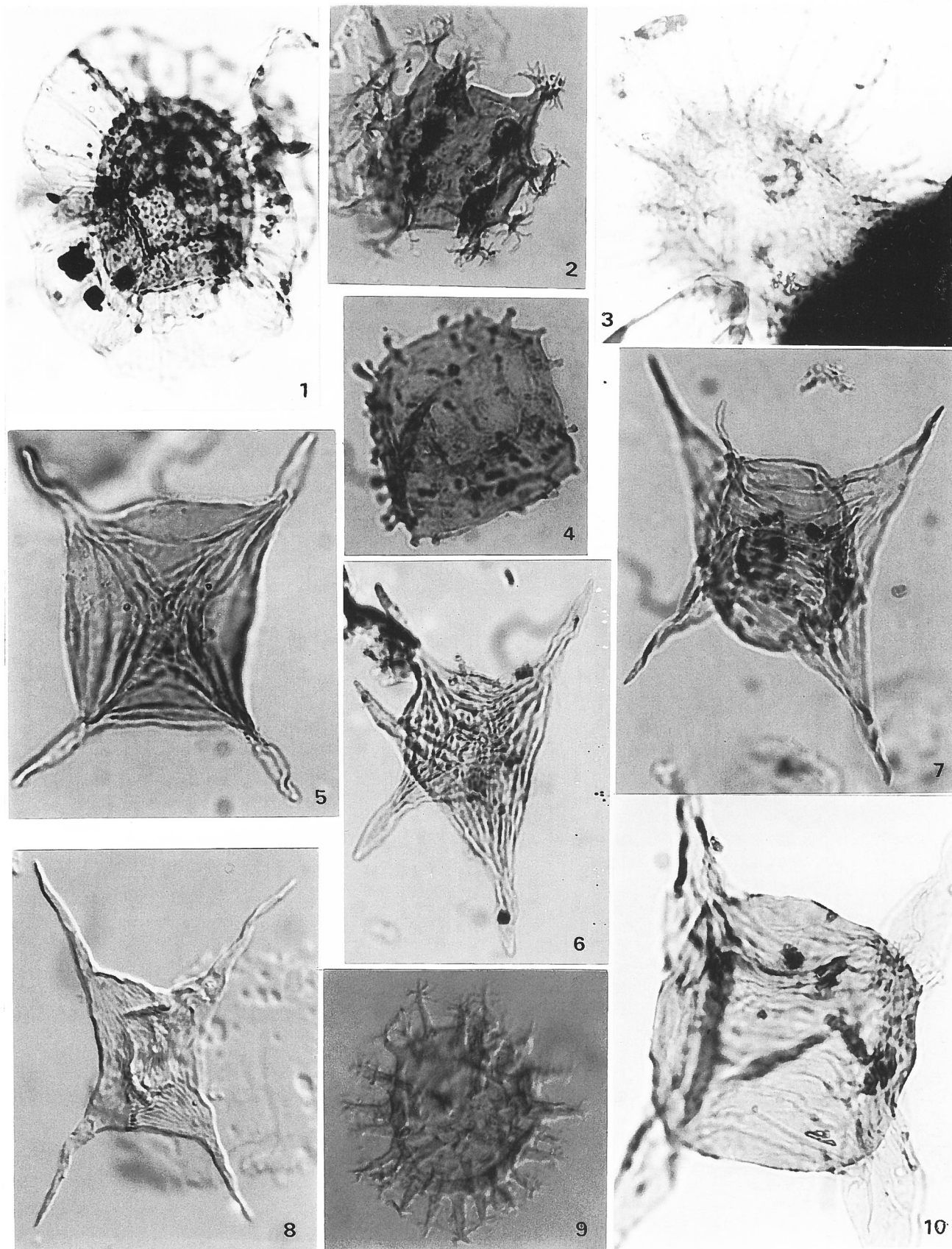
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EXPLANATION OF PLATE 5

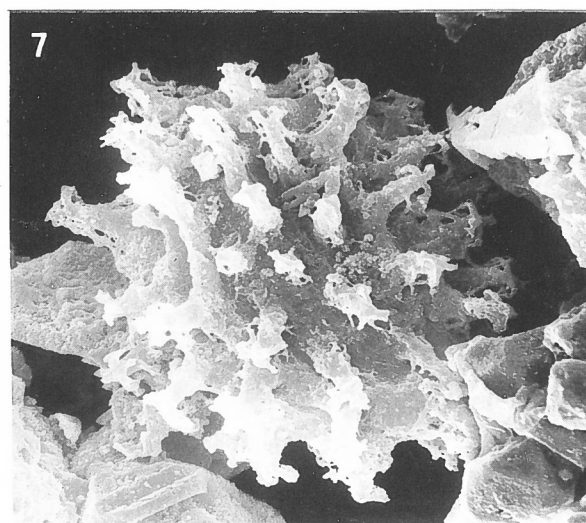
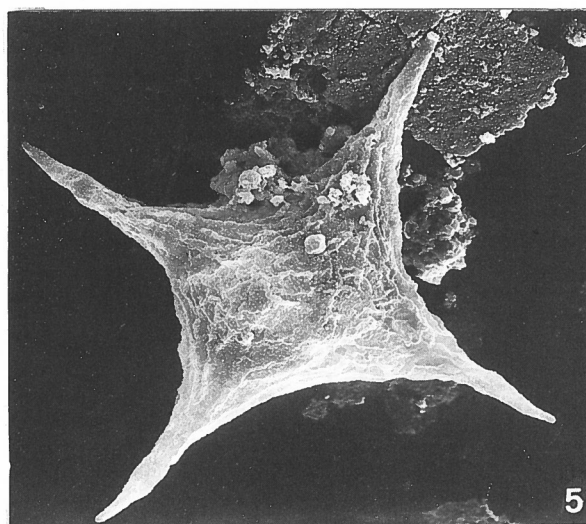
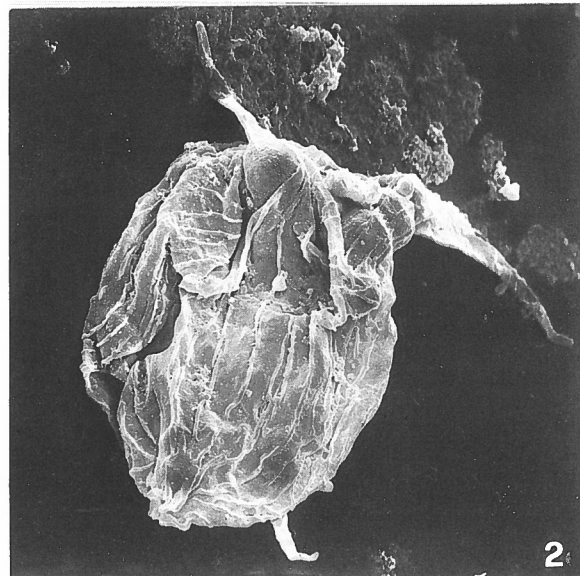
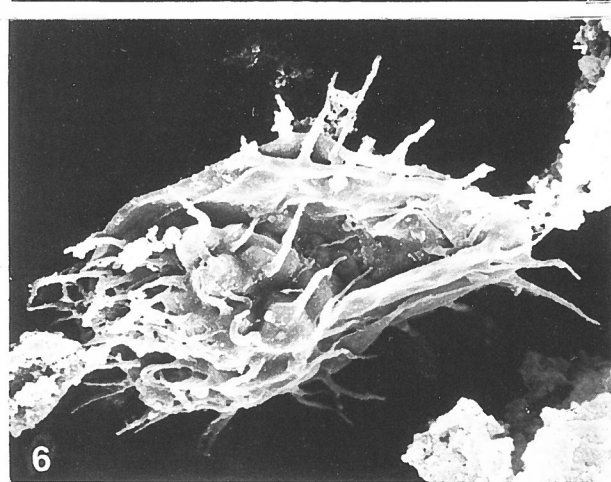
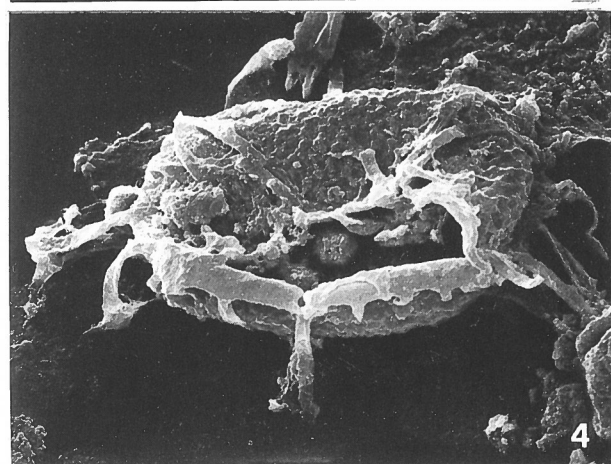
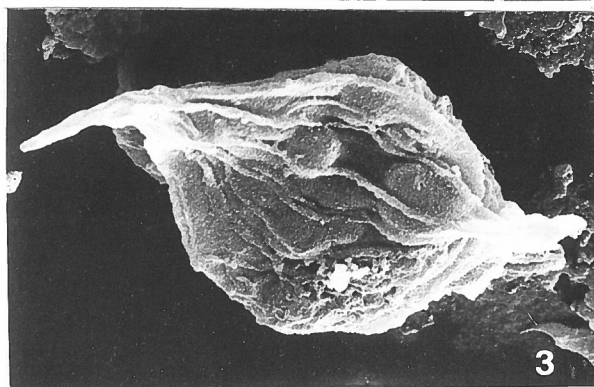
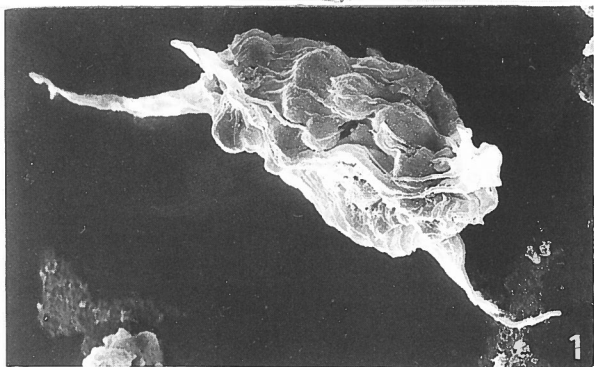
- Fig. 1 - *Cymatiogalea granulata* Vavrdová, 1966: LH9, LPPM 6289b, Y29/2. x1000.
Fig. 2 - *Adorfia hoffmanensis* (Cramer, Kanes, Díez & Christopher) Ottone *in* Ottone *et al.*, 1992: LH8, LPPM 6288a, C28/3. x900.
Fig. 3 - *Stellechinatum* sp. cf. *S. brachysolum* Turner, 1984: LH7, LPPM 6287b, V37/1. x1650.
Fig. 4 - *Coryphidium miladae*-*C. tadla* group: LH7, LPPM 6287b, M40/1. x1200.
Fig. 5 - *Striatotheca principalis parva* Burmann, 1970: LH8, LPPM 6288a, S30/2. x1400.
Fig. 6 - *Striatotheca transformata* Burmann, 1970: LH9, LPPM 6289b, G36/4. x1000.
Figs. 7, 10 - *Eisenackidium orientalis* Rubinstein sp. nov. 7) LH9, LPPM 6289b, S31/3. x1000. Paratype. 10) LH7, LPPM 6287b, H38/3. x1400. Holotype; showing profusely wrinkled outer wall extending outwards to form processes.
Fig. 8 - *Striatotheca microrugulata* (Vavrdová) Martin, 1977: LH8, LPPM 6288a, W20/2. x1000.
Fig. 9 - *Ammonidium multipugiunculatum* (Cramer & Díez) Rubinstein comb. nov.: LH8, LPPM 6288a, Y20/0. x1000.



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EXPLANATION OF PLATE 6

- Figs. 1-3 - *Eisenackidium orientalis* Rubinstein sp. nov., SEM. 1) LH9, LPPM 6289. x2000; note pyrite inclusions. 2) LH9, LPPM 6289. x2300; showing wrinkled outer wall. 3) LH9, LPPM 6289. x2000; showing outer wall extending to form processes.
- Fig. 4 - *Cymatogalea granulata* Vavrdová, 1966: SEM LH9, 6289. x3300.
- Fig. 5 - *Striatotheca* sp.: SEM LH9, 6289. x1600.
- Fig. 6 - *Acanthodiacrodium costatum* Burmann, 1968 *sensu* Cramer & DíEZ 1977: SEM LH9, 6289. x2200.
- Fig. 7 - *Ammonidium multipugiunculatum* (Cramer & DíEZ) Rubinstein comb. nov.: SEM LH9, 6289. x3300.



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