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Taxonomy and evolution of *Kockelella* (Conodonta) from the Silurian of Sardinia (Italy)

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ABSTRACT – Relatively abundant specimens of *Kockelella* found in Sardinia permit a revision of many taxa of this important genus and an attempt at a more complete reconstruction of the phylogeny of the whole group.

Besides the two new taxa recently (1998) proposed by us (*K. maenniki* and *K. v. ichnusae*), which are here re-described and re-discussed, a new subspecies, *K. absidata sardoa* of the *K. absidata* group, is proposed. Furthermore the reconstruction of the apparatus of *K. crassa* is presented. The biostratigraphic value of the taxa of the genus *Kockelella* is also stressed.

RIASSUNTO – [Tassonomia ed evoluzione del genere *Kockelella* (Conodonta) nel Siluriano della Sardegna (Italia)] – Un numero abbastanza elevato di *Kockelelle* provenienti dai terreni siluriani della Sardegna ha permesso di effettuare una revisione di diversi taxa di questo importante genere e di tentare una più completa ricostruzione della filogenesi del gruppo.

Oltre ai due nuovi taxa proposti recentemente da noi (*K. maenniki* e *K. v. ichnusae*), che vengono qui ridescritti e ridiscussi, viene anche proposta una nuova sottospecie, *K. absidata sardoa*, del gruppo della *K. absidata*. Inoltre è presentata la ricostruzione dell'apparato di *K. crassa*. Viene infine discussa l'importanza stratigrafica dei diversi taxa del genere *Kockelella*.

INTRODUCTION

Research in Sardinia during the past three decades by one of us (E.S.) and more recently, by a team from Modena University in connection with the preparation of the ECOS VII field trip, has allowed the recovery, from about 70 samples, of conodont elements belonging to several taxa of the genus *Kockelella*. More precisely, 673 Pa elements, hundreds of Pb (187), M (236), and numerous ramiform elements (918) not yet assigned (Tab. 1), have been identified.

The large number of specimens of *Kockelella* elements stimulated us to revise the many taxa of this important Silurian genus and to attempt a more complete reconstruction of the phylogeny of the group.

Kockelella, first recorded by Serpagli (1967) from Sardinia, have been recovered from Silurian sediments either in the "Orthoceras limestone" facies (Fluminimaggiore Fm) of the SW or in the "Ockerkalk" facies of the SE. As has been summarised by Ferretti & Serpagli (1996), two distinct types of Silurian successions occur in Sardinia and are similar to the sequences exposed in Bohemia and Thuringia, respectively (see also Corradini & Serpagli, 1999, this volume).

The stratigraphic distribution of *Kockelella* species is related to the biozonation proposed by Corradini & Serpagli (1998) and discussed further in this symposium volume (Corradini & Serpagli, 1999).

THE PHYLOGENY OF KOCKELELLA

The first reconstruction of the phylogeny of *Kockelella* was presented by Barrick & Klapper in their authoritative paper of 1976. Subsequently, the problem has been discussed by Kleffner (1994), with regard to some Wenlockian forms, and by Fordham (1991), who, in his cladistic reconstruction of the whole Silurian conodonts, also presented a phylogenetic tree for the *Kockelella*-*Polygnathoides* Group (p. 9, Fig. 2d).

It is well known (Sweet, 1988) that the oldest species of genus *Kockelella* evolved during the middle of Llandovery, probably from species like *Ozarkodina abrupta* (Aldridge, 1972) and the last species became extinct within the *Pol. siluricus* Zone. With the present study, the number of taxa assigned to *Kockelella* increases from twelve to sixteen. Therefore, we try to contribute to the understanding of the phyletic relations within the genus *Kockelella* as inferred from the Sardinian sequences as well as from the literature.

Three main lineages, mainly based on the Pa element, can be recognised, all originating from the common ancestor *K. ranuliformis* (Text-fig. 1).

One lineage starts in the latter part of the *K. ranuliformis* interval Zone with *K. walliseri* (early forms) evolving from *K. ranuliformis* by developing a lateral process adjacent of the cusp. *K. walliseri* lasted up to the *K. crassa* Zone, without producing any important descendant. In fact, both *K. cf. stauros sensu* Bischoff,

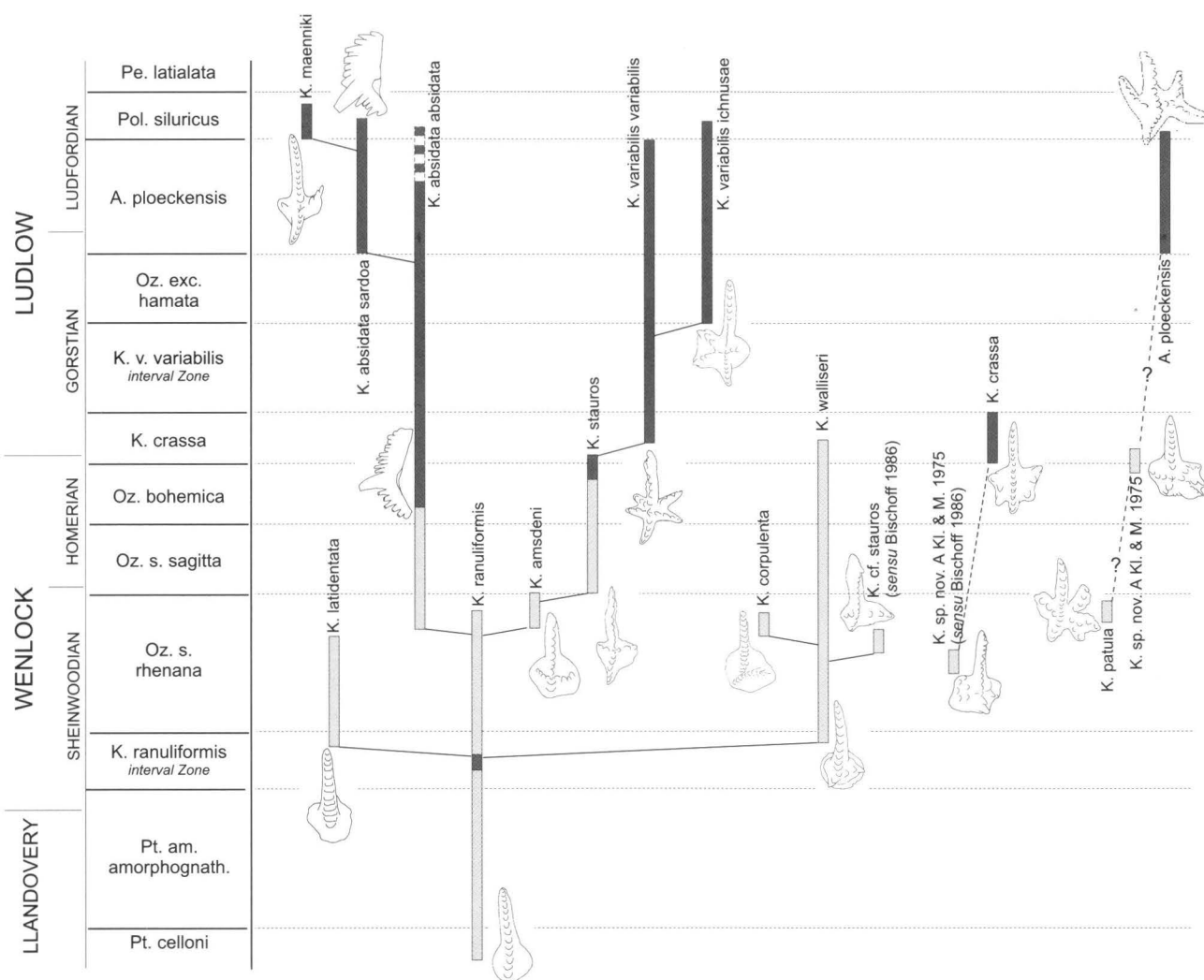
1986 and *K. corpulenta* became extinct soon in the late *Oz. s. rhenana* Zone. The first became differentiated through a more developed lateral process; the second through a robust blade bearing laterally expanded denticles similar to transverse ridges.

Also in the *K. ranuliformis* interval Zone, a population of *K. ranuliformis* started to develop ridge-like denticles on the blade, giving rise to *K. latidentata*, which become extinct before the end of the succeeding *Oz. s. rhenana* Zone.

In the late *Oz. s. rhenana* Zone, *K. ranuliformis* gave rise to more successful stock, which, after having provided forms with two small lateral processes (*K. amsdeni*), evolved to Pa elements characterised by an even more complex platform, which expanded into a true posterior process (*K. stauros*-*K. variabilis* Group).

K. v. variabilis evolved from *K. stauros* through bifurcation of lateral processes and restriction of the basal cavity to the area under the processes. At the base of the *Oz. exc. hamata* Zone, it produced *K. v. ichnusae*, in which one lateral process became simple and sub-rounded, and denticles nearly completely fused just anterior to the cusp. The lineage ends with *K. v. ichnusae* in the early *Pol. siluricus* interval (Text-fig. 1).

The third lineage includes three taxa and is characterised by Pa elements in which the cusp is always clearly differentiated from the other denticles. It apparently evolved directly from *K. ranuliformis* by increasing the number of denticles posterior to the main denticle, which gradually become a true cusp. From *K. absidata absidata*, which is the ancestor of this stock, evolved *K. a. sardoa* through development of crowded



Text-fig. 1 - Tentative reconstruction of the origin and phylogeny of the genus *Kockella* based on previous studies (Barrick & Klapper, 1976; Kleffner, 1994) and on the data from Sardinia. Relationship between any branch of the tree and the *K. crassa* stock remain indefinite, as well as with *K. patula* and its possible descendant *A. ploekensis*. The occurrence of different taxa in Sardinia is shown in dark grey; dotted lines indicate highly speculative connections.

denticles on the anterior process of the Pa element and an anterior constriction of the basal cavity. *K. a. sardoa* finally produced *K. maenniki* by developing a long, denticulate lateral process. This lineage starts within the late *Oz. s. rhenana* Zone and survives into the late *Pol. siluricus* Zone, therefore including the youngest *Kockelella* species before the extinction of the genus.

More difficult to place in this phyletic scheme are the *K. crassa* stock and *K. patula* stock, which, we prefer to consider them as a separate groups, apparently not linked each other nor to the main tree.

We believe that *K. crassa* evolved from forms characterised by a wider platform (*Kockelella* sp. nov. A Klapper & Murphy, 1975 *sensu* Bischoff, 1986), which bears a few nodes on its inner side. This form has a more or less rounded-subquadrate outline of the platform, which became almost quadrate in its descendant, *K. crassa*, in which some variations in the pattern of platform denticles also occurred. This connection is, however, speculative, because of the wide stratigraphic gap between the two taxa.

Even more speculative are the relations between *K. patula* and its possible descendants, which Fordham (1991) indicates are *Kockelella* sp. nov. A Klapper & Murphy, 1975 and *Ancoradella ploeckensis*. Therefore, we prefer to consider this stock as a separate group, apparently not linked to any other, as Barrick & Klapper (1976, fig. 5) did.

Looking at the *Kockelella* phylogenetic tree, as we have tentatively reconstructed it (Text-fig. 1), some comments can be presented about the evolutionary history of the genus.

After its appearance in the late Llandovery, probably derived from *Ozarkodina abrupta*-type forms (Sweet, 1988; p.97), the genus *Kockelella* lasted for about thirteen million years (from 428 Ma to 415 Ma) into the early Ludfordian. The stock flourished with varying success, being twice affected by crises before the final extinction (Text-fig. 1).

The first crisis took place in late *Oz. s. rhenana* Zone and led to the extinction of nearly all species usually lacking a well defined posterior process (*K. ranuliformis*, *K. latidentata*, *K. corpulenta*, *K. amsdeni*, *K. cf. stauros* *sensu* Bischoff, 1986, *Kockelella* sp. nov. A Klapper & Murphy, 1975 *sensu* Bischoff, 1986) as well as *K. patula*. The second crisis occurred during the *K. crassa* Zone, just above the Wenlock-Ludlow boundary, and affected *K. stauros*, *Kockelella* sp. nov. A Klapper & Murphy, 1975, *K. walliseri* and *K. crassa*. The survivors, *K. v. variabilis* and *K. a. absidata*, successfully evolved, producing descendants that persisted into the late *P. siluricus* Zone, when the entire lineage came to an end. No *Kockelella* has been recorded in sediments younger than the *Pol. siluricus* Zone (which corresponds to the *leintwardinesis* (*fritschii linearis*) graptolite Zone), when the closely related taxon, *Ancoradella ploeckensis*, also became extinct.

BIOSTRATIGRAPHICAL MEANING

The biostratigraphic value of kockelellids has been demonstrated by Walliser (1964) and Klapper & Murphy (1976), who used some taxa to name biointervals. With the present study, this value is enhanced because 3 of the new 4 taxa proposed (or re-proposed) here can be of great help in making biostratigraphic determinations. *K. crassa* was apparently a short-ranged species, limited the basal Gorstian. *K. maenniki* also ranged briefly together with *Pol. siluricus*, but didn't survive through the latest part of the nominate zone. *Kockelella v. ichnusae* and *K. a. sardoa* have a slightly lower biostratigraphic significance, being the more successful among the new taxa (Text-fig.1).

SYSTEMATIC PALAEOONTOLOGY

All studied specimens are stored in the Department of Earth Sciences (Palaeontology), Modena University.

KOCKELELLA ABSIDATA Barrick & Klapper, 1976

Based on the morphological differences of the Pa and the M elements, two phyletically connected subspecies can be distinguished in *K. absidata*: *Kockelella absidata absidata* Barrick & Klapper and *K. absidata sardoa* n. spp. *K. a. sardoa* evolved from *K. a. absidata* in late Gorstian time (Text-fig.1). Specimens with intermediate features have been observed in samples from the *Oz. exc. hamata* and *A. ploeckensis* zones.

It should be pointed out that a further subspecies of this group may be represented by *K. ortus ortus* (Walliser, 1964) *sensu* Jeppsson, 1997.

KOCKELELLA ABSIDATA ABSIDATA Barrick & Klapper, 1976 Pl. 1, figs. 8-13

- Pa element
- 1957 *Spathognathodus cf. primus* (Branson & Mehl) - WALLISER, pl. 1, figs. 1-2.
 - 1964 *Ozarkodina fundamentata* (Walliser) - WALLISER, pl. 23, figs. 5-9, 11-15, 21 (?) [only].
 - 1969 *Ozarkodina fundamentata* (Walliser) - SCHÖNLAUB, pl. 1, fig. 22.
 - 1971 *Ozarkodina fundamentata* (Walliser) - SERPAGLI, pl. 21, fig. 13.
 - 1976 *Kockelella absidata* n.sp. - BARRICK & KLAPPER, pp. 76-77, pl. 2, figs. 15-16.
 - 1978 *Kockelella absidata* Barrick & Klapper - REXROAD, NOLAND & POLLOCK, pl. 1, fig. 31.
 - 1983 *Kockelella absidata* Barrick & Klapper - WANG & ZIEGLER, fig. 3, n. 5.
 - 1983 *Kockelella absidata* Barrick & Klapper - BARRICK, fig. 18G.

- 1993 *Kockelella absidata* Barrick & Klapper - SCHÖNLAUB (in Kriz *et al.*), pl. 1, fig. 16.
 1998 *Kockelella absidata* Barrick & Klapper - SERPAGLI, CORRADINI & FERRETTI, pl. 1.2.1, fig. 8.
 1998a *Kockelella absidata* Barrick & Klapper - FERRETTI, CORRADINI & SERPAGLI, pl. 2.2.1, fig. 12; pl. 2.2.2, fig. 5.

Description – Pa ELEMENT. Representative specimens have a stout, laterally compressed blade, bearing denticles, that are usually more crowded on the anterior part. The anterior process is higher than the posterior one; it is more or less straight and bears up to thirteen closely spaced, laterally compressed denticles. In some specimens the three or four denticles just anterior to the cusp are fused almost up to their apexes. The posterior process is lower, arched downward and gently incurved; it bears two to six, sometime discrete denticles. The cusp is laterally compressed, reclined and slightly larger than adjacent denticles.

The “*spathognathodus*-like” basal cavity is widest beneath the cusp. It narrows gradually towards the posterior end of the specimen, whereas anteriorly, after a gentle constriction just anterior to the cusp, it extends as a narrow groove up to the distal end of the anterior process.

Pb, M, Sa, Sb and Sc ELEMENTS. These are (apparently) indistinguishable from the corresponding elements of *K. v. variabilis*.

Remarks – The Pa element of *K. a. absidata* has a more stout appearance, the anterior blade is usually higher than the posterior one, and has the basal cavity a “*spathognathodus*-like” outline. Juvenile representatives have a Pa element with a very narrow blade, with densely located denticles, a similar thickness of the anterior and posterior processes and a basal cavity with an “heart-shaped” outline.

M elements of *K. a. absidata* differ from the corresponding ones of *K. a. sardoa* in lacking a true anterior process.

Range – In Sardinia *K. a. absidata* appears during the *Oz. bohémica* Zone, whereas in the literature representatives of this subspecies are known also from the *Oz. s. rhenana* Zone. The last certain occurrence of *K. a. absidata* is recorded from the *A. ploeckensis* Zone. However, a probable (fragmentary) specimen of this taxon has been recovered in the sample GCIU 4, coming from the *Pol. siluricus* Zone in Sardinia.

Studied material – 77 (+2 questionable) Pa and 28 M elements from samples GA 1, GA 2, FRU 0, GCIU 4, SIL I° 1, SIL I° 2, SIL I° 3, GALE BK 50, GALE BK 14, GALE BK 18, GALE BK 23, GALE BK 8, GALE BK 21, SF BK 3, SF 7, SF 9, SF BK 12, SF BK 16, PF 1A, PF 11A, PF 10, PF 1D, PF 1Q, PF 1F, PF 11B and SAD BK 6.

KOCKELELLA ABSIDATA SARDOA n. ssp. Pl. 1, figs. 1-7

Pa element

- 1964 *Ozarkodina fundamentata* (Walliser) - WALLISER, pl. 23, figs. 16, 18-19, 22-24 [only].
 ? 1971 *Ozarkodina fundamentata* (Walliser) - REXROAD & CRAIG, pl. 80, fig. 20 [only].
 1972 *Spathognathodus fundamentatus* Walliser - LINK & DRUCE, pl. 9, figs. 1-11.
 1975 *Kockelella variabilis* Walliser - KLAPPER & MURPHY, pl. 10, figs. 8-11.
 1992 *Kockelella absidata* Barrick & Klapper - BARCA *et al.*, pl. 11, fig. 5.
 1995 *Kockelella absidata* Barrick & Klapper - BARCA *et al.*, pl. 4, fig. 11.
 1998 *Kockelella absidata* Barrick & Klapper - SERPAGLI, CORRADINI & FERRETTI, pl. 1.2.1, fig. 7.
 1998 *Kockelella absidata* Barrick & Klapper - CORRADINI *et al.*, pl. 1.3.1, fig. 16.

M element

- 1957 *Prioniodina excavata* (Branson & Mehl) - WALLISER, pl. 2, fig. 16.

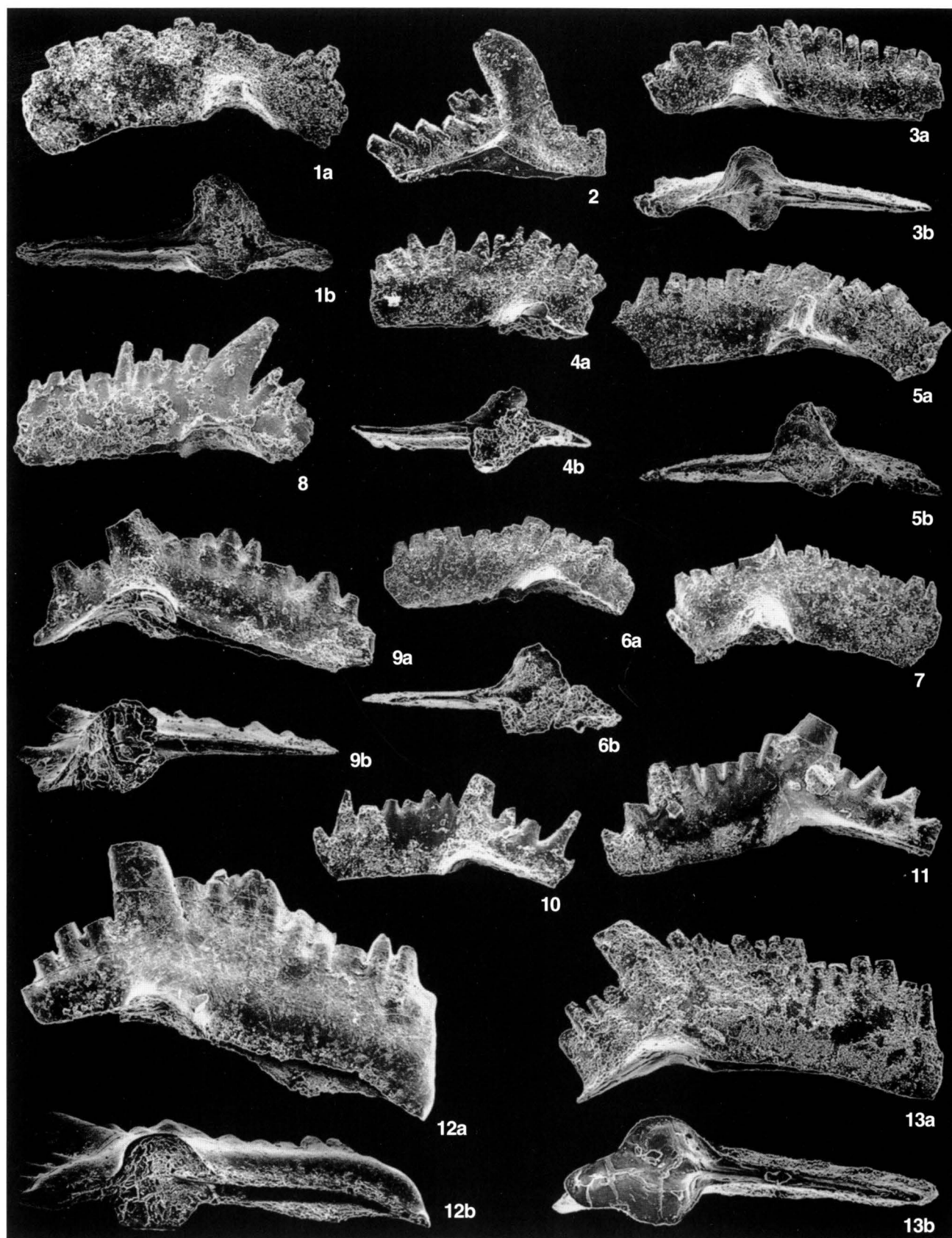
EXPLANATION OF PLATE 1

Figs. 1-7 - *Kockelella absidata sardoa* n. ssp.

- 1) Paratype, IPUM 25857, sample GCIU 3 (*Pol. siluricus* Zone); lateral view (a) and lower view (b) of Pa element; x80;
- 2) Paratype, IPUM 27480, sample GCIU 3 (*Pol. siluricus* Zone); inner-lateral view of M element; x66;
- 3) Holotype, IPUM 27481, sample GCIU 3 (*Pol. siluricus* Zone); lateral view (a) and lower view (b) of Pa element; x66;
- 4) Paratype, IPUM 27482, sample SIL I° 6 (*A. ploeckensis* Zone); lateral view (a) and lower view (b) of Pa element; x66;
- 5) Paratype, IPUM 25858, sample SIL I° 7 (*Pol. siluricus* Zone); lateral view (a) and lower view (b) of Pa element; x80;
- 6) Paratype, IPUM 27483, sample SIL I° 9 (*Pol. siluricus* Zone); lateral view (a) and lower view (b) of Pa element; x80;
- 7) Paratype, IPUM 27484, sample SIL I° 10 (*Pol. siluricus* Zone); lateral view of Pa element; x80.

Figs. 8-13 - *Kockelella absidata absidata* Barrick & Klapper, 1976.

- 8) IPUM 25861, sample PF 11B (*Oz. exc. hamata* Zone); lateral view of Pa element; x80;
- 9) IPUM 27476, sample GALE BK 18 (*K. crassa* Zone); lateral view (a) and lower view (b) of Pa element; x66;
- 10) IPUM 27479, sample PF 1Q (*A. ploeckensis* Zone); lateral view of Pa element; x80;
- 11) IPUM 25860, sample PF 1Q (*A. ploeckensis* Zone); lateral view of Pa element; x70;
- 12) IPUM 27477, sample SF BK 3 (*Oz. bohémica* Zone); lateral view (a) and lower view (b) of Pa element; x66;
- 13) IPUM 27478, sample PF 1D (*Oz. exc. hamata* Zone); lateral view (a) and lower view (b) of Pa element; x66.



- 1957 *Prioniodina* cf. *armata* (Hinde) - WALLISER, pl. 2, fig. 22 [only].
 1964 *Neoprionodus multiformis* WALLISER, pl. 29, figs. 19, 23 [only].

Holotype – the specimen illustrated on Pl. 1, Fig. 3a,b, IPUM 27481.

Paratypes (figured) – IPUM 25857-25858, 27480, 27482-27484.

Locus typicus – Genna Ciuerciu section, close to the Silius village, South East Sardinia, Italy.

Stratum typicum – GCIU 3.

Derivatio nominis – latin *sardous*, from Sardinia.

Diagnosis – The Pa element is characterised by a laterally compressed, densely denticulated blade. No significant differences exist in thickness between the anterior and posterior part of the blade. The “heart-shaped” basal cavity has a sharp constriction just anterior to the cusp and gradually tapers posteriorly.

Description – Pa ELEMENT. Representative specimens have a very narrow, laterally compressed blade bearing crowded denticles. The anterior process is more or less straight and bears up to twelve closely spaced laterally compressed denticles. The short posterior process is arched downward and gently incurved; it bears two to five closely spaced denticles. The height of the anterior and posterior parts of the blade is similar. The cusp is laterally compressed, reclined and slightly larger than the adjacent denticles. The basal cavity is shallow and slightly flared on both sides below the cusp. The outer flare of the cavity is usually better developed and may bear a small denticle. The basal cavity has a “heart-like” shape, because it tapers gradually towards the posterior end of the unit, whereas, after a more or less sharp constriction just anterior to the cusp, it continues as a narrow groove below the anterior process.

M ELEMENT (Pl. 1, fig. 2). Specimens are slightly curved and sometimes arched, with a long stout,

biconvex cusp, which is gently curved and slightly twisted to the posterior. The posterior process is twisted and bears up to nine laterally compressed, reclined, discrete denticles. The denticles closer to the cusp are smaller than others, and more densely spaced. A short anterior process is deflected outwards and, in some specimens, descends downwards from the cusp. This process usually bears two denticles. The basal cavity is widest below the cusp and has a prominent flaring on the inner side of the element, and opens somewhat to the posterior.

Pb, Sa, Sb and Sc ELEMENTS. These elements are apparently indistinguishable from the corresponding elements of *K. v. variabilis* and *K. a. absidata*.

Remarks – Pa ELEMENT. The Pa element of *K. absidata sardoa* differs from that of *K. a. absidata* in three main features:

- the general outline of the blade: in *K. a. absidata* the anterior process is higher than the posterior one, and the blade has a more stout appearance;
- the outline of the basal cavity: in *K. a. absidata* tapers anteriorly more gently whereas in *K. a. sardoa* it has a “heart-like” shape;
- the pattern of denticulation: in *K. a. sardoa* denticles are closely spaced on both processes, whereas in *K. a. absidata* they may be less crowded, up to discrete, on the posterior process.

K. absidata sardoa is similar to *K. maenniki*, and differs from it mainly in the lack of lateral processes.

M ELEMENT. The M element of *K. a. sardoa* differs from the corresponding element of *K. a. absidata* in having a true anterior process; it is different from the M element of *K. maenniki* because in the latter the denticles are closely spaced and the posterior process is strongly arched.

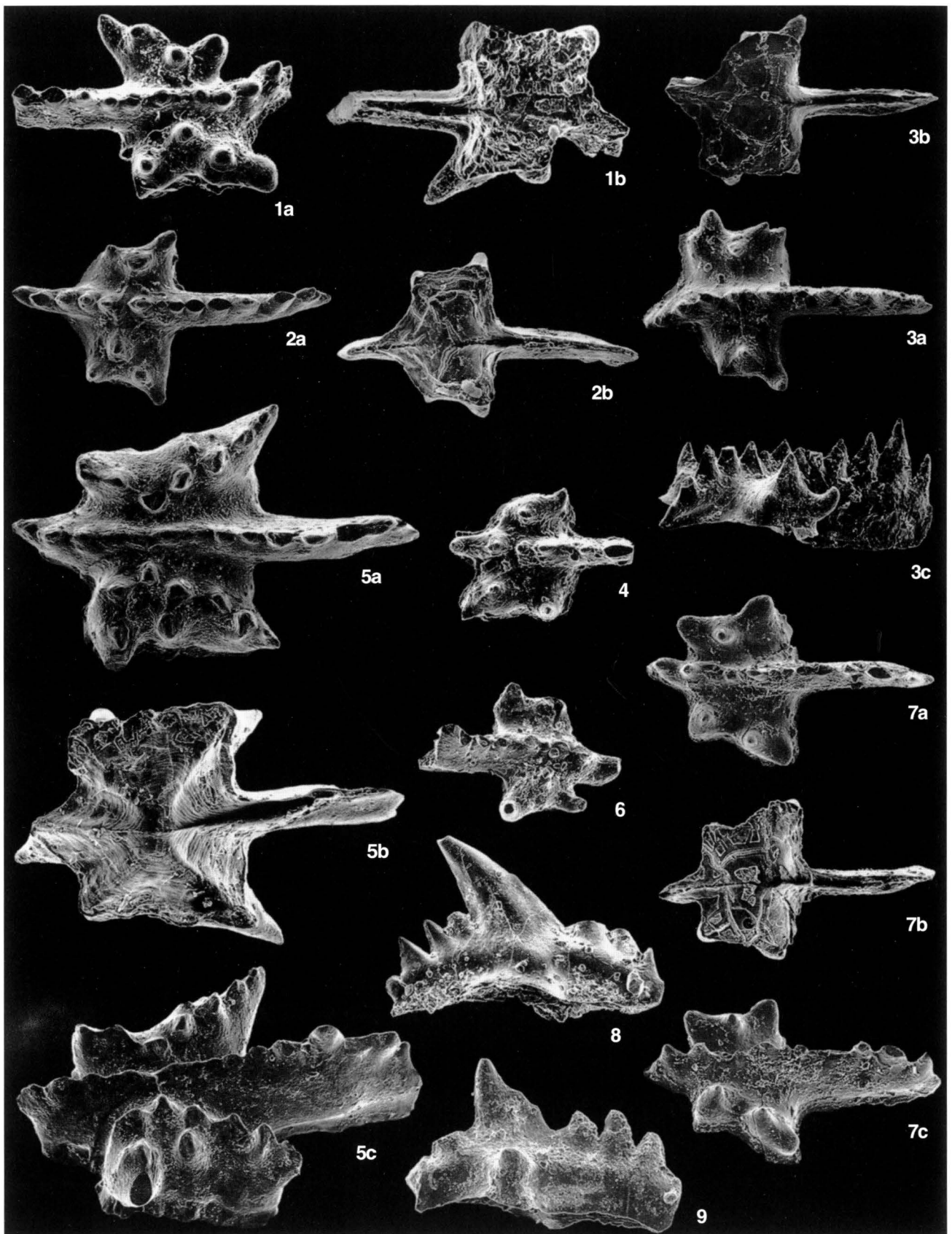
K. a. sardoa has excellent biostratigraphical value, spanning an interval from the base of the *A. ploeckensis* Zone to within the *Pol. siluricus* Zone. In fact all our material, as well as the specimens reported on the synonymy list, is from this interval.

The specimens illustrated from Cellon by Walliser (1964) as *Oz. fundamentata* and here reported in the

EXPLANATION OF PLATE 2

Figs. 1-9 – *Kockelella crassa* (Walliser 1964).

- 1) IPUM 27488, sample SAD BK 2 (*K. crassa* Zone); upper view (a) and lower view (b) of Pa element; x66;
- 2) IPUM 25841, sample GALE BK 18 (*K. crassa* Zone); upper view (a) and lower view (b) of Pa element; x80;
- 3) IPUM 26137, sample SAD BK 2 (*K. crassa* Zone); upper view (a), lower view (b) and lateral view (c) of Pa element; x80;
- 4) IPUM 27489, sample SF 7 (*K. crassa* Zone); upper view of Pa element; x90;
- 5) IPUM 25842, sample GALE BK 18 (*K. crassa* Zone); upper view (a), lower view (b) and upper-lateral view (c) of Pa element; x60;
- 6) IPUM 25843, sample PF 1A (*K. crassa* Zone); upper view of Pa element; x80;
- 7) IPUM 25840, sample SAD BK 2 (*K. crassa* Zone); upper view (a), lower view (b) and upper-lateral view (c) of Pa element; x80;
- 8) IPUM 25917, sample PF 1A (*K. crassa* Zone); lateral view of Pb element; x85;
- 9) IPUM 25916, sample PF 11A (*K. crassa* Zone); lateral view of Pb element; x80.



		GA 1	GA 2	GA 3	GA 4	FRU A	FRU 0	FRU B	GCIU 0	GCIU 1	GCIU 2	GCIU 3	GCIU 4	GCIU 5	SIL I° 1	SIL I° 2	SIL I° 3	SIL I° 4	SIL I° 5	SIL I° 6	SIL I° 7	SIL I° 8	SIL I° 9	SIL I° 10	SIL I° 11	SIL I° 12
		ploekensis	ploekensis	siluricus	siluricus	hamata	hamata	hamata	siluricus	siluricus	siluricus	siluricus	siluricus	siluricus	hamata	hamata	hamata	ploekensis	ploekensis	ploekensis	siluricus	siluricus	siluricus	siluricus	siluricus	siluricus
K. a. absidata	Pa	1										1?			4	1	1?									
	M	3					4								8		1									
K. a. sardoa	Pa	1		4					1		17		3		2?			3	9		5		4	3	4	2
	M		6	1							5							5	2	2		1	1	4		
K. crassa	Pa																									
K. maenniki	Pa			5					2	2	21		3							1	4	10			1	
	M			1	2						4									2	4	1				
K. ranuliformis	Pa																									
K. stauros	Pa					1	6	3							4	3	14	20	16	5						
K. v. variabilis	Pa	9													1	4	1	2	13	4	4	2				
K. v. ichnusae	Pa		1					1	2	3		3			6		4	14	10	2	2	2				
"variabilis group"	M	7	2			1	1	3	5	3		1?														
not assigned	Pb	1	3	1	3	2	2	2			3	4		3	10	4		2	13	4	2	3	4			
ramiforms	Sa	1	5	5	1	3	2	3	1	4	7	9			11	7	1	13	24	4	7	13	4			2
	Sb	3	7	2	2	2	5	5	3	5	11				16	15	1	14	30	7	4	10	7	2	1	1
	Sc	3	7	5	4	1	6	6	2	2	3	2	1		20	7	5	17	21	4	11	11	4	2	2	2

		RMC 0	RMC 1	RMC 1A	RMC 1B	RMC 1C	RMC 1D	SBF 5	GALE BK 40	GALE BK 50	GALE BK 18	GALE BK 23	GALE BK 8	GALE BK 13	GALE BK 21	GALE BK 14	SF BK 3	SF BK 17	SF 7	SF 8	SF 9	SF 12	SF BK 12	SF BK 16	SF BK 5	CB III BK 1a
		ploekensis	ploekensis	ploekensis	siluricus	siluricus	siluricus	ploekensis	bohemica	crassa	crassa	variabilis	ploekensis	siluricus			crassa	crassa	crassa	crassa	variabilis	variabilis	ploekensis	ploekensis	siluricus	siluricus
K. a. absidata	Pa									3	7	3	2		2	1	10		2		4		1	9		
	M									1	2				1?							1				
K. a. sardoa	Pa					2	1						5													3
	M						2																			
K. crassa	Pa									1?	3						1	1	10	3						
	Pb																									
K. maenniki	Pa				1?	2								6												2
	M				1									3												
K. ranuliformis	Pa																									
K. stauros	Pa								1	1	1						2	3								
K. v. variabilis	Pa	2	4	9				6	1?			92	18								1	1	8			
K. v. ichnusae	Pa		1		4	2		1					1	3												
"variabilis group"	M	1	2	2	2	2		1	1		1	19	4	1			3	3					3	3		
not assigned	Pb	3	3	4	3	3		2	1	4	9	18	10	7			10	3					5	3		
ramiforms	Sa	1		3	3	1		3		13	17	5	12				4	4					4	9	1	
	Sb	3	2	2	2	2		2	5	5	16	28	6	6	3	2	3	2					6	5	3	
	Sc	3	3	7			1	3	4	3	16	55	18	14	6		3	4					6	6	2	

		PF 1A	PF 11A	PF BK G	PF 9	PF 10	PF 1D	PF 0	PF 1Q	PF 1F	PF 11B	PF 1H	PF 5	ARGC	FTM 2A	FTM 1	FTM 2	SAD BK 2	SAD 21	SAD BK 3A	SAD BK 6	TOTALE
		crassa	crassa	variabilis	variabilis	variabilis	hamata	hamata	ploekensis	ploekensis	ploekensis	siluricus	siluricus	ranuliformis	siluricus?	siluricus	siluricus	crassa	ham./silur.			
K. a. absidata	Pa	2	2			1	13		2	2	2										3	77
	M	1					1		3	2	1											28
K. a. sardoa	Pa										2	2	1				5		1	4		82
	M											2										32
K. crassa	Pa	8	2															8				36
	Pb	1	2																			7
K. maenniki	Pa										7	5			1	1						73
	M														1							19
K. ranuliformis	Pa													2								2
K. stauros	Pa																					8
K. v. variabilis	Pa			2	2	7	24	1	19		31											308
K. v. ichnusae	Pa								2		15	1			3	1	4		5			81
"variabilis group"	M	4		2	1	3	9	3	3	4	13				2		3	1				155
not assigned	Pb		1	1		5	3		4		8				1		2	4				180
ramiforms	Sa		1			1	5		7		5	4			1		3	3				237
	Sb	3	3	3	1	11		3	5	12	2				1	10	3	1				309
	Sc	1	1	1	1	19		5		12	8				4	6	7	3	3	3		372

Table 1 – Distribution of the different species of *Kockelella* in samples from Sardinia. Locality abbreviations: SE Sardinia: GA=Genna Arrela, FRU=Monte Fruccas, GCIU=Genna Ciuerciu, SIL I°=Silus I°, RMC=Riu Murrù de Callus, SBF=San Basilio Fenugu; SW Sardinia: GALE=Galemmu, SF=Sentiero Flumini, CB III=Corti Baccas 3rd, PF=Perd'e Fogu, ARG=Argiola, FTM=Fontanamare, SAD=San't Antonio Donigala.

synonymy list, come from the *A. ploeckensis* (Pl. 23, figs. 16, 18) or from the *Pol. siluricus* Zone (Pl. 23, figs. 19, 22-24); the Australian specimens figured by Link & Druce (1972) are from the same stratigraphical interval. The specimens from Nevada, recorded by Klapper & Murphy (1975) as *Oz. (=Pb)* elements of *K. variabilis*, come from the samples where *Pol. siluricus* and/or *Oz. confluens* are also present.

Range – From the base of the *A. ploeckensis* Zone to the *Pol. siluricus* Zone.

Studied material – 82 (+2 questionable) Pa and 32 M elements from samples GA 1, GA 2, GA 4, GCIU 0, GCIU 3, GCIU 5, SIL I° 1, SIL I° 4, SIL I° 5, SIL I° 6, SIL I° 7, SIL I° 9, SIL I° 10, SIL I° 11, SIL I° 12, RMC 1C; RMC 1D, GALE BK 13, PF 11B, PF 1H, PF 5, FTM 2, SAD BK 3A and SAD BK 6.

KOCKELELLA CRASSA (Walliser, 1964)

Pl. 2, fig. 1-9

Pa element

- 1964 *Kockelella variabilis* Walliser - WALLISER, pl. 16, figs. 2, 8, 11 (only).
- 1968 *Kockelella variabilis* Walliser - IGO & KOIKE, p. 10, pl. 3, figs. 6-9.
- 1969 *Kockelella variabilis* Walliser - SCHÖNLAUB pl. 1, fig. 16.
- 1975 *Kockelella variabilis* Walliser - KLAPPER & MURPHY, pl. 9, fig. 10.
- ? 1983 *Kockelella variabilis* Walliser - WANG & ZIEGLER, pl. 3, fig. 7.
- 1992 *Kockelella variabilis* Walliser - BARCA *et al.*, pl. 10, fig. 1.
- 1993 *Kockelella variabilis* Walliser - SCHÖNLAUB (*in* Kriz *et al.*), pl. 1, fig. 15.
- 1998 *Kockelella circaquadra* n.sp. - SERPAGLI & CORRADINI, pp. 79-80, pl. 1, figs. 3 a-c, 4, 7.
- 1998a *Kockelella circaquadra* Serpagli & Corradini - FERRETTI, CORRADINI & SERPAGLI, pl. 2.2.1, fig. 15; pl. 2.2.2, fig. 15.

Pb element

- 1964 *Ozarkodina crassa* n.sp. - WALLISER, p. 55, pl. 7, fig. 9; pl. 24, figs. 14-17.
- ? 1969 *Ozarkodina crassa* Walliser - FÄHRAEUS, p. 12, tab. 1, pl. 2, fig. 5.
- 1974 *Ozarkodina crassa* Walliser - WALMSLEY, ALDRIDGE & AUSTIN, fig. 3.
- 1976 "*Ozarkodina*" *crassa* Walliser - BARRICK & KLAPPER, pl. 2, figs. 12, 13.
- 1991 *Polygnathoides crassus* Walliser - FORDHAM, p.92.
- 1971 *Ozarkodina crassa* Walliser - SERPAGLI, p. 89, pl. 21, figs. 10, 11.
- 1993 *Ozarkodina crassa* Walliser - SCHÖNLAUB (*in* Kriz *et al.*), pl. 1, figs. 17, 18.
- 1998 *Polygnathoides crassus* (Walliser, 1964) - FERRETTI, CORRADINI & SERPAGLI, pl. 2.2.1, fig. 7; pl. 2.2.2, fig. 8.

Diagnosis – Pa ELEMENT (after Serpagli & Corradini, 1998). The Pa element is characterised by a widely expanded, almost symmetrical, basal cavity with a quadrate-subquadrate outline. The platform bears three-five denticles on each side (up to nine in larger

specimens), usually arranged in an X pattern. A portion of platform free of denticles occurs on both sides of main blade, therefore no ridge connects the cusp with the first denticle of the platform. Posterior process is short and generally straight. The length/width ratio⁽¹⁾ of the whole element is usually very high (avg. close to 2).

Pb ELEMENT (after Walliser, 1964). Ozarkodiniform element characterised by a stout cusp, triangular in cross section, and by a massive blade, sometimes flaring on one side of the platform.

Description – Pa ELEMENT. The anterior blade is long and straight and bears 8 to 9 closely spaced erect denticles, which are larger in size near the distal part of the blade except for the last one, which usually is very small. In the largest specimens, denticles of the middle part of the blade are partially fused. The cusp is only slightly larger than the adjacent denticles. The posterior blade is short and generally straight and bears 3 to 5 closely spaced sub-erect denticles. The basal cavity is widely expanded and nearly symmetrical with an almost quadrate outline. The upper surface of the platform bears three to five denticles on each side; in larger specimens the number may increase up to eight to nine. Denticles are usually arranged irregularly on one side, whereas on the other they are almost aligned close to the outside margin, parallel to the blade. No ridge is present between the cusp and the nearest platform denticle; thus a smooth (unornamented) portion of the platform lies on each side of the blade.

Pb ELEMENT. The cusp is stout, reclined, usually triangular in cross section with the anterior and the posterior margins very sharp. The anterior process is slightly longer than the posterior one and bears up to six (exceptionally seven) stout, biconvex denticles; the posterior process is slightly lower than the other and carries up to four, usually discrete, denticles. One side of the blade is slightly expanded in connection of the cusp; this flared area sometimes may bear a knob (Pl. 3, fig. 8-9) or even can develop into a small lateral process (*i.e.*: Walliser, 1964, Pl. 24, fig. 17). The basal cavity extends as a groove under both processes and appears asymmetrically developed under the cusp.

M, Sa, Sb and Sc ELEMENTS. No description of these elements is supplied, owing to the poorness of the available material. However, they are apparently similar to those described under *K. v. variabilis*.

Remarks – The idea that "*Oz. crassa*" Walliser, 1964 represents the Pb element of an apparatus including as Pa element *K. circaquadra* Serpagli & Corradini, 1998

¹⁾ Length = distance between the anterior and posterior ends of the blade; width = extent of the anterior margin of the platform, measured perpendicularly to the blade.

has been kindly suggested to us by Jim Barrick (pers. comm. 11/03/1999). It follows that, according to the priority laws, the species must be named *Kockelella crassa* (Walliser, 1964).

Pa elements belonging to *K. crassa* differ from both *K. v. variabilis* and *K. patula* in the general shape of the basal cavity. Sinuses in the margin of the cavity of this species are not developed as between the secondary processes of both of the latter species. Further differences are:

- in *K. v. variabilis* the basal cavity is usually less expanded and the length/width ratio is lower;
- *K. patula* has also a large platform, but the basal cavity is clearly asymmetrical (non quadrate) with well developed secondary processes; furthermore, the posterior process is typically curved.

K. crassa appears to have good biostratigraphical value, being limited to the basal Ludlow; in fact representatives of *K. crassa* have been reported from the lowermost Gorstian, only.

Three Pa elements recorded at Cellon as *K. variabilis* are here reported in the synonymy list as *K. crassa* on the basis of camera lucida drawings of the basal cavity kindly supplied by O. Walliser in December 1997. These specimens are from level C.15B₁, i.e. the base of the *K. crassa* Zone (see Corradini & Serpagli, 1999, this volume). The specimens from Bohemia (Schönlaub, 1993 in Kriz *et al.*), either Pa or Pb, are from the same zone, being reported from the *C. colonus* graptolite Zone, which is equivalent to the *K. crassa* Zone. The Pa elements from Malaya (Igo & Koike, 1968) and from Nevada (Klapper & Murphy, 1975) fit in the same interval.

The 13 Pa elements recorded in Sardinia by Serpagli (1971; tab.1, p.80) as *Kockelella variabilis* from samples SF 7 and SF 8 (but not illustrated) and occurring with the Pb element "Oz." *crassa* actually belong to *K. crassa*.

Range – *K. crassa* Zone.

Studied material – 36 (+1 questionable) Pa elements and 7 Pb elements from samples GALE BK 18, GALE

BK 50, SF BK 3, SF BK 17, SF 7, SF 8, PF 1A, PF 11A and SAD BK 2.

KOCKELELLA MAENNIKI Serpagli & Corradini, 1998
Pl. 3, fig. 1-12

Pa element

- ? 1975 *Kockelella variabilis* Walliser - KLAPPER & MURPHY, pl. 9, figs. 1, 4.
- 1976 *Kockelella variabilis* Walliser - FLAJS & SCHÖNLAUB, pl. 4, figs. 17-19 (only).
- 1992 *Kockelella variabilis* Walliser - GNOLI & KOVACS, pl. 1, fig. 1.
- 1998 *Kockelella manniki* n.sp. SERPAGLI & CORRADINI, p. 80, pl. 1, figs. 5 a-b, 6 a-c.
- 1998 *Kockelella manniki* Serpagli & Corradini - SERPAGLI, CORRADINI & FERRETTI, pl. 1.2.1, fig. 9.
- 1998b *Kockelella manniki* Serpagli & Corradini - CORRADINI *et al.*, pl. 1.3.1, figs. 10-12.
- 1998a *Kockelella manniki* Serpagli & Corradini - FERRETTI, CORRADINI & SERPAGLI, pl. 2.2.1, fig. 14; pl. 2.2.2, fig. 12.
- 1998 *Kockelella* sp. – MÄNNIK & MALKOWSKI, pl. 2, fig. 12.

Holotype – The specimen illustrated by Serpagli & Corradini (1998) on Pl. 1, Fig. 5a,b, and here reillustrated on Pl. 3, Fig. 10a,b; IPUM 25845.

Paratypes (figured) – IPUM 25846-46853, 26148, 27485-27487.

Locus typicus – Genna Ciuerciu section, near Silius village, SE Sardinia, Italy.

Stratum typicum – Level GCIU 3 (= GCIU 1 of Barca *et al.*, 1995).

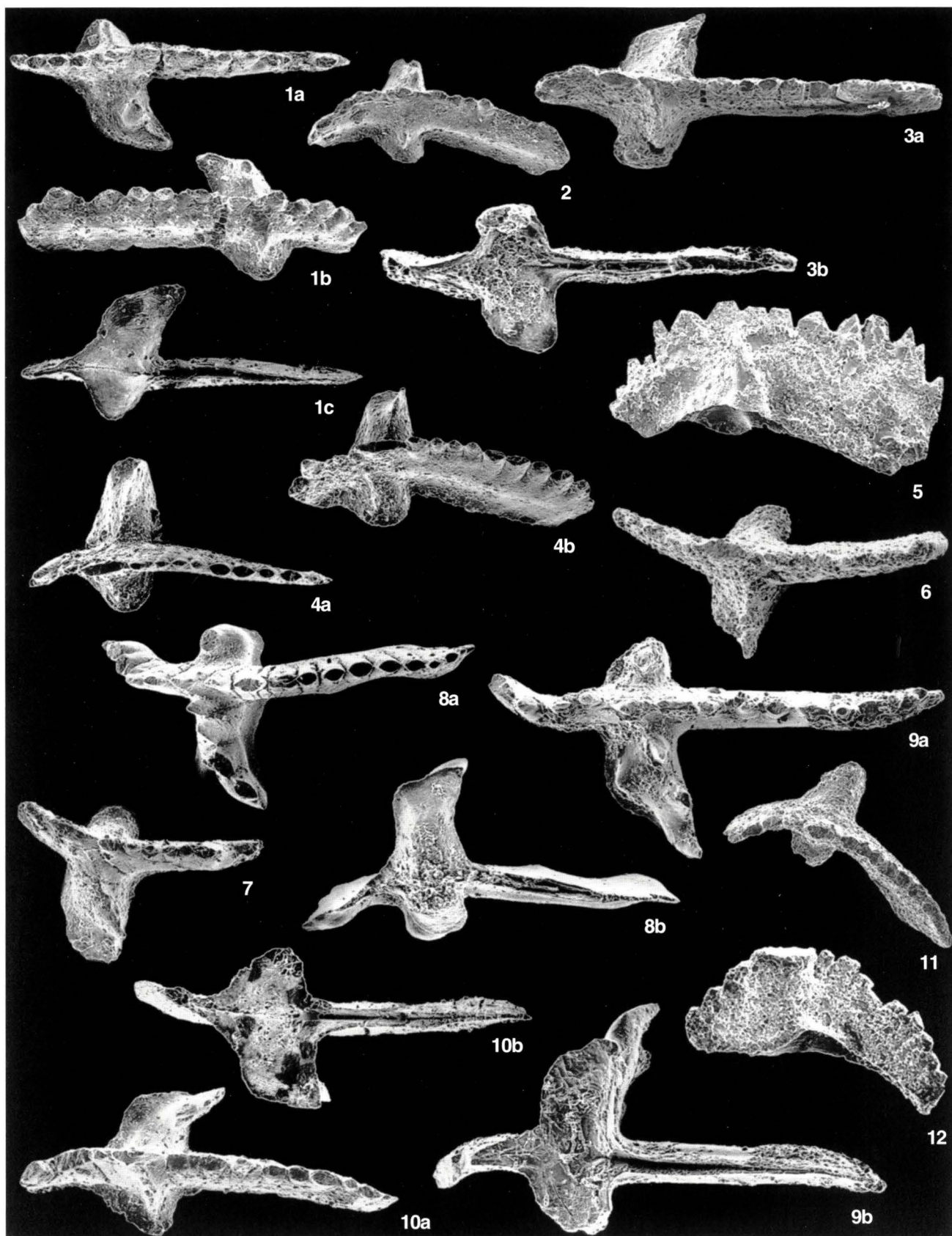
Derivatio nominis – After dr. Peep Männik, Tallinn (Estonia), student of Silurian conodonts.

Diagnosis (after Serpagli & Corradini, 1998) – Pa element narrow, laterally compressed, slightly curved and arched. Platform strongly asymmetrical, bearing a well developed denticulate lateral process on the widest part; other side usually smooth. Posterior process

EXPLANATION OF PLATE 3

Figs. 1-12 – *Kockelella maenniki* Serpagli & Corradini, 1998.

- 1) Paratype, IPUM 25846, sample GCIU 3 (*Pol. siluricus* Zone); upper view (a), upper-lateral view (b) and lower view (c) of Pa element; x80;
- 2) Paratype, IPUM 25848, sample GCIU 2 (*Pol. siluricus* Zone); upper-lateral view of Pa element; x80;
- 3) Paratype, IPUM 25850, sample GCIU 3 (*Pol. siluricus* Zone); upper view (a) and lower view (b) of Pa element; x80;
- 4) Paratype, IPUM 27485, sample GA 4 (*Pol. siluricus* Zone); upper view (a) and upper-lateral view (b) of Pa element; x80;
- 5) Paratype, IPUM 25853, sample PF 11B (*Pol. siluricus* Zone); lateral view of Pa element; x80;
- 6) Paratype, IPUM 26148, sample GCIU 3 (*Pol. siluricus* Zone); upper view of Pa element; x80;
- 7) Paratype, IPUM 25849, sample GCIU 3 (*Pol. siluricus* Zone); upper view of Pa element; x80;
- 8) Paratype, IPUM 27486, sample SIL I° 9 (*Pol. siluricus* Zone); upper view (a) and lower view (b) of Pa element; x66;
- 9) Paratype, IPUM 26141, sample PF 1H (*Pol. siluricus* Zone); upper view (a) and lower view (b) of Pa element; x80;
- 10) Holotype, IPUM 25845, sample GCIU 3 (*Pol. siluricus* Zone); upper view (a) and lower view (b) of Pa element; x80;
- 11) Paratype, IPUM 25847, sample GCIU 3 (*Pol. siluricus* Zone); upper view of Pa element; x80;
- 12) Paratype, IPUM 27487, sample GCIU 3 (*Pol. siluricus* Zone); inner-lateral view of M element; x80.



conspicuous, usually curved on one side and arched downward. Cusp well developed and differentiated from the other denticles.

Description – Pa ELEMENT is slender, slightly curved and arched. Blade is very narrow and laterally compressed; its anterior part is usually straight and bears from 8 to 12 closely spaced, laterally compressed denticles. The conspicuous posterior blade is usually curved to one side and arched downward; it bears up to 6 closely spaced, laterally compressed denticles.

The slightly reclined cusp is well developed, always separable from the other denticles and located on the posterior third of the unit.

Platform is strongly asymmetrical and typically is strongly developed on outer side, where a simple long process bears up to five (commonly three) aligned denticles, which are usually slightly proclined. The inner side of the platform is usually smooth, but in some specimens a single small denticle may occasionally be present. The basal cavity is wide below the platform and extends as a narrow groove to the ends of the processes.

M ELEMENT (Pl. 3, fig. 12). Specimens are slightly curved and usually arched, with a long, stout, biconvex cusp. The cusp is gently curved and slightly twisted to the posterior. The posterior process, usually strongly arched and twisted, bears up to ten laterally compressed, reclined, closely spaced denticles. An antiscusp-like anterior process bears two or three laterally compressed denticles crowded adjacent to the cusp. The basal cavity has a prominent flaring of margin on the inner side of the unit and opens somewhat to the posterior.

Pb, Sa, Sb and Sc ELEMENTS. These elements are apparently indistinguishable from the corresponding elements of *K. v. variabilis* and *K. a. absidata*.

Remarks – Pa ELEMENT. The Pa element of *K. maenniki* differs from that of *K. absidata sardoa* by the occurrence of a lateral process; it is unlike *K. stauros* Barrick & Klapper in having a typically asymmetrical basal cavity and a single lateral process. The outer lateral process is usually anteriorly bent, but in few specimens it is perpendicular to the blade, or even posteriorly directed. Some juvenile specimens have a

“*spathognathodus*-like” appearance and, if denticles on lateral process are not yet developed, is not easy to separate them from true “*Spathognathodus*”.

M ELEMENT. The M element of *K. maenniki* is very similar to that of *K. a. sardoa*, but has a more arched posterior process and a denticulate antiscusp instead of a real anterior process.

K. maenniki has good biostratigraphical value, being limited to the early-middle part of the *Pol. siluricus* Zone. In fact, all our material, as well as the specimens reported on the synonymy list, are from this interval.

Specimens of *K. maenniki* from the “Nördliche Grauwackenzone” (Austria) have been recorded in samples in which *Pol. siluricus* or *Oz. confluens* have been found (Flajs & Schönlaub, 1976, pl. 4, figs. 17-19). Also, the specimen illustrated by Männik & Malkowski (1998, pl. 2, fig. 12) from the *Pol. siluricus* Zone in the Goldap Core (Poland), and identified as *Kockelella* sp., is in reality *K. maenniki*.

Range – Early-middle part of the *Pol. siluricus* Zone.

Studied material – 73 (+1 questionable) Pa and 19 M elements from samples GA 3, GA 4; GCIU 0, GCIU 2, GCIU 3, GCIU 5; SIL I 7, SIL I 8, SIL I 9, SIL I 12; RMC 1B, RMC 1C; GALE BK 13; CB III-BK 1a; PF 1H, PF 5; FTM 1 and FTM 2.

KOCKELELLA RANULIFORMIS (Walliser, 1964) Pl. 7, fig. 10

Pa element

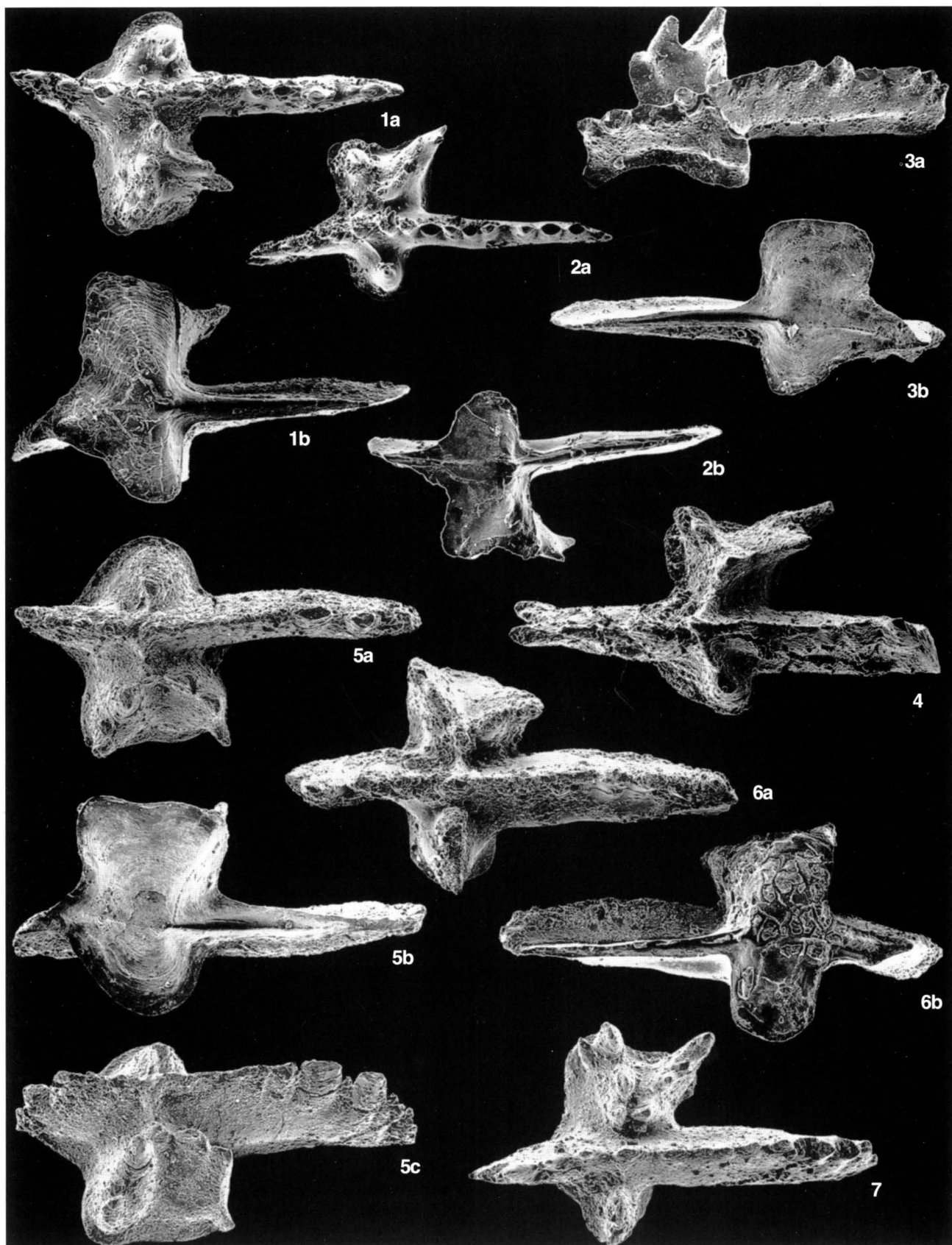
- 1964 *Spathognathodus ranuliformis* WALLISER, p. 82, tav. 6, fig. 9; pl. 22, figs. 5-7.
- 1976 *Kockelella ranuliformis* (Walliser) - BARRICK & KLAPPER, p. 76, pl. 2, figs. 1-11.
- 1983 *Kockelella ranuliformis* (Walliser) - BARRICK, fig. 18I.
- 1995 *Kockelella ranuliformis* (Walliser) - SIMPSON & TALENT, p. 135, pl. 6, figs. 2-7 (only) (*cum syn.*).
- 1998a *Kockelella ranuliformis* (Walliser) - CORRADINI, FERRETTI & SERPAGLI, pl. 3.3.1, fig. 4a, b.

Remarks – The round basal cavity at the posterior end of the Pa element, and the absence of lateral processes are the main features of this species. No more

EXPLANATION OF PLATE 4

Figs. 1-7 – *Kockelella variabilis ichnusae* Serpagli & Corradini, 1998.

- 1) Paratype, IPUM 25839, sample PF 11B (*Pol. siluricus* Zone); upper view (a) and lower view (b) of Pa element; x80;
- 2) Paratype, IPUM 27490, sample FTM 2 (*Pol. siluricus* Zone); upper view (a) and lower view (b) of Pa element; x66;
- 3) Paratype, IPUM 25836, sample SIL I° 5 (*A. ploeckensis* Zone); upper view (a) and lower view (b) of Pa element; x80;
- 4) Paratype, IPUM 27491, sample SBF 5 (*A. ploeckensis* Zone); upper view of Pa element; x66;
- 5) Holotype, IPUM 25834, sample SIL I° 5 (*A. ploeckensis* Zone); upper view (a), lower view (b) and upper-lateral view (c) of Pa element; x60;
- 6) Paratype, IPUM 25838, sample PF 1Q (*A. ploeckensis* Zone); upper view (a) and lower view (b) of Pa element; x60;
- 7) Paratype, IPUM 25835, sample SBF 5 (*A. ploeckensis* Zone); upper view of Pa element; x80.



information can be supplied with the scarce available material.

Range – From the *Pt. celloni* Zone (*Pt. am. angulatus* Subzone) to *Oz. s. rhenana* Zones

Studied material – 2 Pa elements from sample ARG C.

KOCKELELLA STAUROS Barrick & Klapper, 1976
Pl. 7, figs. 8-9

Pa element

- 1976 *Kockelella stauros* BARRICK & KLAPPER, p. 76, pl. 3, figs. 1-11.
1983 *Kockelella stauros* Barrick & Klapper - BARRICK fig. 18N.
1994 *Kockelella stauros* Barrick & Klapper - KLEFFNER, fig. 10.20.

Remarks – The few specimens from Sardinia come from the late *Oz. bohémica* Zone and from the early *K. crassa* Zone.

According to the left-hand columns of the Silurian Times n.3 (1995), a *K. stauros* Zone, equivalent to the *colonus-nilssoni* graptolite interval, is claimed to be used for global correlations in the Early Ludlow. However we believe that true *K. stauros* is in North America limited to the Homerian (Barrick & Klapper, 1976), whereas in Sardinia it reaches the lowermost Gorstian, occurring in few samples with *K. crassa*. The “*stauros*-like” specimens often occurring in the *Oz. exc. hamata* and *A. ploeckensis* zones are actually juvenile specimens of *K. variabilis variabilis* (text-fig. 2).

Range – From the *Oz. s. sagitta* Zone to the lowermost *K. crassa* Zone.

Studied material – 8 Pa elements in SF BK 3; SF BK 17; GALE BK 18, GALE BK 40 and GALE BK 50.

KOCKELELLA VARIABILIS Walliser, 1957

Based on the morphology of the Pa element, two subspecies were recognised in *K. variabilis*: *Kockelella variabilis variabilis* Walliser and *K. variabilis ichnusae* Serpagli & Corradini.

KOCKELELLA VARIABILIS VARIABILIS Walliser, 1957
Pl. 5, figs. 1-13; pl. 6, figs. 1-9; pl. 7, figs. 1-7

Pa element

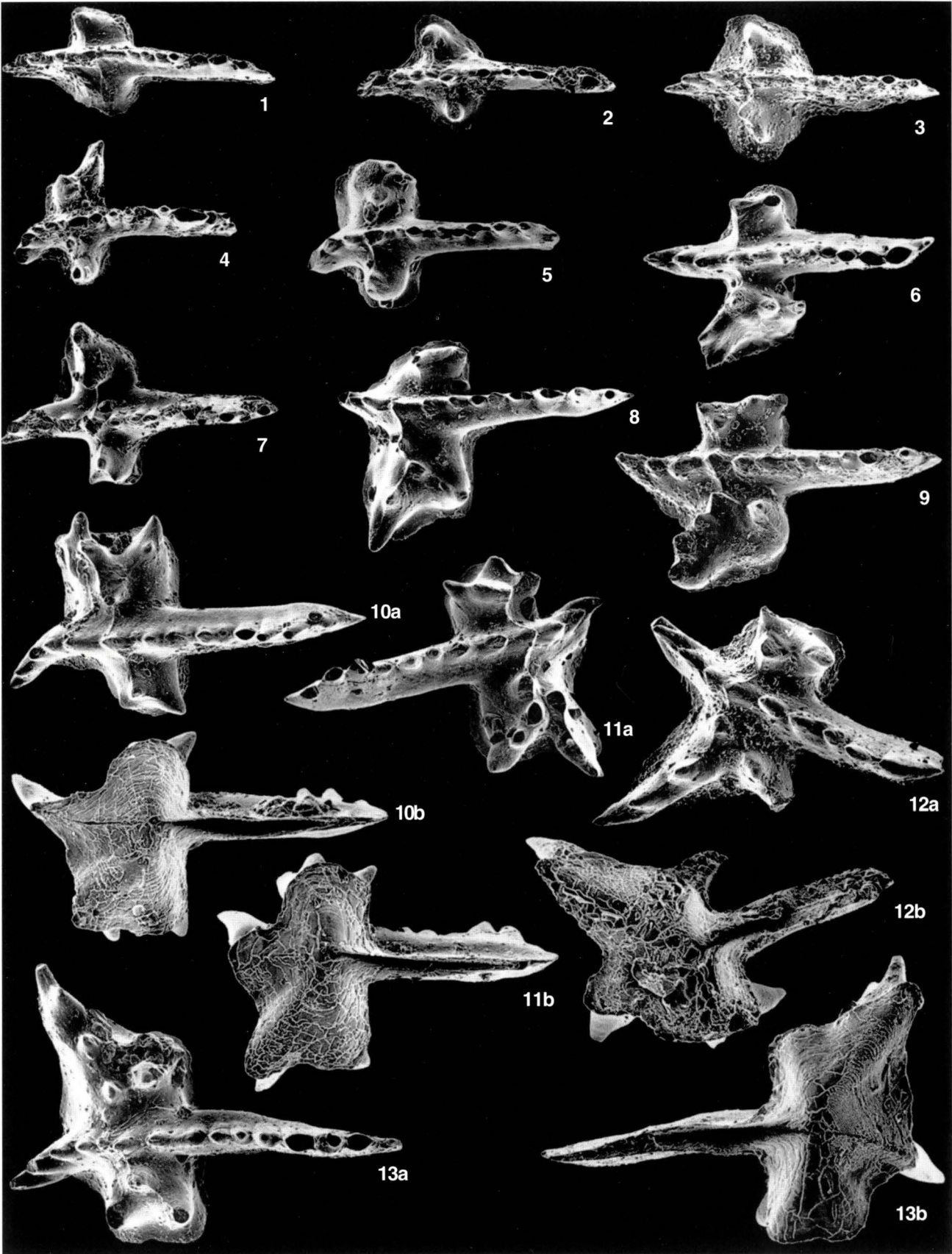
- 1957 *Kockelella variabilis* n.sp. WALLISER, p. 35, pl. 1, figs. 3-10.
1962 *Kockelella variabilis* Walliser - ETHINGTON & FURNISH, p. 1270, pl. 172, figs. 4-5.
1962 *Kockelella variabilis* Walliser - REICHSTEIN, p. 538, fig. 2.
1962 *Kockelella variabilis* Walliser - RHODES & NEWALL, figs. 1-6.
1964 *Kockelella variabilis* Walliser - WALLISER, p. 35, pl. 16, figs. 3-4, 6, 9-10, 13?, 14-15.
1965 *Kockelella variabilis* Walliser - VAN DEN BOOGAARD, p. 34-36, figs. 2-5.
1971 *Kockelella variabilis* Walliser - SERPAGLI, pl. 22, fig. 13.
1972 *Kockelella variabilis* Walliser - LINK & DRUCE, pl. 4, figs. 1, 4-5.
1972 *Kockelella variabilis* Walliser - VAI, pl. 32, figs. 2, 7.
1975 *Kockelella variabilis* Walliser - KLAPPER & MURPHY, pl. 9, figs. 5?, 6-9, 11; pl. 10, figs. 1-7.
1976 *Kockelella variabilis* Walliser - BARRICK & KLAPPER, pl. 3, figs. 12-17.
1976 *Kockelella variabilis* Walliser - EBNER, pl. 2, figs. 1-2.
1978 *Kockelella variabilis* Walliser - REXROAD, NOLAND & POLLOCK, pl. 1, figs. 37-38.
1980 *Kockelella variabilis* Walliser - ALDRIDGE, figs. 8-11.
1981 *Kockelella variabilis* Walliser - UYENO, pl. 8, figs. 9-10.
1983 *Kockelella variabilis* Walliser - BARRICK, fig. 18J.
1983 *Kockelella variabilis* Walliser - WANG & ZIEGLER, pl. 3, fig. 7.
1985 *Kockelella variabilis* Walliser - ALDRIDGE, pl. 3.4, fig. 5.
1998 *Kockelella variabilis variabilis* Walliser - SERPAGLI, CORRADINI & FERRETTI, pl. 1.2.1, fig. 13.

EXPLANATION OF PLATE 5

In order to show variation from juvenile to adult Pa elements, all specimens illustrated in this plate come from the same sample and have the same magnification. Two additional specimens belonging to the same growing series are illustrated in the next plate (Pl. 6, figs. 8-9).

Figs. 1-13 - *Kockelella variabilis variabilis* Walliser, 1957. All specimens from sample GALE BK 23 (*K. v. variabilis* Zone); x66.

- 1) IPUM 27493/1; upper view of Pa element;
- 2) IPUM 27493/2; upper view of Pa element;
- 3) IPUM 27493/3; upper view of Pa element;
- 4) IPUM 27493/4; upper view of Pa element;
- 5) IPUM 27493/5; upper view of Pa element;
- 6) IPUM 27493/6; upper view of Pa element;
- 7) IPUM 27493/7; upper view of Pa element;
- 8) IPUM 27493/8; upper view of Pa element;
- 9) IPUM 27493/9; upper view of Pa element;
- 10) IPUM 27493/10; upper view (a) and lower view (b) of Pa element;
- 11) IPUM 27493/11; upper view (a) and lower view (b) of Pa element;
- 12) IPUM 27493/12; upper view (a) and lower view (b) of Pa element;
- 13) IPUM 27493/13; upper view (a) and lower view (b) of Pa element.



- 1998a *Kockelella variabilis variabilis* Walliser - FERRETTI, CORRADINI & SERPAGLI, pl. 2.2.1, fig. 17; pl. 2.2.2, fig. 16.
 1998 *Kockelella variabilis* Walliser - MÄNNIK & MALKOWSKI, pl. 2, fig. 8.

Pb element

- 1957 *Ozarkodina ziegleri* n.sp. WALLISER, p. 41, pl. 1, figs. 26-30.
 1964 *Ozarkodina ziegleri ziegleri* Walliser - WALLISER, p. 63, pl. 8, fig. 11; pl. 25, figs. 1-10; text-fig. 3 i, k.

M element

- 1957 *Prionodina* cf. *armata* (Hinde) - WALLISER, pl. 2, fig. 21 [only].
 1964 *Neopronodus multiformis* n.sp. WALLISER, pl. 29, figs. 14, 17-18, 21-22, 25 [only].
 1971 *Neopronodus multiformis* Walliser - SERPAGLI, pl. 22, fig. 9.
 1992 *K. variabilis* Walliser, M element - BARCA *et al.*, pl. 10, fig. 2.

Sa element

- 1957 *Trichonodella inconstans* n.sp. WALLISER, pp. 50-51, pl. 3, figs. 10-17.
 1964 *Trichonodella inconstans* Walliser - WALLISER, p. 90, pl. 8, fig. 11; pl. 30, figs. 10-11.

Sb element

- 1957 *Lonchodina greilingi* n.sp. WALLISER, pp. 38-39, pl. 3, figs. 20-26.
 1964 *Lonchodina greilingi* Walliser - WALLISER, p. 44, pl. 8, fig. 7; pl. 30, figs. 7-9.

Sc element

- 1957 *Ligonodina diversa* n.sp. WALLISER, p. 36, pl. 2, figs. 11, 13-14 [only].
 1964 *Ligonodina salopia* Rhodes - WALLISER, p. 41-42, pl. 8, fig. 9; pl. 32, figs. 5, 10.

Amended diagnosis – The Pa element [of *K. variabilis variabilis*] is characterised by lateral processes typically branched (adult specimens) and a length/width ratio usually very low (avg. close to 1.6). The wide, slightly asymmetrical basal cavity, has a heart-shaped (subtriangular) outline in small specimens and a polygonal (approximately subrectangular) in large ones, and is generally confined to the area under the lateral processes and posterior blade.

Description – Pa ELEMENT. Representative specimens are straight to slightly curved, with a lateral bifurcated

process on both sides of the blade in the posterior part of the element.

The anterior process is long, straight and relatively thick; it bears up to 11 laterally compressed denticles; they are very closely spaced (up to fused) proximally, whereas one or two, stout, high and discrete, occur in the distal part; the blade ends with one or two short, small denticles.

The denticle placed where the ridges of the lateral processes meet the junction of the anterior and posterior processes can be considered as the cusp, which, however, does not differ in size from the adjacent denticles.

The posterior process is short and curved and bears up to five laterally compressed, closely spaced, sometime partially fused denticles.

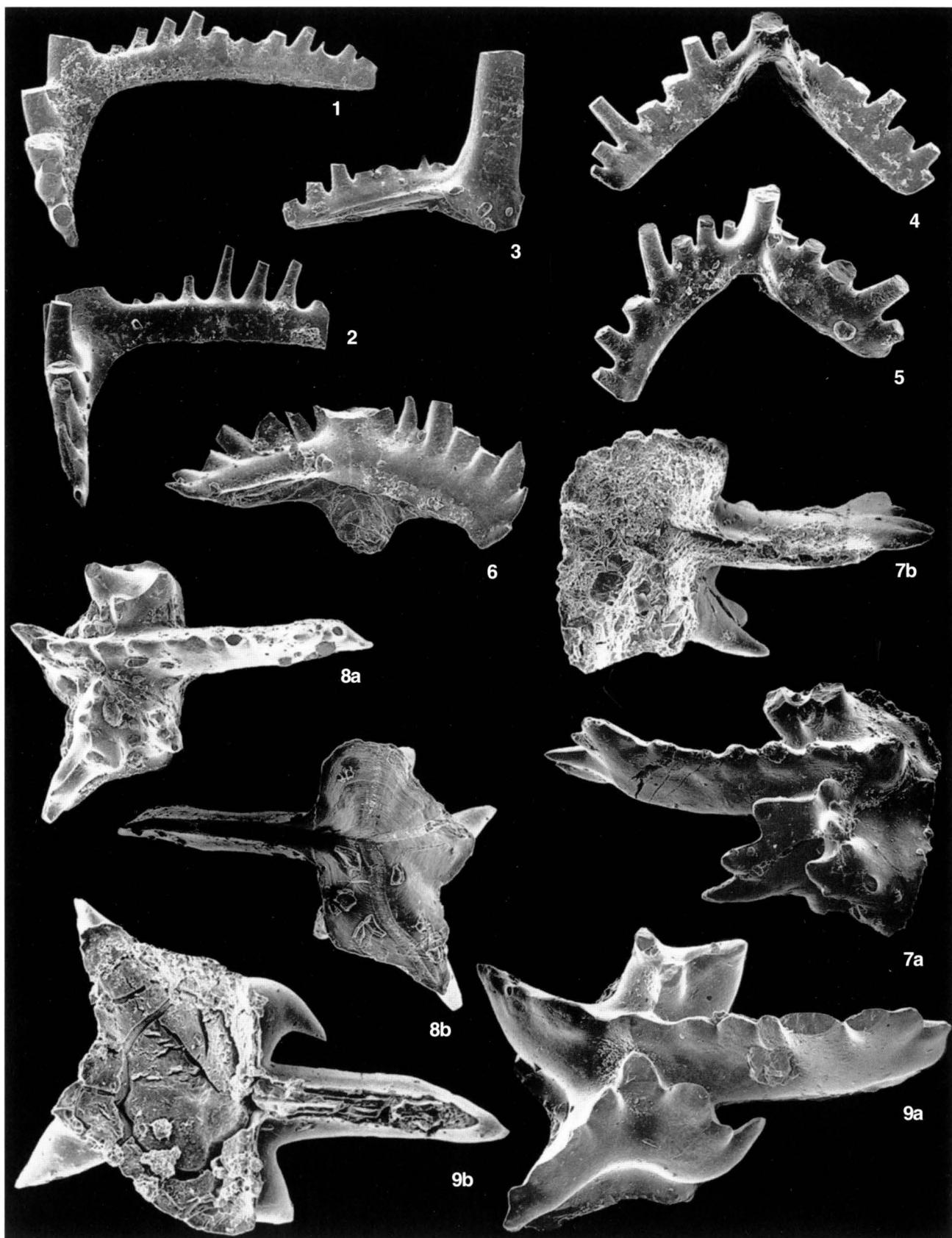
Bifurcated lateral processes are present on both sides of the blade. They are connected by a narrow ridge. The outer lateral process is usually more developed than the inner one; it bears two ridges of 3-5 denticles. The angle between these ridges is up to 90°. In adult specimens the ridges protrude out of the platform, generally the posterior one is better developed than the other. In few specimens these ridges may branch further. The denticle pattern on the inner lateral process is extremely irregular, when the denticles form two short ridges bearing 1-3 denticles each.

The basal cavity is wide and slightly asymmetrical, having a heart-shaped (subtriangular) outline in small specimens and a polygonal (approximately subrectangular) in large ones, owing to the strong development of the posterior ridge of the outer lateral process. The basal cavity extends as a deep groove under the anterior blade.

Pb ELEMENT (Pl. 6, fig. 6; pl. 7, fig. 5). Cusp is large biconvex and reclined. Anterior and posterior processes are more or less equal in length and bear six to eight slightly compressed denticles. The anterior process is usually more robust than the posterior one and denticles on it may be partially fused. The basal cavity extends as a groove under both processes and appears under the cusp as a rounded flaring expansion, definitely larger on the outer side. The anterior groove is narrower and deeper than the posterior one.

EXPLANATION OF PLATE 6

- Figs. 1-9 - *Kockelella variabilis variabilis* Walliser 1957. All specimens from sample GALE BK 23 (*K. v. variabilis* Zone).
 1) IPUM 27493/21; inner-lateral view of Sc element; x50;
 2) IPUM 27493/22; inner-lateral view of Sc element; x66;
 3) IPUM 27493/18; inner-lateral view of M element; x50;
 4) IPUM 27493/19; posterior view of Sa element; x50;
 5) IPUM 27493/20; posterior view of Sb element; x66;
 6) IPUM 27493/17; inner-lateral view of Pb element; x50;
 7) IPUM 27493/14; upper view (a) and lower view (b) of Pa element; x66;
 8) IPUM 27493/15; upper view (a) and lower view (b) of Pa element; x66;
 9) IPUM 27493/16; upper view (a) and lower view (b) of Pa element; x66.



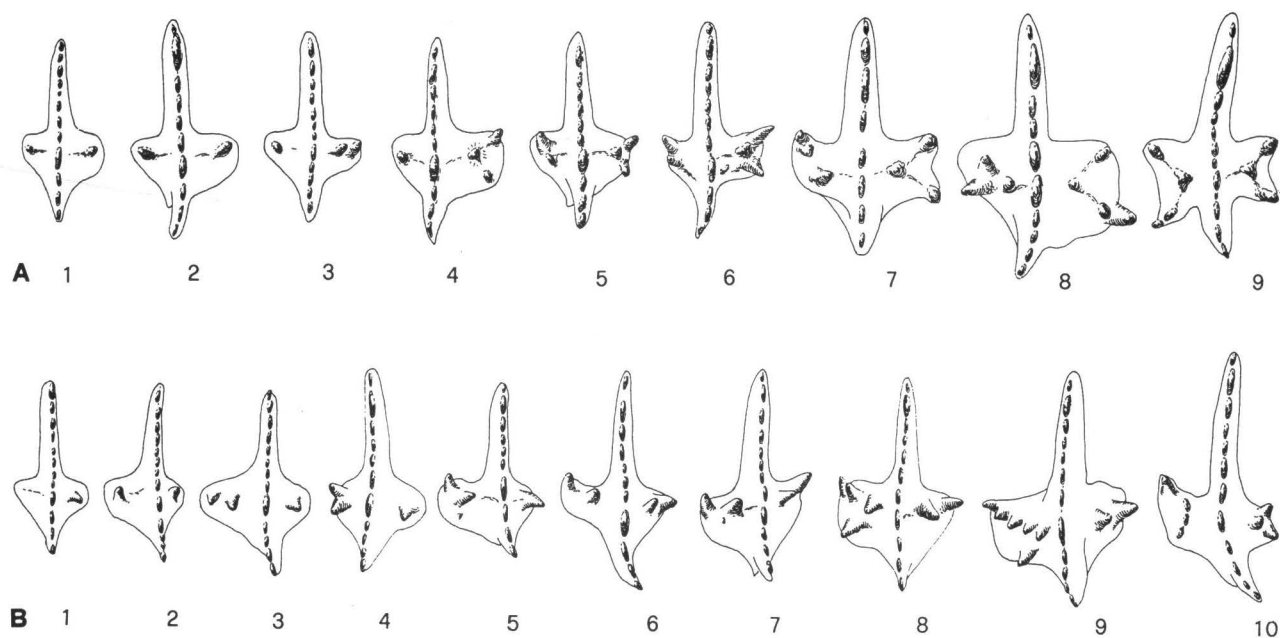
M ELEMENT (pl. 6, fig. 3; pl. 7, fig. 7). Specimens are slightly curved with a long stout, biconvex cusp, which is gently curved and slightly twisted to the posterior. The posterior process bears six to nine erect, discrete denticles, (sub)round in cross section. A true anterior process is missing, whereas a short antiscusp-like extension has been observed in some specimens. Sometimes, a small, partially fused with the cusp denticle may be present on the anterior margin; also a second denticle has been occasionally observed. The basal cavity opens somewhat to the posterior and has a prominent flaring margin on the inner side of the element.

Sa ELEMENT (pl. 6, fig. 4). Specimens are symmetrical with a slender, long cusp, sub-oval in cross section, which sometimes bears a narrow keel on both lateral sides. The two straight, equal, lateral processes are directed sharply downwards from the cusp and diverge at an angle close to 90° . Each process bears about six round, erect, discrete denticles. A more or less developed posterior expansion of the basal cavity, in form of a rounded lip, is always present.

Sb ELEMENT (Pl. 6, fig. 5; pl. 7, fig. 4). Specimens are asymmetrical and bowed, with two arched

processes of different length. The cusp is long, slender and reclined, sometimes bearing a narrow keel on both lateral sides. The posterior process, longer than the anterior one, arches sharply downwards from the cusp and is slightly incurved; it bears 6 to 7 round, erect, discrete denticles. The anterior process, somewhat twisted, forms an angle of about 90° with the posterior and bears 4 to 6 denticles. The processes lie on different planes, forming an angle up to 90° degrees in strongly bowed specimens. The basal cavity is expanded posteriorly as a round protrusion that gradually closes towards the end of the processes.

Sc ELEMENT (Pl. 6, figs. 1-2; pl. 7, fig. 6). Specimens have a long, stout reclined cusp, sometimes bearing a narrow keel in the anterior part of the inner side. The cusp has a sub-oval cross section near the base, whereas in the upper part it shows a flat anterior margin. The posterior process is long, sometimes slightly arched and turned towards the outer side, bearing up to twelve reclined, discrete denticles, rounded in cross section. Antero-lateral process forms a more or less square angle with the posterior process and descends sharply downward from the cusp at different angles; it bears five to seven discrete, slightly posteriorly bent denticles, rounded in cross section.



Text-fig. 2 – Camera lucida drawings of some specimens of *K. v. variabilis* arranged in sequences to show gradual morphologic changes from juvenile to adult specimens. Each sequence is based on specimens of the same sample to point out that some juvenile specimens can be wrongly referred to *K. stauros*. Magnification: $\times 40$. A) sample GALE-BK 8 (*A. ploeckensis* Zone), “*Orthoceras* lm.” of the Fluminimaggiore Fm., *A. ploeckensis* Zone, SW Sardinia; the fourth and eighth specimens have been drawn reversed. B) sample SIL I° 4, (*A. ploeckensis* Zone), “Ockerkalk” facies, SE Sardinia.

Remarks – Pa ELEMENT. In several samples from Sardinia, from both the Ockerkalk and *Orthoceras* limestone facies, it is possible to recognise complete sequences from juvenile to adult specimens, showing all intermediate stages (Text-fig. 2; pls. 5, 6). Sequences begin with “*Spathognathodus*-like” specimens without any denticulate lateral process (Text-fig. 2, A₁, B₁; pl. 5, fig. 1), showing only a crest on one or both sides of the blade, followed by “*stauros*-like” specimens with one or two denticles on each side (Text-fig. 2, A₂₋₃, B₂₋₃; pl. 5, figs. 2-3). The sequence continues, after further intermediate stages, with specimens bearing one branched lateral process (Text-fig. 2, A₄, B₄₋₅; pl. 5, figs. 4-5) and ends with specimens bearing branched lateral processes on both sides of the element (Text-fig. 2, A₈₋₉, B₁₀; pl. 5, figs. 11-13; pl. 6, figs. 8-9).

The Pa element of *K. v. variabilis* differs from that of *K. v. ichnusae* mainly in having a more symmetrical platform, no rim on its margin and by the lack of a true crest produced by some fused denticles anteriorly to the cusp. Furthermore, in adult specimens of *K. v. variabilis* both lateral processes are branched and the length/width ratio in *K. v. ichnusae* is higher. Finally, in lower view, the posterior process of *K. v. variabilis* is apparently undifferentiated from the main part of the basal cavity, whereas in *K. v. ichnusae* it is always recognisable because the cavity narrows posteriorly.

However, intermediate forms between *K. v. variabilis* and *K. v. ichnusae* have been observed in samples coming from the *K. v. variabilis* and the *Oz. exc. hamata* Zones.

The Pa element of *K. v. variabilis* differs from the equivalent of *K. crassa* in the shape of the basal cavity, which is usually less expanded and irregularly developed. Furthermore, in *K. v. variabilis* lateral processes are always well developed and a ridge usually connects the cusp with the nearest denticle on the platform (no “unornamented area” exists close to the blade).

M ELEMENT. The M element of *K. v. variabilis* never possesses an anterior process, differing, therefore, from the same elements of *K. a. sardoa* and *K. maenniki*.

SC ELEMENT. We believe that this element is much more similar to *Ligonodina salopia* (*sensu* Walliser, 1964, but not to *L. salopia sensu* Rhodes, 1953), than to *L. silurica* Branson & Mehl (*sensu* Walliser, 1957).

Range – From the late *K. crassa* Zone to the top of the *A. ploeckensis* Zone.

Studied material – 308 (+1 questionable) Pa elements from samples GA 2, FRU A, FRU 0, FRU B, SIL I° 1, SIL I° 2, SIL I° 3, SIL I° 4, SIL I° 5, SIL I° 6, RMC 0, RMC 1, RMC 1A, GALE BK 40, GALE BK 23, GALE BK 8, SF 9, SF 12, SF BK 12, PF BK G, PF 9, PF 10, PF 1D, PF 0, PF 1Q and PF 11B.

KOCKELELLA VARIABILIS ICHNUSAE

Serpagli & Corradini, 1998

Pl. 4, fig. 1-7

Pa element

- 1964 *Kockelella variabilis* Walliser - WALLISER, pl. 16, figs. 1?, 5?, 7, 12.
- 1971 *Kockelella variabilis* Walliser - REXROAD & CRAIG, pl. 82, figs. 8-10.
- 1971 *Kockelella variabilis* Walliser - REXROAD & NICOLL, pl. 2, fig. 8.
- 1972 *Kockelella variabilis* Walliser - LINK & DRUCE, pl. 3, figs. 11, 12, 15, 16; text-fig. 21.
- 1972 *Kockelella variabilis* Walliser - VAI, pl. 32, fig. 1.
- 1975 *Kockelella variabilis* Walliser - SCHÖNLAUB & ZEZULA, pl. 1, fig. 1.
- 1976 *Kockelella variabilis* Walliser - EBNER, pl. 2, fig. 3.
- ? 1977 *Kockelella variabilis* Walliser - COOPER, pl. 17, figs. 1, 5.
- ? 1980 *Kockelella variabilis* Walliser - SCHÖNLAUB, pl. 6, fig. 1.
- 1995 *Kockelella variabilis* Walliser - BARCA *et al.*, pl. 4, fig. 15.
- 1998 *Kockelella variabilis ichnusae* n.sp. SERPAGLI & CORRADINI, pp. 80-82, pl. 1, figs. 1a-c, 2.
- 1998 *Kockelella variabilis ichnusae* Serpagli & Corradini - SERPAGLI, CORRADINI & FERRETTI, pl. 1.2.1, fig. 10.
- 1998b *Kockelella variabilis ichnusae* Serpagli & Corradini - CORRADINI *et al.*, pl. 1.3.1, fig. 14.
- 1998a *Kockelella variabilis ichnusae* Serpagli & Corradini - FERRETTI, CORRADINI & SERPAGLI, pl. 2.2.1, fig. 16; pl. 2.2.2, fig. 14.
- 1998 *Kockelella variabilis* Walliser - MÄNNIK & MALKOWSKI, pl. 2, fig. 5.
- 1998 *Kockelella* aff. *variabilis* - MÄNNIK & MALKOWSKI, pl. 2, fig. 10.

Holotype – The specimen illustrated by Serpagli & Corradini (1998) on Pl. 1, Fig. 1a-c and here reillustrated on Pl. 4, fig. 5a-c; IPUM 25834.

Paratypes (figured) – IPUM 25835-25839, 27490-27491.

Locus typicus – Silius I° section, near Silius village, SE Sardinia, Italy.

Stratum typicum – Level SIL I° 5.

Derivatio nominis – From *Ichnusa*, the ancient Greek name of Sardinia.

Diagnosis (after Serpagli & Corradini, 1998) – The stout Pa element is characterised by fused denticles anterior to the cusp, and by a wide asymmetrical platform bordered by a rim; the inner side of the platform is short and rounded, and bears a simple lateral process. The posterior process is arched downward and gently deflected.

Description – Pa ELEMENT. The Pa element is usually robust and large in size. The anterior blade is relatively thick, long and straight, and bears nine to fourteen denticles. Anterior to the cusp, two to four denticles are fused together forming a crest (the number of fused

denticles increases in largest specimens). The blade ends anteriorly with three stout, high and discrete denticles followed by one or two very short denticles. In the largest specimens, these small denticles increase in number (up to 5) and decrease in size towards the end of the blade, producing a serrated outline on the anterior margin.

The short posterior blade is arched downward and gently incurved. It bears three to four stout, erect denticles, followed by a small one.

A wide asymmetrical platform is bordered by a rim. On the inner side of the element the platform is short and rounded, and bears a lateral process with one or two denticles aligned perpendicularly to the blade. The outer platform is better developed, has a polygonal outline and bears a complex process with three to eight discrete or closely spaced denticles, sometimes forming a fan-shaped ridge usually more or less parallel to the blade.

The cusp is erect, only slightly larger than adjacent denticles. It is usually connected to the closest denticles on the lateral processes by narrow ridges.

One side of the wide basal cavity is larger than the other one. The cavity extends as a narrow groove to the anterior and posterior ends of the main processes.

Pb, M, Sa, Sb and Sc ELEMENTS. These are apparently indistinguishable from the corresponding elements of *K. v. variabilis*.

Remarks – Pa ELEMENT. The most typical features of *K. v. ichnusae* (robust blade, posterior process arched downward and gently deflected, wide asymmetrical platform bordered by a rim, short and rounded inner platform with a simple process, fused denticles anteriorly to the cusp, and serrated outline of the anterior margin) co-occur only in adult specimens. In juvenile specimens only some of these features are present. Furthermore, in these specimens, the inner platform may be undenticulated.

The Pa element of *K. v. ichnusae* differs from that of *K. v. variabilis*, Walliser 1957 mainly by the wider

platform, that is bordered by the characteristic rim, by the unbranched inner process and by the occurrence of a crest on the anterior blade.

Few specimens of *K. v. ichnusae* have a subtriangular basal cavity like that of *K. stauros* Barrick & Klapper, which, however, has always a simple outer process.

The specimen from New South Wales (Australia) figured by Link & Druce (pl. 3, figs. 11, 12, 15, 16; text-fig. 21) possess most of the features of *K. v. ichnusae* (including fused denticles anterior to the cusp and fan-shaped ridge of the outer process denticles), except number of denticles on the short inner lateral process.

Range – From the base of the *Oz. exc. hamata* Zone to the middle part of the *Pol. siluricus* Zone.

Studied material – 81 Pa elements from samples GA 3, FRU B, GCIU 1, GCIU 3, SIL I° 1, SIL I° 2, SIL I° 3, SIL I° 4, SIL I° 5, SIL I° 6, SIL I° 7, SIL I° 8, RMC 1, RMC 1B, RMC 1C, SBF 5, GALE BK 8, GALE BK 13, PF 1Q, PF 11B, PF 1H, FTM 1, FTM 2, FTM 2A and SAD 21.

CONCLUSIONS

The main results of the studies of the taxonomy and evolution of *Kockelella* are the following:

- 1 - The number of *Kockelella* taxa increases, changing from twelve to sixteen;
- 2 - Both *Kockelella variabilis* and *K. absidata* have been subdivided into two subspecies;
- 3 - The old problem of the reconstruction of the *K. crassa* apparatus is finally solved;
- 4 - The reconstruction of the phyletic relations within the genus *Kockelella* (which largely follows that one of Barrick & Klapper, 1976) shows that three main lineages, all originating from the common ancestor *K. ranuliformis*, are recognisable (Text-fig. 1);
- 5 - *Kockelella patula* and its possible descendants are still a problem, being difficult to place in our

EXPLANATION OF PLATE 7

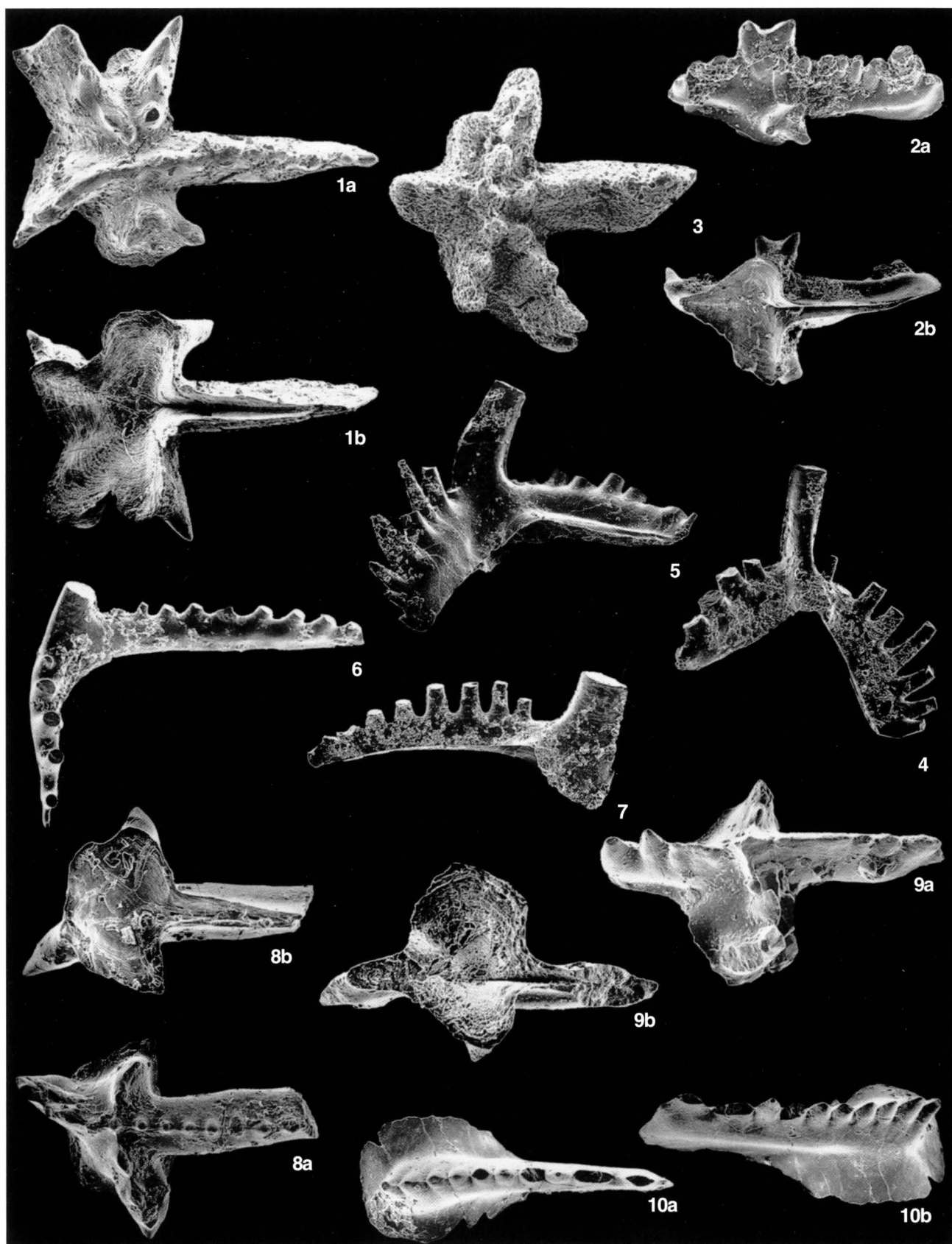
Figs. 1-7 - *Kockelella variabilis variabilis* Walliser, 1957.

- 1) IPUM 25855, sample PF 11B (*Oz. exc. hamata* Zone); upper view (a) and lower view (b) of Pa element; x60;
- 2) IPUM 25856, sample PF 1Q (*A. ploeckensis* Zone); upper view (a) and lower view (b) of Pa element; x80;
- 3) IPUM 25854, sample SIL I° 3 (*Oz. exc. hamata* Zone); upper view of Pa element; x80;
- 4) IPUM 27494/1, sample PF 11B (*Oz. exc. hamata* Zone); posterior view of Sb element; x55;
- 5) IPUM 27494/2, sample PF 11B (*Oz. exc. hamata* Zone); inner-lateral view of Pb element; x55;
- 6) IPUM 27494/3, sample PF 11B (*Oz. exc. hamata* Zone); inner-lateral view of Sc element; x60;
- 7) IPUM 27494/4, sample PF 11B (*Oz. exc. hamata* Zone); inner-lateral view of M element; x66.

Figs. 8-9 - *Kockelella stauros* Barrick & Klapper, 1976.

- 8) IPUM 27474, sample GALE BK 18 (*K. crassa* Zone); upper view (a) and lower view (b) of Pa element; x66;
- 9) IPUM 27475, sample SF BK 3 (*K. crassa* Zone); upper view (a) and lower view (b) of Pa element; x66.

Fig. 10 - *Kockelella ranuliformis* (Walliser, 1964). IPUM 25862, sample ARG C (*K. ranuliformis* Zone); upper view (a) and lateral view (b) of Pa element; x80.



phyletic scheme;

- 6 - The *K. crassa* stock up to date does not show a clear link to the main tree and therefore is left to open interpretation;
- 7 - Two main crises affected the *Kockelella* stock. The first one took place during the late *Oz. s. rhenana* Zone and led to the extinction of *K. ranuliformis*, *K. latidentata*, *K. corpulenta*, *K. amsdeni*, *K. cf. stauros* *sensu* Bischoff, 1986, *Kockelella* sp. nov. A Klapper & Murphy, 1975 (*sensu* Bischoff, 1986), as well as *K. patula*. The second crisis occurred just above the Wenlock-Ludlow boundary and affected *K. stauros*, *Kockelella* sp. nov. A Klapper & Murphy 1975, *K. walliseri* and *K. crassa*;
- 8 - The surviving taxa, *K. v. variabilis* and *K. a. absidata*, successfully evolved, producing descendants that reached the late *Pol. siluricus* Zone, when the whole lineage became to the end;
- 9 - The new species *K. crassa* and *K. maenniki* have good stratigraphic value, both being restricted to a short intervals of the Gorstian and of the Ludfordian, respectively.

ACKNOWLEDGEMENTS

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APPENDIX 1

REMARKS ON SAMPLE LOCATION.

Locality abbreviations:

SE Sardinia: GA=Genna Arrela, FRU=Monte Fruccas, GCIU=Genna Ciuerciu, SIL I°=Silius I°, RMC=Riu Murru de Callus, SBF=San Basilio Fenugu;

SW Sardinia (environs of Fluminimaggiore): GALE=Galemmu, CB III=Corti Baccas 3rd, PF=Perd'e Fogu, SF=Sentiero Flumini [samples SF 7, 8, 9, 12 from Serpagli, 1971];

SW Sardinia (other areas): ARG=Argiola, FTM=Funtanamare, SAD=San't Antonio di Santadi-Donigala.

For the detailed location of the localities visited during the ECOS VII Sardinia field trip refer to the Guide-book (Serpagli, ed., 1998):

Genna Ciuerciu (Corradini *et al.*, 1998b; fig. 1.3.1, p. 113), Silius (Serpagli *et al.*, 1998; fig. 1.2.1, p. 105),

Perde Fogu (Ferretti *et al.*, 1998a; fig. 2.2.1, p. 157) Argiola (Corradini *et al.*, 1998a; fig. 3.3.1, p. 195).

Remarks on the other localities are as follows:

Genna Arrela and Monte Fruccas: refer to Corradini & Olivieri (1997, fig. 1);

Riu Murru de Callus: this locality is about 1 Km SE of stop 4.1 of the ECOS VII- Sardinia Field trip Guidebook (Ferretti *et al.*, 1998b, fig. 4.1.1, p. 202);

San Basilio Fenugu: this locality is about 1 Km E of stop 1.1 of the ECOS VII- Sardinia Field trip Guidebook (Ferretti *et al.*, 1998c, fig. 1.1.1, p. 97);

Galemmu, Sentiero Flumini and Corti Baccas: these outcrops are located in the Fluminimaggiore area: refer to the map in Fig. 2.2.1 of the ECOS VII- Sardinia Field trip Guidebook (Ferretti *et al.*, 1998a, p. 157);

Funtanamare: village on the south-west coast, 2 Km South of Nebida.

San't Antonio Donigala: San't Antonio di Santadi-Donigala area, South of Oristano; outcrops close to Case Casti.

APPENDIX 2

INDEX OF THE REILLUSTRATED SPECIMENS

With this paper a general synthesis of the whole *Kockelella* of Sardinia is presented. It is, therefore, useful to show again figures of specimens reported on the ECOS VII Sardinia Field-excursion Guide Book (Serpagli, ed., 1998).

<i>This paper</i>	<i>ECOS VII Sardinia Field-excursion guidebook</i>
Pl. 1, fig. 1	Corradini <i>et al.</i> , 1998a, Pl. 1.3.1, fig. 16.
Pl. 1, fig. 5	Serpagli <i>et al.</i> , 1998, Pl. 1.2.1, fig. 7.
Pl. 1, fig. 8	Ferretti <i>et al.</i> , 1998a, Pl. 2.2.1, fig. 5.
Pl. 1, fig. 11	Ferretti <i>et al.</i> , 1998a, Pl. 2.2.1, fig. 12.
Pl. 2, fig. 1	Serpagli & Corradini, 1998, Pl. 1, fig. 6.
Pl. 2, fig. 2	Corradini <i>et al.</i> , 1998a, Pl. 1.3.1, fig. 10.
Pl. 2, fig. 3	Corradini <i>et al.</i> , 1998a, Pl. 1.3.1, fig. 12.
Pl. 2, fig. 5	Ferretti <i>et al.</i> , 1998a, Pl. 2.2.2, fig. 12.
Pl. 2, fig. 10	Serpagli & Corradini, 1998, Pl. 1, fig. 10.
Pl. 3, fig. 2	Serpagli & Corradini, 1998, Pl. 1, fig. 4.
Pl. 3, fig. 5	Serpagli & Corradini, 1998, Pl. 1, fig. 7.
Pl. 3, fig. 6	Ferretti <i>et al.</i> , 1998a, Pl. 2.2.1, fig. 15.
Pl. 3, fig. 7	Serpagli & Corradini, 1998, Pl. 1, fig. 3.
Pl. 3, fig. 8	Ferretti <i>et al.</i> , 1998a, Pl. 2.2.1, fig. 7.
Pl. 3, fig. 9	Ferretti <i>et al.</i> , 1998a, Pl. 2.2.2, fig. 8.
Pl. 4, fig. 1	Ferretti <i>et al.</i> , 1998a, Pl. 2.2.2, fig. 14.
Pl. 4, fig. 3	Serpagli <i>et al.</i> , 1998, Pl. 1.2.1, fig. 10.
Pl. 4, fig. 5	Serpagli & Corradini, 1998, Pl. 1, fig. 1.
Pl. 4, fig. 6	Ferretti <i>et al.</i> , 1998a, Pl. 2.2.1, fig. 16.
Pl. 4, fig. 7	Serpagli & Corradini, 1998, Pl. 1, fig. 2.
Pl. 5, fig. 1	Ferretti <i>et al.</i> , 1998a, Pl. 2.2.2, fig. 16.
Pl. 5, fig. 2	Ferretti <i>et al.</i> , 1998a, Pl. 2.2.1, fig. 17.
Pl. 5, fig. 3	Serpagli <i>et al.</i> , 1998, Pl. 1.2.1, fig. 13.
Pl. 5, fig. 10	Corradini <i>et al.</i> , 1998b, Pl. 3.3.1, fig. 4.

APPENDIX 3

During the restudy of the sections Silius I° and Genna Ciuerciu (both in SE Sardinia) in connection to the preparation of the ECOS VII Field Trip (June 1998), new samples were collected. Because the old sample numeration was already complex, we decided to replace it with a new, more simple one. Therefore, a comparative chart of the numbers reported in the preliminary paper (Barca *et al.*, 1995) and the new ones used in the ECOS VII Field trip Guidebook (Serpagli *et al.*, 1998; Corradini *et al.*, 1998b)

is presented below. The new numbers are also marked on the outcrops.

SE SARDINIA (env. of Silius)		Genna Ciurciu section	
Silius I° section			
<i>old</i>	<i>new</i>	<i>old</i>	<i>new</i>
1	1	0/2	
2	2		0
2A	3	0/1	1
3	4	0	2
3A	5	1	3
3B	6	1A	4
4	7	1B	5
4A	8	2	6
	9	2W	7
5	10	2X	8
6	11	2X1	9
6A	12	2A	10
	13	2Y	11
6B	14	2Y1	12
6C	15	2B	13
7	16	3	14
7A	17		15
7B	18	3A	16
8	19		17
8X	20	4	18
8A	21	5	19
8Y	22	5A	20
8B	23	5B	21
9	24	6	22
10	25	6A	23
10A	26	7	24
	27	7A	25
11	28	7B	26
11B	29	8	27
11C	30	8A	28
12	31	9	29
12A	32	9A	30
13	33	9B	31
	34	10	32
14	35	10X	33
	36		
15	37		
15A	38		
16	39		
19	50		
20	60		

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