

An unusually preserved foraminiferal association from the Upper Silurian-Lower Devonian beds in southwestern Sardinia

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ABSTRACT — *A foraminiferal fauna, consisting of agglutinated forms and for the most part of secondarily phosphatized inner moulds, is described and illustrated for the first time from U. Silurian-L. Devonian beds of southwestern Sardinia.*

RIASSUNTO — [Foraminiferi del Siluriano superiore-Devoniano inferiore della Sardegna sud-occidentale] — *Viene descritta ed illustrata per la prima volta nei terreni del Siluriano superiore-Devoniano inferiore della Sardegna sud-occidentale una fauna a foraminiferi, composta prevalentemente da riempimenti interni fosfatizzati e da forme agglutinanti.*

INTRODUCTION

During the last years, detailed paleontological and stratigraphical investigations of Silurian and Devonian rocks in southwestern Sardinia carried out by members of the Paleontological Institute of the University of Modena have furnished a rich collection of fossils among which some Upper Silurian and Lower Devonian foraminifers are present.

Many papers have been published on conodonts, cephalopods and phyllocarids, and other are in progress (for a complete reference list see Serpagli & Gnoli, 1984).

Silurian and Devonian formations cropping out in southwestern Sardinia are mainly represented by shales with interbedded dark cephalopod limestones (U. Silurian), micritic limestones (Lowermost Devonian) and dacroconarid bearing grey nodular limestones (Lower Devonian). All these rocks are generally strongly affected by tectonics and it was necessary to collect a great amount of samples for obtaining enough material for stratigraphic purposes (Gnoli & Serpagli, 1985). A total amount of several hundreds kilograms of limestone has been processed, mainly for recovering conodonts; besides secondarily phosphatized mandibles of phyllocarids (Gnoli & Serpagli, 1984), the acid-resistant residues yielded also foraminifers.

A collection of about 250 specimens of phosphatized foraminifers has been accumulated. Because nobody seems to have been seriously interested in this kind of fossils from the Sardinian Paleozoic, the present paper is, therefore, the first to describe foraminifers and related forms from this area, in particular those collected from the Upper Silurian-Lower Devonian limestones.

Our samples have been recovered in the Fluminese region and only one in Domusnovas area (437/1). The outcropping localities are situated in the narrow belt of autochthonous Siluro-Devonian sediments going from Domusnovas to Fluminimaggiore neighbourhood. For detailed location of the sections and outcrops named in this paper see Gnoli (1983), Mastandrea (1985), Serpagli (1970, 1983) and Serpagli *et al.* (1978). The « Mason Porcus » section is at present under study by Gnoli, Křiž, Olivieri and Serpagli, so detailed stratigraphy and lithology will be available in forthcoming contributions. The conodont biostratigraphy of the « Corti Baccas 3rd » section was recently published by Mastandrea (1985).

It is interesting to point out that foraminifers seem to be very rare in the studied samples: only 13 of them, for a total weight of 75 Kg of rocks, among the tens processed, yielded such kind of fossils. This scattered occurrence seems apparently in

good agreement with the general record of the foraminifers throughout the Paleozoic. Furthermore, it is during the Late Silurian-Early Devonian times that one of the lowest degree of occurrence has been reported (Conkin & Conkin, 1964, 1967, 1982; Ebner, 1985; Mound, 1968).

STRATIGRAPHICAL REMARKS, AGE AND CORRELATIONS

At the present stage of the research on Sardinian Paleozoic foraminifers it seems difficult to detect their stratigraphic importance especially because several samples came from isolated outcrops, sometime of very limited extension. However, for most of them we have a valid control based on conodonts; it was possible to distinguish four groups with different stratigraphic ranges which can be referred to Lower-Middle Ludlow (form-group 5), Ludlow-Pridoli (form-group 6), Pridoli-Lower Lochkov (*P. cava* and form-groups 1a, 2, 3, 4, 7) and Lower Lochkov (? *Webbinelloidea* sp., *Tolypammmina bransonii*, *T. devoniana* and form-groups 1b, 1c), respectively.

A comparison of the distribution and ranges of the Sardinian foraminiferal fauna was tended with faunas from areas from which the foraminifers are adequately known. The closer areas where the Paleozoic sequence are comparable with the Sardinian one are the Carnic Alps, Austria, Thuringia, Spain and Montagne Noire (S. France). Whereas the forms re-

ported from Carnic Alps, Austria and Thuringia (Blumenstengel, 1961, 1963; Ebner, 1973, 1985; Langer, 1969) are quite different and come mainly from younger horizons, unfortunately no records of foraminifers are reported from Spain and Montagne Noire. Thus, today correlations and comparisons are practically impossible.

STATE OF PRESERVATION

With the exception of some specimens, found in the light fraction of one sample in which the tests were preserved and easily recognizable as typical agglutinated foraminifers and here formally described, the main part of the fauna was found in the heavy fractions. There the tests are represented by few phosphatic spherical forms, mostly empty, and massive tubular « objects » of different shape and size (0.05-0.18 mm in diameter).

These last specimens display a peculiar preservation among foraminifers because they represent internal phosphatized moulds of forms probably originally agglutinated.

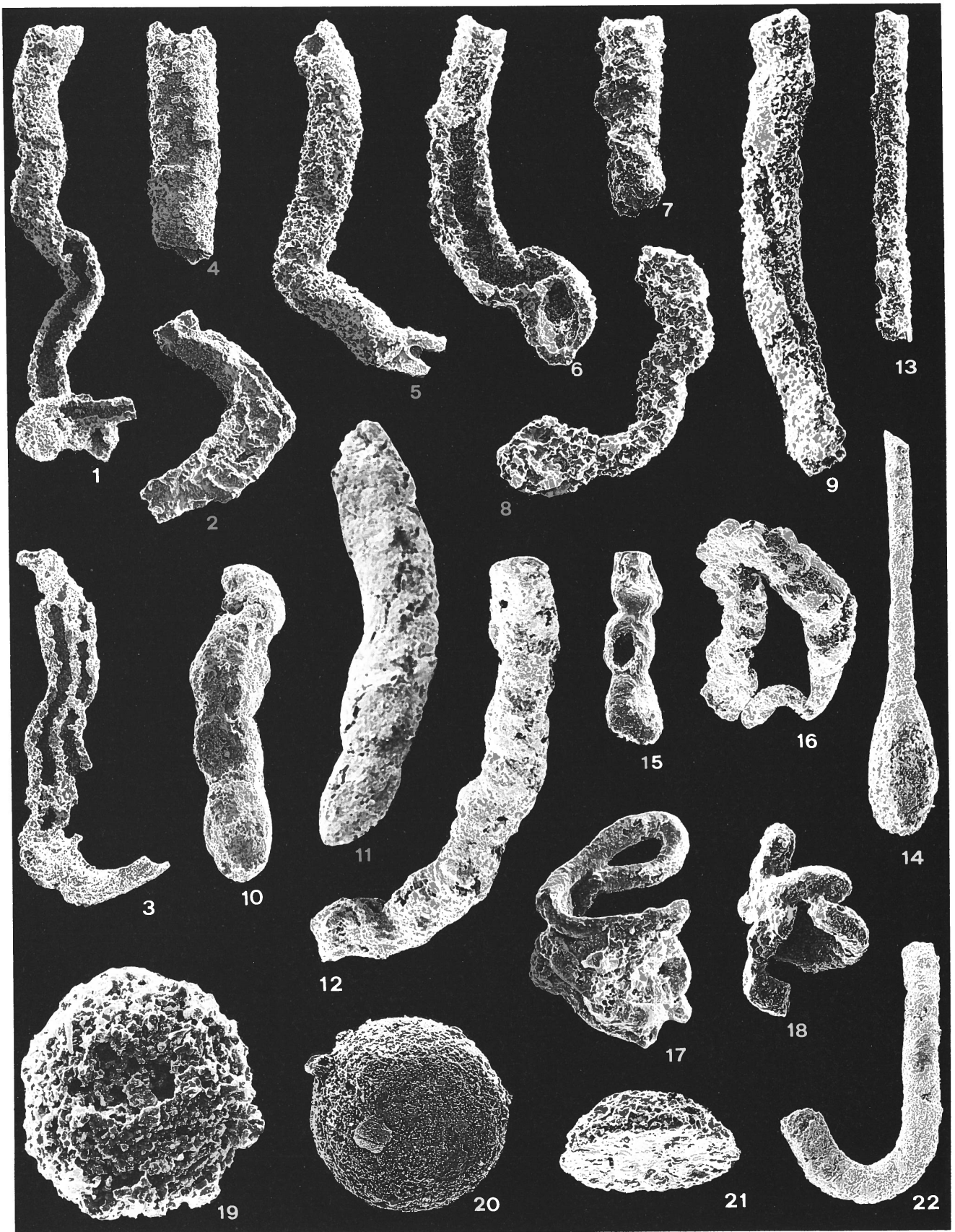
As far as we known, nobody has reported this type of preservation among Paleozoic foraminifers.

Due to the impossibility of checking and comparing the test of our specimens, which are often fragmentary, some doubts arise on the taxonomic assignment of

EXPLANATION OF PLATE 1

Letters and numbers following the catalog number in brackets represent sample numbers in our files (MP = « Mason Forcus » section, CB III = « Corti Baccas » section).

- Figs. 1-6 - *Tolypammmina bransonii* Conkin, Conkin & Canis.
1, (n. 20564, CB III A) x 50; 2, attached lower surface (n. 20565, CB III A) x 50; 3, attached side showing mature portion of second chamber adnate to the early one (n. 20566, CB III A) x 50; 4, (n. 20567, CB III A) x 50; 5, unattached surface (n. 20568, CB III A) x 100; 6, attached side (20569, CB III A) x 100; 16, proloculus and early stage preserved as secondarily phosphatized internal mould (n. 20583, CB III A) x 100.
- Figs. 7-9 - *Tolypammmina devoniana* (Crespin).
7, free fragment of 2nd chamber (n. 20571, CB III A) x 100; 8, attached side of the proloculus and early stage (n. 20572, CB III A) x 100; 9, fragment showing longitudinal attachment scars (n. 20573, CB III A) x 100.
- Figs. 10-12 - Form-group 1a - Hyperamminoid-type forms preserved as phosphatic.
10, (n. 20575, MP 3a) x 100; 11, (n. 20576, MP 10f) x 100; 12, (n. 20577, MP 3a) x 100.
- Figs. 13-14 - Form-group 1b.
13, arenaceous fragment of 2nd chamber (n. 20579, CB III A) x 100; 14, phosphatized specimen with large proloculus (n. 20581, MP 7) x 100.
- Fig. 15 - *Oxinosis*-type form (n. 20582, MP 5) x 50.
- Figs. 17-18 - Form-group 2 - *Trepeilopsis*-type.
17, (n. 20586, MP 3a); 18, (20587, MP 10e), both x 100.
- Figs. 19-20 - *Psamosphaera cava* Moreman.
19, specimen with arenaceous test (n. 20589, CB III A) x 200; 20, phosphatized specimen (n. 20590, MP 3) x 200.
- Fig. 21 - ? *Webbinelloidea* sp. Ventro-lateral view to show the different texture of the attached and unattached side (n. 20592, CB III A) x 100.
- Fig. 22 - Form-group 1c. *H. carinthiaca*-type form (n. 20584, MP 10 f) x 100.



several forms. For this reason we decided to describe them informally.

SYSTEMATIC DESCRIPTION

All the specimens described belong to the Paleontological Collection of the University of Modena and are stored at the Museum of the Institute of Paleontology under the catalog numbers 20564-20625.

Order FORAMINIFERIDA Eickwald, 1830
Suborder TEXTULARIINA Delage & Hérouard, 1896
Family SACCAMMINIDAE Brady, 1894
Subfamily PSAMMOSPHAERINAE Haeckel, 1894
Genus PSAMMOSPHAERA Schulze, 1875

PSAMMOSPHAERA CAVA Moreman, 1930

Pl. 1, figs. 19, 20

- 1930 *Psammospaera cava* MOREMAN, p. 48, pl. 6, fig. 12.
1968 *Psammospaera cava* Moreman - MOUND, pp. 14, 75, pl. 5, figs. 13, 15, *cum syn.*
1971 *Psammospaera cava* Moreman - KRISTAN - TOLLMANN, pp. 255-259, pl. 2, fig. 3, *cum syn.*
1973 *Psammospaera cava* Moreman - EBNER, p. 408, pl. 7, figs. 1-5, *cum syn.*
1974 *Psammospaera gracilis* Ireland - TOOMEY, p. 332, pl. 1, fig. 10.
1983 *Psammospaera cava* Moreman - OLEMPKA, pp. 401, 402, pl. 15, figs. 3, 5, 6.

Material — 11 isolate specimens, several hundred in thin sections.

Dimensions — External diameter = 0.17-0.21 mm.

Description — Spherical wall composed of fine quartz silt grains. Some specimens, preserved as phosphatic, show a very smooth outer surface and variable wall thickness. The latter could represent a

particular fossilization of the inner organic lining of this agglutinated species.

Remarks — Dimension and test composition of our specimens are practically the same of *P. gracilis* Ireland reported by Toomey (1974) in the Pennsylvanian of Leavenworth Limestone. This species, however, was considered synonym of *P. cava* by Mound (1968, p. 74) and by Kristan-Tollmann (1971, pp. 225-256). In general *P. gracilis* has a smaller diameter than *P. cava* but, as pointed out by Ireland (1956, p. 841) « simple spherical forms are difficult to separate into species ». However, leaving aside this problem for the time being, we can consider our specimens to belong to *P. cava* type A of Ebner (1973, p. 408).

This form was recovered at level A of the « Corti Baccas 3rd » section (Lower Lochkovian) and at levels 3 and 5 (very abundant) of the « Mason Porcus » section (Uppermost Pridolian, *eosteinhornensis* Zone).

Occurrence — See Ebner (1973, p. 408).

Subfamily HEMISPHAERAMMINAE

Loeblich & Tappan, 1961

Genus WEBBINELLOIDEA Stewart & Lampe, 1947
emend. Conkin & Conkin, 1970

? WEBBINELLOIDEA sp.

Pl. 1, fig. 21

Material — One specimen.

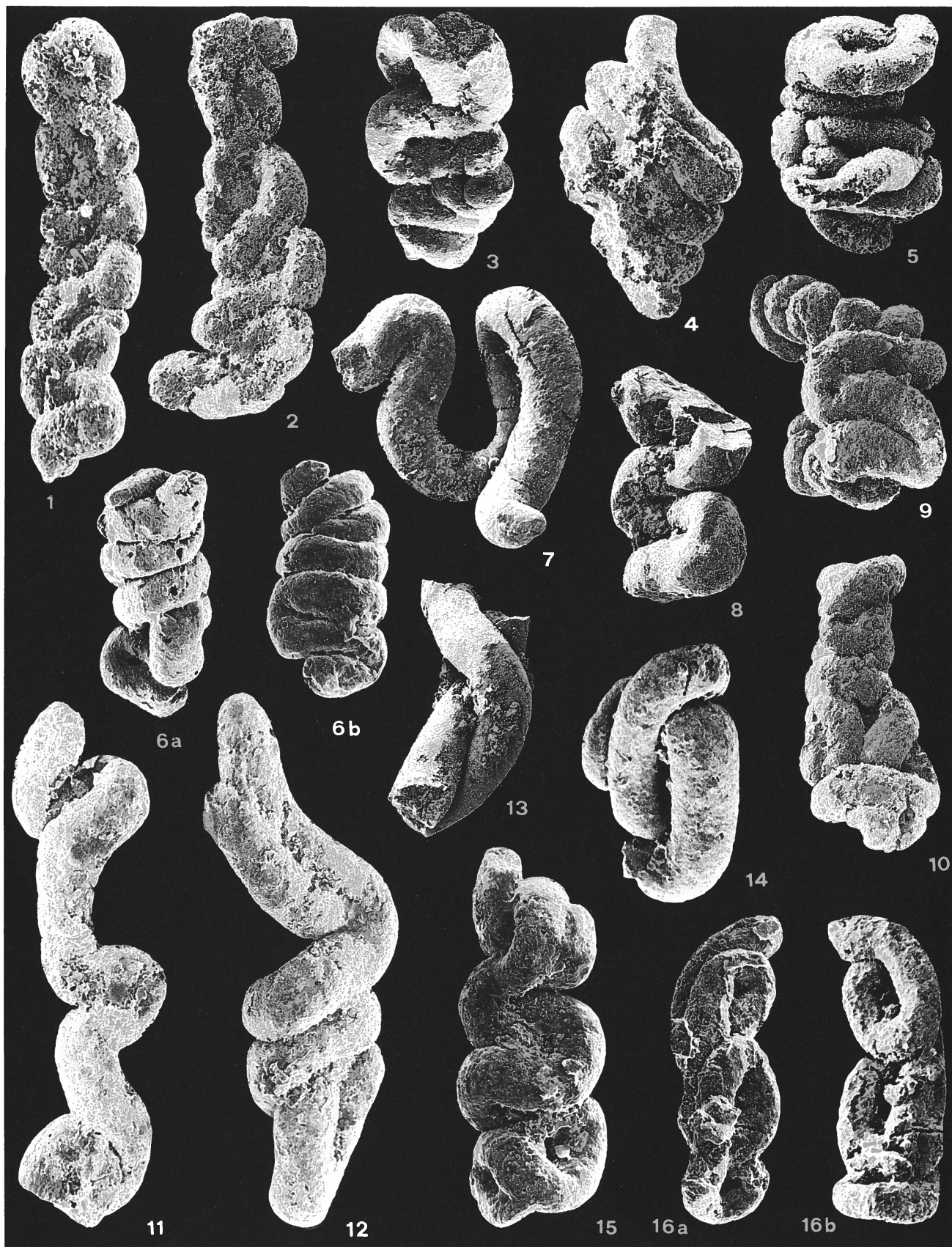
Dimensions — Main diameter = 0.32 mm, transverse diameter = 0.27 mm, thickness = 0.15 mm.

Description — Single-chambered, plano-convex, form. Elliptical outline in dorsal view. Flattened attached side shows a finer grained texture than the unattached which is medially inflated. No apertures are recognizable on the test.

EXPLANATION OF PLATE 2

All the specimens illustrated in this plate are preserved as phosphatic. Letters and numbers following the catalog numbers in brackets represent sample numbers in our files (MP = « Mason Porcus » section, CB III = « Corti Baccas 3rd » section).

- Figs. 1-10 - Form-group 3 - Ammoverrellid-type specimens. All x 100.
1, 2, specimens showing several meanders, attached sides, (n. 20592, 20593, MP 10e); 3, specimen with inflated proloculus, few meanders, then freely winding, unattached side, (n. 20594, MP 3a); 4, (n. 20594, MP 10e); 5, fragment of later stage freely winding (n. 20595, 433/5); 6a, b, two different views of another specimen with proloculus, two meanders and later coiled (n. 20596, MP 3a); 7, 8 open and close zig-zags in early stages (n. 20597, 20598, MP 3a); 9, 10, irregular zig-zags followed by free spiral winds (n. 20599, MP 10f) (n. 20600, MP 10e).
- Figs. 11-16b - Form-group 4 - All x 100 if not differently specified.
11, specimen which alternatively winds and zig-zags (n. 20602, MP 11); 12, 13, specimens which chambers, winding back adnate on themselves, appear as twisted forms (n. 20603, MP 10e), (n. 20604, MP 3a) x 50; 14, 15, catenulate forms (n. 20605, n. 20606, MP 3a); 16a, 16b ventral and dorsal view of a squeezed-spiral form (n. 20607, MP 3a).



Remarks — This form closely resembles in shape the specimen illustrated by Eickoff (1970, pl. 31, figs. 11, 12) as *Webbinelloidea hemisphaerica* Stewart & Lampe 1947, but seems smaller. Furthermore, the lack of visible aperture leaves some doubt about the generic assignment. However, we prefer to consider our specimen belonging to the genus *Webbinelloidea* instead of *Hemisphaerammina* on the basis of the different texture between the attached and unattached sides.

This species occurs at level A of the « Corti Baccas 3rd » section (Lower Lochkovian).

Subfamily TOLYPAMMININAE Cushman, 1928

Genus TOLYPAMMINA Rhumbles, 1895

TOLYPAMMINA BRANSONI Conkin,

Conkin & Canis, 1968

Pl. 1, figs. 1-6, 16

1968 *Tolypammina bransoni* Conkin, Conkin & Canis, p. 163, pl. 3, figs. 1-8.

1973 *Tolypammina bransoni* Conkin, Conkin & Canis - CONKIN & CIESIELSKI, pp. 27, 28, pl. 2, figs. 8A-9B.

1981 *Tolypammina bransoni* Conkin, Conkin & Canis - CONKIN & CONKIN, pp. 25, 26, figs. 4A, 4B.

Material — Several fragments of the second chambers.

Dimensions — Diameter of 2nd chambers = 0.10-0.22 mm, wall thickness = 0.03-0.04 mm.

Remarks — Specimens available fit well the original description of this species with the exception of the proloculus, which was never found in our material. Specimens comparable to this form are also represented by those described by Crespin (1961, p. 408, pl. 67, figs. 6-8) and revised by Conkin & Con-

kin (1968, pp. 607, 608, pl. 115, figs. 5-8) as *T. nexuosa*, from the Upper Devonian of Australia, but this species seems to be of doubtful status (Conkin & Conkin, 1968, p. 608).

T. bransoni is present in Sardinia only in level A of the « Corti Baccas 3rd » section (Lower Lochkovian).

Another fragment, illustrated here in pl. 1, fig. 16, and represented by a secondarily phosphatized mould of proloculus at an early stage, could tentatively belong to this species.

This last fragment has been recovered at level 10e of the « Mason Porcus » section (Lower Lochkovian).

Occurrence — See Conkin & Conkin (1981, p. 26).

TOLYPAMMINA DEVONIANA (Crespin, 1961)

Pl. 1, figs. 7-9

1961 *Hyperammina devoniana* Crespin, pp. 406, 407, pl. 64, figs. 1-6.

1968 *Tolypammina devoniana* (Crespin) - CONKIN & CONKIN, pp. 606, 607, pl. 114, figs. 1-4, 9, text-figs. 1A, E.

Material — Several fragments of the 2nd chambers and one with proloculus.

Dimensions — Diameter of proloculus = 0.15 mm, average diameter of 2nd chamber = 0.10 mm.

Remarks — All our fragments showing straight or gently curved second chambers with attachment scars slightly developed and partially attached, irregularly shaped, proloculus are considered to belong to *T. devoniana*.

As pointed out by Conkin & Conkin (1968, p. 607) this last feature concerning the proloculus per-

EXPLANATION OF PLATE 3

All the specimens figured in this plate are preserved as phosphatic.

Letters and numbers following the catalog numbers in brackets represent sample numbers in our files (MP = « Mason Porcus » section).

Figs. 1-6 - Form-group 5.

1, elongated, slightly curved specimen, dorsal view (n. 20609, 433/5) x 50; 2a, straight large specimen showing its attached ventral side (n. 20610, 433/3) x 50; 2b, the same in dorsal view x 50; 2c, enlargement of fig. 2a to show the particular arrangement of tubes and attachment scars, x 100; 3, another gently twisted specimen, attached side (n. 20611, 437/1) x 50; 4, (n. 20612, 433/3) x 50; 5a, b, dorsal and ventral view of a straight specimen, tubes are less packed and more irregularly arranged than in the specimen of fig. 2 (n. 20613, 433/5) x 50; 6, (n. 20614, 433/15iv) x 50.

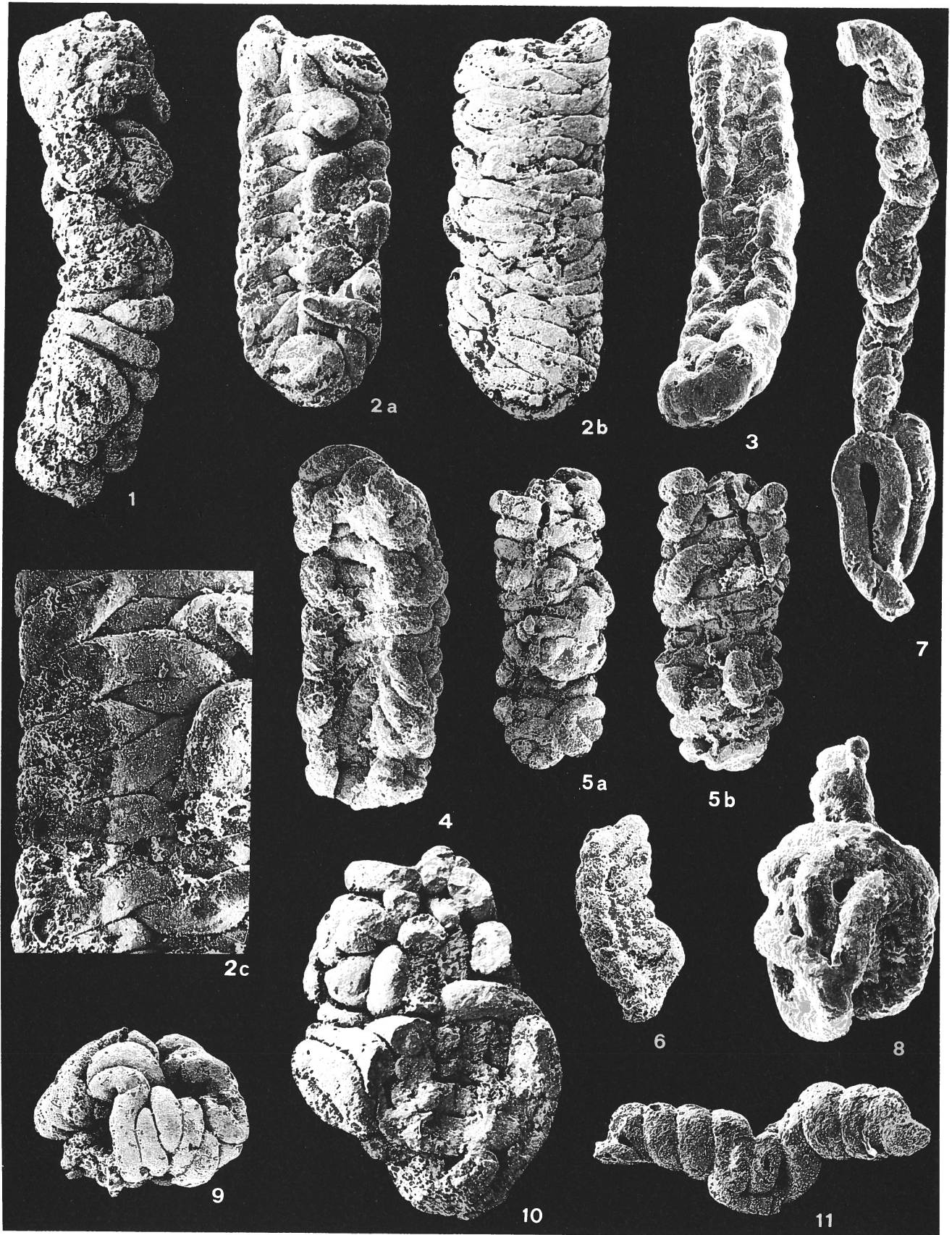
Figs. 7-8 - Form-group 7.

7, specimen with free zig-zags later coiled in closely winding spiral (n. 20619, MP 10f) x 200; 8, another specimen with glomospiroid early stage (n. 20620, MP 3a) x 200.

Figs. 9-10 - Form-group 6 - Glomospiroid-type.

9, (n. 20616, MP 3a) x 50; 10, large specimen showing probable attachment scars in its early stage (n. 20617, 433/5) x 50.

Fig. 11 - *Turbienta*-type form (n. 20622, MP 3a).



mits the distinction of *T. devoniana* from other similar species, like *T. bulbosa* (Gutschick & Treckman, 1959), with free and spherical proloculus. We found this species at level A of the «Corti Baccas 3rd» section (Lower Lochkovian).

Occurrence — See Conkin & Conkin (1968, p. 607).

INFORMAL DESCRIPTION OF PHOSPHATIC REMAINS

1) A first group is represented by a few straight or gently curved tubular specimens, with prolocula sometimes preserved, whose shapes recall hyperamminoid-type forms. Inside this group, these specimens can be clustered in three sub-groups and compared to already known species of the genus *Hyperammina*.

1a) Specimens representing this sub-group are illustrated at pl. 1, figs. 10-12. They show a large, elongated, ogival proloculus (0.12 mm wide) separated from the second chamber by a faint constriction. Tubular to compressed second chambers are gently curved and enlarge almost imperceptibly with irregularly spaced slight constrictions.

Forms comparable with this material could be the megalospheric specimens described and illustrated by Ireland (1956, pp. 844, 845, text-figs. 3-15, 16) as *Hyperammina elegantissima* Plummer. The specimen here illustrated at pl. 1, fig. 12 shows some analogies regarding the shape of the proloculus also with *H. clavacoidea* Plummer.

Specimens belonging to this sub-group have been recovered at level 3a (Uppermost Pridolian, *eosteinbornensis* Zone and 10f (Lower Lochkovian) of the «Mason Porcus» section.

1b) Only one specimen with proloculus and several fragments of the second chambers with preserved fine grained test (pl. 1, fig. 13) belong to this sub-group of forms. These are characterized by a large, drop-shaped, proloculus (0.22 mm long, 0.13 mm wide) and thin straight second chamber, whose diameter is about 0.06 mm.

Despite the different type of preservation, we consider the specimens mentioned above as conspecific on the basis of the inner diameter of the second chambers. In fact, as good example of what has previously been pointed out, the specimen of pl. 1, fig. 14 could actually represent a secondarily phosphatized mould of a specimen similar to that of pl. 1, fig. 13.

Because of its very large proloculus, we found difficulties when comparing this form with other

known species, even if the long-range and widely distributed *H. rockfordensis* Gutschick & Treckman (see Ebner, 1973, p. 403), and in particular the specimen shown by Conkin (1961) at pl. 21, fig. 12, seems to be the closest one. Our forms were collected at level A of the «Corti Baccas 3rd» section and at level 7 of the «Mason Porcus» section, both Early Lochkovian in age.

1c) Few curved and slightly twisted, hook-shaped, fragments of second chambers (pl. 1, fig. 22) with an average diameter of 0.08 mm represent this last sub-group.

Size and shape very closely recall the specimens shown by Ebner (1973, pl. 5, figs. 3, 5) as *Hyperammina carnica* (= *H. carinthiaca* Ebner, 1974).

We found these specimens at levels 10e and 10f (Lower Lockovian) of the «Mason Porcus» section.

2) The second form-group includes few *Trepeilopsis*-type fragments (pl. 1, figs. 17, 18). They consist of tubular second chambers, with a diameter ranging from 0.05 to 0.07 mm, more or less flattened in correspondence of their attached portion, which wind spirally, partly irregularly, along and around a slender subcylindrical object.

Species comparable to our form could be represented by ?*Trepeilopsis tornella* (Ireland, 1956).

These fragments were recovered at levels 3a (Uppermost Pridolian) and 10e (Lower Lochkovian) of the «Mason Porcus» section.

3) Several specimens and fragments can be included in this third group represented by Ammovertellid-type forms (pl. 2, figs. 1-10).

Prolocula, sometimes preserved (pl. 2, figs. 2, 3, 6), are slightly inflated and probably attached. Tubular second chambers (0.08 to 0.10 mm in diameter), apparently undivided from the proloculus, show faint attachment scars in early stages. These last are arranged in strongly packed zig-zags (3 to 10 meanders) lying on the same plane or gently coiled according to the availability and shape of an attaching object. Later stages, mainly free and imperceptibly enlarged, closely wind spirally with a more or less regular pattern.

At present it seems difficult to closely compare any already known species of *Ammoverbella* and related genera with the forms described in this group.

With the exception of one specimens (pl. 2, fig. 5) found in a displaced block (433/5, M. Ludlow, *siluricus* Zone), all the other specimens are from levels 3a (Upper Pridolian) and 10e, 10f (Lower Lochkovian) of the «Mason Porcus» section.

4) This group is characterized by long tubular fragments, with diameter ranging from 0.07 to 0.18 mm, which alternatively winds and zig-zags in a more or less regular pattern (pl. 2, fig. 11). Winding back together, adnate on themselves, and following the same pattern, these fragments sometimes appear as twisted (pl. 2, figs. 12, 13), catenulate (pl. 2, figs. 14, 15) and squeezed-spiral forms (pl. 2, figs. 16a, b). In general they show a mixture of features characteristic either of the genus *Tolypammina* or *Ammovertella*.

The local stratigraphical distribution of these specimens is the same of those described above in the form-group 3.

5) Another form-group is represented by relatively large attached specimens (pl. 3, figs. 1-6) with a very long, apparently undivided and not enlarging, second chamber, tubular in shape and 0.1 mm in diameter. Tubes are arranged in closely packed, more or less regular, zig-zag and hemicircular winds (pl. 3, fig. 2c) to form a thick elongate body, straight (pl. 3, figs. 2, 4, 5) or gently curved (pl. 3, figs. 1, 3, 6), concavo-convex in cross section and rounded at one of its terminal ends. The best preserved specimens (1.1-1.8 mm long and 0.4-0.5 mm wide) show adnation scars on their concave attached side.

In thin section fine silt quartz grains are sometimes preserved in the free interspaces between phosphatized tubes.

This form-group may represent a further complication of the development pattern shown by form-groups 3 and 4.

No comparable material seems to exist among the already known Paleozoic foraminifers with the exception of some phosphatized specimens collected by us in one level (33b, Muslovka Quarry) of the Kopanina Formation in Bohemia.

Forms considered here were recovered from some displaced blocks (433/3, 433/5, 433/15iv, 437/1) of Upper Silurian cephalopod limestone ranging, in terms of conodont biostratigraphy, from *crassa* to *siluricus* Zones.

6) Specimens with long, irregularly coiled, tubular second chamber with an average diameter of 0.1 mm represent this sixth group. The interwoven coils are closely packed to form large (1.5-2.5 mm in diameter) glomospiroid-type knots (pl. 3, figs. 9, 10). These forms seem to be free, but one broken specimen reveals probable attachment scars in its early stage (pl. 3, fig. 10).

Some species of the Cambrian-Ordovician genera *Reitlingerella*, *Lebedevaella* and *Glomovertella*, illustrated by Vologdin (1958, p. 406, figs. 21, 22), Reit-

linger (1948, pl. 1, fig. 5) and Bykova (1961, pl. 24, figs. 7-10), apparently recall our specimens in shape but these last are 6-7 times larger in size. Furthermore the genera mentioned above, originally regarded as foraminifers, are now considered of doubtful systematic position (Loeblich & Tappan, 1964, p. 787).

Specimens of this group occur in Middle Ludlovian (*siluricus* Zone) cephalopod limestone and at level 3a (Upper Pridolian, *eosteinhornensis* Zone) of the «Mason Porcus» section.

7) Few fragmentary specimens belong to this last group of forms. They are probably free and very thin in diameter (0.03-0.035 mm) and show glomospiroid (p. 3, fig. 8) or free zig-zag (pl. 3, fig. 7) patterns in early stages, and later closely wind spirally around a straight elongated axis.

Also for this form-group it seems very difficult to find comparable material. These fragments were collected at levels 3a and 10f of the «Mason Porcus» section.

In addition to the specimens described above, we have found at level 5 (Uppermost Pridolian) of the «Mason Porcus» section a fragment closely comparable with *Oxinaxis*-type form (pl. 1, fig. 15) and at level 3a of the same section (Upper Pridolian) another fragment, here illustrated at pl. 3, fig. 11, practically identical in shape, but not in size, to *Turbienta bifida* Bykova (1961, pp. 65, 66, text-fig. 32, pl. 24, figs. 1-6).

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