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SEDIMENTOLOGY, STRATIGRAPHY AND MICROPALEONTOLOGY OF THE TRIASSIC EVAPORITIC SEQUENCE IN THE SUBSURFACE OF BOCCHEGGIANO AND IN SOME OUTCROPS OF SOUTHERN TUSCANY (ITALY)

ROSSANA MARTINI */**, ANNA GANDIN* & LOUISETTE ZANINETTI**

Key-words: Triassic, Carnian, Norian, Burano Formation, Southern Tuscany, Italy, Sedimentology, Diagenesis, Sabkha, Stratigraphy, Micropaleontology.

Riassunto. Nella Toscana Meridionale e nell'area di Boccheggiano in parte affiorano ed in parte sono stati incontrati da sondaggi gli orizzonti evaporitico-dolomitici della Formazione di Burano. Tali orizzonti, in sondaggio, si collocano tra le Filladi di Boccheggiano a letto e le formazioni in facies ligure a tetto. In affioramento, in seguito alla dissoluzione dei solfati, hanno assunto l'aspetto di una breccia nota con il nome di Calcare Cavernoso.

Le analisi sedimentologica, micropaleontologica e stratigrafica hanno permesso di datare al Carnico-Norico la Formazione di Burano nella Toscana meridionale. L'ambiente deposizionale è riferito ad un complesso di sabkha, prospiciente un'area marina confinata ad alta salinità, che si colloca in un dominio paleogeografico intermedio tra quello Spezino e quello Umbro. Inoltre lo studio approfondito del contatto Filladi di Boccheggiano-Formazione di Burano ha messo in evidenza che il passaggio è di tipo stratigrafico.

Abstract. The Burano Formation, consisting of evaporitic-dolomitic horizons, has been encountered partly in boreholes and partly as scattered outcrops in Boccheggiano and southern Tuscany areas. In the boreholes, this unit overlies the Filladi di Boccheggiano Formation and is overlain by the Calcare Cavernoso or the Ligurian Nappe. In outcrops, this evaporitic-dolomitic sequence, following sulphate dissolution, is represented by the brecciated unit known as Calcare Cavernoso. Sedimentological, micropaleontological and stratigraphical analyses have allowed to assign a Carnian-Norian age to the Burano Formation in southern Tuscany.

The depositional paleoenvironment corresponds to a sabkha complex bordering a more or less restricted marine water body. The paleogeographic setting of the Triassic southern Tuscany is located between the La Spezia and Umbria domains.

Following a detailed study, the contact between the Filladi di Boccheggiano and the Burano Formation is shown to be stratigraphic and gradual.

* Dipartimento di Scienze della Terra, Università di Siena, via delle Cerchia 3, 53100 Siena, Italia.

** Département de Géologie et Paléontologie et Département de Zoologie, Université de Genève, 13 Rue des Maraîchers, 1211 Genève 4, Suisse.

Introduction.

Evaporitic-dolomitic horizons have been encountered in many boreholes in the region of Boccheggiano-Poggio Villori. They are equally exposed in some scattered outcrops in southern Tuscany (Fig. 1). This evaporitic-dolomitic sequence has been referred to the Burano Formation (Martinis & Pieri, 1964; Giannini et al., 1972; Giannelli & Puxeddu, 1978).

In the area of Boccheggiano (Fig. 1C) occurs one of the largest and most discussed geological bodies of southern Tuscany. A fault system delimits a horst structure, within which the Burano Formation occurs in subsurface while in outcrop the Tocchi Forma-

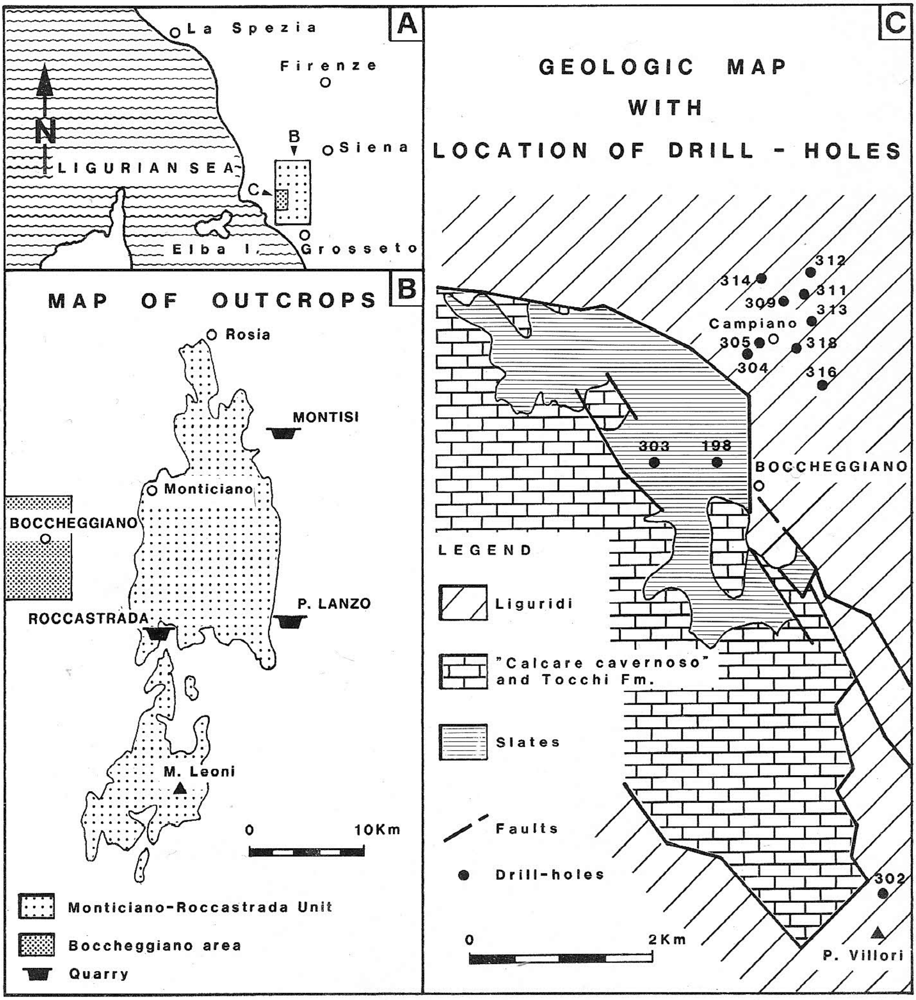

Fig. 1 - A-B) Location of the Monticiano-Roccastrada Unit and the Boccheggiano area in Tuscany. C) Schematic geological map of the Boccheggiano area and position of the drill-holes.

tion and the Calcare Cavernoso are found. In the northern part of the area, these formations overlay the Filladi di Boccheggiano, which are believed to be the oldest deposits in Tuscany (Burgassi et al., 1980) (Fig. 2). The most remarkable structural element is the Boccheggiano-Riotorto normal fault, separating the Triassic evaporitic deposits from the Cretaceous formations of the Ligurian Nappe.

The outcrops of the evaporitic-dolomitic sequence where some quarries have been studied, are located in the Middle-Tuscan Ridge (Monticiano-Roccastrada sequences) of the Siena region (sheet 120 of the Geological Map of Italy). The dolomitic lithofacies, commonly strongly tectonized, are less represented than the sulphate facies.

The quarry of Roccastrada (Fig. 1B) has been cut through a dolomitic and anydritic horizon about 2 km long, sitting on top of the Tocchi Formation. These Triassic deposits are covered by Pliocene clayey and sandy-marly conglomeratic sediments.

The quarry of Podere Montisi (Fig. 1B) has a front wall about 150 m long and has been dug into a large sulphatic-dolomitic body. The Triassic lithotypes are here overlain by sediments belonging to the Argille con Calcari palombini Unit, which, according to Signorini & Pieruccini (1968), protected the sulphates from dissolution. However, the presence of clayey levels also below the evaporitic horizons (discovered by drilling, A. Lazzarotto personal communication) suggests that the evaporites are sandwiched within the impermeable Ligurian Nappe.

The quarry of Podere Poggio Lanzo (Fig. 1B), as the Montisi one, shows sulphatic-dolomitic deposits overlain by Ligurian formations. It is difficult here to determine the substratum of the evaporites. Survey data suggest that it might be the Verrucano Formation.

Stratigraphy.

The evaporitic-dolomitic sequence of the Burano Formation is, in the Boccheggiano subsurface, intercalated between the Filladi di Boccheggiano at the base and the Calcare Cavernoso or the Ligurian formations at the top. In outcrop, this evaporitic-dolomitic unit is represented by the Calcare Cavernoso (Fig. 2) (Trevisan, 1955; Vighi, 1965).

From the analyses of bore-holes it results that the transition to the underlying Filladi di Boccheggiano consists of millimetric to centimetric alternations of phyllitic, calcitic and evaporitic levels. A similar setting has been described for the drainage tunnel of Boccheggiano by Trevisan (1955), who considered the brecciated horizon between the Filladi di Boccheggiano and the overlying evaporitic-dolomitic sequence as the equivalent of the Tocchi breccias.

Another similar evaporitic horizon, between the Filladi di Boccheggiano and the Calcare Cavernoso, in the Boccheggiano area has been related to the Tocchi Formation by Cocozza et al. (1979).

The Filladi di Boccheggiano consist of quartzites, black and dark-grey phyllites, and associated chloritic-sericitic, calcitic and graphitic thin laminae. Anhydrite lenses

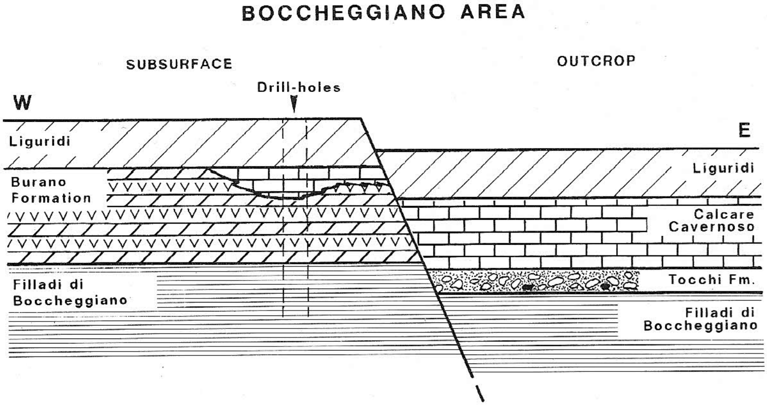

Fig. 2 - Schematic relationship, in outcrop and subsurface, between sequences and formations of the Boccheggiano area.

are sometimes intercalated, as well as thin layers of pyrite (Giannini et al., 1972; Cocozza et al., 1979; Azzaro et al., 1976), metabasites and leucoxenic metagraywackes (Giannelli & Puxeddu, 1979). The original deposits have been affected by a dynamic metamorphism resulting in greenschist facies. A further thermal metamorphic event seems to have produced the hornblende facies in the deeper part of the Filladi di Boccheggiano unit (Franceschelli, 1980; Lattanzi & Tanelli, 1982).

The depositional environment of this mainly siliciclastic sequence has been interpreted by Franceschelli (1978, 1980) as a confined, slightly anoxic basin, characterized by a low sedimentation rate.

The Filladi di Boccheggiano contain in the volcanoclastic metamorphic levels abundant pre-tectonic pyrite crystals, whose genesis is related to that of the sulphides (Giannelli & Puxeddu, 1979). Studies carried out by Giannelli & Puxeddu (1978) on the pyrite deposits in the area of Massa Marittima have led to the hypothesis of a primary exhalative-sedimentary origin for the pyrites of Gavorrano (Massa-Boccheggiano, Valmaggiore), Niccioleta and Campiano. In their opinion the sulphide formation is related to bacterial or inorganic reduction of sulphates deposited in deep water, as it happens in the Red Sea today.

There are contradictory opinions concerning the age of the Filladi di Boccheggiano: Triassic (Trevisan, 1955; Giannini et al., 1972), Permian (Cocozza et al., 1974, 1979; Cocozza & Vai, 1978) or Devonian (Bagnoli et al., 1978, 1980; Giannelli & Puxeddu, 1979). However, a Triassic age has been proposed by Cortecci et al. (1981, 1983, 1988) on the basis of isotopic analyses carried out on the sulphur of the sulphides and sulphates intercalated in the Boccheggiano phyllites, and by comparison with the isotopic values published by Claypool et al. (1980).

The Calcare Cavernoso has been interpreted as having originated by autoclastic-tectonic processes acting on alternated evaporitic-dolomitic layers, and followed by weathering of the exposed deposits (Trevisan, 1955; Signorini, 1967; Passeri, 1975). The correspondence between the calcitic-dolomitic breccias of the Calcare Cavernoso and the alternating carbonate-sulphate sequences is now generally accepted (Burckhart, 1946; Trevisan, 1955; Vighi, 1965; Lazzarotto, 1967; Passeri, 1976; Costantini et al., 1980), and the authors relate this brecciated body, found both in bore-holes and outcrops, to the Burano Formation.

Lithofacies and carbonate microfacies.

The evaporitic-dolomitic sequence encountered in bore-holes consists of rather regular alternations of strongly folded sulphate and carbonate rocks (Fig. 3). The total thickness may reach 500 m. The transition to the underlying Filladi di Boccheggiano is made up of anydritic-dolomitic-phyllitic cycles. In the middle part of the sequence the siliciclastic fraction gradually disappears, and in the upper part the dolomitic intercalations prevail over the sulphates in thickness and in frequence.

The dolomitic layers in all the studied bore-holes are affected by replacement of carbonate by sulphates, and by brecciation whose intensity seems to be linked to the original thickness of the carbonate beds. In the central and upper part of the sequence the carbonate lithotypes mainly consist of breccias with sharp-edged elements floating in a sulphate matrix, whereas in the lower part the thick dolomitic beds are crossed by a network of sulphate-filled fractures. These replacement and brecciation processes are believed to have originated during early diagenesis, and then intensified during the Alpine Orogeny (Costantini et al., 1980).

The carbonates are mainly represented by dolomites, and secondarily by dolomitic limestones which change in colour from yellow to light grey and to black. They occur as thin (up to 10 cm thick), mostly brecciated layers. The cement of the breccias usually is anhydrite. The elements, with variable grain-size and very irregular morphology, generally consist of only one microfacies, but associations of several microfacies can also be found. It can be seen that every clast of the breccia underwent minor movements and rotations resulting from the combined action of anhydrite recrystallization and enlargement of thin fractures in the carbonate layers.

The genesis of this breccia can be explained by variations of the sulphate volume and appears to be related to sulphatization processes which gradually led to the replacement of the carbonate by the anhydrite, and eventually to complete digestion of the carbonate.

The dolomitic lithotypes have been grouped into four microfacies.

Mudstone. Homogeneous or laminated dolomicrite-dolomicrosparite, sometimes with patches of microsparite. Peloidal laminae occur in the laminated facies. The peloids display ghosts of organic filaments and may therefore be interpreted as of cryptalgal origin. The origin of most peloids can be related to shrinking of originally cryptalgal and/or muddy laminae, either in a subaerial environment owing to desiccation, or subtidally by synaeresis resulting from salinity variations of the interstitial brines

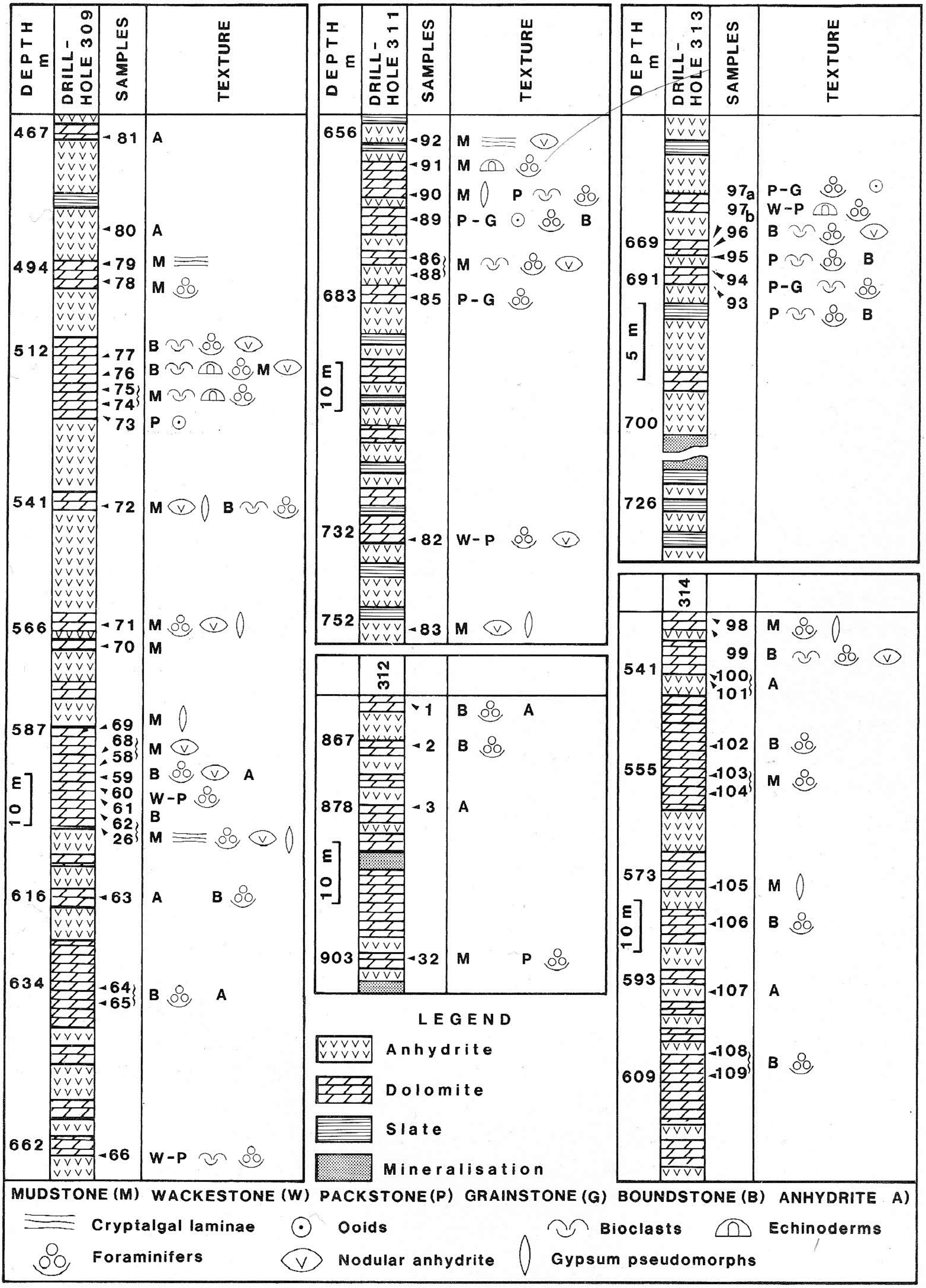

Fig. 3 - Logs of the drill-holes bearing stratigraphically meaningful assemblages of foraminifers.

(Donovan & Forster, 1972; Baria, 1977).

Small stylolitic seams also occur, along which Fe-oxides and pyrite are concentrated. Anhydrite pseudomorphs after gypsum, anhydrite laths and nodules are scattered in the matrix (Pl. 1, fig. 1). The fauna is represented by rare ostracod carapaces and molluscs with very thin shells, or by spines and small plates of echinoderms. Also ghosts of micritized or recrystallized foraminifers are present. In anhydrite-rich mudstones, fossil remains have never been found.

This facies implies a low-energy depositional environment. For the mud facies without fossils or with ostracods only, a lagoonal environment can be suggested, whereas the facies with echinoderm remnants can be situated in the normal-marine subtidal zone.

Wackestone-Packstone. Dolobiomicrosparite, sometimes with dolomicritic patches. The grains consist mainly of peloids, subordinately of ooids and bioclasts. Among the peloids, rounded or irregular forms occur. They are often associated with peloids of rectangular shape, which can be interpreted as fecal pellets (Pl. 1, fig. 2).

The depositional setting for the coprolite facies, can be located in supratidal ponds, and in the intertidal zone for the facies containing remnants of stenohaline marine organisms.

The ooids are commonly deformed and sometimes exhibit a micritic coating. They have been divided into two types: the first comprises completely micritized grains, where concentric laminae can only rarely be recognized; the second is represented by ooids whose core has been dissolved and replaced by anhydrite or anhedral dolomite (Pl. 1, fig. 3). The organic remains are represented by foraminifers, rare ostracods with thick, smooth carapaces, mollusc shells and echinoderm plates with syntaxial overgrowths.

The genesis of the irregular-shaped peloids can be related to micritization, which deeply affected the different carbonate grains and part of the foraminifer tests. Purser (1980) defines as "pseudo-ooliths" the completely micritized ooids and considers them to be the synsedimentary product of boring micro-organisms such as algae, fungi or bacteria. They are a typical feature of quiet shallow-water environments. Oomolds commonly form by dissolution of aragonitic grains in a freshwater diagenetic environment (Friedman, 1964; Mazzullo, 1977).

Cryptalgal Boundstone. Two cryptalgal structures have been recognized: the first type correponds to planar cryptalgal mats with faint, but continuous, laminations. The laminae are weakly ondulated and present rare LHH structures and frequent desiccation cracks (Pl. 1, fig. 4). Cryptalgal laminae of dolomicrosparite alternate with laminae composed of dolomicritic peloids. The second type includes disjointed cryptalgal mats. It is characterized by the discontinuity of the cryptalgal laminae, and the fragments of algal mats are separated by dolosparitic or, more frequently, anhydritic cement (Pl. 1, fig. 5,6). In a further stage of fragmentation, the sediment assumes a grainstone texture, but it is still possible to reconstruct the original laminae by fitting together the elements of the jigsaw puzzle.

The granular facies composed of cryptalgal elements is the most frequent. It appears that the grains, formed after desiccation of algal mats, have never undergone any transport but only slight in-situ displacement and rotation. Therefore, they cannot be interpreted as grains of a mobile sediment, although they give rise to a grainstone fabric as a consequence of cementation. This type of genesis seems to be due only to a further diagenetic evolution of the disjointed cryptalgal mats, that is, to its complete fracturation and cementation.

The depositional setting can be related to the intertidal and supratidal zones of a tidal flat. The abundance of anhydrite and gypsum pseudomorphs as well as the desiccation structures point to periodical subaerial exposure and early cementation in a sabkha environment.

Grainstone. Granular facies representing carbonate sands are very rare. The grains consist of micritized or recrystallized foraminifer tests, micritized skeletal fragments of ostracods, molluscs, echinoderms and, more rarely, ooids (Pl. 1, fig. 7). The cement is made up of short blades and forms isopachous fringes around the grains.

The depositional environment of this facies, which represents an original sandy sediment, can be located in the higher-energy shallow subtidal zone.

Diagenetic-features.

The chronology of the diagenetic events affecting the carbonates of the Burano Formation in the Boccheggianò and Monticiano-Roccastrada areas can be established on the basis of microtextural analyses. The cements have been defined by cathodoluminescence.

Desiccation and shrinking of the cryptalgal mats and muds indicate early diagenetic processes typical of a hot and arid environment similar to that of the present Persian Gulf sabkhas (Bathurst, 1971; Purser, 1980; Gandin et al., 1987).

Anhydritic pseudomorphs after gypsum as well as anhydrite idiomorphs, nodules and rosettes are also typical of this diagenetic stage. Evidence of their formation during early diagenesis and before precipitation of intergranular cement is supported by the fact that sulphate crystals grow within grains and never within cements. Pseudomorphs of crystals and nodules thus represent syndiagenetic crystalline aggregates, whose displacive growth gradually led to the replacement of most of the carbonates (sulphatization process), and often to the complete obliteration of the original depositional structures.

A later diagenetic stage in a phreatic environment resulted in the formation of elongated blades forming isopachous fringes around the grains in the disjointed cryptalgal mat facies, and of stubby blades in the intergranular pores of the grainstone facies. The cement crystals of the disjointed cryptalgal mats are smaller in size and flatter in shape than those in the grainstone. The cement of the algal mats precipitated in small-sized pores, and the limited space between the grains accounts for the morphology and size of the crystals (James & Ginsburg, 1979). In the grainstone, limited pore space is to be related to the small size of the grains (mostly peloids) and to a reduction of intergranular porosity probably due to compaction prior to cementation. This is also proven by the occurrence of isopachous rinds around deformed grains without evidence of pressure-solution of the crystals.

The first-generation non luminescent cements found in disjointed cryptalgal mats and grainstones are commonly followed by a second generation of blocky luminescent cement which fills the pores between the grains.

Botryoidal pyrite, which is abundant in the mudstone facies but which also occurs in some grains of the other microfacies most probably originated during early diagenesis. Pyrite idiomorphs, however, often show pressure shadows formed during the burial stage. The pressure shadows indicate that recrystallization of pyrite occurred prior to the Alpine tectonic stress.

The burial stage was probably syntectonic. Associated are processes which led to the partial replacement of sulphates by albite and chalcedony, as well as to remobilization of suplhates and formation of anhydrite mosaics.

Vertical distribution of the microfacies.

The four microfacies are irregularly distributed in the studied sections. An estimation of the thickness and an evaluation of the sedimentary development of the sequence is made difficult by the poor preservation of the carbonates.

In the holes drilled in the Boccheggiano area, mudstone prevails over wackestone-packstone and boundstone; grainstone is quite rare and has been found in only two of the logs. These microfacies appear to be arranged in thin elementary cycles. The reduced thicknesses may be due to the processes by which the carbonate was replaced by the anhydrite.

Facies association 1 (Fa1) is represented by the elementary sequence mudstone - wackestone - packstone - planar cryptalgal mat. It is very common, although the wackestone - packstone facies is often missing (boreholes 309, 302, 304, 314, 316, 318).

Facies association 2 (Fa2) displays the elementary sequence packstone - disjointed cryptalgal mats - grainstone. It has been found only in the drill-holes 311 and 313.

The outcrops in the quarry of Roccastrada are characterized by Fa1 (with abundant mudstone), those of Podere Poggio Lanzo by Fa2. The sequence of the Podere Montisi quarry differs from those in the quarries and from the drill-holes in which the mudstone and grainstone facies are absent, and where the boundstone prevails.

Micropaleontology.

The foraminifer associations found in the dolomitic facies of the Burano Formation coming either from the outcrops (Monticiano-Roccastrada area) or from the drill-holes (Boccheggiano area) show affinities with the Triassic microfaunas found in the La

Spezia region (Coregna Dolomite, Lower Carnian-Norian; La Spezia Formation, Norian-Rhaetian; Ciarapica & Zaninetti, 1984) as well as with the lower part of the Burano Formation in Umbria (Norian-Rhaetian; Ciarapica et al., 1987). They are composed essentially of *Glomospira* and *Glomospirella*. The complete associations are:

- in the quarry samples:

Glomospira spp.
Glomospirella ex gr. *amplificata/hoae* Kristan-Tollmann, 1970
Glomospirella capellinii Ciarapica & Zaninetti, 1984
Glomospirella rosetta Ciarapica, Cirilli & Zaninetti (in Ciarapica et al., 1987)
Glomospirella sp. 2
Glomospirella spp.
Gandinella apenninica Ciarapica & Zaninetti, 1985
Agathammina sp.
Aulotortus tumidus (Kristan-Tollmann, 1964)
Aulotortus sp.

- in the drilling samples:

Glomospira spp.
Glomospirella ex gr. *amplificata/hoae* Kristan-Tollmann, 1970
Glomospirella rosetta Ciarapica, Cirilli & Zaninetti (in Ciarapica et al., 1987)
Glomospirella sp. 1
Glomospirella spp.
Gandinella apenninica Ciarapica & Zaninetti, 1985
"*Trochammina*" sp.
Agathammina sp.
Aulotortus communis (Kristan, 1957)
Aulotortus sp.
Triadodiscus eomesozoicus (Oberhauser, 1957)

All the microfaunas from southern Tuscany are basically uniform in their composition, although the samples of the Monticiano-Roccastrada quarries contain richer associations than those in the drill-holes of Boccheggiano.

In the whole, their assemblages are comparable with those of the La Spezia sequences (Coregna Dolomite and La Spezia Formation) and Burano Formation in Umbria, but they do not contain *Triasina hantkeni* and only few *Involutinacea* (*Aulotortidae* and *Triadodiscidae*). Owing to the absence of *Triasina hantkeni* as well as of dasycladacean algae, the tuscan evaporitic-dolomitic sequences cannot be correlated with the Monte Cetona Formation, which is totally included in the *Triasina hantkeni* biozone and is also very rich in dasycladacean algae (Ciarapica et al., 1987).

Age of the sequences.

Although the available data are still too incomplete to give a more precise dating of the Burano Formation in southern Tuscany, the composition of their foraminifer associations implies an age interval comprised between the Carnian (characterized by *Glo-*

mospirella capellinii described in the Carnian formation of the Coregna Dolomite; Ciarapica & Zaninetti, 1984) and the Upper Norian (characterized by *Glomospirella* ex gr. *amplificata/hoae, Glomospirella rosetta, Gandinella apenninica, Agathammina* and *Aulotortinae;* Ciarapica & Zaninetti, 1985).

Moreover, the occurrence of *Triadodiscus eomesozoicus* in the association of Boccheggiano area suggests its slightly older age (Carnian-Norian?) compared with the Monticiano-Roccastrada sequences, which can be referred to as Upper Norian. A Rhaetian age cannot be proposed because of the absence of *Triasina hantkeni*, even if *Glomospirella rosetta* and *Gandinella apenninica* (two forms previously described in the Rhaetian *Triasina hantkeni* biozone of the Monte Cetona; Ciarapica et al., 1987) are frequent. On the other hand, west of Boccheggiano, near the Niccioleta Mine, the Burano Formation is stratigraphically overlain by the Cetona Formation (= Calcari e Marne a *Rhaetavicula contorta)* which must be referred to the Rhaetian; even there also *Triasina hantkeni* is missing, because the *Rhaetavicula contorta* beds gradually pass to the Hettangian Calcare Massiccio (Cocozza & Gandin, in press).

Depositional environment and paleoecology.

All of the sedimentological and micropaleontological evidences for the dolomitic and evaporitic deposits of the Burano Formation from Boccheggiano and Monticiano-Roccastrada suggest that these sediments were laid down in lagoonal, peritidal and sabkha environments under a tropical, arid climate. The vertical distribution of the facies indicates a variable topography in which the following sub-environments can be recognized:

- tidal flat, characterized by the extensive growth of cryptalgal mats and sulphates, and by desiccation and early dolomitization;

- ponds, where mudstone and skeletal-peloidal wackestone accumulated. The organic fraction is mainly represented by fecal-pellets, ostracods and occasional small gastropods. This association attests that restricted conditions of the environment, but probably allows for more oxygenation than the areas where unfossiliferous mud was produced;

- intertidal and subtidal zone, characterized by generally low energy. The grains never exceed the silt-size, and the grainstone facies are extremely rare. In this zone, remnants of marine organisms (echinoderms, molluscs, ostracods and foraminifers) are frequent. However, their small size and low diversity still indicate restricted living conditions. The low diversity of the foraminifer assemblages characterized by *Glomospirella* and *Involutinacea*, as well as the absence of bioturbation and of dasycladacean algae suggest a slight hypersalinity of the offshore water body.

The cyclical arrangement of the different carbonate and sulphate facies implies small fluctuations of the subsidence, of the carbonate-sulphate sedimentation, and/or of the sea level (Milankovitch cycles; Fischer, 1964). A very slow rate of subsidence is confirmed by the widespread desiccation features.

Conclusions.

The comparison between the evaporitic-dolomitic sequences drilled in the subsurface of the Boccheggiano area and those exposed in the Monticiano-Roccastrada Unit (Roccastrada, Podere Poggio Lanzo and Podere Montisi) suggests a paleoenvironment corresponding to a sabkha complex bordering a more or less restricted marine water body.

The microfaunas are characterized by low-diversity assemblages consisting of small-sized molluscs, echinoderms, ostracods and foraminifers. The latter are dominated by *Glomospirella-Aulotortus* associations.

From a chronological point of view, the most indicative forms suggest an age ranging between Carnian for the associations in the lower part (Boccheggiano subsurface) and Norian for the associations of the upper part of the sequences (Boccheggiano and Monticiano-Roccastrada areas). A Rhaetian age cannot be ascribed because of the absence of *Triasina hantkeni*, although other forms generally associated with *Triasina hantkeni* commonly occur in the studied sequences.

A Carnian-Norian age is moreover consistent with the geometrical position of the buried sequences, which west of the Boccheggiano area are stratigraphically overlain by the *Rhaetavicula contorta* Limestone (equivalent of the Monte Cetona Formation) of Rhaetian age.

The comparison between the foraminifer assemblages of the Burano Formation in the Boccheggiano and Monticiano-Roccastrada areas and those occurring in the La Spezia region (Coregna Dolomite; lower part of La Spezia Formation) and in the lower part of the Burano Formation in Umbria demonstrates the intermediate character of the tuscan microfaunas, and consequently suggests a paleogeographic setting for southern Tuscany which is located between the La Spezia and the Umbria domains.

It can also be better than proven that the Filladi di Boccheggiano, regarded as Paleozoic (Permian, Devonian) by some authors, gradually pass into the Burano Formation of Carnian-Norian age. In the lower part of the Burano Formation at Boccheggiano, an alternation of siliciclastic, anhydritic and sometimes dolomitic layers occurs, whereas in the upper part of the Filladi di Boccheggiano, lenticular bodies of dolomite-sulphate are intercalated. The latter are commonly associated with a pyrite mineralization, whose origin has been related to exhalative sedimentary processes (Giannelli & Puxeddu, 1979). A Triassic age has been inferred from the sulphur isotopic values (Cortecci et al., 1981, 1983).

It is noteworthy that in outcrop the Filladi di Boccheggiano are overlain by the Calcare Cavernoso (Fig. 1C), with the intercalation of an horizon referred to as Tocchi Formation by Cocozza et al. (1979). This horizon is made up of alternating phyllites and carbonates, and breccias composed of elements of these two lithotypes. It can be regarded as the equivalent of the basal part of the Burano Formation in subsurface, whose sulphatic fraction would have been dissolved by weathering, such as it has been suggested for the Tocchi Formation (Costantini et al., 1983). Accordingly, the overlying

Calcare Cavernoso in this area can also be considered to be the product of similar processes acting on the exposed Burano Formation.

On the ground of these evidences, and in order to establish a basis for further research, one can assume that at least the upper part of the siliciclastic suite of the Filladi di Boccheggiano is Triassic in age (Trevisan, 1955; Giannini et al., 1972), and possibly coeval with the Punta Bianca sequence. The Filladi di Boccheggiano share the synsedimentary volcanism with the Punta Bianca Rift (Martini et al., 1986; Passeri, 1988; Rau et al., 1988), as well as a complex geologic-metamorphic history. The Filladi di Boccheggiano-Burano Formation sequences would therefore represent deposits accumulated in a more proximal and confined basin which was related to the Punta Bianca rifting.

In consequence, the sedimentary evolution of the Filladi di Boccheggiano-Burano deposits would have been different from that of the Punta Bianca one: the evaporitic deposition persisted up to the Upper Triassic, until the *Rhaetavicula contorta* Limestone was laid down during the Rhaetian transgression.

In the wider paleogeographic context proposed by Passeri & Zaninetti (1988), the hypothetical Punta Bianca-Boccheggiano Rift might correspond to the western side of the northern branch of the Tethys.

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PLATE 1

Fig. 1 - Mudstone with anhydrite pseudomorphs after gypsum and anhydrite laths. Drill-hole 311; Boccheggiano area. IGS 90A; 10 x.
Fig. 2 - Packstone with fecal pellets. Drill-hole 311; Boccheggiano area. IGS 85C; 20 x.
Fig. 3 - Packstone with peloids, ooids and oomolds. Drill-hole 312; Boccheggiano area. IGS 176; 10 x.
Fig. 4 - Cryptalgal Boundstone (first type): planar cryptalgal mats with desiccation cracks. Drill-hole 309; Boccheggiano area. IGS 63A; 10 x.
Fig. 5,6 - Cryptalgal Boundstone (second type): disjointed cryptalgal mats. Drill-hole 309; Boccheggiano area. 5) IGS 66; 10 x. Drill-hole 309; Boccheggiano area. 6) IGS 73; 20 x.
Fig. 7 - Grainstone, the grains are represented by recrystallized foraminifer tests, fragments of ostracods, molluscs and echinoderms. Drill-hole 311; Boccheggiano area. IGS 89; 10 x.

PLATE 2

Fig. 1, 2, 4?, 5? - *Triadodiscus eomesozoicus* (Oberhauser, 1957). Drill-hole 313; Boccheggiano area. 1, 4, 5) IGS 94; 2) IGS 97A; 160 x.
Fig. 3 - *Aulotortus* sp. Drill-hole 313; Boccheggiano area. IGS 97B; 160 x.
Fig. 6 - *Aulotortus communis* (Kristan, 1957). Drill-hole 313; Boccheggiano area. IGS 97A; 160 x.
Fig. 7, 8, 14 - *Agathammina* sp. Drill-hole 313; Boccheggiano area. 7) IGS 94; 8, 14) IGS 97A; 160 x.
Fig. 9-11, 12? - *Gandinella apenninica* Ciarapica & Zaninetti, 1985. Drill-hole 313; Boccheggiano area. 9) IGS 94A; 10, 12) IGS 94; 11) IGS 93; 160 x.
Fig. 13 - *Glomospirella* sp. 1. Drill-hole 313; Boccheggiano area. IGS 93; 160 x.

PLATE 3

Fig. 1-6 - *Glomospirella rosetta* Ciarapica, Cirilli & Zaninetti (in Ciarapica et al., 1987). Drill-hole 313; Boccheggiano area. 1, 3, 5, 6) IGS 94; 2, 4) IGS 95; 160 x.
Fig. 7, 8 - *Glomospirella* ex gr. *amplificata/hoae* Kristan-Tollmann, 1970. Drill-hole 313; Boccheggiano area. 7) IGS 97A; 8) IGS 97B; 160 x.
Fig. 9-15 - *Glomospirella* sp. Roccastrada quarry. 9, 11) R 2; 10, 13, 14) R 3; 12, 15) ER 9; 160 x.

PLATE 4

Fig. 1-7, 19-22 - *Glomospira* spp. Drill-hole 309; Boccheggiano area. 1-7) IGS 66; 19, 20, 22) IGS 94; 21) IGS 93; 160 x.

Fig. 8-10, 15-18 - *Glomospirella* spp. Drill-hole 309; Boccheggiano area. 8) IGS 65; 9) mt 669; 10) mt 658; 160 x. Drill-hole 314; Boccheggiano area. 15) IGS 99; 16-18) IGS 94; 160 x.
Fig. 11, 12?, 14 - *Aulotortus* sp. Drill-hole 311; Boccheggiano area. 11, 12) IGS 89; 160 x. Drill-hole 309; Boccheggiano area. 14) mt 658; 160 x.
Fig. 13 - *Trochammina* sp. Drill-hole 314; Boccheggiano area. IGS 108; 160 x.

PLATE 5

Fig.1-10 - *Glomospirella rosetta* Ciarapica, Cirilli & Zaninetti (in Ciarapica et al., 1987). Podere Montisi quarry. 1, 4, 5, 8, 10) EM 11; 2, 3, 6, 7, 9) EM 3; 160 x.
Fig.11-15- *Agathammina* sp. Podere Montisi quarry. 11, 13-15) EM 11; 12) EM 3; 160 x.

PLATE 6

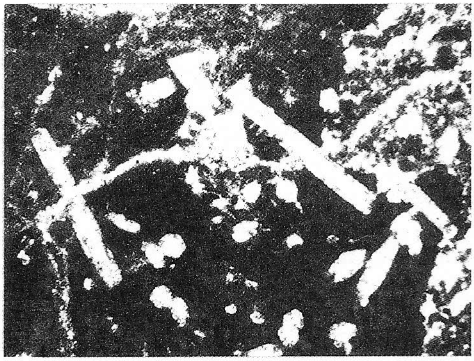
Fig. 1-4 - *Glomospirella capellinii* Ciarapica & Zaninetti, 1984. Roccastrada quarry. 1) ER 7; 2-4) ER 9; 160 x.
Fig. 5 - *Gandinella apenninica* Ciarapica & Zaninetti, 1985. Roccastrada quarry. R 4; 160 x.
Fig. 6, 7, 8-12? - *Glomospirella* ex gr. *amplificata/hoae* Kristan-Tollmann, 1970. Roccastrada quarry. 6, 8) R 4; 7, 9) ER 6; 160 x. Podere Montisi quarry. 10) EM 11; 11, 12) EM 3; 160 x.

LATE 7

Fig. 1-8, 9?, 10?, 11?, 12-14 - *Agathammina* sp. Roccastrada quarry. 1, 2, 4-6, 11) ER 6; 3) ER 9; 7) ER 7; 8, 9) ER 4; 10) ER 2; 160 x. Podere P. Lanzo quarry. 12) EL 3; 13) EL 2; 14) EL 1; 160 x.
Fig. 15, 16, 17?, 18? - *Glomospirella rosetta* Ciarapica, Cirilli & Zaninetti (in Ciarapica et al., 1987). Roccastrada quarry. 15, 16) ER 6; 17, 18) ER 9; 160 x.

PLATE 8

Fig. 1 - *Glomospirella capellinii* Ciarapica & Zaninetti, 1984. Podere Montisi quarry. EM 11; 110 x.
Fig. 2, 3, 5, 6 - *Glomospirella* sp. 2 (big form). Podere Montisi quarry. 2, 3) EM 11; 110 x. Podere P. Lanzo quarry. 5) EL 2; 6) EL 1; 110 x.
Fig. 4 - *Aulotortus tumidus* (Kristan-Tollmann, 1964). Podere P. Lanzo quarry. EL 1; 110 x.
Fig. 7-9, 10?, 11? - *Glomospirella* ex gr. *amplificata/hoae* Kristan-Tollmann, 1970. Podere Montisi quarry. 7, 10, 11) EM 11; 8, 9) EM 3; 110 x.
Fig. 12, 13 - *Glomospirella rosetta* Ciarapica, Cirilli & Zaninetti (in Ciarapica et al., 1987). Podere P. Lanzo quarry. 12) EL 2; 13) EL 3; 110 x.



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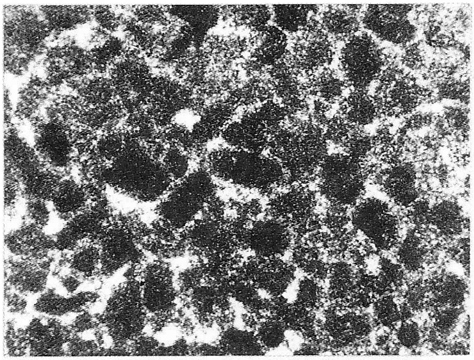

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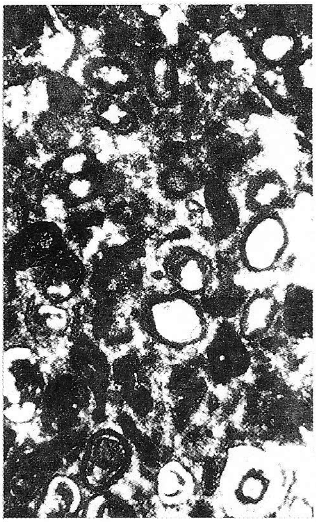

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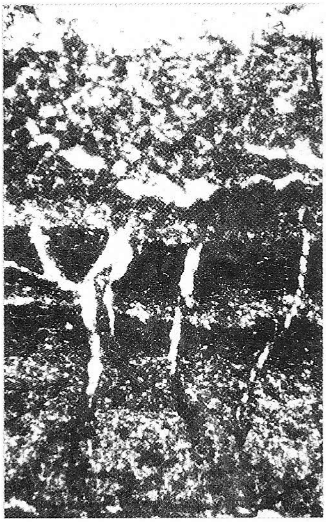

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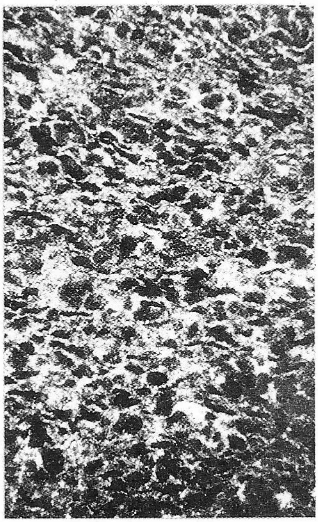

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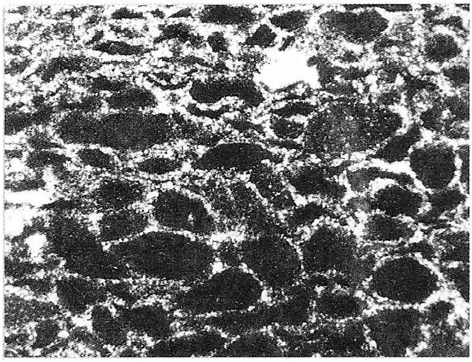

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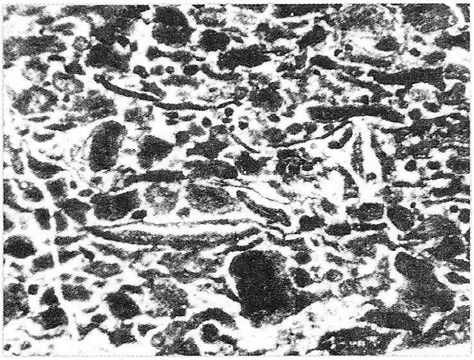

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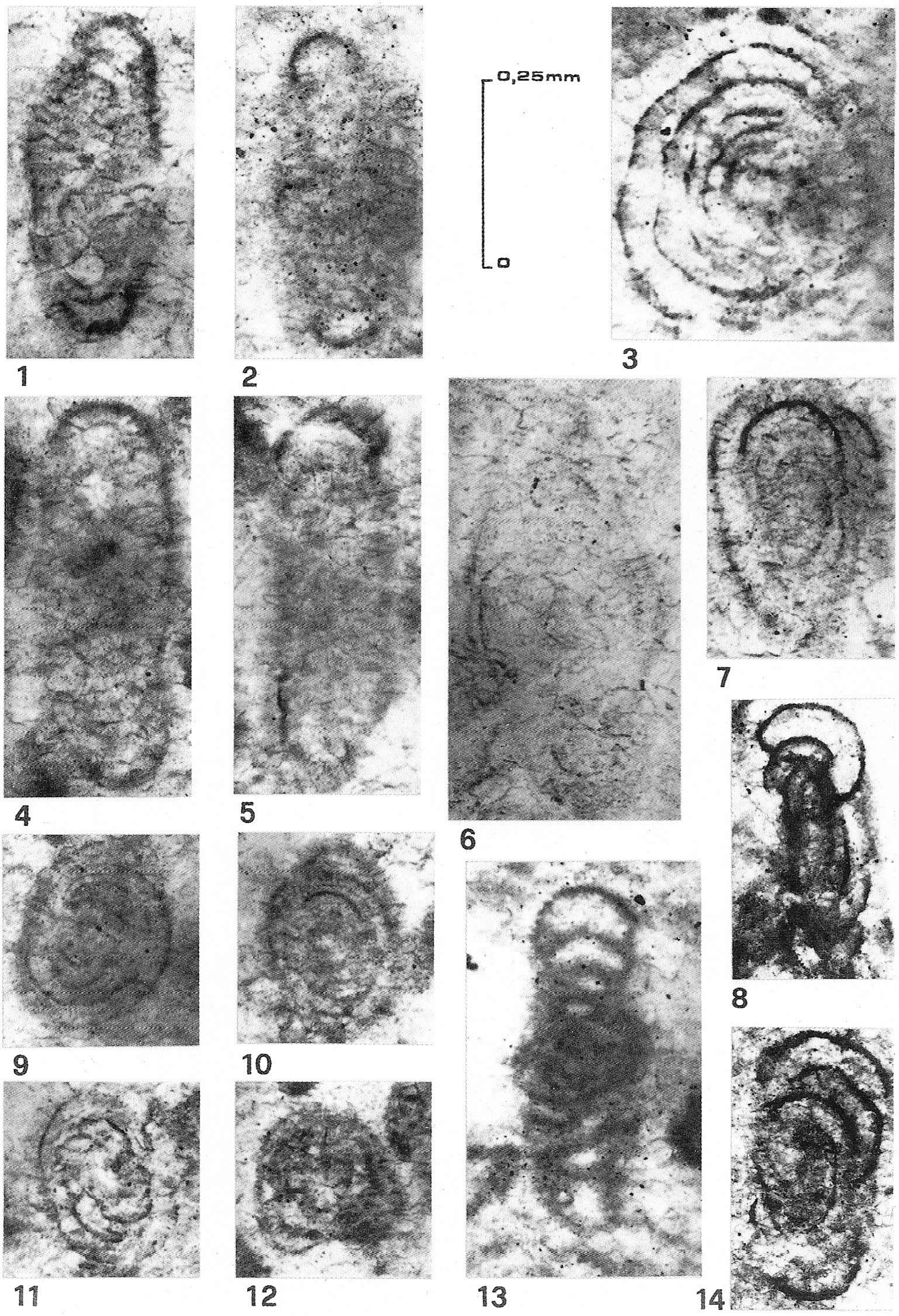
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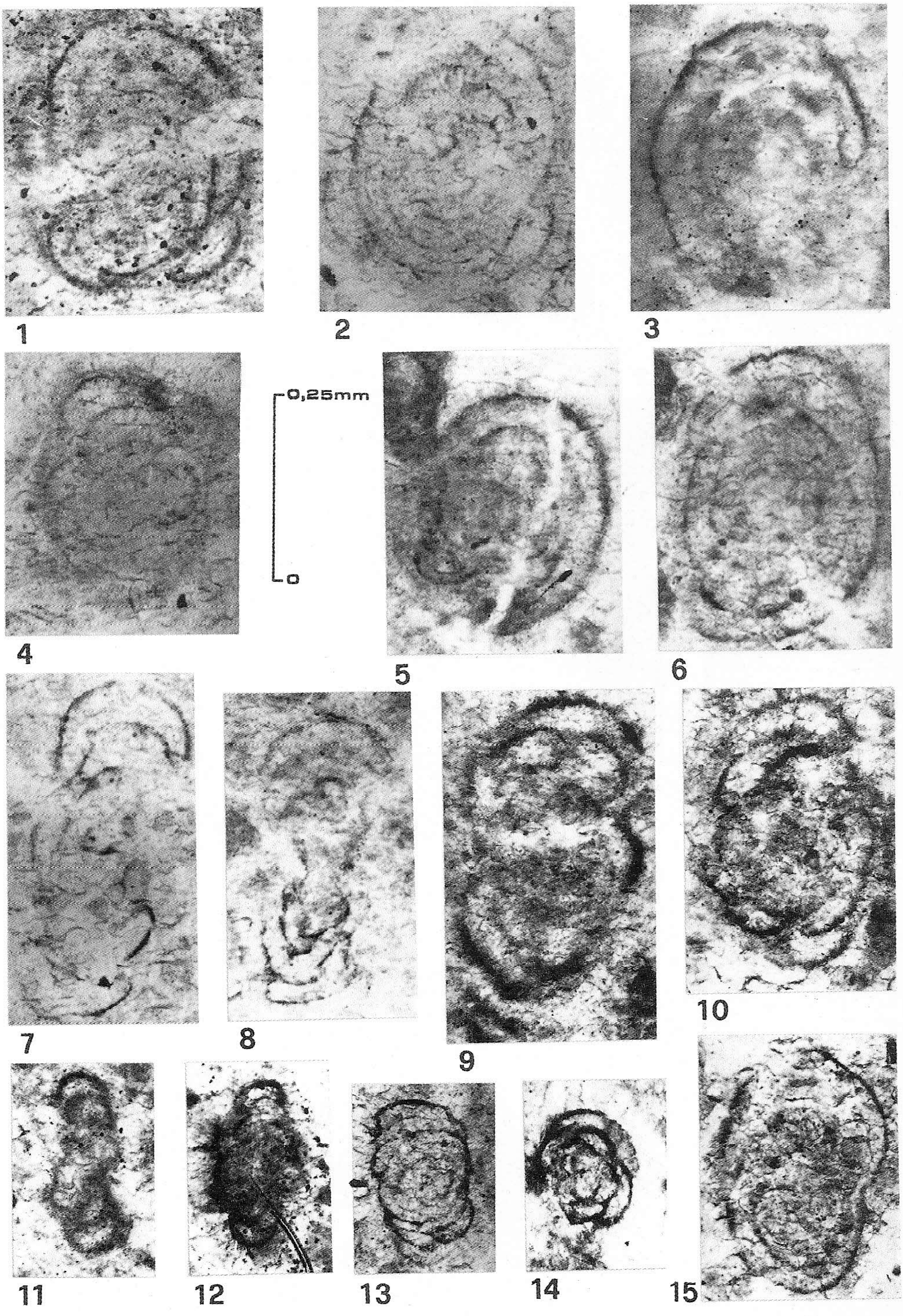
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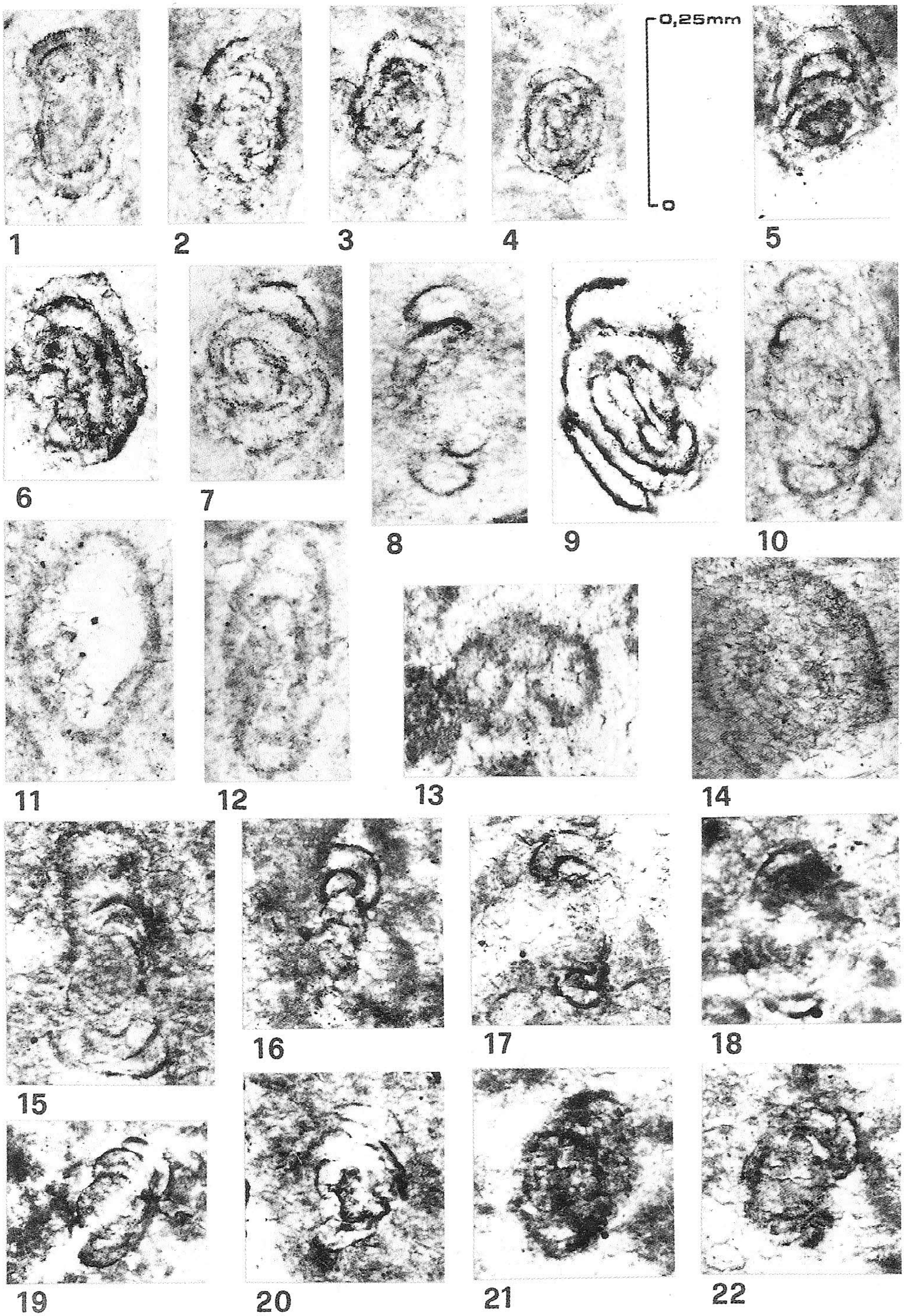
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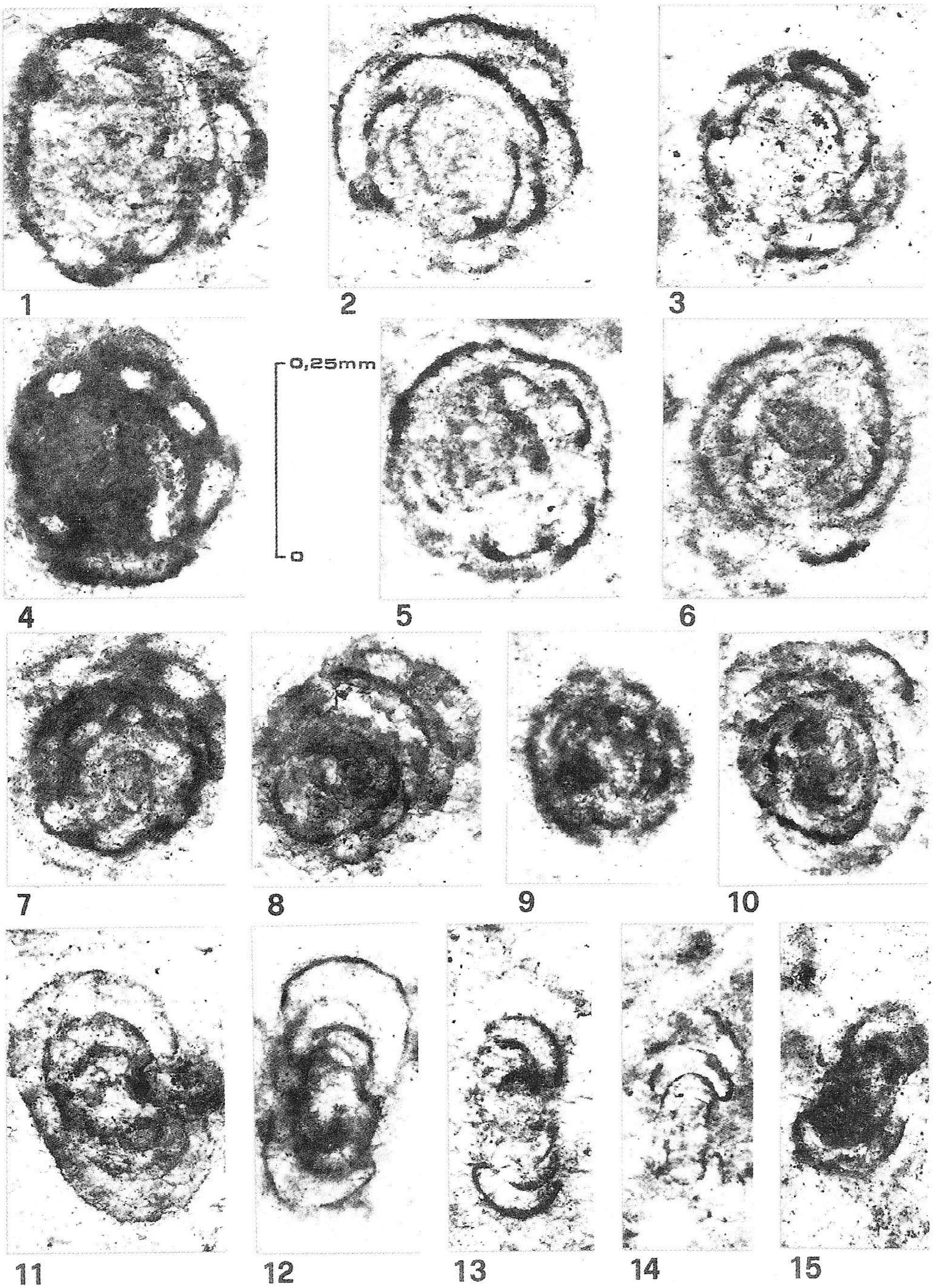
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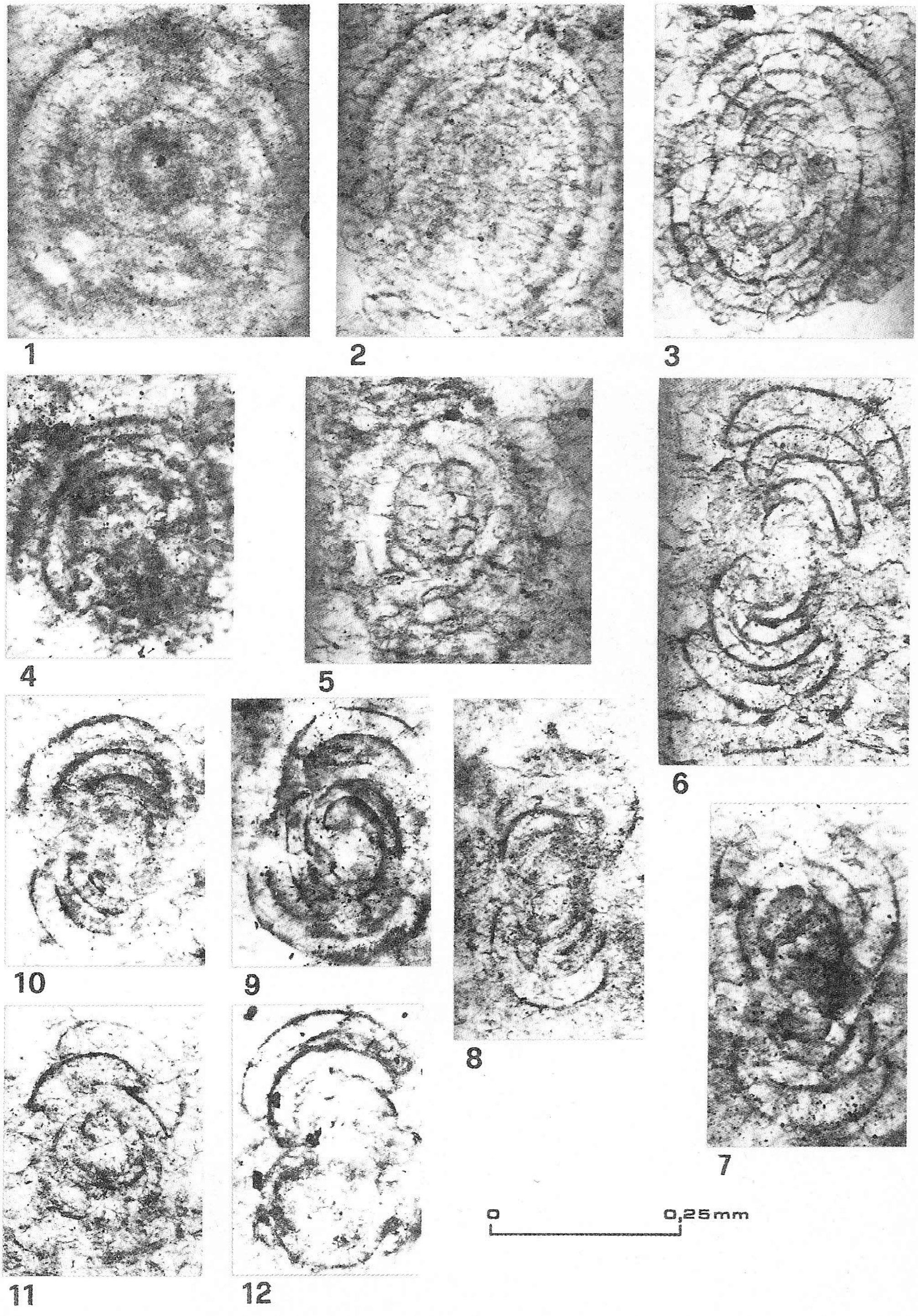
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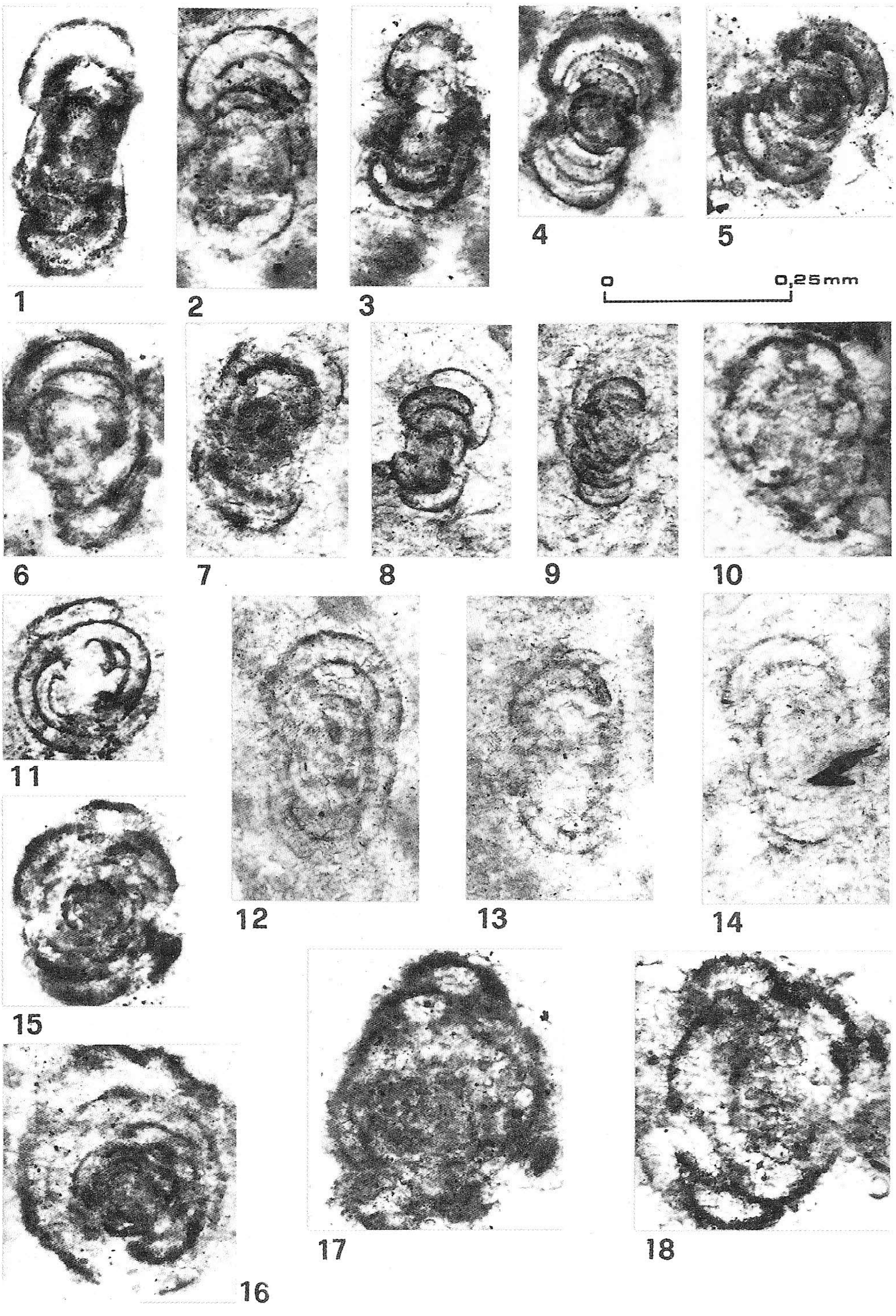
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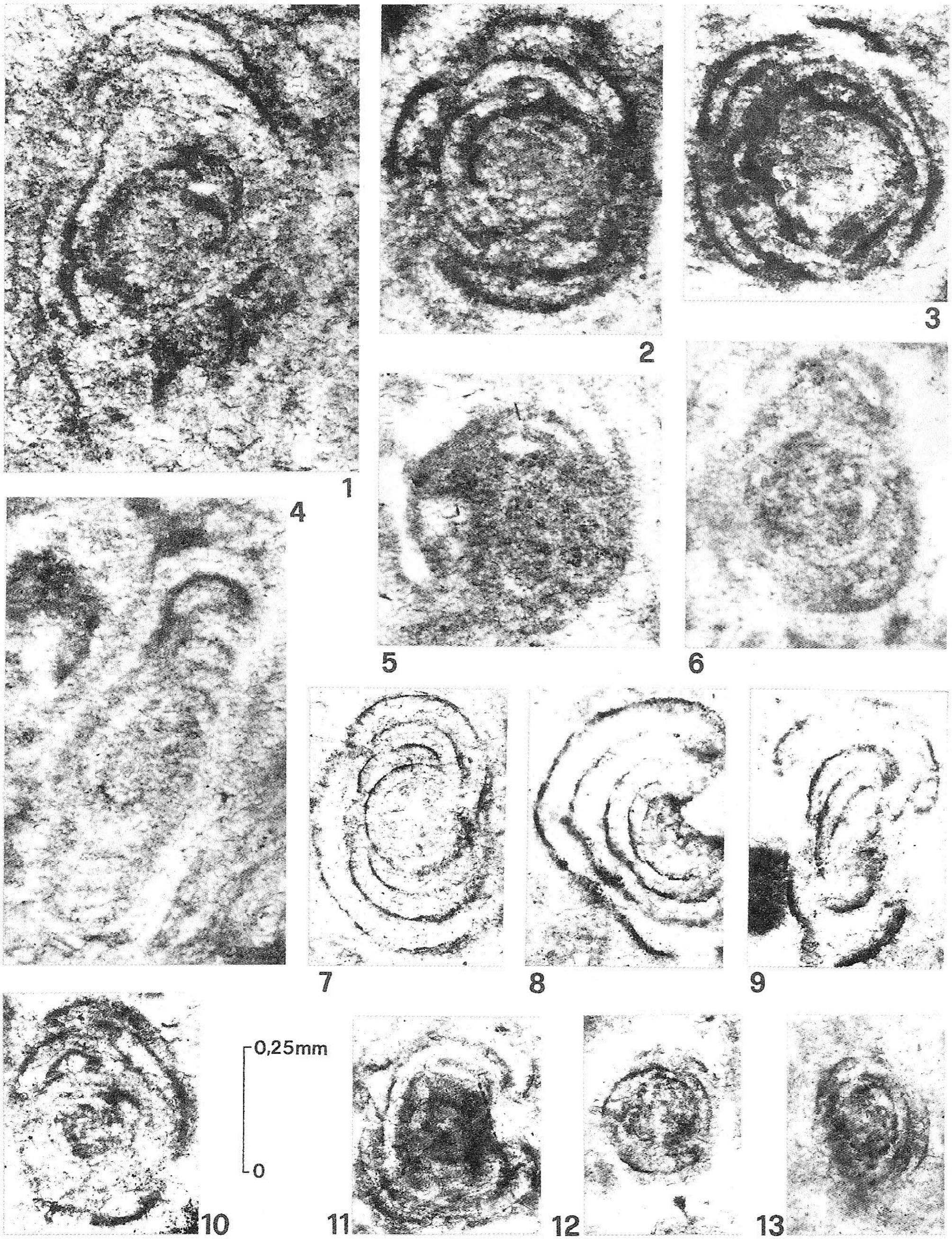
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