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BIOSTRATIGRAPHY AND DEPOSITIONAL SETTING OF PUNTA MANNA MEMBER TYPE-SECTION (NEBIDA FORMATION, LOWER CAMBRIAN, SW SARDINIA, ITALY)

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Key-words: Stratigraphy, Sedimentology, Biostratigraphy, Archaeocyaths, Trilobites, Lower Cambrian (Botomian), Sardinia, Italy.

Riassunto. Il membro di Punta Manna è il termine superiore della Formazione di Nebida del Cambriano inferiore della Sardegna Sud-occidentale. La sezione-tipo, istituita da Rasetti nel 1972 e da lui brevemente descritta, è stata studiata con lo scopo di caratterizzarla dal punto di vista sedimentologico e biostratigrafico.

La sequenza è stata suddivisa, in base ai suoi caratteri litologici, in tre intervalli.

L'intervallo inferiore (Orizzonte oolitico) è essenzialmente costituito da biocostruzioni a *Girvanella* ed archeociati alternate a sabbie oolitiche ed arenarie, che talora contengono accumuli di frammenti di Trilobiti. L'ambiente deposizionale corrisponde ad una zona littorale, caratterizzata dall'apporto alterno di materiale terrigeno dal continente e di materiale carbonatico dal mare aperto, dove le biocostruzioni venivano periodicamente sepolte da barre migranti.

Le biocostruzioni e gli archeociati praticamente scompaiono nel secondo intervallo, mentre i resti di Trilobiti vengono localmente accumulati da correnti ed onde. Le sabbie terrigene e carbonatiche (oolitiche) sono prevalenti, ma gradualmente compaiono sabbie quarzitiche e fanghi carbonatici precocemente dolomitizzati, che indicano una tendenza del clima verso condizioni aride in un ambiente deposizionale che evolve verso una laguna tidale.

Nella terza unità, ai carbonati, qui rappresentati da dolomie a stromatoliti planari, si alternano quarziti siltiti ed argilliti. L'ambiente lagunare evolve quindi verso una sabka, dove sono ancora cospicui gli apporti di sabbie dalle aree emerse sottoposte ad un clima sempre più arido.

La bassa diversità delle faune in tutta la sequenza rispecchia le difficili condizioni di vita degli organismi in un ambiente soggetto a ampie variazioni, sia dell'energia sia della salinità delle acque.

Abstract. Punta Manna Member is the younger unit of the Lower Cambrian Nebida Formation in southwestern Sardinia. Sedimentological analyses aim to characterize the type-section, formally and and briefly described by Rasetti in 1972.

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The sequence has been divided into three units on the basis of its lithological features.

The lower unit (Oolitic Unit) mainly consists of *Girvanella* - archaeocyathan mounds alternated with oolitic grainstones and/or sandstones containing scattered accumulations of trilobite debris. The depositional setting corresponds to a littoral environment characterized by the alternated input of land and sea-derived sands, and where the mounds were periodically destroyed or buried by migrating sand waves.

In the middle unit bioconstructions and archaeocyaths virtually disappear whereas trilobites were accumulated by currents and waves. Siliciclastic and oolitic sands prevail but are gradually replaced by quartzitic sands and early dolomitic muds. The appearance of these latter suggests a climatic trend towards arid condition in a depositional environment evolving to a tidal lagoon.

In the upper unit the development of early dolomitic algal mats alternating with quartzitic sandstones, siltstones and shales, attests the establishment of a sabkha complex at first influenced by siliciclastic input coming from an arid continent.

The low diversity of the fauna throughout the section appears to reflect the severe conditions of life resulting from the high variability in energy and salinity of the depositional setting.

Introduction.

Punta Manna Member was established by Rasetti in 1972, for the youngest part of the Nebida Formation. It is well represented in all Iglesiente and Western Sulcis, lying conformably on Matoppa Member, the oldest Cambrian unit of this area. It gradually passes upward to the "Dolomia rigata" (laminated dolomite), the lower member of Gonnesa Formation. It is composed of alternated siliciclastic and carbonate lithotypes, the carbonates commonly prevailing at the base of the sequence.

According to Rasetti (1972), the type-locality of the sequence was chosen on the ridge of the Punta Manna Hill (Fig. 1), in the area of Nebida, because of the better exposure and presence of richer assemblage of trilobites in comparison with nearby areas.

The first description of the section, given by Rasetti consists of a rather undefined description of the lithologies, particularly of the carbonates, always regarded as "massive dolomites". Three fossiliferous levels were then found, the first, 7g with *Giordanella meneghinii* (Bornemann), the second, 7d with *Dolerolenus* sp. and the third, 7c with *Enantiaspis enantiopa* (Bornemann) and *Nebidella limbata* Rasetti.

The thickness of the entire section appears to have been overestimated by Rasetti. Consequently his values of the distances above base of the fossiliferous beds are different from those given in this paper. However the *Enantiaspis* bed was found exactly in the locality illustrated for the 7c level by Rasetti (1972, fig. 3 and pl. 1).

Later researches have shown that the Punta Manna Member is characterized by other organisms than the trilobites, the only group quoted by Rasetti, and by various carbonate lithologies (Brasier, 1976; Cocozza & Gandin, 1977; Debrenne et al., 1979; Fanni et al., 1981; Carmignani et al, 1986). Thus, the revision of the type-section appears to be essential to make biostratigraphic and paleogeographic correlations.

Characters of Punta Manna type-section

Description of the section from top to bottom (Fig. 2).

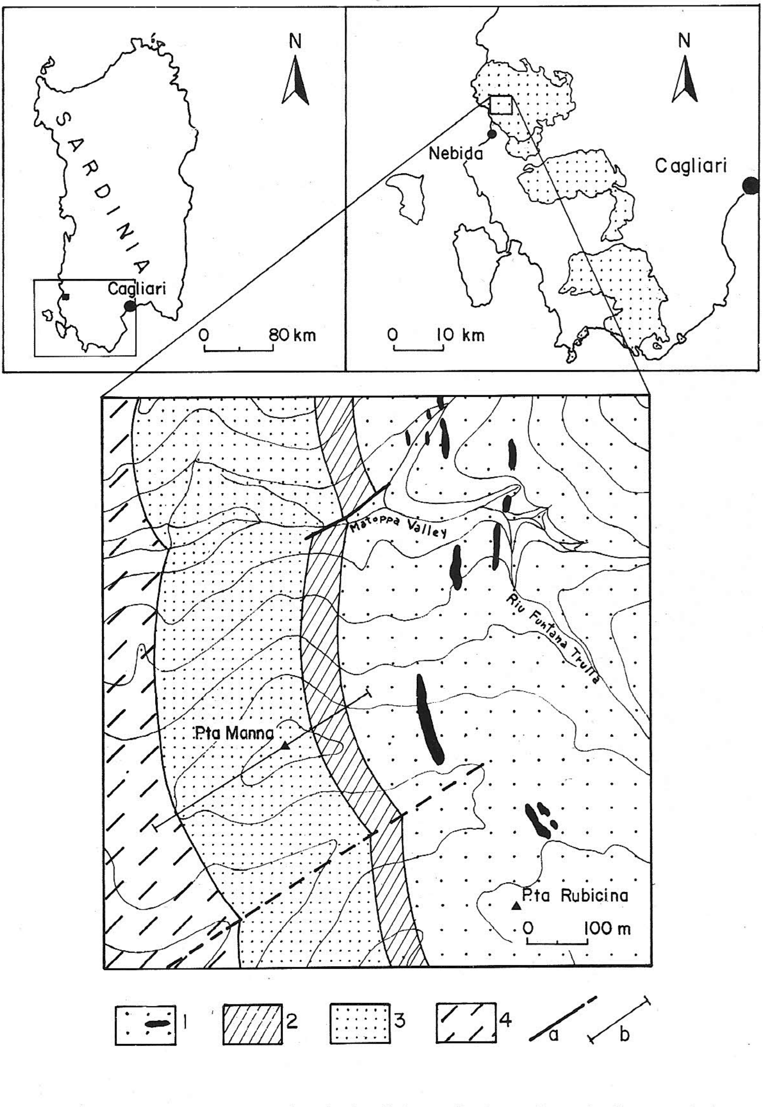
N
SARDINIA
Cagliari
0
80 km
N
Nebida
Cagliari
0
10 km
Matoppa Valley
Riu Funtana Trulla
Pta Manna
Pta Rubicina
0
100 m
1
2
3
4
a
b

Fig. 1 - Location of Punta Manna type-section in Sardinia, and schematic geologic map. 1) Matoppa Mb; 2) Oolitic Unit of Punta Manna Mb; 3) Middle and Upper Units of Punta Manna Mb, not distinguished in the map; 4) Gonnesa Fm; a) faults; b) measured section.

Laminated dolostone (early dolomite) at the base of the Dolomia Rigata Member;

24) quartzitic sandstone (17 m); algal-laminated dolostone (early dolomite) with vadose pisolite layers (6 m) - 23 m;

23) quartzitic sandstone (14 m); homogeneous or algal-laminated dolostone (early dolomite) (5 m) - 19 m;

22) quartzitic sandstone (6 m); algal-laminated dolostone (early dolomite) (1 m) - 7 m;

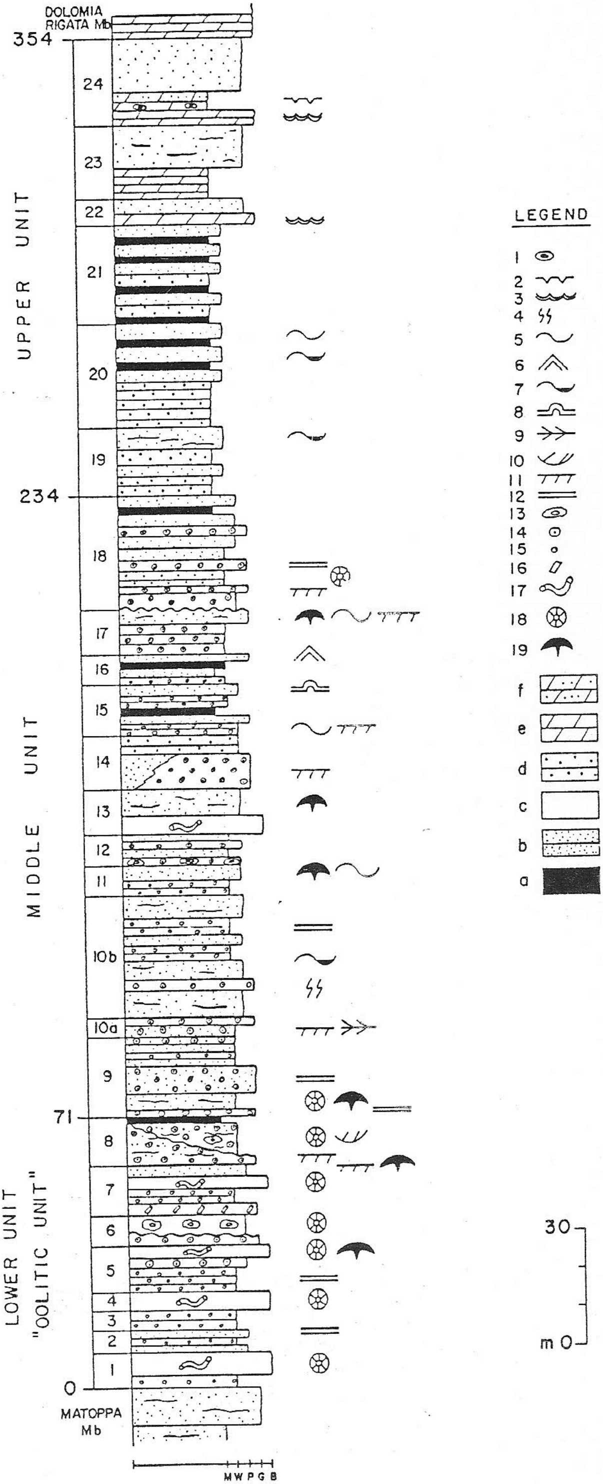
DOLOMIA RIGATA Mb
354
24
23
22
21
20
19
234
18
17
16
15
14
13
12
11
10b
10a
9
71
8
7
6
5
4
3
2
1
0
MATOPPA Mb
UPPER UNIT
MIDDLE UNIT
LOWER UNIT "OOLITIC UNIT"
MWPGB
LEGEND
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
f
e
d
c
b
a
30
m 0

Fig. 2 - Lithostratigraphic log of the type-section of Punta Manna Member. 1) Vadose pisolite; 2) mud cracks; 3) cryptalgal mat; 4) bioturbation; 5) ?*Scolicia* and *Planolites* traces; 6) ripple marks; 7) flaser bedding; 8) contorted bedding; 9) bipolar cross-stratification; 10) concave cross-stratification; 11) cross-lamination; 12) planar lamination; 13) oncoids; 14) ooids; 15) peloids; 16) intraclasts; 17) *Girvanella;* 18) archaeocyaths; 19) trilobites. a) Siltstone and shale; b) sandstone; c) limestone and dolostone (=dolomitized limestone); d) sandy dolostone; e) algal-laminated dolostone; f) silty algal-laminated dolostone.

21) alternated siltstone and sandstone (14 m); marly-silty dolostone (early dolomite) with intercalations of siltstone and sandstone (12 m) - 26 m;

20) sandstone with flaser bedding, alternated to siltstone with trace fossils (*Planolites*) (12 m); mottled silty dolostone (early dolomite) (15 m) - 27 m;

19) sandstone with flaser bedding and silty lenses (12.7 m); homogeneous silty grey dolostone (early dolomite) (5.3 m); silty, mottled dolostone (2.7 m) - 18 m;

18) sandstone with oolitic lenses and a silty (1 m) intercalation (14 m); fine-grained grey silty dolostone (early dolomite) with a mould of erismacoscinid and oolitic sandy intercalations with cross and planar laminations (14 m) - 28 m;

17) erosional surface; quartzitic sandstone with cross-bedding, trace fossils (? *Scolicia*), hyolithids and trilobites (*Enantiaspis enantiopa*, *Nebidella limbata*) (7 m), corresponding to the fossiliferous horizon 7c of Rasetti; fine-grained grey oolitic dolostone (5 m) - 12 m;

16) alternated sandstone and siltstone with ripple marks (6 m); grey silty dolostone with stylolites parallel to the bedding (2 m) - 8 m;

15) sandstone with lenticular intercalations of quartzitic sandstone with convolute structures, fine-grained grey dolostone and shale (11 m); fine-grained grey dolostone with *Planolites* and cross laminations (4 m) - 15 m;

14) sandstone with lenses of fine-grained grey limestone (4.5 m) interfingering with, and passing downward to graded oolitic dolostone with cross laminations (10 m) - 14.50 m;

13) quartzitic sandstone with carbonate cement and trilobites (*Giordanella meneghinii*, *Sardoredlichia arenivaga*) (7 m), corresponding to the fossiliferous horizon 7d of Rasetti; mottled dolostone with *Girvanella* (4.5 m) - 11.50 m;

12) graded oolitic sandstone (2 m); sandstone with oolitic lenses (6 m) - 8 m;

11) micaceous sandstone with trace fossils (? *Scolicia*) and rare trilobites (Gen. et sp. ind. 1) (5 m), corresponding to the fossiliferous horizon 7g of Rasetti; fine-grained grey dolostone with planar laminations (3 m) - 8 m;

10b) sandstone with thin intercalations of fine-grained grey dolostone (24 m); oolitic limestone (2 m); fine-grained sandstone with bioturbation, flaser and planar laminations (6.5 m) - 32.50 m;

10a) oolitic limestone (4.5 m) passing downward to banded oolitic sandstone with bipolar cross bedding - 4.50 m;

9) sandstone with carbonate cement and planar laminations, oolitic at the top and with frequent fossiliferous levels rich of trilobites (*Giordanella meneghinii*) and archaeocyaths preserved as molds (20 m); oolitic limestone with planar laminations (1 m) - 21 m;

8) alternated sandstone and silt passing gradually downward to silty dolostone with "lenticular" bedding made up of small oolitic, bioclastic and silty lenses; archaeocyaths in the bioclastic facies are: *Rasetticyathus acutus*, *R. dilatatus*, *Protopharetra densa* and *Erismacoscinida* (8 m). It interfingers and passes downward to graded oolitic dolostone with cross laminations (5.5 m) - 13.50 m;

7) micaceous dolomitic sandstone, with planar and cross lamination and abundant trilobites with limonitized carapaces: *Giordanella meneghinii* and *Sardoredlichia arenivaga* (3 m) passing gradually downward to a mottled silty dolostone with *Girvanella* and rare archaeocyaths (*Rasetticyathus acutus*, *Protopharetra densa*, *Erismacoscinida*) (1.5 m); fine-grained grey dolostone, thin bedded to massive with stylolites parallel to the bedding (6 m); dark-grey silty dolostone with intraclasts (3 m) - 13.50 m;

6) mottled silty dolostone (4m) with small elongated archaeocyaths (*Rasetticyathus acutus*, *R. dilatatus* and *Erismacoscinida*); erosional surface; graded oolitic dolostone (3.6 m) - 7.60 m;

5) mottled silty dolostone (4 m) with *Girvanella* mats, brachiopods, trilobites (*Giordanella meneghinii*) and a varied archaeocyathan assemblage (*Erismacoscinus cancellatus*, *Rasetticyathus acutus*, *R. dilatatus*, *Protopharetra radiata*, *P. densa*, *Agastrocyathus*); fine-grained oolitic dolostone passing downward to grey planar laminated dolostone (9 m) - 13.00 m;

4) mottled dark-grey silty dolostone with *Girvanella* and rare archaeocyaths (*Erismacoscinida*, *Rasetticyathus dilatatus*, *Agastrocyathus*) - 5 m;

3) massive grey dolostone - 4 m;

2) laminated grey dolostone alternated with fine-grained sandstone - 4.50 m;

1) mottled dark-grey silty dolostone (8 m) with *Girvanella* and small archaeocyaths (*Erismacoscinus cancellatus, Rasetticyathus acutus, Protopharetra radiata, P. densa*); homogeneous grey limestone (2 m) - 10 m;
- sandstone at the top of Matoppa Member.

Lithofacies analysis and depositional setting (A. Gandin).

The sequence can be subdivided into three units on the ground of its lithologic characters (Fig. 2). The lower unit (71 m thick), from levels 1 to 8, consists mainly of carbonates. The second one (163 m), corresponding to levels 9 to 18 is composed of alternated carbonates, sandstones, siltstones and minor shales. The third one (120 m) from levels 19 to 24 corresponds to alternated carbonates, siltstones and quartzitic sandstones.

The carbonates occurring in the lower and middle unit appear to be dolomitized or recrystallized limestone. They commonly contain a various amount of sand or silt-size siliciclastic fraction. The uppermost unit is characterized by siliciclastic-free early dolomite.

Six main facies were recognized on the field and defined by microscopic examination as follow:

Facies 1. Mottled dark-grey or yellowish silty dolostone.

Boundstone with archaeocyaths. Dolosparitic masses display relics of *Girvanella* tissue (Pl. 53, fig. 11), which also binds archaeocyath and trilobite skeletals. Siliciclastic-rich dolomitic seams and patches, containing articulated or disarticulated *Lingula* phosphatic shells (Pl. 53, fig. 7), sponge spicules and echinoderm plates, separate the dolosparitic masses. The texture corresponds to a subhedral idiotopic dolomite mosaic with irregular patches and seams of euhedral dolomite mixed with silt-size quartz and mica.

Facies 2. Mottled dark-grey or yellowish silty-sandy dolomite.

Wackestone-packstone or rudstone, bioclastic, oolitic or oncolitic. The carbonate matrix contains abundant silt- to sand-size quartz and mica, and locally includes patches of subhedral idiotopic dolomite (Pl. 52, fig. 3, 4, 6).

In the bioclastic facies the allochems are represented by archaeocyaths, trilobite fragments, echinoderm plates, fragments of *Girvanella* tissue and ooids. They are locally sorted in monotypic concentrations of archaeocyaths, echinoderms or ooids (Pl. 52, fig. 5). The archaeocyaths are locally oriented, sometimes telescoped together (Pl. 52, fig. 1). Cement and/or siliciclastic-rich matrix, as well as ooids, fill their central and inter-septa cavities (Pl. 52, fig. 4, 6; Pl. 53, fig. 8). The central cavity is frequently lined by a microbial crust (Pl. 53, fig. 6) or filled by fibrous cement - now replaced by xenotopic dolomite - or geopetal sediment, which random orientation in the different cups (Pl. 52, fig. 5) indicates an early cementation before dispersal. The echinoderm plates display large syntaxial overgrowths.

In the oncolitic facies, the "oncoid" builders are here related to *Girvanella*-like forms (*Cladogirvanella*) owing to the occurrence of preserved filaments (Pl. 53, fig. 4) and the similarities of their morphology with better preserved samples from other localities (Gandin & Debrenne, 1984). The *Girvanella* fragments and the "oncoids" are replaced by xenotopic dolomite though microsparitic relics of their original texture can still be found. The archaeocyath skeletons, the trilobite carapaces and the ooids are commonly replaced by subhedral idiotopic dolomite.

In the oolitic facies, the ooids are mostly recrystallized (Pl. 53, fig. 8) though sometimes retain the original pseudo-uniaxial cross. They display a core made up of bioclasts (echinoderms or trilobite fragments) and traces of a well developed micritic coating, so that their size reachs 4 millimeters in some levels (Pl. 53, fig. 9).

Facies 3. Dark-grey dolostone or limestone.

Grainstone, bioclastic or oolitic. The cement of the bioclastic facies is replaced by subhedral idiotopic dolomite. The allochems and their diagenetic features are the same that in facies 2.

The dolomitized oolitic grainstone consists of a dolomitic subhedral-idiotopic mosaic where ghosts of the ooids are still recognizable.

The calcareous oolitic grainstone is recrystallized, the cement consisting of an anhedral-subhedral mosaic. The ooids, replaced by an euhedral mosaic, still retain the pseudo-uniaxial cross and microsparitic ghosts of the outer coating, probably of microbial origin (Cocozza & Gandin, 1977). The ooids are locally affected by pressure-solution deformations (Pl. 53, fig. 10) and their core is made up of trilobite or echinoderm fragments.

Facies 4. Light-grey fine-grained limestone with well developed stylolites parallel to the bedding.

Grainstone-packstone, peloidal and/or skeletal. It consists of well packed, well sorted recrystallized grains referred to peloids and tiny echinoderm plates (Cocozza & Gandin, 1977). The scarce matrix or cement, commonly recrystallized, frequently contains scattered silt-size quartz and mica grains.

Facies 5. Light-grey in exposure, dark-grey dolostone (early dolomite).

Mudstone, dolomicrosparitic mudstone with frequent tiny quartz pseudomorphs after gypsum (Pl. 53, fig. 5).

Facies 6. Light-grey in exposure, dark-grey algal-laminated dolostone (early dolomite).

Boundstone, algal-mat. Evenly laminated dolomicrosparite alternated with laminae of fine-grained subhedral dolomite. Locally vadose pisolite facies are associated. The vadose pisoids are made up of algal-mat fragments coated by microbial crusts (Pl. 53, fig. 12).

In the lower unit the mounds (facies 1) prevail, cyclically alternated with the bioclastic, oncolitic and peloidal sands (facies 2, 3 and 4). Planar laminations are more common in the lower part of the unit, while low-angle cross-laminations, concave cross-laminations and erosional surfaces characterize the upper part.

Archaeocyaths are almost exclusively of this unit and represented by oligotypic associations in the mounds and poorly diversified taphocoenosis in the granular facies (facies 2 and 3). Displaced specimens have been occasionally found in the upper part of the second unit.

The depositional setting of the lower unit can be related to a shallow marine environment where *Girvanella*-archaeocyathan mounds colonized sheltered sites (levels 1-8). Their lenticular geometry, irregular thickness and alternation with lime-sand bodies suggest a patch-reef morphology. The location of the patch-reefs appears to have been controlled by the underlying sand-wave occurring at the top of Matoppa Member (Fig. 2). The patch-reef system was periodically overlapped by migrating oolitic or peloidal shoals (facies 3 and 4) transported by strong currents, as the prevailing plane parallel laminations indicate. Scattered siliciclastic material always occurs in the mound frame, while is lacking in the oolitic and peloidal grainstone as well as in the ooid cores. Such a feature suggests an alternated trend-direction of the currents and a terrigenous-free site of production of the lime sands. Scour surfaces and storm structures in poorly-sorted bioclastic-siliciclastic sands (levels 6 and 8) indicate episodic erosional events responsible from exhuming organisms from nearby bioconstructions and mixing them with the land-derived siliciclastic material.

In the second unit (levels 9-18) a sand-shoal system developed. The occurrence on top of a thick siliciclastic sand-wave (level 9), of planar cross-bedding and bi-directional cross lamination (herringbone type, level 10a) evolving in well sorted oolitic sands (facies 3) attests the tidal nature of the currents. Decrease in depth and energy is recorded in the overlying fine-grained carbonate (facies 4) and siliciclastic deposits, by the frequent flaser and bioturbation structures (level 10a), typical of a more protected overbank environment. Alternations of oolitic grainstones with sandstones, quartzitic sandstones and siltstones still reveal evidence of both seaward- and landward-bound currents. Higher energy events are recorded by graded ooid sand-waves (level 4), cross-bedding and scour surfaces (level 18). In the middle and upper part of the unit two different lagoonal facies occur. The former is characterized by shale deposition, low-angle cross-stratification and ripple marks (levels 15-17), the latter by the first appearance of early dolomitized evaporitic mudstone (facies 5). These episodes as well as the reappearance of the biotic mounds (level 13) suggest a change of the depositional processes and climate, resulting in the gradual replacement of the shoal environment by a tidal - lagoon system. Fossil remains are represented by fragments of trilobites contained in sandstones (levels 11, 13, 17) and by a single cup of a badly preserved archaeocyath (erismacoscinid) contained in early dolomitic lagoonal mudstone (level 18). All of them are clearly transported. However the archaeocyath cup was likely floated from the seaward side of the lagoon while the trilobites were probably merely displaced and disarticulated by the currents in their living environment.

The lagoonal-tidal flat system of the third unit was still periodically influenced by siliciclastic input. However the carbonate deposition, characterized by early dolomitized mudstone (facies 5), algal laminated boundstone and vadose pisolite (facies 6) indicates a progressive shallowing of the lagoon and the establishment of an arid algal flat.

No fossils have so far be found, though signs of life can be found in the trace fossils. Early dolomitic mudstone and algal mats replaced the carbonate granular facies in a more proximal area of the lagoon where the siliciclastic intercalations of siltstone and quartzitic sandstone represent the last land-derived input coming from a desertic continent. The early dolomitized carbonate muds containing scattered gypsum crystals, forecast the advent of evaporitic conditions, achieved in the upper part of the sequence with the establishment of the exclusively-carbonate sabkha system that will fully develop in the Lower Gonnesa Formation (Dolomia rigata Member).

Paleontologic analysis.

Archaeocyatha (F. Debrenne).

Archaeocyaths have been mainly found in the lower unit of the section. They are relatively abundant in level 1, level 6, level 8, and with less numerous samples in level 5, rare but present in levels 4 and 7, only known as moulds in levels 9 and 18 (Fig. 2).

The characteristic of the fauna is the scarcity of different species and genera: 4 genera, 5 species, one undetermined species and a group of fossils belonging to the order *Erismacoscinida*, without any possibility of finer determination (Fig. 3).

The fauna is highly dominated by the small narrow cylindrical form of *Rasetticyathus acutus* (Bornemann) (85% of the fauna in level 1, 30% in level 5, 97% in level 6, 48% in level 8). *Rasetticyathus dilatatus* Debrenne is dominant only in level 4 (50%) and nearly equivalent in level 8 (42.8%) (Fig. 4). The ribbon-like form *Erismacoscinus cancellatus* (Bornemann) is relatively scarce except in level 5 where it represents 25% of the fauna very close to the percentage of *R. acutus* (Bornemann) in this horizon (30%). Irregulars are represented by one undetermined species of *Agastrocyathus*, present only by few samples in level 4 and level 5 - and by two species of *Protopharetra*, *Protopharetra radiata* Bornemann, relatively abundant in level 5 but, absent or nearly absent in the other horizons and *Protopharetra densa* Bornemann mostly in level 7. Both species are represented by a few number of cups (Fig. 4).

Rasetticyathus acutus (Bornemann) is known in Matoppa Member, but is especially well developed in Punta Manna Member. The same observation is available for *Erismacoscinus cancellatus* (Bornemann): the long ribbon-like forms are characteristic of the Punta Manna Member, the Matoppa Member forms are less expanded ones. *Rasetticyathus dilatatus* Debrenne, *Protopharetra radiata* Bornemann and *Protopharetra densa* Bornemann are characteristic of the Punta Manna Member. The entire fauna is Botomian in age.

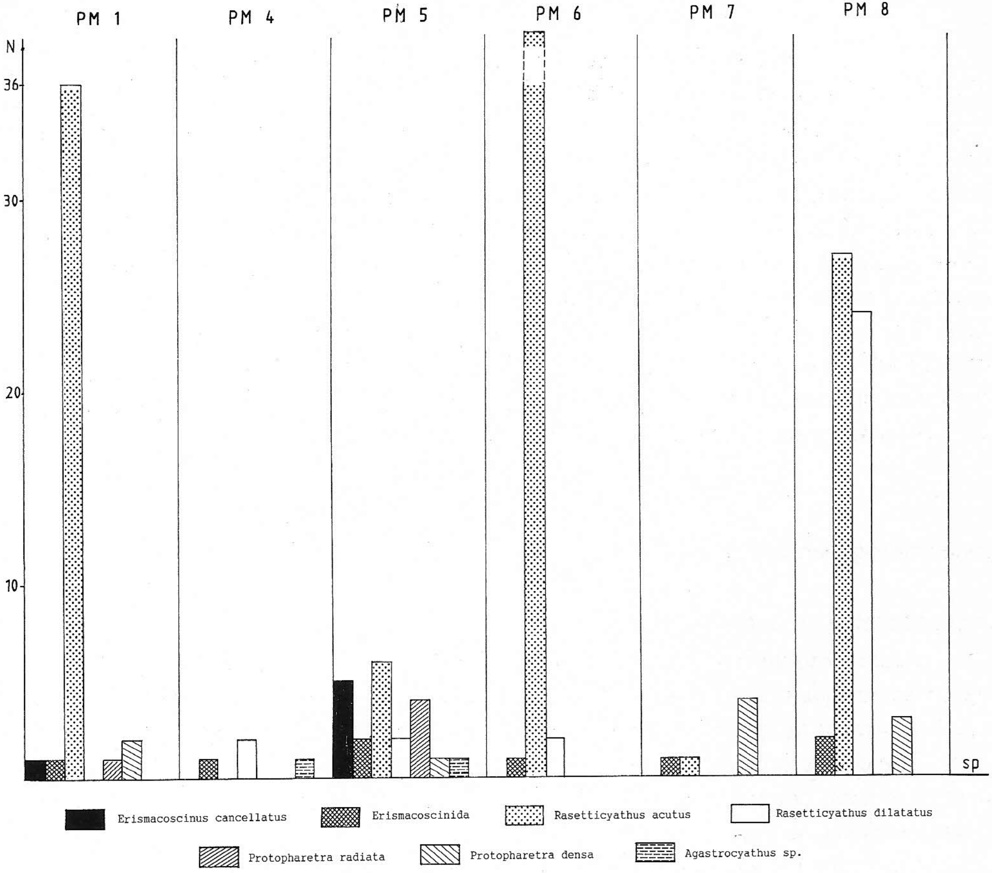

Fig. 3 - Number of specimens determined in the different archeocyathan taxa occurring in the fossiliferous beds of Punta Manna type- section.

Trilobita (G.L. Pillola).

Different fossiliferous beds containing trilobites have been recognized in the type-section of Punta Manna Member; from base to top: level 5, at 33 m; level 7, at 58 m; level 9, 91 to 71 m; level 11, at 135 m (including the bed 7g of Rasetti); level 13, at 150 m (including the bed 7d of Rasetti); and finally level 17, at 190 m (*Enantiaspis* beds, 7c of Rasetti).

Trilobites are relatively abundant within the sandstones and fragments are also found sporadically in the quartzite and carbonate facies. The exoskeletons, always limonitized (except in the limestones), are sometimes affected by tectonic deformation. They are generally fragmentary, especially within level 9, in which fragments of *Gior-*

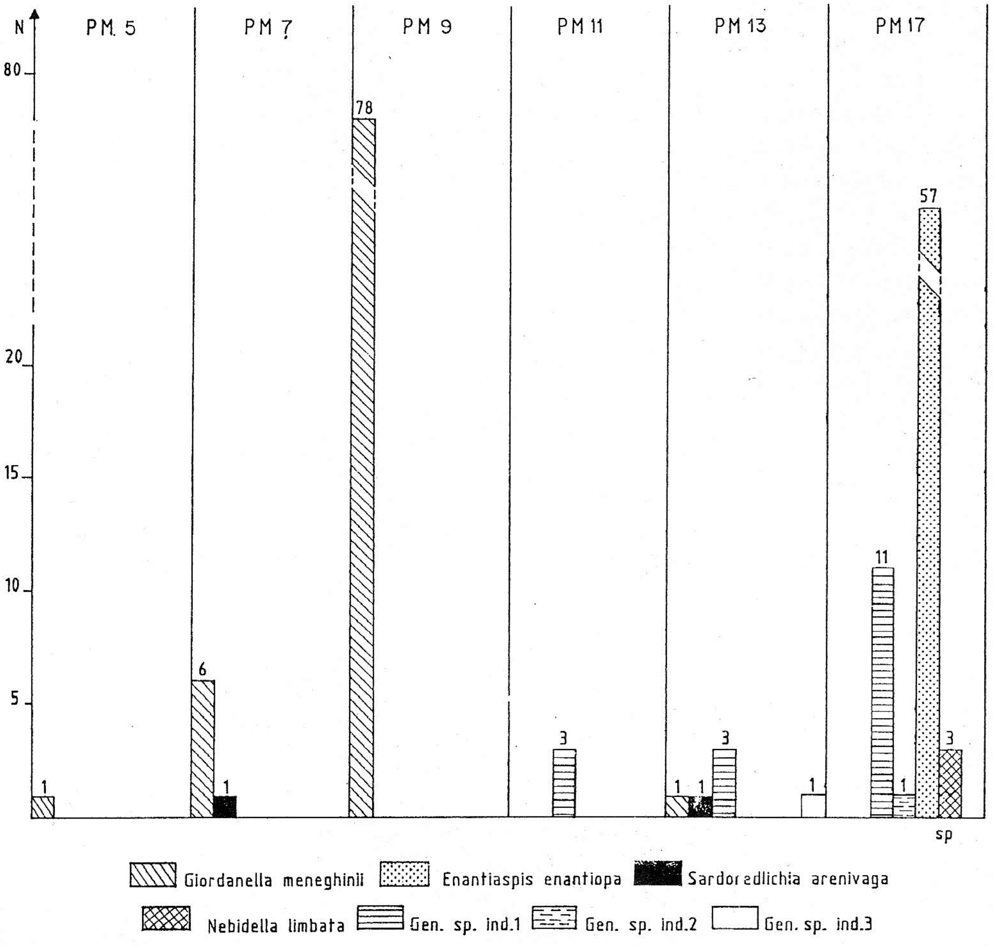

Fig. 5 - Number of specimens determined in the different trilobite taxa occurring in the fossiliferous horizons of Punta Manna type-section.

danella meneghinii (Bornemann) are randomly dispersed, sometimes showing traces of erosion and of breakage before fossilization.

The trilobites are frequently associated with archaeocyaths or, more rarely, with hyolithids (*Enantiaspis* beds, level 17).

The fauna is characterized by a limited number of genera and species, totalling 7 genera and 7 species, 3 genera are in open nomenclature.

Giordanella meneghinii (Bornemann) is dominant within the three lower fossiliferous levels, especially in level 9 (Fig. 5). *Sardoredlichia arenivaga* (Meneghini) is present in level 7 (one librigena) and in level 13 (one cranidium).

Three cranidia attributed to *Nebidella limbata* Rasetti were collected within the upper fossiliferous horizon of the section (level 17). This horizon is characterized by the prevalence of *Enantiaspis enantiopa* (Bornemann) (about 80% of the total trilobites there) and by the abundance of hyolithids.

The upper 140 m of the section are poorly exposed and no identifiable trilobites were found.

Giordanella meneghinii (Bornemann) and *Sardoredlichia arenivaga* (Meneghini) are also known in Matoppa Member (Pillola & Gross, 1982); on the contrary, *Enantiaspis enantiopa* (Bornemann) and *Nebidella limbata* Rasetti are characteristic of Punta Manna Member.

There is no paleontological element to fix the exact age of the trilobite associations in the Punta Member section. The age of the Lower Cambrian "*Dolerolenus* fauna" has been previously compared by Rasetti (1972) with the trilobite zones III and IV of Morocco, with part of the *Nevadella* zone of North America and with the Kameshky horizon of the Sayan - Altai folded region. A Lenian age (now Botomian) was proposed by Brasier (1976).

Discussion.

The lithologic, sedimentologic and faunistic features lead to subdivide the Punta Manna type-section into three units.

The lower one, made up mainly of carbonates, is characterized by low-diversity assemblages comprising archaeocyaths, trilobites, echinoderms, brachiopods, sponge spicules, *Girvanella* and *Cladogirvanella*. *Girvanella* and the archaeocyaths concur to build small mounds established in a low-energy shallow-marine environment. The salinity of the waters was apparently higher than normal as suggested by the low diversity of the faunas, the only occurrence of *Girvanella*-like algae and the radial texture of the ooids in the associated lithofacies (Gandin & Debrenne, 1984). Periodically oolitic, peloidal or siliciclastic sands overflowed the bioconstructions. Higher-energy episodes are marked by erosional surfaces and channel-filling sequences. The siliciclastic input appears to be persistent during the deposition of the mounds more as a diffuse supply than as consistent intercalations. The depositional setting corresponds to a shallow marine environment where mounds, carbonate and siliciclastic sands periodically overlapped.

The characters of this unit lead to correlate it with the "Oolitic Unit" (Fanni et al., 1981) found at the base of the Punta Manna Member in all the Iglesiente-Western Sulcis area even if the facies associations are not exactly the same than in the corresponding outcrops of Sant'Angelo, Bega-tza (Cocozza & Gandin, 1977), Guardia Manna (Debrenne et al., 1976), Cuccuru Perdiassa and Rio Cannas (Debrenne et al., 1979), Monte Azziedas, Gennarta Lake, Casa Beneck, Cuccuru Maiori, Cuccu Egaiu and Seddas Moddizis.

In the middle unit only trilobite hyolitid faunas and traces of ?*Scolicia* and *Planolites* occur; stranded archaeocyath cups can be occasionally found. Arkosic sandstone, siltstone, minor shales and quartzitic sandstone prevail on the carbonates represented by oolitic and peloidal sands, by thin layers of ooids in quartz sands and in the upper part, by early dolomitized mudstone. High energy episodes marked by channel-filling sequences, are followed by fining- and shallowing-upward cycles, that prevail in the upper part of the unit. The depositional environment appear to evolve from a sand ridge to a tidal lagoon where the marine carbonate input alternated with the continental siliciclastic one. This unit differs in details but can be compared with the equivalent sequences of the Monte Azziedas, Su Girili de Belicai, Monte San Giovanni, Monte sa Gloria, Genna Corriga and Guardia Manna, where mounds with archaeocyaths can still be locally found, indicating a diverse morphology of the lagoon system and a different paleogeographic position of the sections.

The upper unit is characterized by siltstone and massive quartzitic sandstone alternated with early-dolomitized muds and algal mats. Fossils are missing, only some *Planolites* trace-fossils occur. The depositional environment corresponds to the more proximal part of the lagoon, still affected by detritic input. The disappearance of the siliciclastic material and the occurrence of supratidal features marks the settlement of the sabkha and the beginning of the purely-carbonate deposition of Gonnesa Formation (Gandin, in press). This unit is comparable with other equivalent ones in Antas (Carmignani et al., 1986; Gandin, in press), Monte San Giovanni, Canal Grande, Monte Azziedas, Su Girili de Belicai, Guardia Manna though the thickness of the carbonate beds is here less developed.

A characteristic facies mosaic results from the detailed analysis of the Punta Manna Member in the type-section, as well as in the other localities already studied (Gandin, in press). The shallowing-upward trend and the cyclic composition of the entire sequence, the mixed carbonate and siliciclastic sedimentation as well as the vertical distribution of the faunas are consistent with a highly diversified paleogeography. The general depositional setting can be referred to a tide-dominated, deltaic system evolving, concomitantly with climate, toward a prograding sabkha-environment.

The low diversity of the faunal and algal assemblages occurring in Punta Manna type-section appears to reflect severe and recurring chemical and physical stresses, typical of such highly variable depositional system.

From a biostratigraphic point of view, the Botomian archeocyaths *Rasetticyathus dilatatus, Protopharetra densa, P. radiata*, are characteristic of Punta Manna Member and are everywhere found in other localities of the same stratigraphic position in Sardinia. Among the trilobites, *Enantiaspis enantiopa* and *Nebidella limbata* occur only in Punta Manna Member but their areal distribution is so far poorly known due to the rarity of Cambrian trilobites in Sardinia.

It is important to know exactly the faunal composition and depositional characters of Punta Manna type-section. The results of this analysis, compared with data coming from other localities of equivalent stratigraphic position in Nebida Formation will led to a better understanding of the paleogeography and biostratigraphy of the area during Punta Manna time.

Systematic paleontology

Archaeocyatha (F.Debrenne)

Family *Densocyathidae* Vologdin, 1937

Genus *Rasetticyathus* Debrenne, 1971

Type species: *Rasetticyathus acutus* (Bornemann, 1887) - pro *Rasetticyathus iglesiensis* Debrenne, 1971, *jun. syn.*

Diagnosis. Two-walled cup with nearly imperforate radiating septa. Outer wall with simple pores in alternating vertical rows. Inner wall with one S-shaped pore-tube per intersept.

Rasetticyathus acutus (Bornemann,1887)

Pl. 52, fig. 1, 2, 5; Pl. 53, fig. 6; Text-fig. 6 A-B

1887 *Archaeocyathus acutus* Bornemann, p. 50, pl. 8.
1964 *Inessocyathus acutus* - Debrenne, p. 143.
1971 *Rasetticyathus iglesiensis* Debrenne, p. 193, fig. 1,2.

Material. Level 1: 36 cups; level 5: 6; level 6: 127; level 7: 21; level 8: 27.

Description. Cylindroconical cups, long and narrow. The height may reach 35 mm for a maximum diameter of 6 mm. Variations of the intervallum coefficient (IK = intervallum width/diameter) and septal coefficient (RK = number of septa/diameter) are plotted in Fig. 6 A-B. An attempt has been made here to delimitate *iglesiensis* from *acutus* as it was previously proposed on the base of the septal coefficient (Debrenne F. in Debrenne et al., 1976, p. 1515). But comparisons with specimens coming from the area of Bornemann's *locus typicus* of *acutus* (i.e. Canal Grande - Monte sa Gloria), from Guardia Manna (Debrenne et al., 1976), Mt. Cuccurinu (Debrenne, 1971) and the fauna of Punta Manna studied here, show that *iglesiensis* and *acutus* belong to the same set (Fig. 6 A-B). Despite the fact that holotype of *acutus* is lost, and because a large collection has been made in the *locus typicus*, the name *acutus* can be used again.

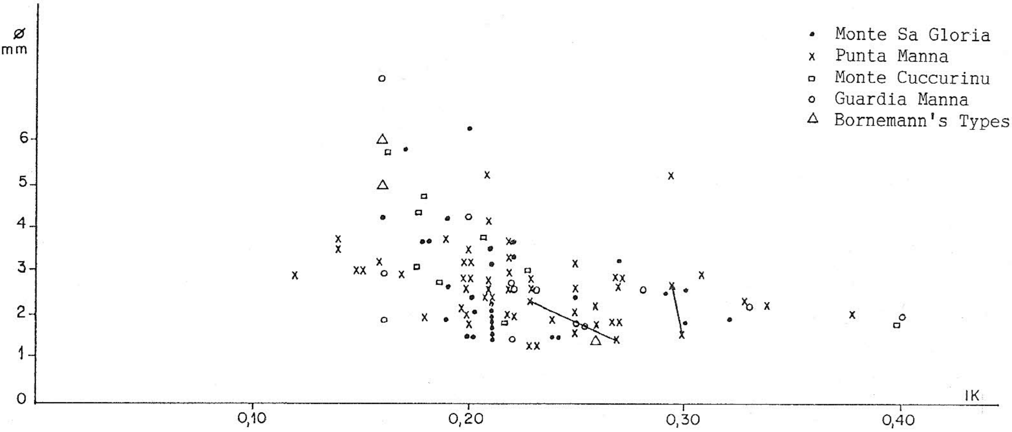

Fig. 6A - Variation of the intervallar coefficient (IK) of *Rasetticyathus acutus* (Bornemann).

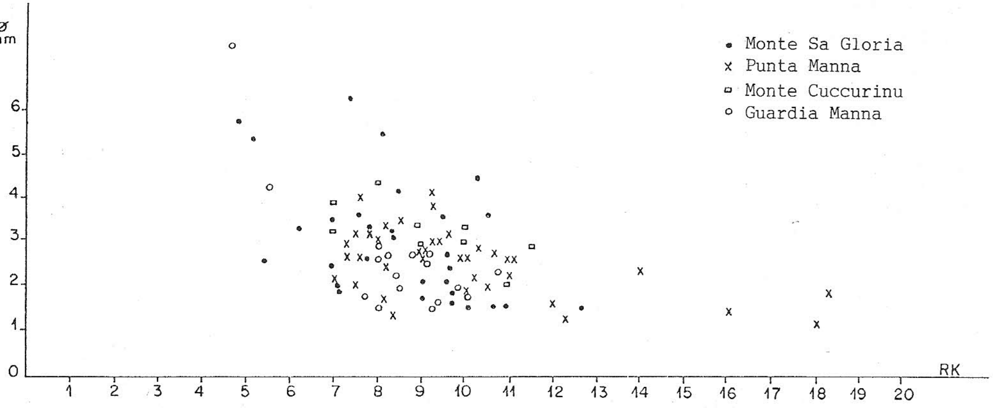

Fig. 6B - Variation of the radial coefficient (RK) of *Rasetticyathus acutus* (Bornemann). The comparison of the IK and RK values of specimens of *R. acutus* coming from Bornemann's *locus typicus* and from Punta Manna type-section, with the values of specimens referred to *R. iglesiensis* coming from other localities of the Oolitic Unit of Punta Manna Member, indicate that the two types belong to the same homogeneous species.

Dimensions: height: 30 mm; diameter: average 2 mm, maximum 6 mm; distance between septa: 0.20-0.30 mm. Outer wall: 3 pores in alternating vertical rows; diameter: 0.05 mm; lintel: 0.03 mm; thickness: 0.06 mm. Inner wall: 1 S-shaped pore-tube per intersept in alternating rows; diameter: 0.15 mm; lintel: 0.07 mm; thickness: 0.19 mm. The preservation is generally poor and very few samples show porosity good enough to be measured.

Geographic and stratigraphic distribution. Iglesiente - Sulcis. Present in Matoppa Member, Botomian (Mt. Cuccurinu), it reaches its acme in Punta Manna Member, Botomian (Monte sa Gloria, Guardia Manna, Punta Manna).

Rasetticyathus dilatatus Debrenne, 1976

Pl. 52, fig. 1, 4; Pl. 53, fig. 8

1976 *Rasetticyathus dilatatus* Debrenne F. in Debrenne et al., p. 1515, fig. 5a.

Material. Level 4: 2 cups; level 5: 2; level 6: 2; level 8: 24.

Description. Beginning with a cylindroconical part, narrow (2.5 mm diameter) on 10 mm height, the cup widens out to rapidly reach a saucer-like shape and a diameter of 25 mm. Intervallum remains nearly constant (1.2 mm), distance between septa varies from 0.19 mm at the base to 0.34 mm at the top. Outer wall is simply porous (diameter: 0.03 mm; lintel: 0.15 mm; thickness: 0.07 mm). Inner wall has one pore-tube per intersept, straight and slightly oblique (diameter: 0.15 mm; lintel: 0.07 mm; thickness: 0.22 mm).

Rasetticyathus acutus (Bornemann) is not similar with the conical part of *R. dilatatus* Debrenne. Shape of inner wall pores is different, S-shaped in *acutus*, straight in *dilatatus.*

Geographic and stratigraphic distribution. Guardia Manna, Punta Manna. Punta Manna Member, Botomian.

Family *Erismacoscinidae* Debrenne, 1964

Genus *Erismacoscinus* Debrenne, 1958

Type species: *Erismacoscinus marocanus* Debrenne, 1958.

Remarks. Forms with arched tabulae which appear before septa in ontogenetic development (*Coscinocyathidae*) are now separated from those with flat tabulae which appear after septa (*Erismacoscinidae*).

Erismacoscinus cancellatus (Bornemann, 1887)

Pl. 52, fig. 6

1887 *Coscinocyathus cancellatus* Bornemann, p. 69, pl. 11, fig. 4,5; pl. 20, fig. 1, 4, 7, 8.
1889 *Coscinocyathus cancellatus* - von Toll, p. 45, pl. 5, fig. e-f; pl. 7, fig. 2a, 5a.
1931 *Coscinocyathus cancellatus* - Vologdin, p. 59, pl. 5, fig. 11.
1964 *Erismacoscinus cancellatus* - Debrenne, pp. 176-177, pl. 25, fig. 1, 3, 4; text-fig. 67.
1976 *Coscinocyathus cancellatus* - Debrenne et al., p. 1514, text-fig. 6a.

Material. Level 1: 1 cup; level 5: 5.

Description. Large cups up to 25 mm with thin intervallum (1.5 mm), of contourned shape. Outer and inner wall with simple pores; the outer wall is forming irregular peaks between septa (Pl. 52, fig. 6). The intervallum is crossed by regular septa, about 0.40 mm apart, and by planed tabulae distant of about 0.60 mm from each other. The form occurs in slides as fragments of the intervallum, rarely complete cups.

Comparison with forms from Monte sa Gloria and Guardia Manna shows a great similarity despite the fact that the porosity is not preserved here.

Geographic and stratigraphic distribution. Monte sa Gloria, Punta Pintau, Guardia Manna, Punta Manna, Cuccuru Contu, Gonnesa. Present since the Matoppa Member. Acme in Punta Manna Member, Botomian.

Family *Protopharetridae* Vologdin, 1957

Genus *Protopharetra* Bornemann, 1884

Type species: *Protopharetra polymorpha* Bornemann, 1887.

Protopharetra radiata Bornemann, 1887

Pl. 53, fig. 3

1887 *Protopharetra radiata* Bornemann, p. 48, pl. 7, fig. 1, 2, 5, 6, 7.
1887 *Protopharetra vesiculosa* Bornemann, p. 48, pl. 7, fig. 3, 4.
1964 *Rhizacyathus radiatus* - Debrenne, pp. 229-230, pl. 40, fig. 1-4.
1976 *Protopharetra radiata* - Debrenne et al., p. 1516, fig. 5b.

Material. Level 1: 1 cup; level 5: 4; level 6:1.

Description. Cups of 8 mm in diameter up to 13 mm with a narrow central cavity, sometimes even absent. Taeniae mostly radial, connected by scarce synapticular-like bars. Rare vesicular tissue, presence of stereoplasma in the larger specimens. The outer wall is no porous to simply porous at the upper part of the cup. Inner wall absent or badly defined.

Geographic and stratigraphic distribution. Iglesias, Genna Figu, Gennarta, Seddas Moddizzis, Canal Grande, Monte sa Gloria. Punta Manna Member, Botomian.

Protopharetra densa Bornemann, 1887

Pl. 52, fig. 3

1887 *Protopharetra densa* Bornemann, p. 48, pl. 8, fig. 6c, 7b, 8.
1964 *Protopharetra densa* - Debrenne, p. 215, pl. 39, fig. 1, 2.
1976 *Protopharetra densa* - Debrenne et al., p. 1509, text-fig. 3, 6c.

Material. Level 1: 2 samples; level 5: 1; level 7: 3; level 8: 3.

Description. Small colonial branching cup, with a dense network of skeletal elements in the intervallum and few membranes of vesicular tissue. The average diameter is 3 mm, with an intervallum of 0.85 mm. Taeniae are 0.26 mm apart. Outer wall has small apertures, inner wall has one pore per intertaenial space.

Geographic and stratigraphic distribution. Punta Pintau, Monte sa Gloria, Gennarta, Guardia Manna, Punta Manna. Punta Manna Member, Botomian.

Trilobita (G.L. Pillola)

Methods.

The nomenclature adopted for the systematic description of the trilobites follows Hupé (1953) and Harrington (1959); lateral glabellar furrows and lateral glabellar lobes are respectively numbered from back to front, S1, S2, S3, and L1, L2, L3.

The figured specimens are mainly internal moulds of the exoskeleton, except one external mould (Pl. 56, fig. 2) and two latex casts made from external moulds (Pl. 55, fig. 4,5). Every sample was blackened with Indian ink and then whitened with ammonium chloride, before being photographied with the Leitz Aristophot.

Abbreviations: IM) internal mould; EM) external mould; LM) latex mould; DSTCP) Dipartimento di Scienze della Terra (Cagliari University), Pillola's collection.

Order **Redlichiida** Richter, 1933
Suborder **Redlichiina** Harrington, 1959
Superfamily *Redlichiacea* Poulsen, 1927
Family *Redlichiidae* Poulsen, 1927
Subfamily *Redlichiinae* Poulsen, 1927
Genus *Sardoredlichia* Rasetti, 1972

Type-species: *Anomocare arenivagum* Meneghini, 1888 (= *Sardoredlichia praespinosa* Rasetti, 1972, *jun. syn.*).

Sardoredlichia arenivaga (Meneghini, 1888)

Pl. 54, fig. 1a,b

1883 *Anomocare arenivagum* Meneghini, p. 7, *nomen nudum.*
1888 *Anomocare arenivagum* Meneghini, p. 30, pl. 7, fig. 13 (non pl. 5, fig. 2 et 2c and pl. 6, fig. 9).
1891 *Anomocare arenivagum* - Bornemann, p. 475 (51), pl. 39, fig. 25, 26.
1972 *Sardoredlichia praespinosa* Rasetti, p. 49, pl. 14, fig. 5; pl. 9, fig. 1-25; pl. 13, fig. 9.

Material. Level 7, one librigena, DSTCP 0277; level 13, one cranidium, DSTCP 0278.

Discussion. Rasetti (1972) gave a very good description and comparison of this species with related forms, under the name *S. praespinosa*. However, the species *Anomocare arenivagum* proposed by Meneghini (1888) was originally well figured and described, so that there cannot be any confusion with other forms. Consequently *A. arenivagum* is undoubtedly a valid species and *S. praespinosa* Rasetti has to be considered as a junior synonym.

Zhang & Lin (1980) placed doubtfully *Sardoredlichia* in the subfamily *Metaredlichiinae*, but the components of this subfamily are generally characterized by a subcylindrical glabella and non transglabellar furrows, sometimes the two anterior pairs are oblique forward. I think that, more probably, *Sardoredlichia* belongs to the *Redlichiinae*, even if the posterior ends of the ocular lobes are relatively distant from the dorsal furrows.

Stratigraphic setting. Uppermost Matoppa Member and lower to middle part of Punta Manna Member, at Schina Sa Grutta, Punta Manna, Monte Azzieddas, Punta Rubicina, Sa Pruixina, Su Girili de Bellicai, Case Sant'Antonio.

Genus *Nebidella* Rasetti, 1972

Type-species: *Nebidella limbata* Rasetti, 1972.

Nebidella limbata Rasetti, 1972

Pl. 54, fig. 2,3

1972 *Nebidella limbata* Rasetti, p. 52, pl. 4, fig. 6; pl. 12, fig. 17-26.

Material. Level 17, 3 cranidia, DSTCP 0701-0703.

Description. See Rasetti (1972, p. 52).

Discussion. Several examples show the presence of a mesial preglabellar ridge on the cranidium (Pl. 54, fig. 3 and another unfigured specimen). This mesial ridge is also present on cranidia collected in other localities (Pillola, unpublished thesis). The absence of the ridge may be due to bad preservation.

Stratigraphic setting. Punta Manna Member. The species is relatively abundant in the *Enantiaspis enantiopa* beds, at Punta Manna section and Case Sant'Antonio; very rare in the uppermost *Giordanella meneghinii* range zone of Schina Sa Grutta and Case Sant'Antonio.

Family ? *Dolerolenidae* Kobayashi, 1951

Undetermined gen. and sp. 1

Pl. 54, fig. 4, 5; Pl. 55, fig. 1

Material. Level 11, 2 cranidia, 1 pygidium, DSTCP 0711-0713; level 13, 3 cranidia, DSTCP 0714-0716; level 17, 11 cranidia, DSTCP 0721-0731.

Description. Subquadrangular cranidium with a broad frontal area. Conical glabella, rounded in front - with a length of about 70% of the total length of the cranidium (comprising the occipital ring); the glabella is delimited by rather sharp dorsal furrows; 3 weak pairs of lateral glabellar furrows: S1 nearly transglabellar, S2 less pronounced and S3 obsolete; occipital furrow wide but shallow; occipital ring as broad (sag.) as the occipital furrow; occasional small occipital spine. Frontal area rather wide (sag.), consisting of a preglabellar field and a prominent anterior border of the same width. They are separated by a rather deep anterior border furrow; mesial ridge present. Broad ocular ridge straight, divided by ocular striga near the glabella, but non interrupted by the dorsal furrow. Arched palpebral lobes approximately as wide as the ocular ridge; these lobes are twice as long as the posterior area of the fixigenae (ex sag.); palpebral furrow pronounced.

Posterior areas of the fixigenae short (exsag.), with narrow and deep posterior border furrows. Anterior branches of facial suture diverging at an angle greater than 45°; straight to the furrow delimiting the frontal lobe, then curved inwards. Pygidium subrectangular, nearly as wide as long, rounded behind, nearly completely composed of the rachis; convex articular half ring separated from the remaining rachis by a deep furrow. The rachis bears a very prominent ring and a terminal piece with two rounded humps located in the posterior area; pleural lobes reduced, separated from the rachis by pronounced dorsal furrows at the level of the first axial ring, then reduced backwards; each lobe bears a weak pleural furrow.

Discussion. Some features, generally considered as important at the family, or subfamily level, suggest the comparison of the above described form with the *Pararedlichiinae* (Hupé, 1953); the length (sag.) of the palpebral lobe and the position of its ends are comparable with those of *Eoredlichia intermedia* (Lu), *Pararedlichia* Hupé and *Galloredlichia* Jago (probably junior synonym of *Pararedlichia* Hupé). The most striking difference is the length (sag.) of the preglabellar field and of the anterior part of the ocular ridge; within the *Pararedlichiinae*, the preglabellar field is reduced or nearly absent, while the width of the ocular ridge shortens near the glabella. On the other hand, the development of the preglabellar field rather reminds one of the *Dolerolenidae* s. str. The studied examples, however, show definite differences from *Dolerolenus*, for example the relative dimensions of the palpebral lobe and of the posterior area of the fixigenae, the persistance in the adult stage of a wide ocular ridge and of a pronounced palpebral furrow. Some of the features show the same variability as in *Dolerolenus*, for example, the presence or absence of the preglabellar mesial ridge (more or less wide); the glabellar furrows and the occipital furrow, sometimes well marked or on the contrary obsolete; the presence or absence of the ocular striga near the glabella; and the presence or the absence of a small occipital spine.

The studied cranidia are comparable with those of some *Dolerolenus* sp. ind., figured by Rasetti (1972, pl. 16, fig. 7, 8, 20, 22, 23) where the posterior end of the palpebral lobe is situated at least at the same level as the occipital furrow.

The systematic position of this trilobite put in open nomenclature, is doubtful; in accordance with the importance given to one character or another, it could be classified either in the family *Dolerolenidae* or in the subfamily *Pararedlichiinae* (family *Redlichiidae*).

Undetermined gen. and sp. 2

Pl. 55, fig. 2

Material. Level 17, 1 pygidium, DSTCP 0313.

Description. This single pygidium has a prominent subcircular rachis, and a pleural area consisting principally of 2 large and strong spines. The rachis is made of the articular half ring and of a badly preserved axial area as long as wide which does not show how many axial rings could be there. Pleural areas are developed, half length of the rachis, considerably extended backwards, giving rise to two spines twice as long as the rachis; a doublure is present within the whole pleural area.

Discussion. The specimen figured here may be compared with those described by Bornemann (1891) under the name of *Paradoxides bifidus* (Bornemann, 1891, p. 469, pl. 39, fig. 5, 6).

Lotze (1961, p. 137) quoted ? *Paradoxides bifidus* in Meira Region (Galicia, Spain) while Sdzuy (1961) compared the same specimens with *Dolerolenus formosus* Sdzuy.

Family ?*Metadoxididae* Whitehouse, 1939

Genus *Enantiaspis* Rasetti, 1972

Type-species: *Ptychoparia enantiopa* Bornemann, 1891, by original designation of Rasetti (1972).

Enantiaspis enantiopa (Bornemann, 1891)

Pl. 55 fig. 4-6

1888 *Olenus armatus* Meneghini (pars), p. 14, pl. 12, fig. 8.
1888 *Conocoryphe* sp. indet. Meneghini, p. 32, pl. 7, fig. 8, 8 bis.
1891 *Ptychoparia enantiopa* Bornemann, p. 472 (48), pl. 39, fig. 14, 15.
1972 *Enantiaspis enantiopa* - Rasetti, p. 70, pl. 6, fig. 2; pl. 11, fig. 1-23; pl. 12, fig. 1-16.

Material. Level 17, 44 cranidia, 7 librigenae, 4 pygidia, 2 nearly complete specimens, DSTCP 0636-0692.

Discussion. Rasetti (1972) has given a very detailed description of this species, and placed the genus *Enantiaspis* in the *Polymera* of uncertain affinities. Zhang & Lin (1980) placed doubtfully this monospecific genus in the family *Anadoxididae* Nicosia & Rasetti, 1970 (junior synonymy of *Metadoxididae* Whitehouse, 1939). This assumption, even premature, is strongly probable. *Enantiaspis enantiopa* is at present known only in the lower Cambrian of Sardinia. Many specimens were collected at Punta Manna, but this species is frequent at Case Sant'Antonio, Punta Su Pranu and, in minor quantity, at Schina Sa Grutta, Sa Pruixina, Monte Azzieddas and Seddas Moddizzis.

The specimen called *Conocoryphe* sp. indet. by Meneghini (1888) is placed within the synonymy of *E. enantiopa* because the shape of the very prominent anterior part of the palpebral lobe, the short preglabellar field and the outline of the anterior border show that the specimen undoubtedly belongs to the present species.

Uncertain family

Undetermined gen. and sp. 3

Pl. 55, fig. 3

Material. Level 13, one poorly preserved cranidium, DSTCP 0312.

Description. Cranidium with quadrangular outline; glabella conical, rounded in front, delimited by rather wide dorsal furrows (trans.) and attaining (occipital ring included) about 80% of the cranidial length; narrow occipital ring (sag.) outlined by a deep and narrow occipital furrow. Three pairs of glabellar furrows are directed backwards; S1 transglabellar, well defined in its medial part, S2 and S3 pronounced distally, shallow medially, possibly due to poor preservation. High palpebral lobes extending from opposite S2 to the middle of the L1 lobe. Ocular ridge nearly straight, prominent, not reaching the dorsal furrow. The adaxial end of this ridge is opposite the S3 furrow. Preglabellar field absent; wide and very deep frontal border furrow (sag.); prominent frontal rim larger than the frontal furrow. The fixigena anterior area is convex (between the ocular ridge and the anterior border furrow).

Discussion. The glabellar segmentation may be compared with that of "*Ptychoparia*" *laticeps* Bornemann (Bornemann, 1891, pl. 39, fig. 12) figured by Rasetti (1972, pl. 13, fig. 11) and *Sardaspis papillosa* Brasier, 1976. However, the glabella of "*Ptychoparia laticeps* is proportionally wider and oval in shape. The poor preservation of the studied material does not allow precise comparison.

Incertae sedis

Genus *Giordanella* Bornemann, 1891

Type-species (chosen by Vodges, 1925): *Illaenus meneghinii* Bornemann, 1883.

Giordanella meneghinii (Bornemann, 1883)

Pl. 56, fig. 1-6

1883 *Illaenus meneghinii* Bornemann, p. 274.
1883 *Platypeltis meneghinii* - Meneghini, p. 34, pl. 5, fig. 1c, 3a, 6-9, 11, 12, 14, 15, 17; pl. 6, fig. 7, 10-13.
1888 *Asaphus* (*Platypeltis*) sp. ind. Meneghini, p. 7, fig. 16.
1888 *Asaphus* (*Psilocephalus* ?) *gibber* Meneghini, p. 40, pl. 5, fig. 1a,b, 2a,b, 5b, 10.
1891 *Giordanella meneghinii* - Bornemann, p. 479 (55), pl. 41, fig. 1-3, 5-7, 9, 10, 12-14, 16, 18-27, 36.
1891 *Giordanella dilatata* Bornemann, p. 480 (56), pl. 41, fig. 4, 11, 17, 30, 37, 38.
1891 *Giordanella elongata* Bornemann, p. 480 (56), pl. 41, fig. 8, 15, 28, 29, 31-35n, 39, 40.
1970 *Giordanella meneghinii* - Nicosia & Rasetti, p. 11, pl. 3, fig. 1-14.
1972 *Giordanella meneghinii* - Rasetti, p. 72, pl. 5, fig. 1; pl. 10, fig. 1-24.

Material. Level 5, 1 cranidium, DSTCP 0261; level 7, 1 cranidium, 3 pygidia, 1 librigena, 1 hypostoma, DSTCP 0274-0275; level 9, 13 cranidia, 32 pygidia, 28 librigenae, 1 hypostoma, 1 rostrum, DSTCP 0262-0273; level 13, 1 cranidium, DSTCP 0276.

Discussion. The samples collected do not give new information to complete the previous descriptions of Bornemann (1883, 1891), Meneghini (1888), Nicosia and Rasetti (1970) and Rasetti (1972), which remain the references for this species.

Nevertheless, two points must be emphasized: firstly the strong convexity of the transverse section of the dorsal exoskeleton; the glabellar segmentation does not show up, and, if we juxtapose the fixigenae with the librigenae the latter participate in the regular convexity of the cephalon. Secondly, the thickness of the dorsal carapace is quite remarkable, but is this thickness constant or does it vary with environmental factors (such as the nature of the sediment or the agitation of the water) ? First observations show important differences between internal moulds and latex replicas from external moulds. For example the pygidial segmentation is less obvious and the depth of dorsal furrows less strong on the external surface of the exoskeleton (Pl. 56, fig. 2) than on the internal mould (Pl. 56, fig. 4a).

These preliminary remarks have to be tested by the examination of larger collection coming from various localities.

Giordanella, a monospecific genus, is difficult to classify in a family or superfamily; some of its morphological features are not known among lower Cambrian trilobites (Rasetti, 1972).

Hupé (1953) doubtfully included *Giordanella meneghinii* in the subfamily *Glossopleurinae* Hupé, 1953, of the family *Dolichometopidae* Walcott, 1916.

Lochman-Balk (1959) and more recently Nicosia and Rasetti (1970), and Rasetti (1972), put *Giordanella* in an undetermined family or *Polymera* of incertain affinities.

The classification is all the more difficult in the absence of any known possible ancestor or descendant in the Cambrian.

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PLATE 52

Fig. 1 - *Rasetticyathus dilatatus* Debrenne. MNHN L84213. a) Longitudinal view of the species; b) encased cones of *Rasetticyathus acutus* (Bornemann), in association trilobite fragments and dolomitized ooids; wackestone-packstone facies. Level 8.

Fig. 2 - *Rasetticyathus acutus* (Bornemann). MNHN L84214. Longitudinal section, with tangential view of the inner wall; wackestone facies. Level 8.

Fig. 3 - *Protopharetra densa* Bornemann. MNHN L84215. Transverse section; wackestone facies. Level 7.

Fig. 4 - *Rasetticyathus dilatatus* Debrenne. MNHN L84216. Ribbon-like transverse sections. In association trilobite remains; wackestone facies. Level 8.

Fig. 5 - *Rasetticyathus acutus* (Bornemann). MNHN L84217. Rudstone of *R. acutus* cups, followed by echinoderm plate grainstone. Note the random orientation of the geopetal filling in the archeocyath cups. Level 6.

Fig. 6 - *Erismacoscinus cancellatus* (Bornemann). MNHN L84218. Transverse section, with indented outer wall; wackestone facies of the internal sediment. Level 5.

PLATE 53

Fig. 1 - *Erismacoscinus* sp. MNHN L84219. Oblique longitudinal section. Level 8.

Fig. 2 - *Agastrocyathus* sp. MNHN L84220. Transverse section. Level 5.

Fig. 3 - *Protopharetra radiata* Bornemann. MNHN L84221. Transverse section. Level 6.

Fig. 4 - *Girvanella* (*Cladogirvanella*) "oncoid"; wackestone facies. Level 7.

Fig. 5 - Tiny siliceous lenticular-shaped pseudomorphs after gypsum in dolomitic microsparite. Mudstone facies. Level 18.

Fig. 6 - *Rasetticyathus acutus* (Bornemann) with inner wall lined by a microbial crust; wackestone facies. Level 8.

Fig. 7 - Phosphatic lingulid shell; wackestone facies. Level 4.

Fig. 8 - A cup of *Rasetticyathus dilatatus* Debrenne, filled up by dolomitized ooids; rudstone facies. Level 8.

Fig. 9 - Large ooids with a well developed micritic coating and bioclastic core; packstone facies. Level 12.

Fig. 10 - Deformed ooids still retaining concentric rings and the pseudouniaxial cross. An anhedral calcite mosaic replaces the original cement; grainstone facies. Level 10A.

Fig. 11 - Selectively dolomitized algal structure possibly produced by *Girvanella* filaments; boundstone facies. Level 4.

Fig. 12 - Unsorted angular clasts of algal mat coated by microbial crusts. Vadose pisolite facies. Level 24.

PLATE 54

Fig. 1 - *Sardoredlichia arenivaga* (Meneghini). Cranidium, IM. a) Dorsal view; b) frontal view. DSTCP 0278, level 13; x 9.

Fig. 2,3 - *Nebidella limbata* Rasetti. 2) Cranidium, IM. DSTCP 0701, level 17; x 9. 3) Cranidium, IM. DSTCP 0702, level 17; x 12.

Fig. 4,5 - Gen. et sp. ind. 1. 4) Cranidium, IM. DSTCP 0721, level 17; x 8. 5) Pygidium, IM. DSTCP 0713, level 11;x6.5.

PLATE 55

Fig. 1 - Gen. et sp. ind. 1. Cranidium, IM. DSTCP 0711, level 11; x 4.
Fig. 2 - Gen. et sp. ind. 2. Pygidium, IM. DSTCP 0313, level 17; x 4.
Fig. 3 - Gen. et sp. ind. 3. Cranidium, IM. DSTCP 0312, level 13; x 5.
Fig. 4-6 - *Enantiaspis enantiopa* (Bornemann). 4) Cranidium, LM. DSTCP 0641, level 17; x 4. 5) Cranidium, LM. DSTCP 0640, level 17; x 4. 6) Pygidium, IM. DSTCP 0636, level 17; x 4.

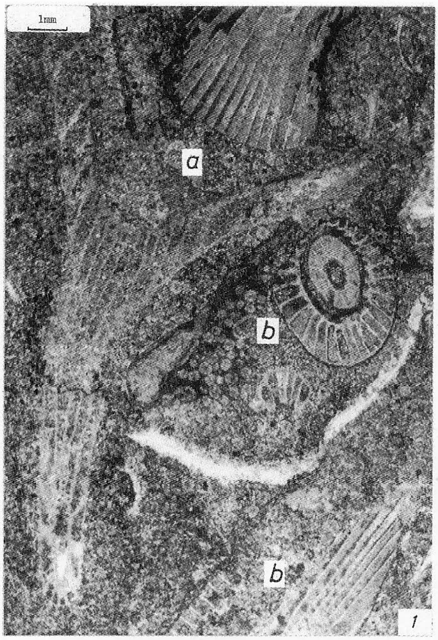
PLATE 56

Fig. 1-6 - *Giordanella meneghinii* (Bornemann). 1) Cranidium, LM. DSTCP 0232, top of Matoppa Member; x 4. 2) Cranidium, external surface of the exosqueleton, EM. DSTCP 0261, level 5; x 4. 3) Pygidium, IM. DSTCP 0270c, level 9; x 4. 4) Pygidium, IM. DSTCP 0270e, level 9; x 4. 5a) Cranidium; 5b) Pygidium, IM. DSTCP 0274 a et b, level 7; x 5. 6) Librigena, IM. DSTCP 0270d, level 9; x 4.

Repository of the specimens:

MNHN (archaeocyaths) Musém National d'Histoire Naturelle - Paris (France).

DSTCP (trilobites) Museo Lovisato - Dipartimento di Scienze della Terra - Cagliari (Italy) (Pillola's collection).



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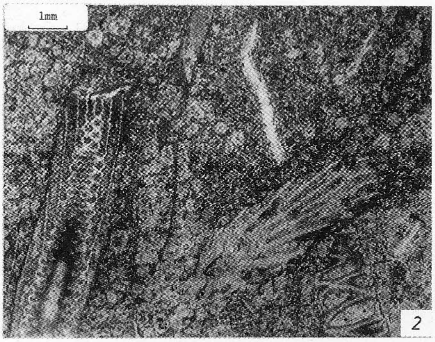

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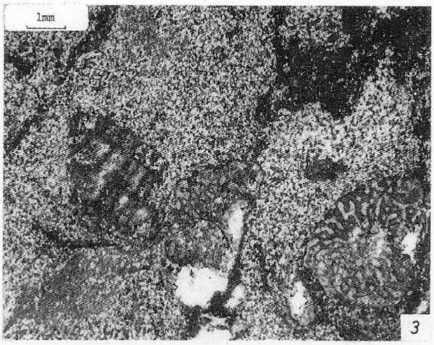

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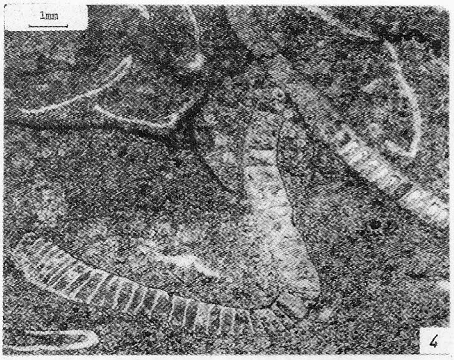

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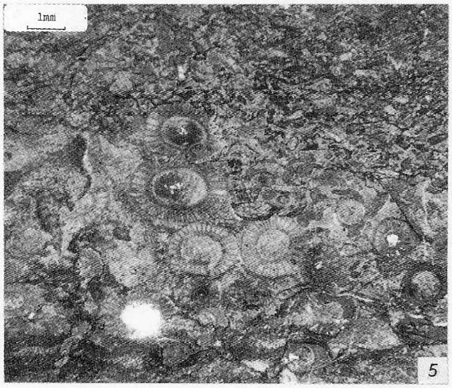

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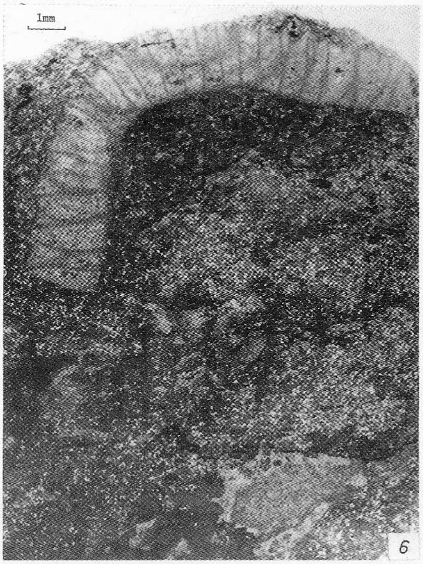

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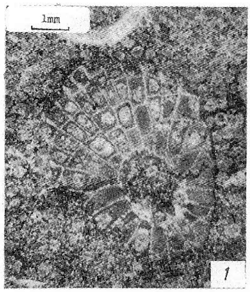

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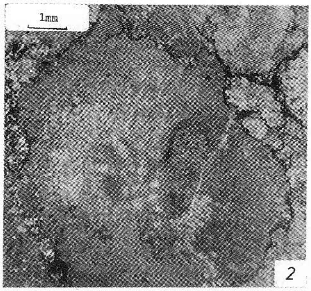

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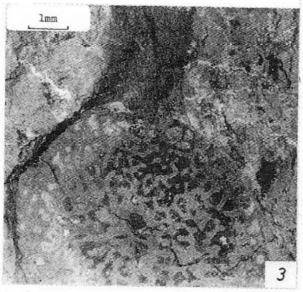

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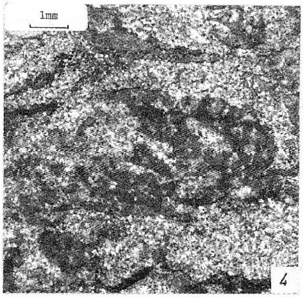

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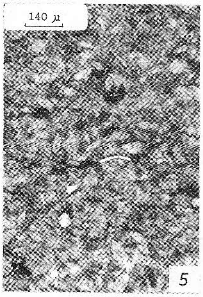

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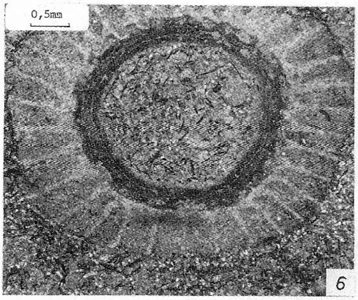

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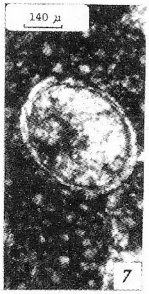

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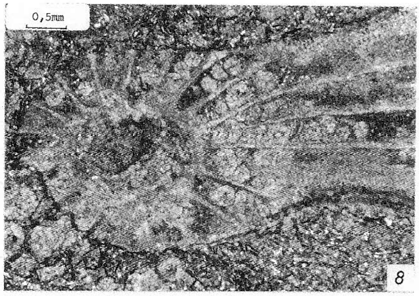

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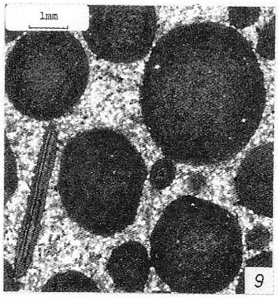

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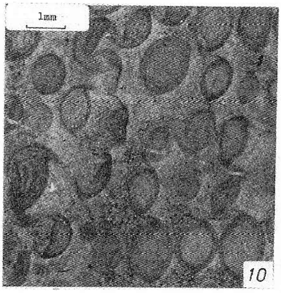

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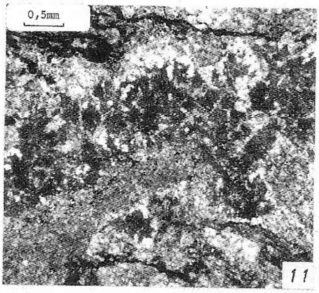

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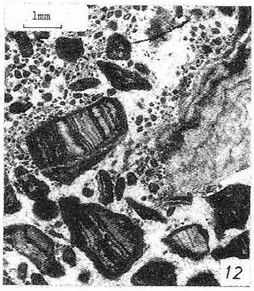

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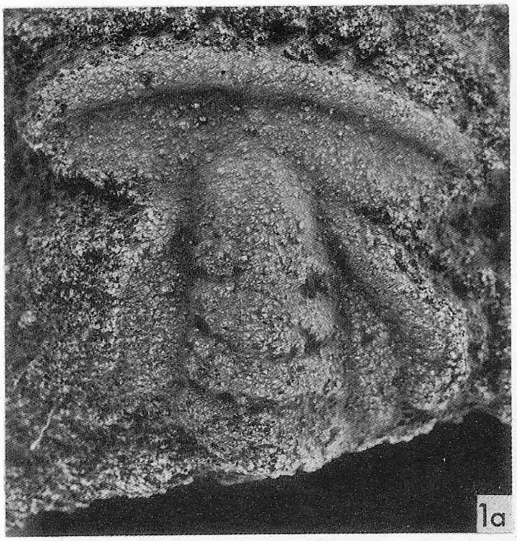
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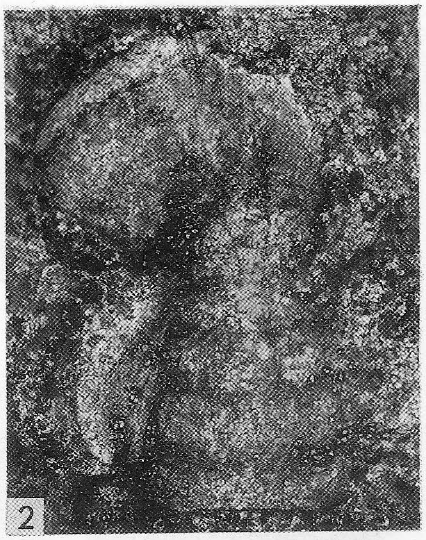
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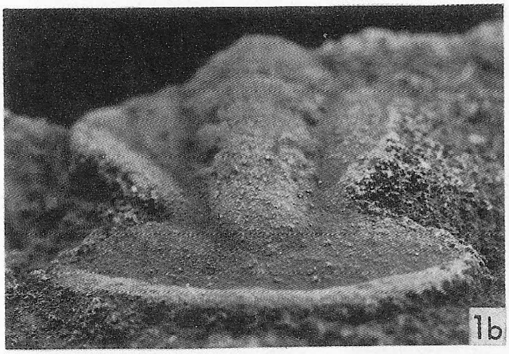
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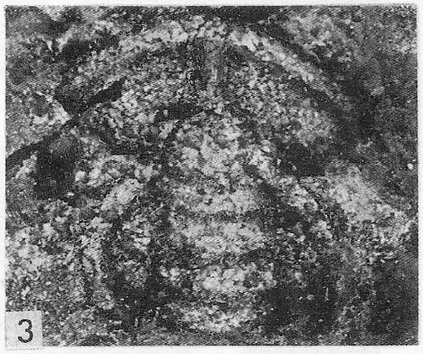
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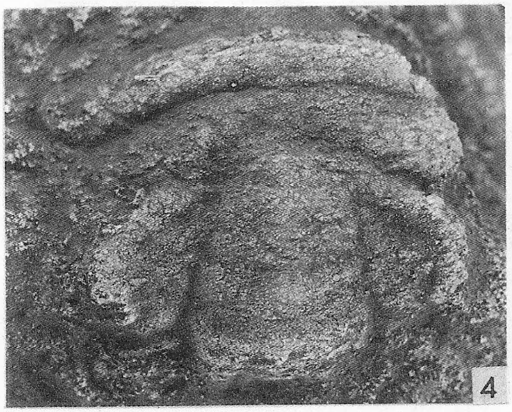
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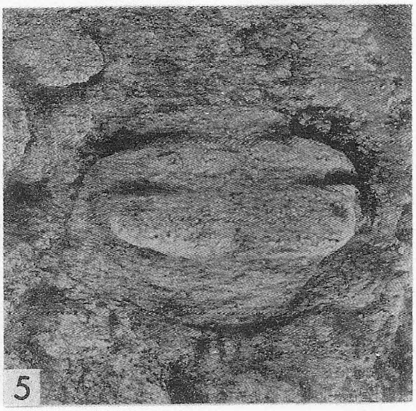
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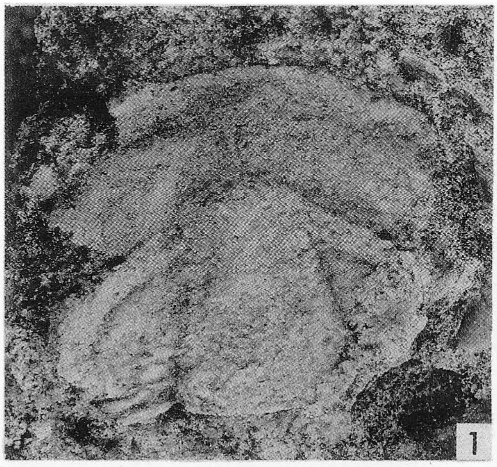
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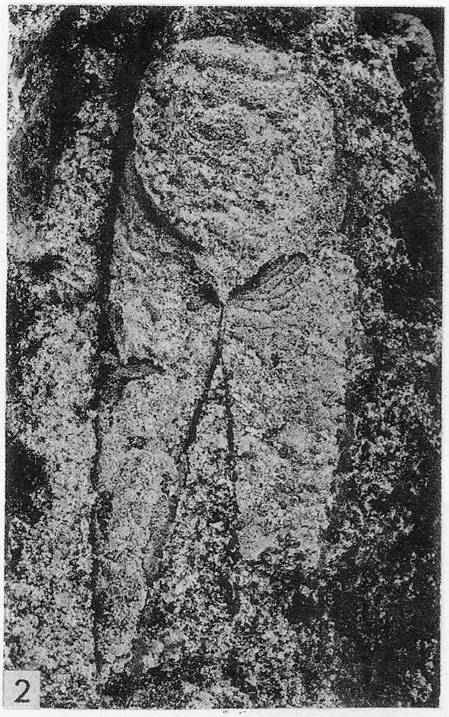
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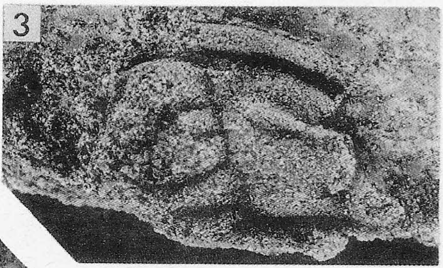
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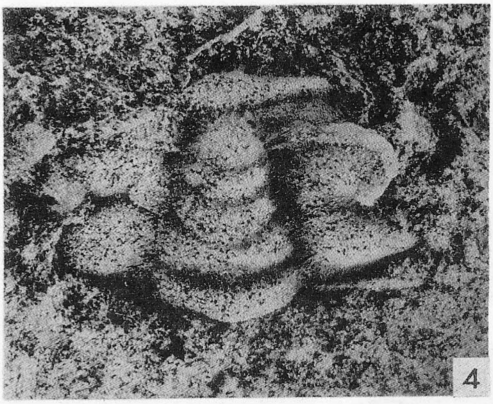
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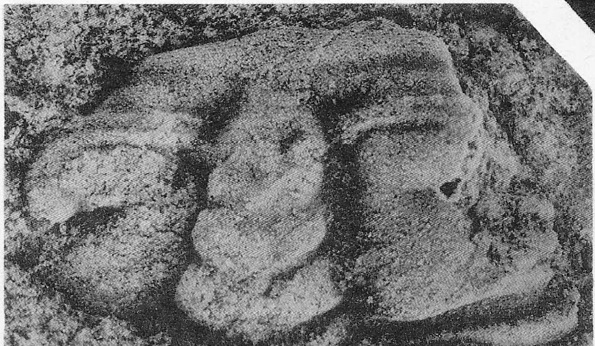
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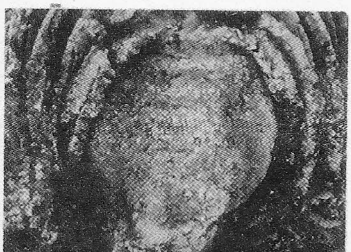
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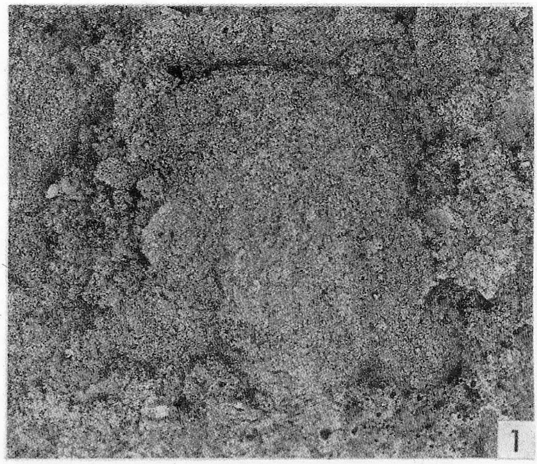
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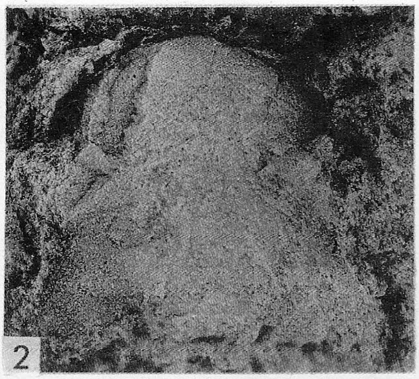
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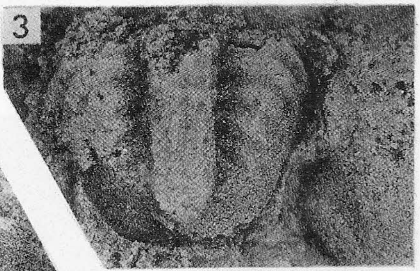
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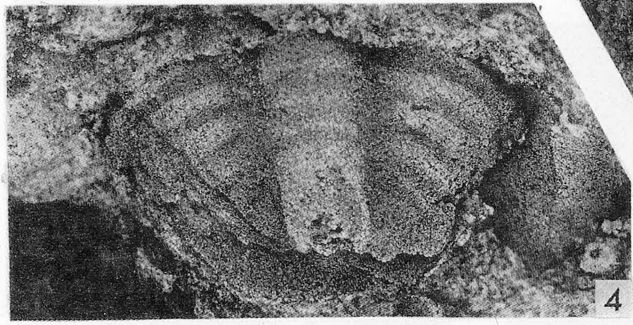
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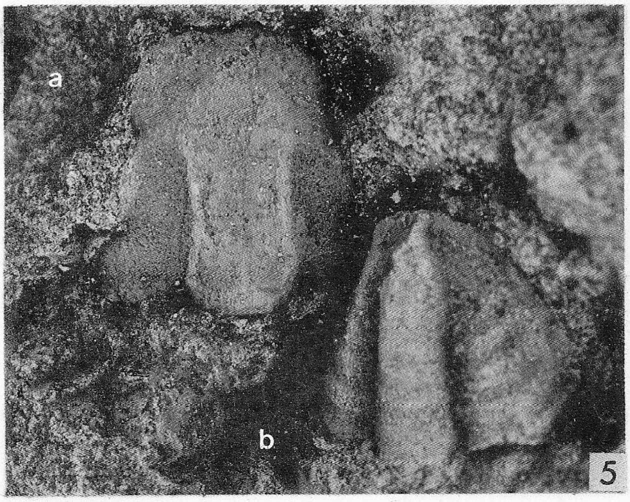

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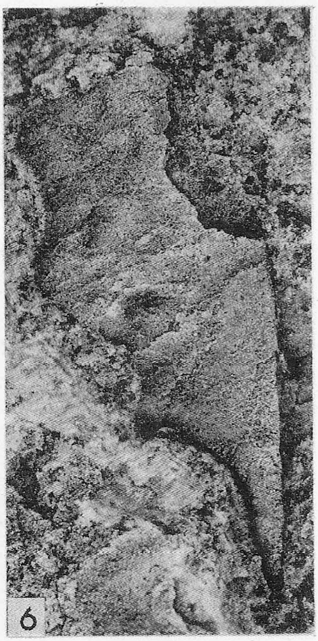
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