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NEW GEOLOGICAL AND STRATIGRAPHICAL DATA AND DISCOVERY OF LOWER ORDOVICIAN ACRITARCHS IN THE SAN VITO SANDSTONE OF THE GENN'ARGIOLAS UNIT (SARRABUS, SOUTHEASTERN SARDINIA)

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Key-words: Geology, Stratigraphy, Paleozoic, Lower Ordovician, Acritarchs, Sardinia.

Riassunto. Vengono esposti nuovi dati geologici e stratigrafici sul Paleozoico del Sarrabus (Sardegna SE). In particolare, nuove campionature per la ricerca di microfossili nei sedimenti terrigeni a basso grado metamorfico delle Arenarie di San Vito hanno fornito acritarchi del Tremadociano (Ordoviciano inferiore).

Questo ritrovamento, oltre a precisare meglio l'età delle Arenarie di San Vito, nelle quali finora erano stati descritti acritarchi solo del Cambriano medio e superiore, consente di correlare più esattamente la formazione del Sarrabus con analoghe formazioni ad acritarchi della Sardegna centro-meridionale e di confermare ulteriormente l'età intraordoviciana (Ordoviciano inf.-medio) della Fase Sarrabese e della corrispondente Fase Sarda dell'Iglesiente-Sulcis (Sardegna SW).

Abstract. The subject of this paper is new geological and stratigraphical data regarding the Paleozoic in the Sarrabus area (Southeastern Sardinia). More particularly Tremadocian (Lower Ordovician) acritarchs have been found in samples taken for microfossils research from the weakly metamorphosed terrigenous sediments of the San Vito Sandstone.

Until recently only acritarchs from the Middle and Upper Cambrian has been found in the San Vito Sandstone. This new finding provides a more precise dating of the San Vito Sandstone, a more exact correlation between this Sarrabus formation and analogous formations with acritarchs in Central- Eastern Sardinia and also further confirmation of the Intraordovician age of the Sarrabese Phase and of the corresponding Sardic Phase of Iglesiente-Sulcis area (Southwestern Sardinia).

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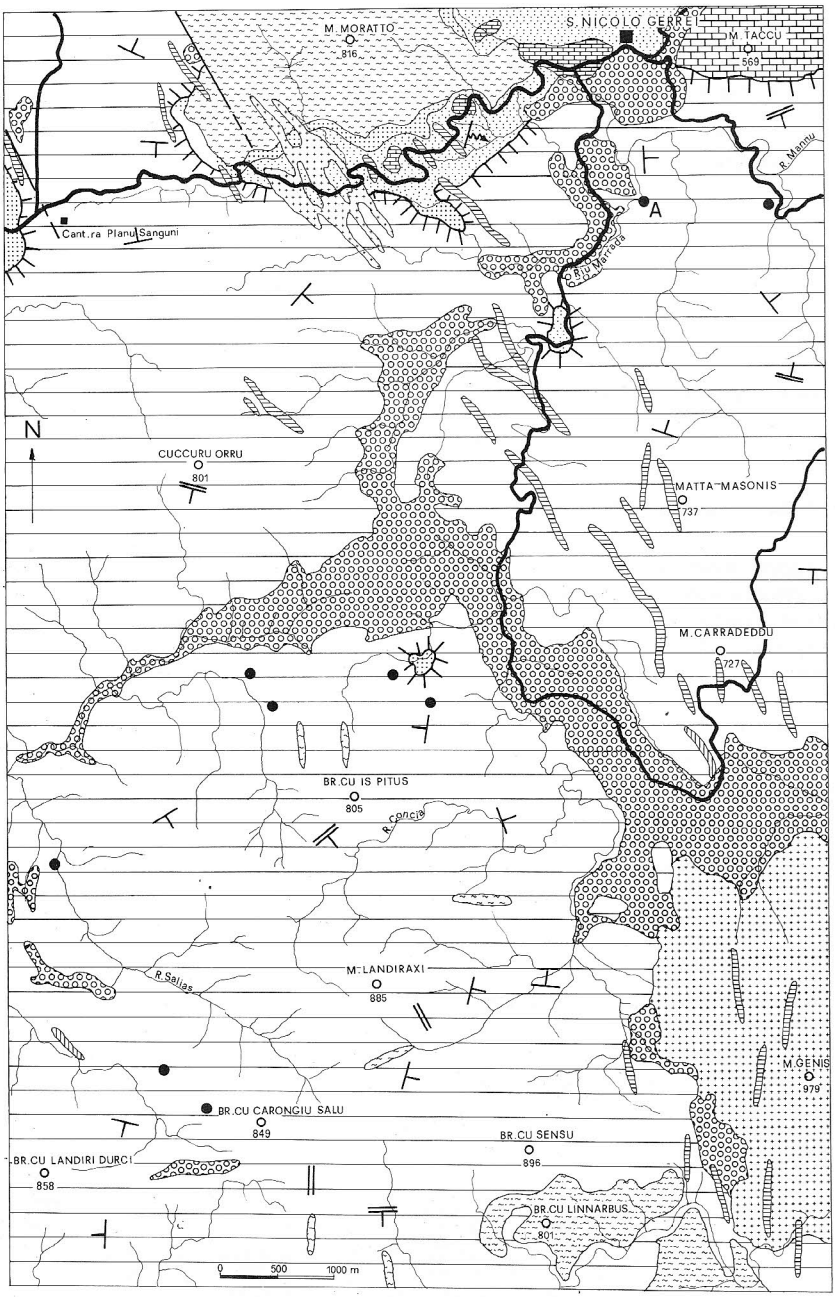
Introduction.

The San Vito Sandstone represents the most ancient formation in the Paleozoic sequence of the Sarrabus region (Southeastern Sardinia) which corresponds structurally to the Hercynian tectonic Unit of Genn'Argiolas (Carmignani et al., 1979).



The age of the San Vito Sandstone was determined on the basis of the acritarch associations of the Middle and Upper Cambrian found at two sites in the Western Sarrabus (Barca et al., 1982a). The age of this formation has, however, been extended to Lower Ordovician because of close facies and lithologic analogies with formations in other parts of the Island: the so-called "Post-gothlandian" Auct. of the Arburese area; the Cabitza Formation in Iglesiente-Sulcis; the Solanas Formation in the Sarcidano, Gerrei and the lower Flumendosa Valley etc. These formations have furnished acritarchs of Tremadocian-Arenigian age and, in the case of the Flumendosa Valley, of Middle-Upper Cambrian age too (Fig. 4). These formations are therefore commonly considered to be the lateral stratigraphic equivalents of the San Vito Sandstone (Barca et al., 1982b, 1984, 1987; Tongiorgi et al., 1982, 1984; Naud & Pittau Demelia, 1985).

The results of stratigraphic research, the subject of this paper, allow us to confirm the above interpretations on a paleontological basis. The latest findings of acritarchs are evidence of the actual presence of the Lower Ordovician (Tremadocian) in the Sarrabus formation; and consequently permit more complete and precise stratigraphic correlations with the other Cambrian-Lower Ordovician formations in Central-Southern Sardinia.

Geological outline.

The study area corresponds to a section of Northern Sarrabus, situated to the South of the San Nicolò Gerrei village (see maps: Tav. 226 II NE "Villasalto" and 226 II NW "San Nicolò Gerrei" of the I.G.M.).

The Paleozoic outcrops belong mostly to the Genn'Argiolas Unit (Fig. 1). This is the highest tectonic Unit of the Hercynian nappe belt in Southeastern Sardinia (Carmignani et al., 1979). The above Unit overthrusts from NNE to SSW, through the "Villasalto Overthrust" (Carmignani & Pertusati, 1979), on the Gerrei tectonic Unit and, in particular, the Monte Lora Unit (Fig. 2). The latter outcrops extensively to the North of the overthrust and may be followed within several tectonic windows to the South (Barca & Argiolas, 1985; Barca et al., 1986a). Some of these tectonic windows are located in this area.

The South-East Sardinian tectonic Units have, furthermore, a certain correlation with those of Central Sardinia (Sarcidano, Barbagia, Gennargentu) and Western Sardinia

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Fig. 1 - Geological map of the studied area in the Northern Sarrabus and location of sampling sites. Genn'Argiolas Unit (Sarrabus): 1) San Vito Sandstone (Middle to Upper Cambrian-Lower Ordovician); 2a) "Grey and White Porphyries" (Pre-Caradocian). Monte Lora Unit (Gerrei): 2b) "Porphyroids" (Pre-Caradocian); 3) Upper Ordovician sediments; 4) Lower Silurian to Lower Devonian sediments; 5) Middle to Upper Devonian sediments. Late-Hercynian magmatism: 6) Granitoid; 7) Dykes of reddish porphyry (a) and grey-green lamprophire (b); 8) Tertiary sediments; 9) Strike and dip of beds: weak dip (a), moderate dip (b), subvertical (c) and twisted (d) beds; 10) Villasalto Overthrust; 11) Main Tertiary faults; 12) Sampling sites for the acritarchs. A) site of the fossiliferous level.

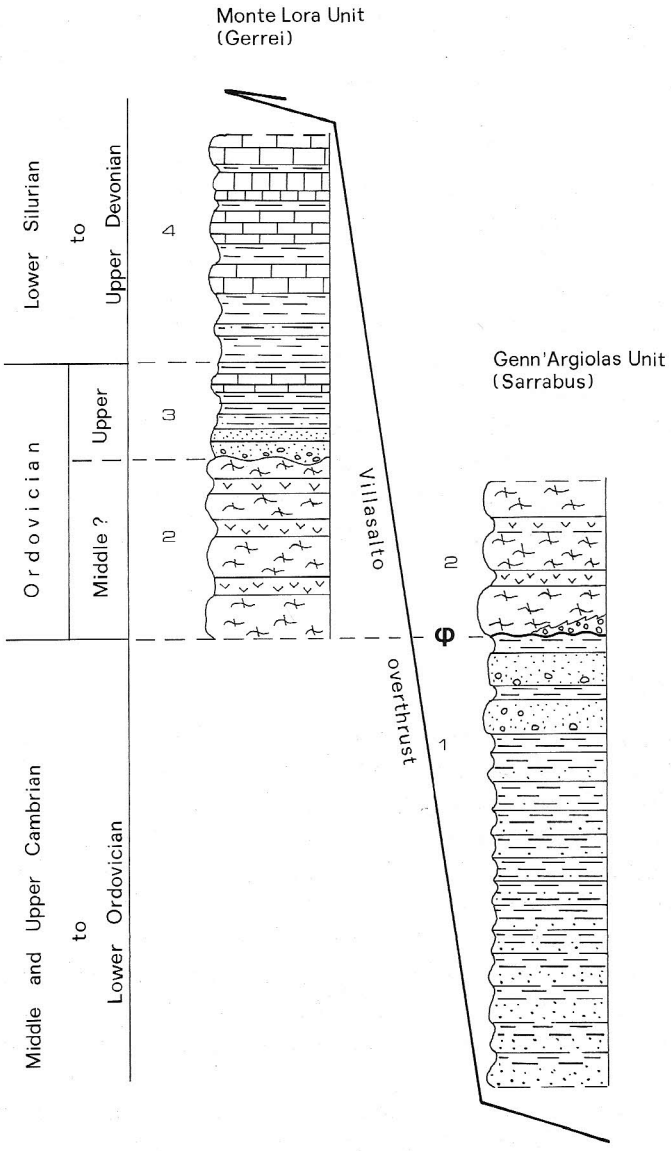

Fig. 2 - Stratigraphic columns (not to scale) of the Genn'Argiolas Unit (Sarrabus) and Monte Lora Unit (Gerrei).1) San Vito Sandstone; φ) Unconformity of Sarrabese Phase; 2) "Grey and White Porphyries", conglomerates and arkosic sandstones (Genn'Argiolas Unit), "Porphyroids" (Monte Lora Unit); 3) Conglomerates, sandstones, siltstones and mostly silicified limestones (Monte Lora Unit); 4) Black shales and limestones (Monte Lora Unit).

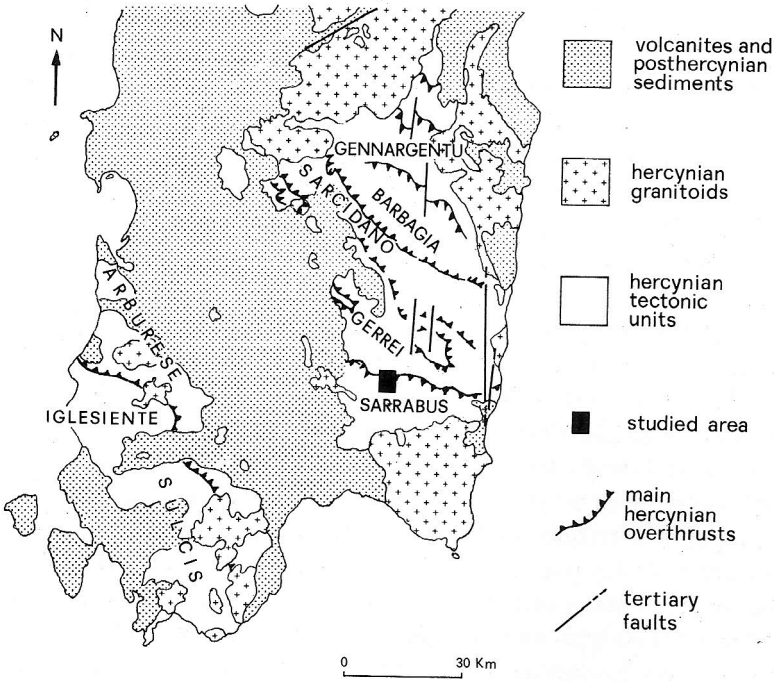

Fig. 3 - Simplified structural sketch-map of Central-Southern Sardinia and location of the studied area.

(Arburese, East Iglesiente-Sulcis) (Carmignani et al., 1979, 1982; Barca et al., 1982b; Barca, 1986; Barca et al., 1986a) (Fig. 3). All these Units are characterised by epimetamorphic (green schist facies) stratigraphic sequences which are often fossiliferous. Their ages range from Middle Cambrian to Lower Carboniferous, but are frequently incomplete because of tectonic thinning or elision. Their lithostratigraphic characteristics are however, quite similar, although there are differences, probably due to different original paleogeographic domains.

The Genn'Argiolas Unit.

This tectonic Unit is represented here only by the most ancient formations: the San Vito Sandstone and the White and Grey Porphyries (Calvino, 1961, 1967). The overlying fossiliferous sediments of the Upper Ordovician, Silurian-Devonian and perhaps Lower Carboniferous ages outcrop a little further to the South in the Southern Sarrabus area (Barca & Di Gregorio, 1980; Barca, 1982; Barca & Mascia, 1982; Barca et al., 1986b).

a) San Vito Sandstone (Calvino, 1961, 1967). It consists of well bedded siliciclastic sediments, at least 500 m thick. Its lower part is dominated by thick beds of quartzites

and darkish or lightish grey greywackes, with thin interlayered siltitic and pelitic levels ranging in colour from grey-green to blackish. This is followed by an intermediate succession which is characterised by densely alternating micaceous siltitic sandstones and lightish-grey, greenish or blackish pelites, rich in sedimentary structures due to submarine current (graded bedding, parallel and convoluted laminations, ripples, flute- casts etc.). Finally, most of the upper sequence is characterised by the presence of thick layers of whitish quarzites and fine- grained quartz-bearing conglomerates with well-rounded pebbles, into which thin grey-green, blackish and reddish siltitic and pelitic levels are interbedded.

The San Vito Sandstone outcropping in the study area is poor in macro- and microfossil remains. For the time being, the only paleontological documents are those reported by Barca et al. (1982a) and Debrenne & Naud (1981): they deal with the finding of Middle and Upper Cambrian acritarchs and of *Medusae* prints.

b) White and Grey Porphyries (Calvino, 1961, 1967). Massive rhyolitic and rhyodacitic volcanites (Memmi et al., 1982), from whitish to dark grey in colour, with an evident porphyritic texture and with "phenocrysts" of quartz, feldspars and biotite which markedly display phenomena of resorption. The groundmasse is generally microcristalline, more or less vitreous. The attitude consists of a complex of original lava-flows and lava-domes with associated volcanoclastic products. There are also dykes and lacolites of varying dimensions which intrude into the San Vito Sandstone. Crossing the latter there are discontinuous presences of arkosic conglomerates and sandstones that mark an important unconformity due to a tectonic phase known as "Sarrabese Phase".

It is realistic to put the age of these volcanites at Middle Ordovician, in that they precede the transgressive fossiliferous sediments of the Caradocian-Ashgillian age (Barca & Di Gregorio, 1980).

The Monte Lora Unit.

As already mentioned, this unit outcrops to the North of the Villasalto Overthrust, and to the South of this structure in a few small tectonic windows (Fig. 1). In this area the terrigenous sediments of the Cambrian-Lower Ordovician age which represent the lower part of the succession and outcrop in the lower Flumendosa Valley, are absent (Carmignani et al., 1982; Naud & Pittau Demelia, 1985).

Because of this the sequence from base to top is the following:

a)"Porphyroids (Calvino, 1961, 1967). They represent a facies largely deformed by the sincinematic Hercynian metamorphism of the pre-Caradocian volcanites outcropping in the Sarrabus area.

In fact, we are dealing also here with original rhyolitic- rhyodacitic volcanic products probably in the form of lava-flows, lava-domes, and subvolcanics bodies (Carmignani et al., 1982; Memmi et al., 1982). They appear a greyish-green, often with an augen texture, with large cataclastic "phenochrysts" of quartz and k-feldspar included in

a micro-crystalline chloritic- sericitic groundmasse. These porphyroids make up the relief of Monte Morattu, where they have a thickness of at least 200 m.

b) Upper Ordovician Sediments. In the lower part there are conglomerates and arkosic sandstones derived from the underlying metavolcanites. These are followed by more or less micaceous siltites and pelites sometimes carbonatic, from grey-green to reddish-purple in colour, often with a marked transversal cleavage. Locally badly preserved benthonic fossils have been recovered (brachiopods, crinoids, bryozoa etc.). In the upper part there are layers of pelitic-carbonatic origin, partially or wholly silicified, dark-grey or greenish-black in colour.

They are analogous to the "Quartzites of Sarrabus" Auct. or "Silicified Limestones" Auct., recently included in the Tuviois Formation of the Caradocian-Ashgillian age (Barca & Di Gregorio, 1980). The overall thickness, which is quite variable, can reach about 100 m.

c) Silurian-Devonian Sediments. Carbonaceous phillites with graptolites are attributed to the Silurian age. Black quartzites ("lidites") and, in the highest part also nodular limestones with orthoceratids and crinoids are interbedded.

The sequence continues with the Lower Devonian sediments represented by fossiliferous limestones (crinoids, orthoceratids, tentaculitids, conodonts etc.) interlayered with dark grey shales sometimes with tentaculitids.

The Middle and Upper Devonian outcrops at Monte Taccu of San Nicolò Gerrei in a thick succession of fossiliferous limestones (orthoceratids, goniatitids, crinoids, conodonts etc.) with thin levels of pelites. Further to the East, near Villasalto, these limestones have provided a conodont fauna of the Lower Tournaisian (Basal Carboniferous) age (Olivieri, 1970). Furthermore, above these limestones there are localised presences of conglomerates and siltites attributable to the Lower Carboniferous age (Teichmüller, 1931; Spalletta & Vai, 1982; Barca & Spalletta, 1984; Barca, 1986) presumably representing the "Sardic Hercynian flysch" sedimentation.

Hercynian Magmatism.

The granitoid rocks of the Sarrabus area are obviously later in relation to the main tectono-metamorphic Hercynian structures. They belong to the small massif of Monte Genis, which consists of mainly of biotitic granite with a micropegmatitic structure due to the presence of large phenocrysts of feldspar and quartz.

Both the granite and the epimetamorphic sequences are crossed by a dyke system of reddish porphyry and grey-green lamprophyre. The prevailing NNW-SSE direction of these obviously follows that of the main Late to Post-Hercynian fractures in the Paleozoic basement.

Data sampling.

About 30 samples have been collected from nine outcrops which are exposed along the North-Western slope of Bruncu Carongiu Salu, on the North of Bruncu is Pitus and at about 1.5 to 2.0 km SSE of the San Nicolò Gerrei village (Fig. 1, 4, 5). The samples for palynology have been chosen from the dark grey and greenish-grey metargillites, which are part of alternating sequences of metasandstones and metapelites of the San Vito Sandstone. Samples have been chemically treated with cold hydrofluoric acid, floated with zinc bromide at 2.0 d and the organic residues have been mounted in Elvacite resin. The acritarchs found are black, sometimes grey coloured and, for this reason, were not bleached.

Only one, collected in the outcrop A (see geological sketch of Fig. 1), in thirty samples yields acritarchs: this sample probably comes from the upper part of the San Vito Sandstone extensively outcropping in the studied area. In fact a few meters further on, the reddish metapelites outcrop along the same section. These reddish layers, generally, are characteristic of the higher stratigraphic levels.

The assemblage is poor in species: among them *Cymatiogalea cuvillieri* (Deunff) Deunff 1964 is well represented, followed by *Goniosphaeridium pungens* (Timofeev) Rauscher 1974.

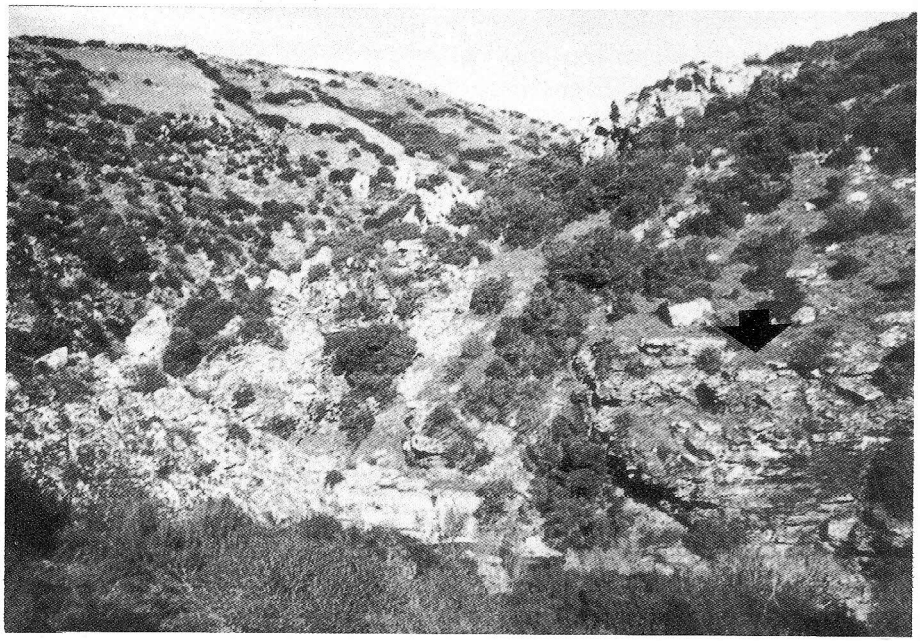

Fig. 4 - San Vito Sandstone outcrop of the fossiliferous locality: SE of San Nicolò Gerrei.

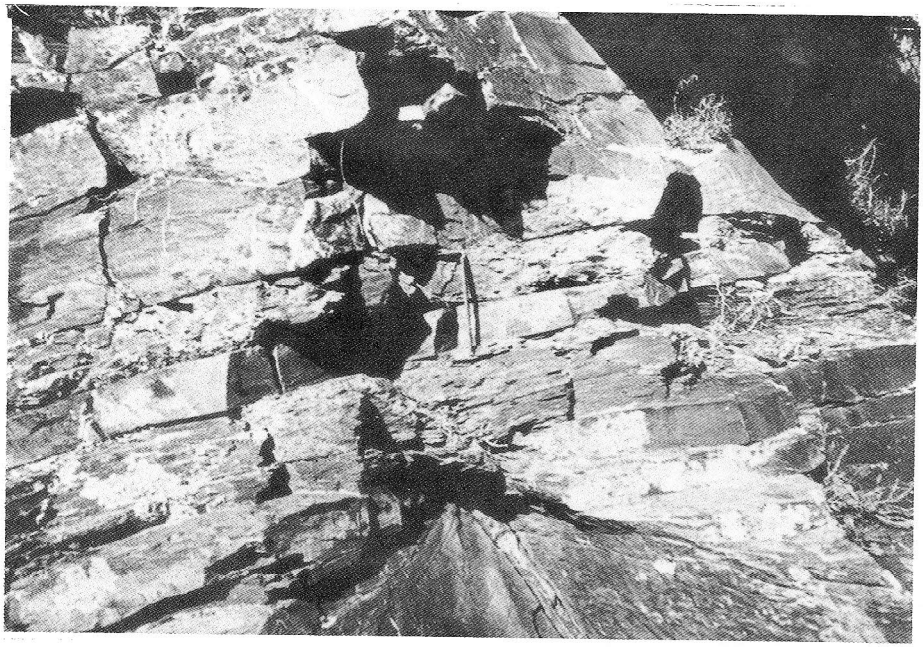

Fig. 5 - Detail of a typical sandstone-siltstone sequence of the San Vito Sandstone. Locality: the same of Fig. 4.

The acritarchs found, avoiding the use of Subgroups, are alphabetically listed below.

Abacum rude (Combaz) Pittau 1985
Acanthodiacrodium hexagonum Pittau 1985
Acanthodiacrodium partiale Timofeev 1959
Acanthodiacrodium cf. *A. serotinum* (Timofeev) Deflandre & Deflandre Rigaud 1962
Cymatiogalea cuvillieri (Deunff) Deunff 1964
Cymatiogalea sp.
Goniosphaeridium dentatum (Timofeev) Rauscher 1974
Goniosphaeridium pungens (Timofeev) Rauscher 1974
Leiosphaeridia sp.
Micrhystridium shinetonense Downie 1958
Micrhystridium stellatum Deflandre 1945
Stelliferidium pseudoornatum Pittau 1985
Stelliferidium sp.
Veryhachium sp.

Taxonomy

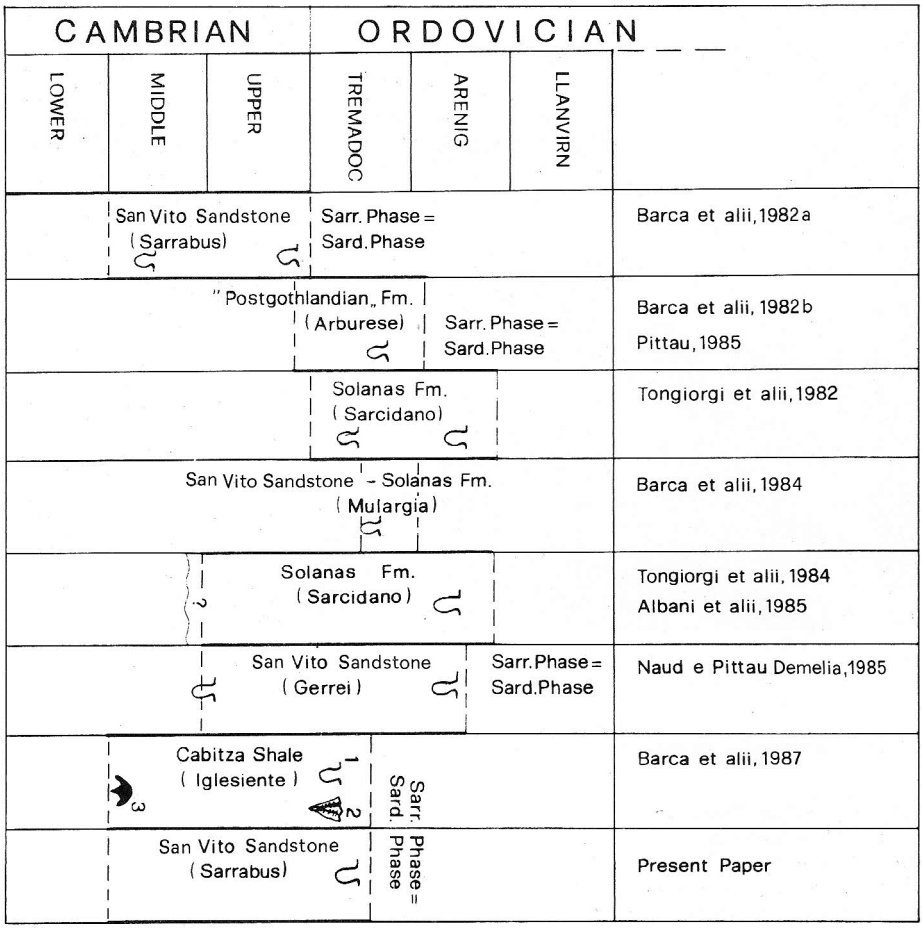

Fig. 6 - Summary of the recent stratigraphic interpretations of the San Vito Sandstone, Solanas Fm., Cabitza Shale and "Postgothlandian" Auct. outcropping in Central and Southern Sardinia, according to different authors. The stratigraphic attributions are inferred from the micropaleontological (acritarchs) and paleontological (trilobites and graptolites) content.

1967 *Virgatasporites rudi* Combaz, p. 12, pl. 1, fig. 27, 28.
1985 *Abacum rudis* - Pittau, p. 167, pl. 8, fig. 9,14; text- fig. 2.

Remarks. The specimens found are similar to those found in the Arburese Unit by Pittau (1985); only on some of them the radial ridges are narrower. The diameter of the vesicle is 19 to 25 μm.

Previous records. Tremadocian, Sahara (Combaz, 1967); Lower Ordovician, Sardinia (Pittau, 1985).

Genus *Acanthodiacrodium* Timofeev 1958 emend. Deflandre & Deflandre-Rigaud 1962

Type species *Acanthodiacrodium dentiferum* Timofeev 1958 (by subsequent designation: Deflandre & Deflandre-Rigaud, 1962)

Acanthodiacrodium hexagonum Pittau 1985

Pl. 48, fig. 3

1985 *Acanthodiacrodium hexagonum* Pittau, p. 174, pl. 5, fig. 8; text-fig. 5.

Remarks. The species is similar to that described in the Arburese Unit by Pittau (1985): four short and conical processes at each pole of the vesicle and the polygonal six sided outline. Their dimensions are somewhat larger than those stated for the species, 35 μm for the longest axis and 25 for the shortest; processes are about 5 μm long.

Previous records. The species has up to now been found in the Lower Ordovician, on the basis of acritarchs, of the Arburese Unit, Sardinia (Pittau, 1985).

Acanthodiacrodium partiale Timofeev 1959

Pl. 48, fig. 6

1959 *Acanthodiacrodium partiale* Timofeev, p. 78, pl.6, fig. 46.
1969 *Acanthodiacrodium partiale* - Martin, p. 124, pl. 1, fig. 2; text-fig. 76, 77.
1985 *Acanthodiacrodium partiale* - Pittau, p. 176, pl. 6, fig. 1, 2.
1987 *Acanthodiacrodium partiale* - Barca et al., p. 1110, pl. 1, fig. 5.

Remarks. Specimens are closely similar to those found in the Arburese Unit (Pittau, 1985). The vesicle is globular, with the polar axis only slightly larger than the equatorial one. On each pole the vesicle has five or six small conical processes and like others found in Sardinia, sizes are less than those stated for the species by Timofeev (1959).

The diameter of the vesicle is 28 to 30 μm for the mayor axis and 23 to 26 μm for the minor one. Coni about 3 μm.

Previous records. Upper Cambrian, Belgium (Martin, 1969); Lower Tremadocian, U.S.S.R. (Timofeev, 1959) and Bohemia (Jagielska, 1962). In Sardinia it has been found in undated sediments, referred to Tremadocian and Arenigian on the basis of acritarchs (Barca et al., 1984; Pittau, 1985; Barca et al., 1987).

Acanthodiacrodium cf. **A. serotinum** (Timofeev)
Deflandre & Deflandre-Rigaud 1962

Remarks. Only large fragments of vesicle have been found. The outline is more or less quadrangular for secondary inner piritisation and the processes, conical and slender, are 13 to 15 μm long. The species is presumably conspecific to Timofeev's species (1959, pl. 7, fig. 9), but a real evaluation is not possible without any integer specimen. A comparison with those previously found in the Arburese Unit (Lower Ordovician) by Pit-

tau (1985, p. 178, pl. 5, fig. 4, 9, text-fig. 7) reveals that the processes are longer than about 25%.

Genus *Cymatiogalea* Deunff 1961, emend. Deunff, Górka & Rauscher 1974

Type species *Cymatiogalea margaritata* Deunff 1961 (by original designation)

Cymatiogalea cuvillieri (Deunff) Deunff 1964

Pl. 48, fig. 4, 5

1961 *Priscogalea cuvillieri* Deunff, p. 41, pl. 1, fig. 2.
1964 *Cymatiogalea cuvillieri* - Deunff, p. 124, pl. 1, fig. 2, 3.
1967 *Cymatiogalea* cf. *cuvillieri* Combaz, p. 21, pl. 3, fig. 82.
1967 *Priscogalea* cf. *cuvillieri* Vanguestaine, p. 596, pl. 2, fig. 18, 19.
1970 *Cymatiogalea cuvillieri* - Martin, Michot & Vanguestaine, p. 343, pl. 1, fig. 1.
1973 *Priscogalea cuvillieri* - Martin, pp. 17-18, pl. 4, fig. 3, 4, 11, 17, 19; pl. 5, fig. 4, 23, 28; pl. 6, fig. 5; text-fig. 6, 7;? pl. 3, fig. 11, 15; pl. 9, fig. 6.
1974 *Priscogalea cuvillieri* - Deunff, Górka & Rauscher, p. 11, pl. 6, fig. 6,8.
1974 *Cymatiogalea cuvillieri* - Rasul, pp. 53-54, pl. 5, fig. 1, 2; pl. 7, fig. 2.
1974 *Cymatiogalea cuvillieri* - Rauscher, p. 66, pl. 1, fig. 27.
1985 *Cymatiogalea cuvillieri* - Albani et al., p. 10, pl. 2, fig. ?8, 9.
1987 *Cymatiogalea cuvillieri* - Barca et al., p. 1110, pl. 1, fig. 6, 7.

Remarks. Several specimens and numerous small and large fragments of *Cymatiogalea cuvillieri* have been found. They are black in colour, but nevertheless the characteristic features of the species are easily recognizable. They generally possess about thirteen polygonal fields with four and five sides: four plates are in the antiapical hemisphere and nine are connected to form the equatorial belt. Along the ridges delimitating the fields, three to five small and conical processes per side are distributed over, the base of which is more or less triangular. The maximum dimension of the plates is 13 to 15 μm. The equatorial diameter is 38 to 43 μm.

Previous records. *C. cuvillieri* is well known in the Lower Tremadocian of North Africa: Algerian Sahara (Deunff, 1961, 1964; Combaz, 1967; Jardiné et al., 1974); Libya (Deunff & Massa, 1975); Morocco (Elaouad-Debbaj, 1987). In the Tremadocian of Europe: Belgium (Vanguestaine, 1967); France (Martin, 1973; Rauscher, 1974); England (Rasul, 1974); Spain (Wolf, 1980). Lower Tremadocian of Canada (Martin in Martin & Dean, 1981). Probably Upper Cambrian-Lower Tremadocian, central Sardinia (Albani et al., 1985) and Lower Tremadocian, *Dictyonema flabelliforme* shales (Barca et al., 1987). Caradocian (reworked specimens?), Belgium (Martin et al., 1970).

Cymatiogalea sp.

Remarks. The state of preservation does not allow any certain specific attribution of the specimens recovered. The shape of the vesicle is globular with a large polar open-

ing, the margin of which is surrounded by a small collar. Numerous, broken processes are linked by ridges. The diameter of the major axis is 38 to 42 μm.

Genus *Goniosphaeridium* Eisenack 1969, Kjellström 1971

Type species *Goniosphaeridium* (ex *Ovum-hispidum*) *polygonale* Eisenack 1969 (by original designation)

Goniosphaeridium dentatum (Timofeev) Rauscher 1974

1959 *Archaeohystrichosphaeridium dentatum* Timofeev, p. 41, pl. 3, fig. 44.
?1969 *Baltisphaeridium (Archaeohystrichosphaeridium) dentatum* - Konzalovà - Mazancovà, p.87, pl. 15, fig. 6.
1969 *Baltisphaeridium lucidum* - Martin, pp. 56-57, pl. 4, fig. 193, 195.
1974 *Goniosphaeridium dentatum* - Rauscher, p. 61, pl. 1, fig. 6.
1977 *"Goniosphaeridium" (Polygonium) dentatum* - Baudelot & Bessière, pl. 41, fig. 11.
1978 *Goniosphaeridium dentatum* - Fournier-Vinas, p. 265, pl. 2, fig. 10.
1982 *Goniosphaeridium dentatum* - Cocchio, p. 28, pl. 1, fig. 2.
1984 *Goniosphaeridium dentatum* - Barca et al., p. 321, pl. 27, fig. 8.
1985 *Goniosphaeridium dentatum* - Pittau, p. 185, pl. 6, fig. 11, 15.
1986 *Goniosphaeridium dentatum* - Welsch, p. 45, pl. 9, fig. 8, 12 (non fig. 9-11).

Remarks. The main features of the species which are common to the specimens found up to now in the Sardinia formations are: the polygonal vesicle with arched sides in the outline; numerous and slender processes with tipped terminations and smooth surface; sizes fluctuating around 25 to 30 μm for the diameter of the central body. Sizes of body and processes in particular are considerably less than those stated for the species.

Previous records. Upper Cambrian to Arenigian of Europe: U.S.S.R. (Timofeev, 1959); Belgium (Martin, 1969); France (Rauscher, 1974; Baudelot & Bessière, 1977; Fournier-Vinas, 1978; Cocchio, 1982); Spain (Wolf, 1980); Norway (Welsch, 1986); Sardinia (Barca et al., 1984; Pittau, 1985; Albani et al., 1985). Tremadocian to Lower Llanvirnian of North Africa: Lybia (Deunff & Massa, 1975); Algeria (Baudelot & Géry, 1979); Morocco (Fournier- Vinas, 1985). Lower Ashgillian of Bohemia (Konzalovà - Mazancovà, 1969).

Goniosphaeridium pungens (Timofeev) Rauscher 1974

Pl. 48, fig. 1

1959 *Archaeohystrichosphaeridium pungens* Timofeev, p. 39, pl. 3, fig. 33.
1969 *Baltisphaeridium pungens* - Martin, p. 60, pl. 1, fig. 16, 23, 24, 34.
1974 *Goniosphaeridium pungens* - Rauscher, p. 62, pl. 1, fig. 7, 8.
1975 *Goniosphaeridium pungens* - Deunff & Massa, p. 22, pl. 1, fig. 8.
1975 *Goniosphaeridium pungens* - Umnova, pp. 60-61, pl. 5, fig. 16.
1977 *Goniosphaeridium pungens* - Martin, p. 24, pl. 2, fig. 3.
1977 *"Goniosphaeridium" (Polygonium) pungens* - Baudelot & Bessière, pl. 41, fig. 22.
1978 *Goniosphaeridium pungens* - Fournier-Vinas, p. 265, pl. 2, fig. 14, 17.
1980 *Goniosphaeridium pungens* - Aristova, pl. 2, fig. 8.
1982 *Goniosphaeridium pungens* - Cocchio, p. 31, pl. 1, fig. 1.
1984 *Goniosphaeridium pungens* - Barca et al., p. 321, pl. 27, fig. 12.

1985 *Goniosphaeridium pungens* - Albani et al., p. 185, pl. 2, fig. 17, 18.
1985 *Goniosphaerisium pungens* - Pittau, p. 185, pl. 6, fig. 14, 23.
1986 *Goniosphaeridium pungens* - Welsch, pl. 9, fig. 9-11.

Remarks. Fifteen conical and slender processes emerge from the globular and polygonal vesicle; the outer surface of processes bears small punctae. Sizes are the same as those found for the species in other formations of Sardinia: diameter of vesicle ranging from 27 to 37 μm; length of processes 10 to 15 μm.

Previous records. Tremadocian and Arenigian of Europe: U.S.S.R. (Timofeev, 1959; Umnova, 1975; Aristova, 1980); Bohemia (Jagjelska, 1962); Belgium (Martin, 1969, 1977); France (Rauscher, 1974; Baudelot & Bessière, 1977; Fournier-Vinas, 1978; Cocchio, 1982); Norway (Welsch, 1986). Tremadocian of North Africa: Lybia (Deunff & Massa, 1975); Algeria (Baudelot et al., 1981). Lower Ordovician of Sardinia (Barca et al., 1984; Pittau, 1985; Albani et al., 1985).

Genus *Stelliferidium* Deunff, Górka & Rauscher 1974

Type species *Stelliferidium (ex Baltisphaeridium) striatulum* (Vavrdovà) Deunff, Górka & Rauscher 1974 (by original designation)

Stelliferidium pseudoornatum Pittau 1985

1985 *Stelliferidium pseudoornatum* Pittau, p. 195, pl. 8, fig. 11, 12; text-fig. 24.

Remarks. Only few specimens with globular test bearing an oval aperture and small coni or punctae distributed over the vesicle surface. Sizes are within the range of the species, oscillating between 23 to 28 μm for the vesicle diameter.

Previous records. Only in the Arburese Unit of Sardinia, Lower Ordovician, on the basis of acritarchs (Pittau, 1985).

Genus *Veryhachium* Deunff (1954) ex Downie 1959 emend. Downie & Sarjeant 1963

Type species *Veryhachium (ex Hystrichosphaeridium) trisulcum* (Deunff) Deunff 1959 (by original designation)

Veryhachium sp.

Pl. 48, fig. 2

Remarks. Incomplete specimens of *Veryhachium* of uncertain specific attribution are rarely present in the association.

Biostratigraphy.

The organic walled microfossils of the association herein described are seriously damaged; they frequently show broken vesicle and a deformation on the preferential

axis: this is very likely due to the tectonic stress which was greater on one direction.

The acritarchs found are typical of the Lower Ordovician age and, except for *Micrhystridium shinetonense* and *Micrhystridium stellatum* which get through Arenigian, almost all are found to be present in the Tremadocian and Arenigian of Europe. Particular consideration is due to the species *Cymatiogalea cuvillieri* which is found only in the Uppermost Cambrian and Tremadocian and is limited to the Lower Tremadocian in most of Western Europe, North Africa, Eastern Canada and Argentina (for reference see this paper and Martin in Martin & Dean, 1981). Only in Great Britain, the Shineton Shales (Rasul & Downie, 1974; Rasul, 1974), *C. cuvillieri* is present throughout the whole Tremadocian. Until now, this species has been found in Sardinia in the oldest fossiliferous levels, dated by acritarchs, of the Arburese Unit (Southwestern Sardinia): it appears in assemblage with *Cristallinum cambriense* (Slavikovà) Vanguestaine, *Timofeevia phosphoritica* Vanguestaine, *Acanthodiacrodium simplex* Combaz, *Stelliferidium cortinulum* (Deunff) Deunff, Górka & Rauscher, as well as several species of *Impluviculus* and *Trunculumarium* sp. This assemblage was considered to belong to the Uppermost Cambrian-Lowermost Tremadocian by Pittau (1985), and more likely to the Early Tremadocian with probable reworked elements due to the turbiditic sedimentation.

In the Cabitza Formation (South Sardinia) *Cymatiogalea cuvillieri* is present in the levels containing *Dictyonema flabelliforme* Eichwald (Pittau Demelia in Barca et al., 1987) and is associated with *Acanthodiacrodium angustum* Downie which abounds there

The Solanas Formation of Central Sardinia (Albani et al., 1985; Naud & Pittau Demelia, 1985) includes a Tremadocian assemblage of acritarchs. Thus the stratigraphic "presence" of *Cymatiogalea cuvillieri* in Sardinia, seems to be in accordance with its known distribution throughout the world, and as elsewhere in Sardinia, this species may considered to be restricted to the Uppermost Cambrian to Lower Tremadocian. As regards the assemblage found we feel strongly that the pertinent sedimentary level should be ascribed to the Lower Tremadocian.

Conclusions.

On the basis of their lithostratigrafic and structural characteristics the Paleozoic successions identified in the study area are ascribed to the tectonic Hercynic Units of Genn'Argiolas (Sarrabus) and Monte Lora (Gerrei). The Genn'Argiolas Unit overlaps the Monte Lora Unit in a segment of the Villasalto Overthrust. The regional importance of the latter is highlighted by the presence of tectonic windows; in fact, corresponding to these tectonic windows neo-Ordovician and Silurian-Devonian formations typical of the Gerrei Unit outcrop under the Cambrian-Lower Ordovician sediments of the Sarrabus Unit.

Finds of Tremadocian acritarchs in the upper part of the San Vito Sandstone of the Genn'Argiolas Unit is particularly interesting. In fact this allows us, on a paleontological basis, to extend the age of the Sarrabus formation from the already known Middle and Upper Cambrian (Barca et al., 1982a) to the Lower Ordovician. As a con-

sequence of this, the Sarrabese Phase can now be ascribed to a post-Tremadocian age (probably Middle Ordovician). The aforementioned Phase separates the San Vito Sandstone from the overlying complex of "White and Grey Porphyries" and from the successive Caradocian-Ashgillian sediments in the South-East of Sardinia. Also the acid volcanites which precede the Caradocian transgression are now reliably dated as post-Tremadocian and therefore attributed to the Middle Ordovician (Llanvirnian-Llandeilian).

Furthermore this new data make more detailed comparisons with other areas of the Island possible: in particular comparisons with Central Sardinia and with Arburese (Northern Iglesiente). In these areas a tectonic phase has settled between the Cambrian-Lower Ordovician terrigenous sediments (very similar to the San Vito Sandstone) and the volcano-sedimentary complexes of the Middle and Upper Ordovician: Monte Corte Cerbos Fm., "Porphyroids", Serra Tonnai Fm., the fossiliferous sediments of the Caradocian-Ashgillian age (Carmignani et al., 1982; Tongiorgi et al., 1982; Albani et al., 1985; Barca et al., 1988 in press).

A closer stratigraphic correspondence now emerges also with the Cabitza Shales in Iglesiente-Sulcis (South-East Sardinia), and with the Sardic Phase.

The latter is highlighted by the classic unconformity between the Cabitza Shales (Middle Cambrian to Lower Ordovician: Barca et al., 1987) and the overlying neo-Ordovician sediments ("Puddinga" and the fossiliferous sediments of the Caradocian-Ashgillian age).

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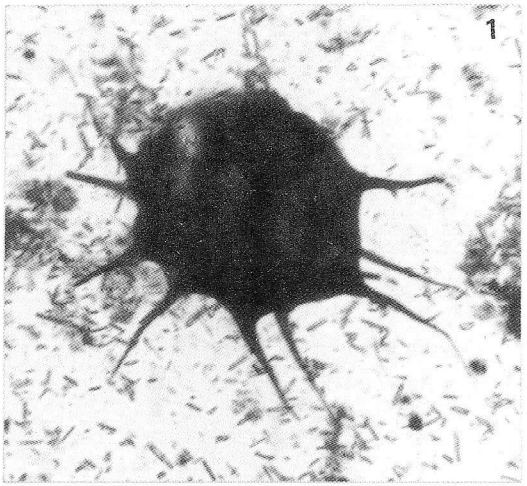
PLATE 48

Fig. 1 - *Goniosphaeridium pungens* (Timofeev) Rauscher 1974
Fig. 2 - *Veryhachium* sp.
Fig. 3 - *Acanthodiacrodium hexagonum* Pittau 1985.
Fig. 4 - *Cymatiogalea cuvillieri* (Deunff) Deunff 1964.
Fig. 5 - *Cymatiogalea cuvillieri* (Deunff) Deunff 1964. Large fragment.
Fig. 6 - *Acanthodiacrodium partiale* Timofeev 1959.
Fig. 7 - *Abacum rude* (Combaz) Pittau 1985. (All magnifications x 1000).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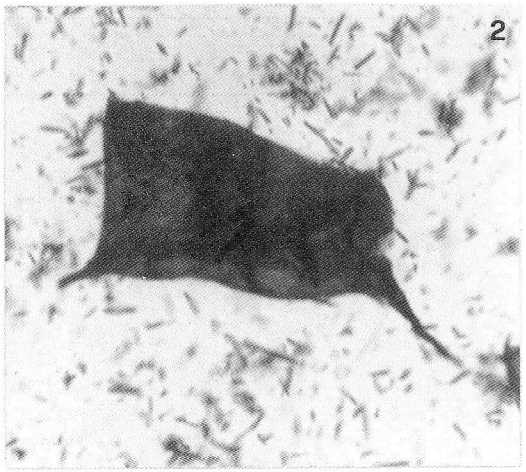
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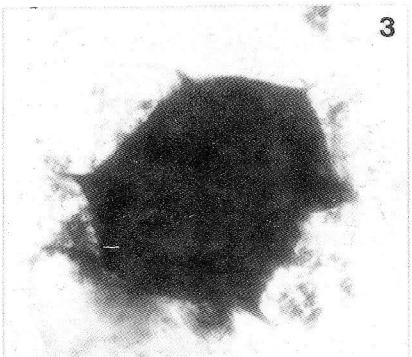
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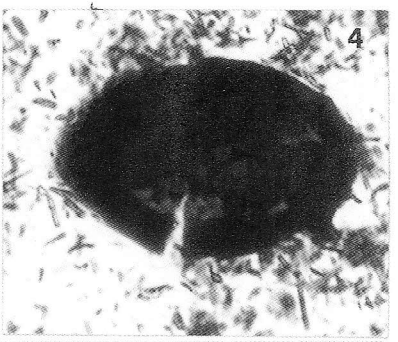
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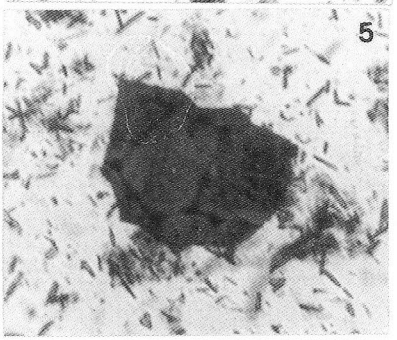
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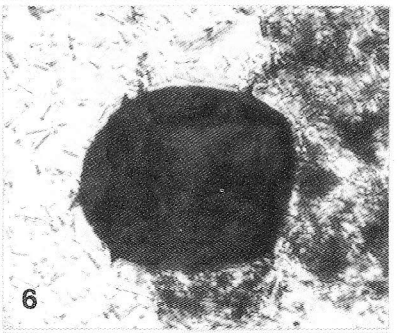
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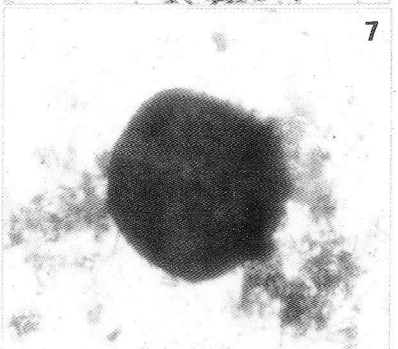
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