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Insect pupation chambers from the Pleistocene paleosols of Santo Stefano Island (Pontine Archipelago, Central Italy)

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SUMMARY - *Insect pupation chambers from the Pleistocene paleosols of Santo Stefano Island (Pontine Archipelago, Central Italy)* - Fossil insect pupation chambers were found on the Santo Stefano Island (Pontine Archipelago, Central Italy) during a survey within a geo-archaeological re-evaluation project of the island. The ichnofossils were discovered within a paleosol interbedded with pyroclastic deposits attributed to the Pleistocene. The specimens show features comparable both to the ichnogenus *Rebuffoichnus* Roselli 1987 and to the ichnogenus *Fictovichnus* Johnston, Eberth & Anderson 1996. The respective ichnotaxonomic characters are here compared.

RIASSUNTO - *Camere pupali di insetti nei paleosuoli pleistocenici dell'Isola di Santo Stefano (Arcipelago Pontino, Italia centrale)* - Alcune camere pupali fossili di insetti sono state rinvenute sull'Isola di Santo Stefano (Arcipelago Pontino, Italia centrale) durante una prospezione geo-archeologica dell'isola. Gli icnofossili sono stati individuati all'interno di un paleosuolo, intercalato a depositi piroclastici riferibili al Pleistocene. Il materiale mostra caratteristiche confrontabili sia con l'icnogenere *Rebuffoichnus* Roselli 1987, sia con l'icnogenere *Fictovichnus* Johnston, Eberth & Anderson 1996. I rispettivi caratteri icnotassonomici sono qui confrontati.

Key words: Fictovichnus, *Rebuffoichnus*, fossil pupation chambers, bioturbation, Pleistocene
Parole chiave: Fictovichnus, *Rebuffoichnus*, camere pupali fossili, bioturbazioni, Pleistocene

1. INTRODUCTION

Some insect pupation chambers were recently discovered within a paleosoil of the Santo Stefano Island (Pontine Archipelago, Central Italy). The trace fossil-bearing level can be assigned to a lithostratigraphic unit ascribed to the Pleistocene. The new finding occurred during a geological and archaeological survey of the island, commissioned by the Soprintendenza per i Beni Archeologici del Lazio, to individuate and document the cultural and natural heritage of the island.

At first the material has been ascribed to *Rebuffoichnus* cf. *casamiquelai* Roselli 1987 (Sacchi & Petti 2007). Subsequent studies re-opened the problem of their ichnotaxonomic attribution. The specimens have been compared with *Rebuffoichnus* Roselli 1987 coming from the Paleogene of Uruguay (Roselli 1987; Genise *et al*. 2002a), from the Upper Cretaceous of Argentina (Genise *et al*. 2002a, 2002b; Genise *et al*. 2007) and from the Pleistocene of Spain (Genise & Edwards 2003), and with *Fictovichnus* Johnston, Eberth & Anderson 1996 from the Upper Cretaceous of Mongolia. This is the first well documented report and the second finding of fossil pupation chambers in Italy. The first finding occurred from a Middle Pleistocene paleosol cropping out in the eastern sector of Rome (Sacchi unpublished data).

2. GEOGRAPHICAL LOCATION AND GEOLOGICAL SETTING

The Santo Stefano Island belongs to the Pontine Archipelago, situated 30 km south of the Gulf of Gaeta and at the border of the continental shelf (Fig. 1). It pertains, with the Ventotene Island, to the Eastern Pontine Islands. Even if the two islands are today well separated they represent the remnants of a huge volcanic edifice, the so called "Ventotene volcano", that was active between 0.92 Ma and 0.33 Ma according to the K/Ar isotopic data (Metrich *et al*. 1988; Bellucci *et al*. 1999a, 1999b). In a recent geological map of the Santo Stefano Island (scale 1:15.000; Bellucci *et al*. 1999b), three lithostratigraphic units have been recognized, namely: the Santo Stefano formation, the Villa Giulia unit, and aeolian deposits at the topmost of the succession (Fig. 2).

The basal unit (Santo Stefano formation) is subdivided into two members. The first one is constituted by lava flows with columnar joints and ramp structures passing upward to scoria layers; these deposits are overlaid by the second member made by massive pyroclastic deposits mainly composed of pumice fragments and followed upward by a black scoria layer. The Santo Stefano formation is replaced upward by trachytic to phonolitic pyroclastic deposits (Villa Giu-

Fig. 1 - Satellite image of the Pontine Archipelago. Scale bar 30 km.
Fig. 1 - Immagine da satellite dell'Arcipelago Pontino. Scala 30 km.

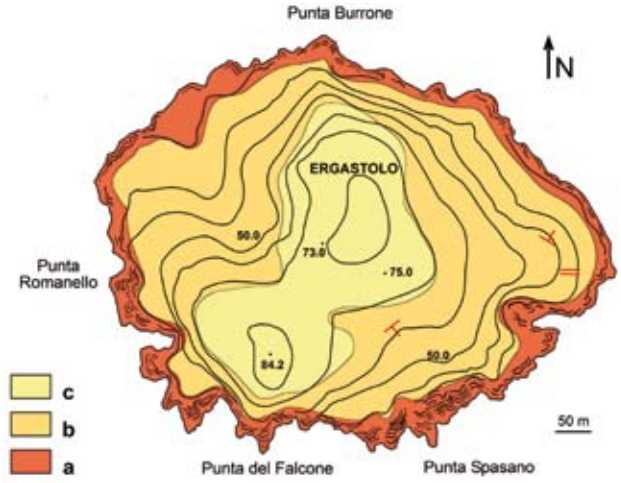


Fig. 2 - Geological map of the Santo Stefano Island. a. Santo Stefano formation; b. Villa Giulia unit; c. aeolian deposits. From Bellucci *et al.* 1999b redrawn and modified.
Fig. 2 - Carta geologica dell'Isola di Santo Stefano. a. formazione di Santo Stefano; b. unità di Villa Giulia; c. depositi eolici. Da Bellucci et al. *1999b ridisegnato e modificato.*

lia unit) through an irregular surface (Fig. 3). These deposits dip radially and are constituted by an alternance of white pumice fall beds, stratified ash beds and paleosols of pyroclastic origin. At the top of the island aeolian deposits have been signalled (Bellucci *et al*. 1999b) although nowadays they are not well recognizable due to the vegetal cover and buildings (Santo Stefano penal complex).

The trace-bearing levels belong to a paleosoil interlayered with pyroclastic deposits (Villa Giulia unit; Bellucci *et al*. 1999a, 1999b). It is possible to chronologically constraint the ichnofossils to a time interval between 0.81±0.02 Ma, the age of the first member of the Santo Stefano formation, and 0.33±0.01 Ma, the age of the last pyroclastic flow of the Ventotene volcano (Bellucci *et al*. 1999a).

3. MATERIAL

Six ichnofossils were collected within an incoherent paleosol (Fig. 4). Each specimen was labelled with the acronym SST (Santo Stefano) followed by a progressive number. The samples were prepared for thin section analysis by first impregnating the samples with epoxy resin to augment cohesion and to prevent loss of material. The material is represented by sub-ellipsoidal structures excavated in the paleosoil, showing the long axis always parallel to bedding (Fig. 5).

The specimens are fragmentary or incomplete, due to the erosion or to the low paleosoil cohesion that does not allow a complete recovery (Fig. 6). Nevertheless, the morphological analysis has allowed to reconstruct the structure of the ichnofossils. The longitudinal section of the chamber shows a sub-elliptical profile with flanks gently bending toward the ends; the transversal section is sub-circular (Fig. 7). Being the chamber an ellipsoid with sub-circular transversal section, we can describe it with two parameters: the long and the short axis. In the collected specimens the length of the long axis is on average 52.0 mm (three specimens), while the average length of the short axis is 24.6 mm (five specimens). However one of the specimens (SST1) has a short axis 25.0 mm in length with a partial long axis of about 53.0 mm (it lacks one of the ends). Taking into account the chamber bending the long axis should probably reach at least 70 mm in length.

To make comparisons with other ichnofossils the long axis-to-short axis ratio has been calculated. It results on average equal to 2.1, except for the SST1. The chambers are completely filled with fine grained sediments and with scattered coarser clasts ranging in diameter from 1 mm to 3 mm. The filling is made of the same sediments in which the chamber has been excavated and does not display any trace of organization such as meniscate structures, suggesting a passive fill of the chamber.

The surface of the filling is often burrowed by roots. Roots probably have preferred the discontinuity surface between the wall and the fill of the chamber.

Chamber surface is smooth showing in some cases a dark brown coating. Since trace fossils are incomplete, there is no evidence of exit holes.

In some cases, around the cavity differential erosion has produced a discrete zone which simulates a three-dimensional wall. However the outermost part of this zone does not show a sharp boundary, which is even not identifiable in the samples analyzed in thin sections. The thickness of this zone is difficult to measure, and it varies approximately from 6 to 10 mm. Grains are not oriented.

4. DISCUSSION

The Santo Stefano ichnofossils have been compared to the similar material described in the literature and referable to fossil insect pupation chambers. On the basis of their

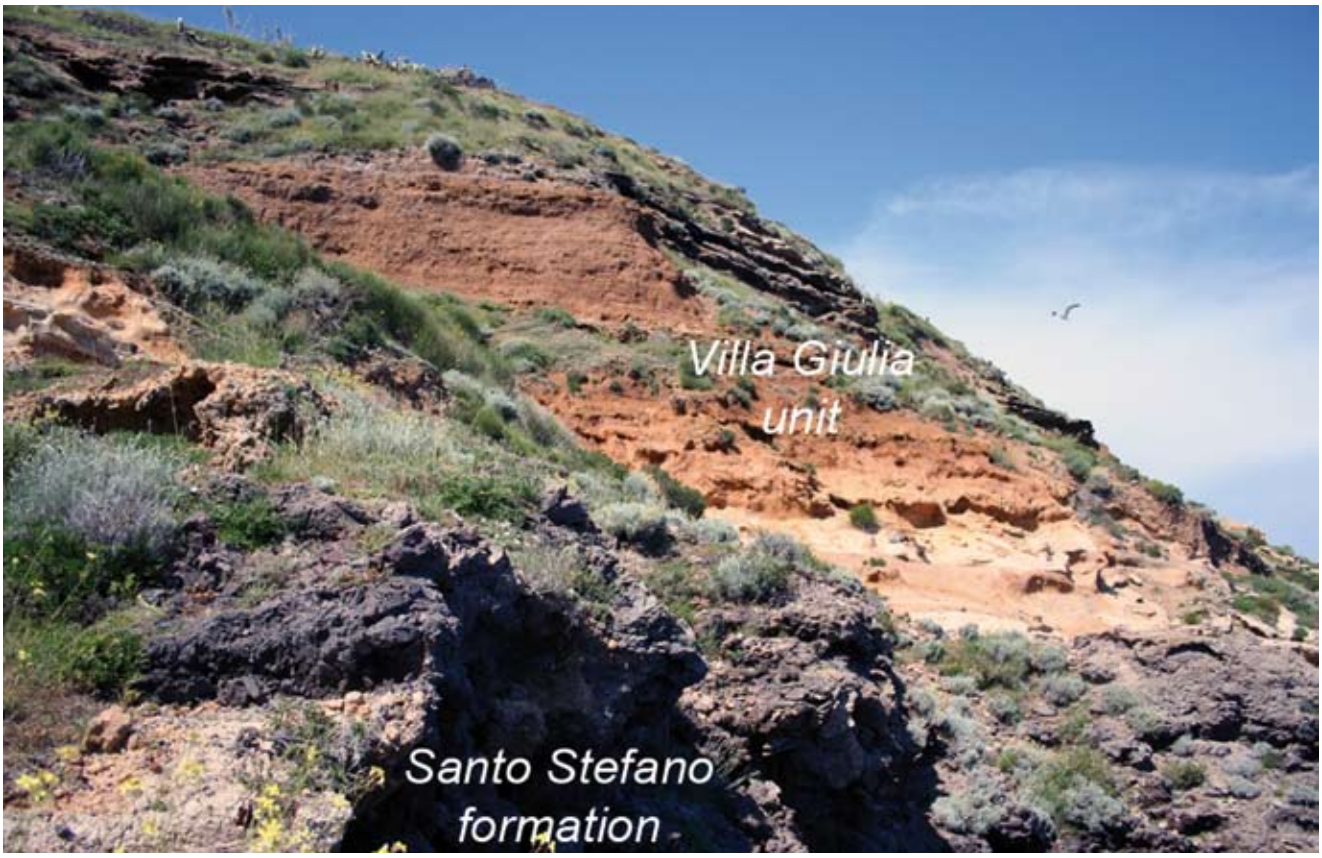


Fig. 3 - Stratigraphic boundary between the Santo Stefano formation and the Villa Giulia unit.
Fig. 3 - Limite stratigrafico tra la formazione di Santo Stefano e l'unità di Villa Giulia.

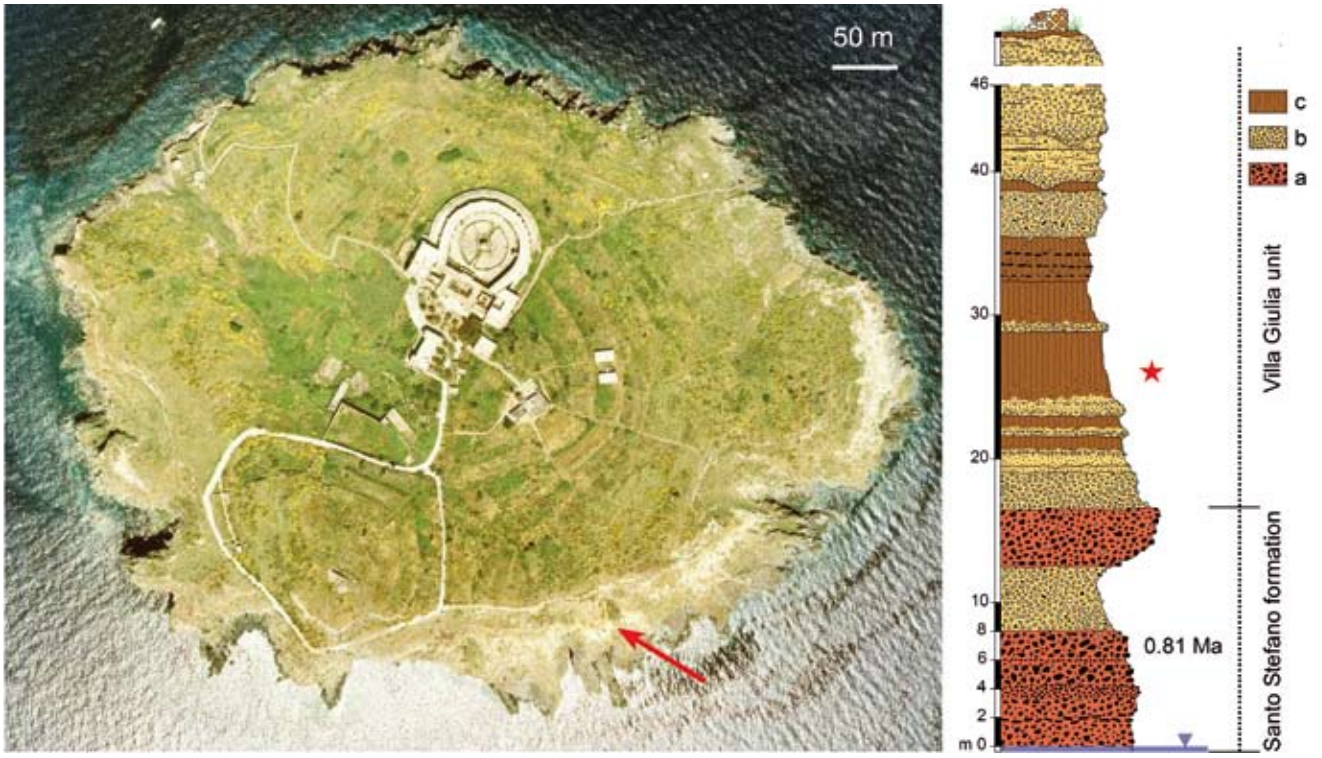
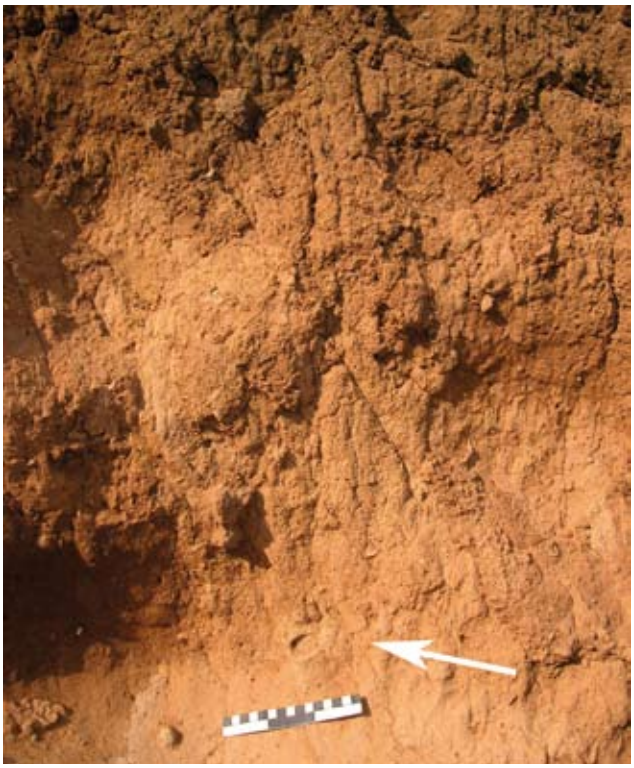


Fig. 4 - Aerial view of the Santo Stefano Island and stratigraphic log of the analyzed section. The arrow indicates the location of the section and the star the trace fossil-bearing level.
Fig. 4 - Foto aerea dell'Isola di Santo Stefano e log stratigrafico della sezione analizzata. La freccia indica l'esatta posizione della sezione, la stella il livello con gli icnofossili.



morphological feature, the discovered morphotypes appear similar to the ichnogenus *Rebuffoichnus* Roselli 1987, coming from Argentina, Uruguay and Spain and attributed to coleopteran pupation chambers (Roselli 1987; Genise *et al*. 2002a, 2002b; Genise & Edwards 2003; Genise 2004; Genise *et al*. 2007). Our specimens share with *Rebuffoichnus* Roselli 1987 morphological features, type of filling (passive fill) and long axis-to-short axis ratio values. In particular *Rebuffoichnus casamiquelai* Roselli 1987, re-described by Genise *et al*. (2002a), has a long axis-to-short axis ratio of about 2 that completely fits with the material from Santo Stefano Island. Genise *et al*. (2007) reported an average long axis-to-short axis ratio of 2.22 for *R. casamiquelai*, still comparable with the Italian specimens. On the other hand, absolute dimensions are well different being the long axis of *R. casamiquelai* 40-60% shorter in comparisons to the values of the examined samples. Nevertheless the similarity between Italian specimens and *R. casamiquelai* figured

Fig. 5 - Fossil pupation chamber within the paleosoil of the Villa Giulia unit. The arrow indicates the ichnofossil.
Fig. 5 - Camera pupale fossile all'interno del paleosuolo dell'unità di Villa Giulia. La freccia indica la posizione dell'icnofossile

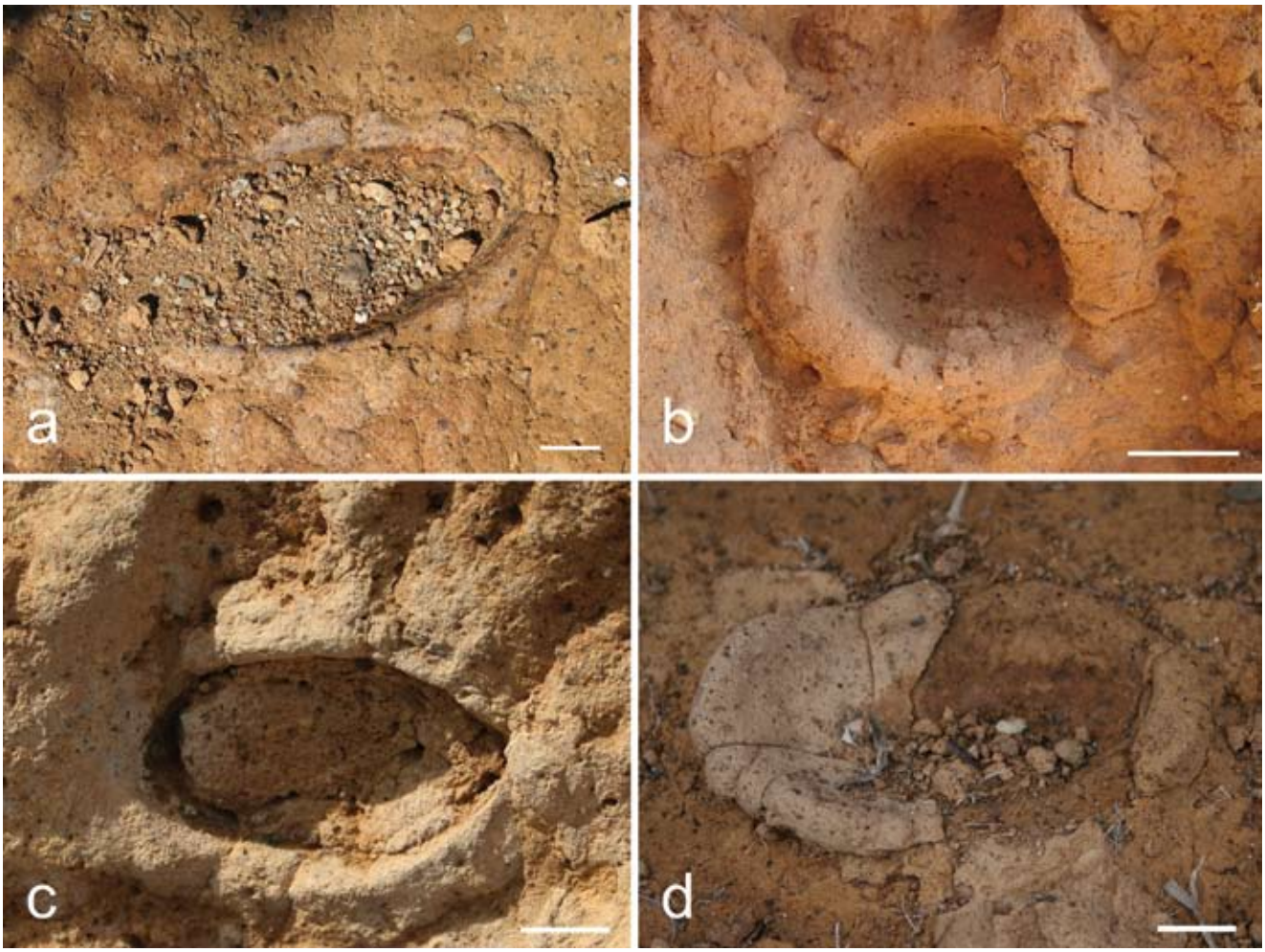


Fig. 6 - Specimens of the Santo Stefano Island fossil pupation chambers. a. SST6; b. SST1; c. SST5; d. SST2. Scale bar 1 cm.
Fig. 6 - Esemplari delle camere pupali fossili dell'Isola di Santo Stefano. a. SST6; b. SST1; c. SST5; d. SST2. Scala 1 cm.

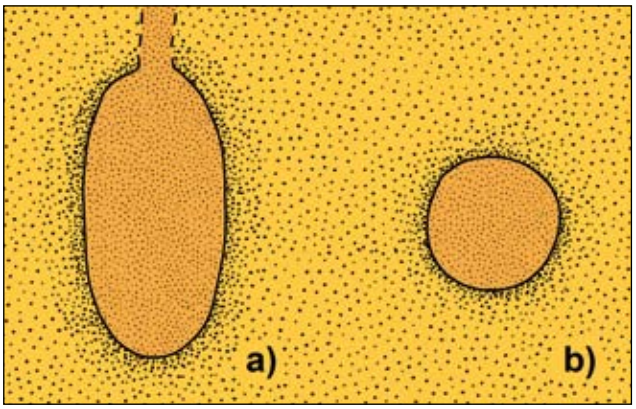


Fig. 7 - Schematic drawing of the Santo Stefano Island fossil pupation chambers. a. Longitudinal section; b. transversal section.
Fig. 7 - Disegno schematico delle camere pupali fossili dell'Isola di Santo Stefano. a. sezione longitudinale; b. sezione trasversale.

by Genise *et al.* (2007: fig. 7A) is remarkable. Also *Rebuffoichnus sciuttoi* Genise *et al.* 2007 has a similar long axis-to-short axis ratio with respect to the studied material, but it is smaller in absolute dimensions; the long axis of the examined specimens is 2/3 longer than for *R. sciuttoi*. The chamber architecture of the two above mentioned ichnospecies is characterized by the occurrence of a constructed wall (*sensu* Genise 2004). As stated by Genise (2004) "each constructed wall in a soil produces at least three surfaces, the inner and outer surface of the constructed structure and the surface of the bearing cavity" (Genise 2004: 423). The Santo Stefano ichnofossils differ from *R. casamiquelai* and *R. sciuttoi* because they only display the surface of the cavity.

The material under examination could be also compared with the ichnogenus *Fictovichnus* Johnston, Eberth & Anderson 1996 from the Upper Cretaceous of Mongolia. This latter, with passive fill and sub-ellipsoidal in shape, has a different long axis-to-short axis average ratio in comparisons with our samples. *Fictovichnus gobiensis* Johnston, Eberth & Anderson 1996 has a long axis-to-short axis ratio of 1.46 (three specimens) and 1.52 (one specimen), both smaller in comparison with the values obtained for the Santo Stefano material. The same happens for *Fictovichnus parvus* Johnston, Eberth & Anderson 1996 whose long axis-to-short axis ratio is 1.48 (three specimens).

All the morphotypes assigned to *Fictovichnus* are remarkably smaller than the specimens from Santo Stefano Island; these latter have a long axis about 1/3 longer than the one of *Fictovichnus gobiensis* and twice compared to the one of *Fictovichnus parvus*. It is worth of note that these latter ichnospecies are considered as synonyms by Genise (2004), because they were diagnosed on the bases of their different size. In *Fictovichnus* chamber is enveloped by a thin clay-rich zone. In the analyzed specimens this thin layer has not been observed.

Finally, the material has been compared with the ichnogenus *Teisseirei* Roselli 1939, coming from Upper Cretaceous-Lower Tertiary deposits of Argentina and Uruguay (Melchor *et al*. 2002; Genise, 2004) and attributed to a fossil coleopteran pupation chamber. *Teisseirei* is sub-ellipsoidal in shape, with an oval cross-section, and has an average proportion of height, width and length of 1:1.5:3.5. Because of these features, this ichnogenus is not comparable with our specimens.

Fossil insect pupation chamber ichnotaxobases are essentially three: type of fill (active or passive), chamber shape, and type of wall structure (Genise 2004).

The type of fill may give information about the chamber function (pupation or breeding chamber), while the type of wall provides information about the trace-maker. The above mentioned ichnogenera as well as our specimens have a passive filling.

The Santo Stefano ichnofossils better fit with *Rebuffoichnus* rather than with *Fictovichnus* on the basis of the shape and of dimensional relationships. As far as chamber architecture is concerned, the following problems arise. The Santo Stefano pupation chambers are characterized by the occurrence of an apparently discrete three-dimensional structure, which in thin-section does not correspond to any granulometric and/or textural change. Our samples could have a "constructed wall", in which fecal or soil pellets could have been welded very tightly by the trace maker or by taphonomic processes. The visible discrete structure thus could be probably a phantom of the original constructed wall in which the original outer surface can now not be recognized. In this case the Santo Stefano ichnofossils should be assigned to the ichnogenus *Rebuffoichnus*.

In contrast, grains could have been pushed radially by the larva during excavation, determining a local change in packing density. In such a case differential erosion and/or diagenetic effects may explain the three-dimensional structure. Thus the specimens under analysis would have not a constructed wall (*sensu* Genise 2004), but a structure caused by the pushing and the moving of the grains as described by Johnston *et al.* (1996). In this case the Santo Stefano material should not be attributed to the ichnogenus *Rebuffoichnus* and could be more comparable to *Fictovichnus*. Nevertheless the different dimensional relationships do not allow a reliable attribution to the latter ichnogenus.

5. CONCLUSIONS

Fossil insect pupation chambers are described from the Santo Stefano Island (Pontine Archipelago, Central Italy). They represent the first well documented report of fossil pupation chambers in Italy. To date similar trace fossils were discovered in Argentina, Uruguay, Spain and Mongolia.

On the basis of the observed features the Santo Stefano ichnofossils can not be attributed to both to *Rebuffoichnus* and *Fictovichnus* icnogenera. Further analysis on the chamber architecture will allow a more reliable attribution to be proposed.

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