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Heterostegina papyracea Seguenza, 1880 from the upper Miocene of Cessaniti (Vibo Valentia, Calabria, southern Italy)

Cesare A. PAPAZZONI Achille SIROTTI
Dipartimento di Scienze della Terra
Università di Modena

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ABSTRACT – Several specimens of *Heterostegina papyracea* Seguenza were collected near Cessaniti (Vibo Valentia) in upper Tortonian sandstones with abundant *Clypeaster* spp. and small pectinids.

The biometric analysis of the inner features of the specimens of *H. papyracea* leads us to insert it into the *H. complanata* lineage. In the Mediterranean area *H. papyracea* probably represents the last species of this group. The *H. costata* lineage is instead represented at similar stratigraphic levels in Spain by *H. gomezangulensis* Perconig.

RIASSUNTO – [*Heterostegina papyracea* Seguenza, 1880 nel Miocene superiore di Cessaniti (prov. di Vibo Valentia, Calabria)] – Uno studio biometrico è stato svolto su una popolazione di *Heterostegina papyracea* Seguenza raccolta vicino a Vibo Valentia, in arenarie poco cementate di età Tortoniano superiore.

Dall'analisi biometrica dei caratteri interni di *H. papyracea* si deduce l'appartenenza di questa specie alla linea evolutiva di *H. complanata*. Data la sua posizione stratigrafica, *H. papyracea* è probabilmente l'ultima specie di questa linea evolutiva presente nel Mediterraneo, mentre la contemporanea *H. gomezangulensis* Perconig rappresenterebbe il termine della parallela linea evolutiva di *H. costata*.

INTRODUCTION

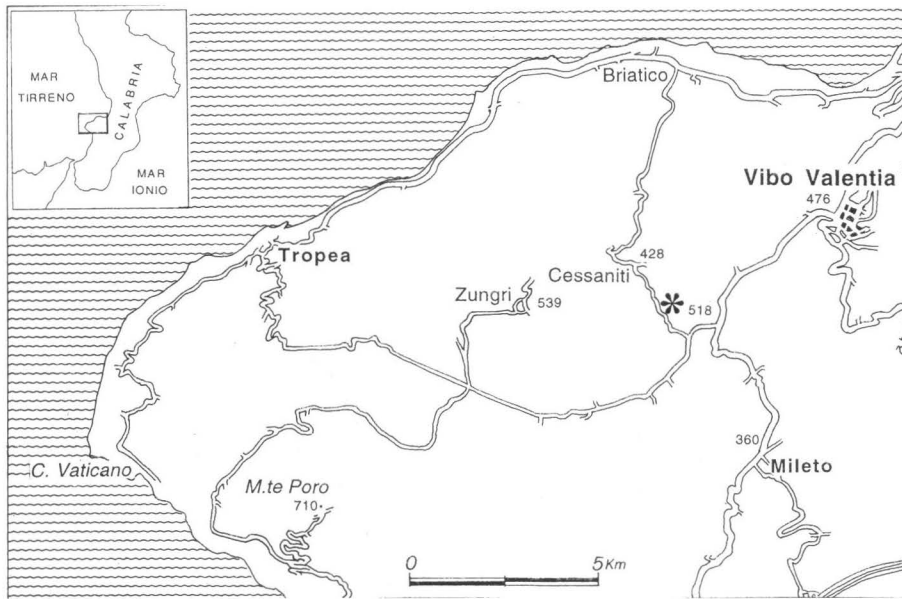
In 1984 a mandible of *Stegotetrabelodon syrticus* Petrocchi was found in the Cava Brunia quarry (Text-fig. 1), near Cessaniti, Vibo Valentia province, Calabria (Torre *et al.*, 1995). The bones were dug out from poorly cemented sandstones with echinoids (*Clypeaster* spp.) dated as Tortonian (Imbesi Smedile, 1958; Nicotera, 1959; Ogniben, 1973; Barbera & Tavernier, 1990). The Cava Brunia stratigraphic section was described by Barbera & Tavernier (1990, fig. 3).

In 1993, during a field inspection to verify the stratigraphic position of the mandible, the sediment (coarse sandstone) from about four metres above the level where the bones were found was sampled, owing to the presence of abundant heterosteginas. This was already reported by Seguenza (1880), who in neighbouring outcrops of the same age erected his new species *Heterostegina papyracea*. He listed "Monteleone" (the ancient name of Vibo Valentia) among the localities in which he found *H. papyracea*. Unfortunately, he did not specify the precise site where he collected his samples, but Nicotera (1959) cited Cessaniti as one of the localities near Vibo Valentia where the heterosteginas are particularly abundant. Thus, our specimens possibly come from one of the type localities of *H. papyracea*. This taxon is the only larger foraminifer present in the sample. The high number of specimens allows a biometric study of the inner features.

The study on the heterosteginas was carried out with the aim to obtain a better knowledge of Seguenza's species and its age.

Planiform *Heterostegina* species, widespread over the whole Mediterranean area during the Neogene, disappeared from the region near the end of the Miocene (Adams, 1976). Several species of this genus were reported from European Miocene sediments, but their phylogenetic relationships are unclear. Limiting our discussion to the flattened ("planiform") species, Freudenthal (1969) stated that only one evolutionary lineage of planiform heterosteginas existed in Europe during the Neogene. Conversely, Hottinger (1966), following Papp & Küpper (1954), regarded the groups of *H. costata* and *H. complanata* as two independently evolving lineages. According to Hottinger (1966), the *costata* group shows a relatively smaller protoconch, a relatively tighter coiling, a more irregular spacing of the primary septa and of the arrangement of the secondary septa, and a smaller number of secondary septa at the same ontogenetic stage than the *complanata* group.

Perconig (1972) seems to agree with the hypothesis of two phylogenetic lineages when describing his new species *H. gomezangulensis* from the upper Tortonian of Spain. Even if he did not state it unequivocally, from his discussion we can argue that *H. gomezangulensis* is related to the *costata* lineage. Moreover, he pointed out that the number of "operculinid" chambers is larger in the *costata* group than in the *complanata* group.



Text-fig. 1 - Map of the surroundings of Cessaniti, with the site (asterisk) where *Heterostegina papyracea* was collected.

PALEOENVIRONMENT AND AGE OF THE SEDIMENTS

The sample contains also smaller benthic foraminifera, planktonic foraminifera, and ostracoda. We recognized 37 species of smaller benthics (here arranged in order of decreasing frequency): *Elphidium craticulatum* (Fichtel & Moll), *Lenticulina* cf. *rotulata* (Lamarck), *Quinqueloculina vulgaris* d'Orbigny, *Biasterigerina planorbis* (d'Orbigny), *Textularia* cf. *sagittula* Defrance, *Cibicides lobatulus* (Walker & Jacob), *Cibicides* sp., *Ammonia* cf. *convexa* (Collins), *Heterolepa floridana* (Cushman), *Brizalina* cf. *spathulata* (Williamson), *Spiroplectammina* cf. *wrighti* (Silvestri), *Marginulina* cf. *costata* (Batsch), *Planorbulina* sp., *Neoponides* cf. *schreibersii* (d'Orbigny), *Cancris auriculus* (Fichtel & Moll), *Nonion* sp., *Textularia* cf. *deperdita* d'Orbigny, *Lenticulina* cf. *cultrata* (de Montfort), *Textularia* cf. *badenensis* Lalicker, *Triloculina* cf. *asymmetrica* Said, *Discorbinella* cf. *bertheloti* (d'Orbigny), *Bannerella* cf. *gibbosa* (d'Orbigny), *Heterolepa* cf. *haidingerii* (d'Orbigny), *Quinqueloculina* sp., *Triloculina* cf. *oblonga* (Montagu), *Lenticulina gibba* (d'Orbigny), *Gyroidinoides* cf. *girardanus* (Reuss), *Elphidium* cf. *gerthi* Van Voorthuysen, *Cycloforina* cf. *vermicularis* (Karrer), *Spiroloculina* cf. *excavata* d'Orbigny, *Quinqueloculina* cf. *alexandri* Luczkowska, *Pseudotriloculina* cf. *granulocostata* (Germeraad), *Plectofrondicularia* cf. *inaequalis* (Costa), *Lenticulina* cf. *costata* (Fichtel & Moll), *Lagena* cf. *apiopleura* Loeblich & Tappan, *Guttulina* cf. *communis* (d'Orbigny), and *G. cf. sadoensis* (Cushman & Ozawa).

This assemblage is not age-diagnostic, but allows some paleoecological considerations. The species richness index α , calculated according to Murray

(1991), is between 9 and 10. This points to an open marine paleoenvironment. The relative abundance of *Rotaliina* (>60%) and the dominance of *Elphidium craticulatum* (Fichtel & Moll) indicate the euphotic zone (0-50 m according to Murray, 1991), whereas the presence of *Nodosariacea* (about 17% of the specimens) suggests a depth near 50 m (Haynes, 1981; Reiss & Hottinger, 1984) for our sample.

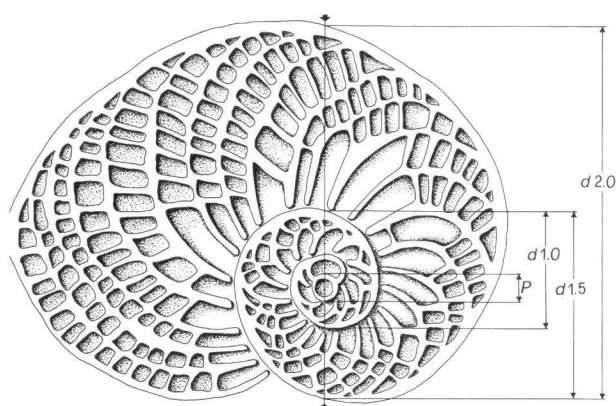
The planktonic foraminifera are lesser represented than benthics, and generally small in size. The species recognized (courtesy of Prof. G. Dieci) are: *Globorotalia* gr. *scitula* (Brady), *G. suterae* Catalano & Sprovieri, *G. cf. nicolae* Catalano & Sprovieri, *G. praehumerosa* Natori, *Globigerina bulloides* d'Orbigny, *Orbulina universa* d'Orbigny, *Globigerinoides obliquus extremus* Bolli & Bermudez, and *G. trilobus* (Reuss).

The presence of *G. suterae* (marker of the homonymous biozone), *G. praehumerosa* and *G. cf. nicolae*, and the relative abundance of individuals referred to *G. scitula* and/or related forms suggest a latest Tortonian-early Messinian age (Iaccarino, 1985).

The ostracods seems to confirm a relatively shallow water paleoenvironment. The species recognized (courtesy of Prof. A. Russo) are: *Flexus triebeli* (Ruggieri), *Aurila semilunata* (Seguenza), *A. perpostata* Miculan, *A. diecii* Sissing, *Aglaocypris miocenica* Russo, *Urocythereis* sp. Miculan, *Loxoconcha ovulata* (Costa), *L. gr. punctatella* Reuss, *L. aff. hostata* Reuss, *Cytheretta* sp., *Echinocythereis* sp., and *Bairdia* spp.

The age deduced from this assemblage is late Tortonian. So, we can date the *H. papyracea* level to the latest Tortonian.

The presence of the proboscidean *Stegotetrabelodon syrticus* mandible in marine sediments can be interpreted as part of a carcass floated from the neighbouring land.



Text-fig. 2 - Idealised equatorial section of *H. papyracea* showing the measured features. In this example the number of chambers is: N1.0=8; N1.5=18; N2.0=29. Drawn after the specimen of Pl. 1, fig. 5, slightly modified. Abbreviations as in Tab. 1.

MATERIAL AND METHODS

To recognize the stratigraphic and evolutionary position of the heterosteginas from Cessaniti, several specimens ascribed to *H. papyracea* Seguenza were collected.

The external features were observed in about sixty specimens of different size. Thirty more specimens randomly chosen were attached to a glass slide on one side, then polished on the other side. The half tests obtained were so thin that we could observe and measure the inner features also by transmitted light.

To allow a comparison with the coeval species *Heterostegina gomezangulensis*, we made our measurements about in the same way as Perconig (1972) did. On the equatorial sections we measured the diameter of the protoconch (P) comprising the thickness of the wall, the diameter of the first (d1.0), first and a half (d1.5) and second (d2.0) whorl comprising the marginal cord, the number of undivided ("operculinid") chambers after the deuteroconch (n), the number of primary chambers in the first (N1.0), first and a half (N1.5) and second (N2.0) whorl (Text-fig. 2). A summary of all the measurements and main statistic parameters is reported in Tab. 1.

TAXONOMY

HETEROSTEGINA PAPYRACEA Seguenza, 1880 Pl. 1, figs. 1-6

1880 *Heterostegina papyracea* SEGUENZA, p. 90, pl. 9, figs. 4, 4a.

1954 *Heterostegina complanata spiralis* PAPP & KÜPPER, p. 121, text-pl. 5, fig. 3; pl. 23, fig. 1.

?1954 *Heterostegina complanata sculpturata* PAPP & KÜPPER, p. 121, text-pl. 5, fig. 5 (non pl. 5, fig. 4).

1966 *Heterostegina* n. sp. aff. *complanata* Meneghini - HOTTINGER, p. 62, pl. 14, fig. 1 (non pl. 14, fig. 7).

	n.o.	min.	max.	med.	mean	se	σ	cv
P	30	148	296	222	219.1	7.318	40.08	18.29
n	22	1	3	1.0	1.364	0.124	0.581	42.61
d1.0	30	740	1887	1092	1157	49.99	273.8	23.67
d1.5	24	1221	3922	1980	2149	141.4	692.6	32.23
d2.0	16	1998	7425	3589	4091	356.7	1427	34.87
N1.0	28	6	9	7.0	7.25	0.151	0.799	11.03
N1.5	28	12	19	15.5	15.36	0.375	1.985	12.93
N2.0	24	19	35	25.0	25.88	0.698	3.418	13.21

Tab. 1 - Statistical values calculated for each measured feature on *H. papyracea* from Cessaniti: P=protoconch diameter (μ m); n=number of operculinid chambers; d1.0=diameter of the first whorl (μ m); d1.5=diameter of the first and a half whorl (μ m); d2.0=diameter of the second whorl (μ m); N1.0=number of primary chambers in the first whorl; N1.5=number of primary chambers in the first and a half whorl; N2.0=number of primary chambers in the second whorl; n.o.=number of observations; min.=minimum value recorded; max.=maximum value recorded; med.=median; se=standard error; σ =standard deviation; cv=coefficient of variation.

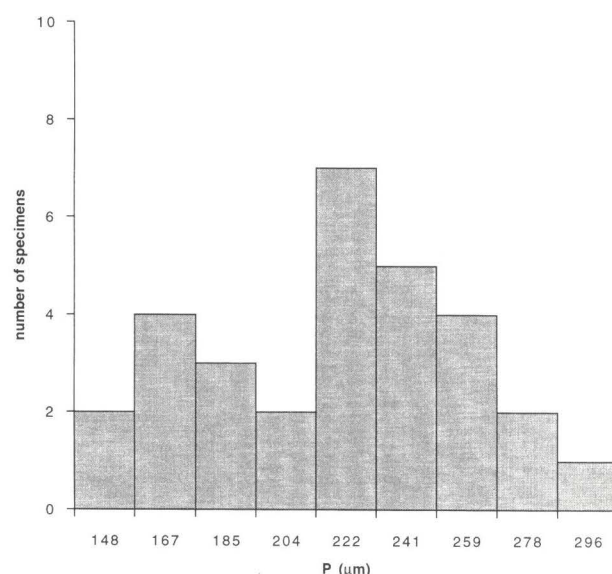
1966 *Heterostegina* cf. *complanata spiralis* PAPP & KÜPPER - HOTTINGER, p. 62, pl. 14, figs. 2-4.

1969 *Heterostegina* (pro parte) - FREUDENTHAL, pp. 141-158.

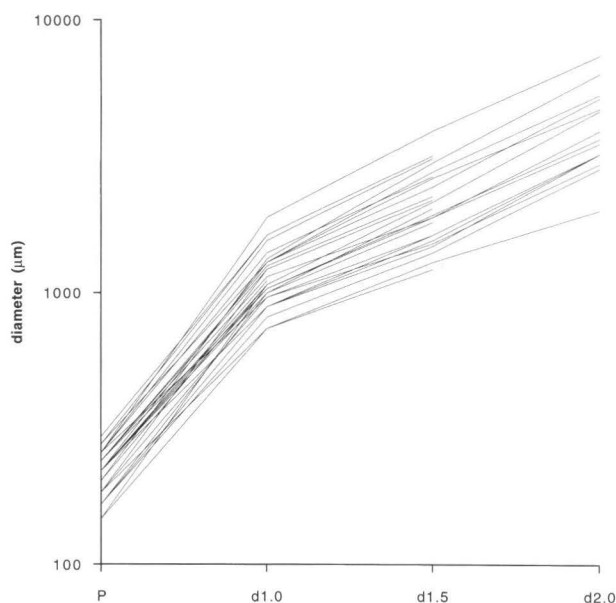
1977 *Heterostegina papyracea* Seguenza - HOTTINGER, p. 109, pl. 45, figs. 1-5.

1977 *Heterostegina complanata* Meneghini s.l. - HOTTINGER, text-figs. 43B-E.

Description - Test quite large, maximum diameter 3 to 10 mm (mainly 5-8 mm), very thin (0.15-0.30 mm). The surface is usually smooth (Pl. 1, fig. 1), rarely a granulation over the primary and secondary septa (due to septal and interseptal piles) produces a distinct ornamentation (Pl. 1, figs. 2, 3). The polar



Text-fig. 3 - Distribution of the protoconch diameters (P) in *H. papyracea*.



Text-fig. 4 - Coiling diagram for all the measured specimens of *H. papyracea*. The diameter of the whorl has been linked to the protoconch diameter (P). The y-axis has a logarithmic scale to emphasise the logarithmic growth of the test.

thickening is usually poorly developed, but it is better marked in the small specimens (Pl. 1, fig. 2). A few specimens show a distinct thickening of the marginal cord ("keel" *sensu* Papp & Küpper, 1954).

In equatorial section (Pl. 1, figs. 4-6) the protoconch size is highly variable, ranging from about 150 to 300 µm. The histogram of distribution of this parameter (Text-fig. 3) shows two definite peaks. This bimodal distribution could be explained admitting the presence of two different species. Because none of the other features shows a similar pattern, we suggest that the different size-classes could correspond to the A1 and A2 generations, as observed in modern foraminifera (Leutenegger, 1977; Lee *et al.*, 1991).

No microspheric specimen has been found, and this is in accord with Hottinger's (1977) observations about the extreme scarcity of B forms in planiform heterosteginas. This could be correlated with a shallow environment promoting the apogamic schizogony (Leutenegger, 1977). The shallow environment

is also suggested by the presence of septal and inter-septal piles.

Conversely, the normal distribution of protoconch diameter in *H. gomezangulensis* might depend on a deeper environment, as suggested by the presence of associated planktonic foraminifera in the type-locality (Perconig, 1972).

The number of undivided chambers is usually one, sometimes two (27% of the specimens), three only in one specimen. The number of primary chambers in each whorl (about 7 in the first, 15 in the first and half, and 25 in the second whorl) is quite constant among specimens and seems to have a taxonomic value (Tab. 1).

In *H. gomezangulensis* Perconig (1972) pointed out a correlation between the protoconch diameter and the diameter of the whorl. We found a weak correlation between P and d1.0 ($r^2=0.514$), while the correlation is less significant for the successive whorls ($r^2=0.405$ for P vs. d1.5; $r^2=0.275$ for P vs. d2.0). Similar relationships of protoconch diameter with the growth rates of the following ontogenetic stages were described and discussed by Pecheux (1995) for the recent *Assilina ammonoides*. We also report the coiling diagram of our specimens to show the range of variation (Text-fig. 4), enabling the comparison of this species with other heterosteginas.

Remarks – We regard *H. complanata spiralis* Papp & Küpper, 1954 as a junior synonym of *H. papyracea* Seguenza, 1880. It is uncertain if our ornamented specimens should be referred to *H. complanata sculpturata* Papp & Küpper, because of the smaller size of the protoconch, the higher number of operculinid chambers and the relative tightness of the spire in the specimens figured by Papp & Küpper (1954, Text pl. 5, figs. 4, 5).

The "Cretan samples" of *Heterostegina* (without further specification) of Freudenthal (1969), in particular that from the Kissamou, Koukounaras and Akrotiri Formations, have been here included among the synonyms of *H. papyracea* for their biometric values, in good accordance with those of our specimens.

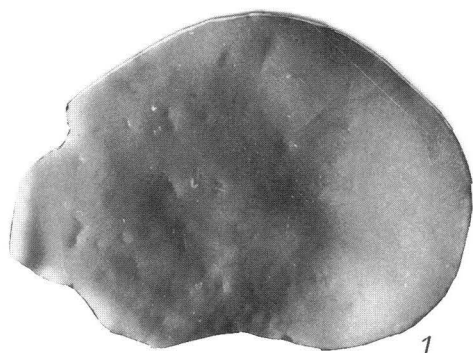
All the features observed contribute to ascribe *H. papyracea* (= *H. complanata spiralis*) to the *H. complanata* group.

The nearly coeval late Tortonian *H. gomezangulensis* Perconig has a distinctly smaller protoconch

EXPLANATION OF PLATE 1

Figs. 1-6 - *Heterostegina papyracea* Seguenza, 1880, A forms.

- 1) Smooth specimen; external view. IPUM 26131 (x 9.6).
- 2) Ornamented specimen with marked granulations and pronounced polar knob; external view. IPUM 26132 (x 15).
- 3) Ornamented specimen with fine granulations following the primary and secondary septa; external view. IPUM 26133 (x 9.6).
- 4) Equatorial section. IPUM 26134 (x 15).
- 5) Equatorial section. IPUM 26135 (x 15).
- 6) Equatorial section. IPUM 26136 (x 9.6).



1



2



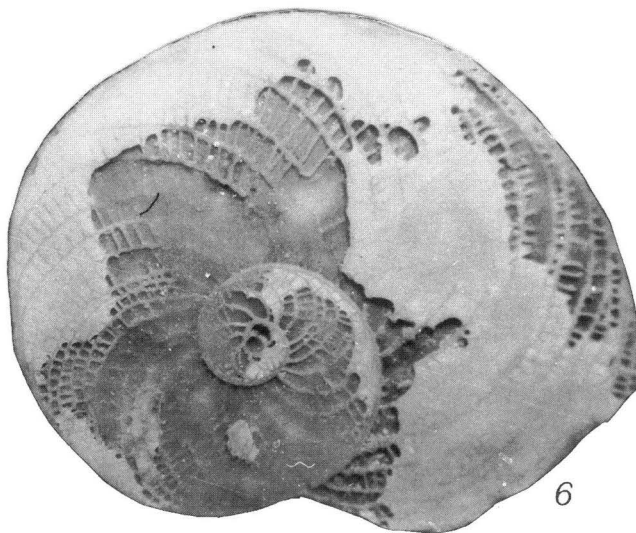
3



4



5



6

and tighter spire and it probably belongs to the *H. costata* lineage. However, *H. gomezangulensis* bears an unimodal distribution of the protoconch diameter (Perconig, 1972, fig. 2).

CONCLUSIONS

In his original description Seguenza (1880) included *Heterostegina papyracea* among the "Helvetian" fossils. According to Imbesi Smedile (1958), Nicotera (1959), and Barbera & Tavernier (1990) this age should be Tortonian. The data obtained from the planktonic foraminifera and ostracoda allow us to restrict the age to the latest Tortonian.

According to Adams (1976) the genus *Heterostegina* (and *Borelis*, too) is not recorded in the Mediterranean after the end of the Miocene. This could probably be correlated with the Messinian salinity crisis, which hardly permitted the survival of larger foraminifera.

Freudenthal (1969) described heterosteginas from the "lower Pliocene" of Crete. In the same paper however, Freudenthal (1969) asserted that the base of the Kissamou and Koukounaras Formations, which contain the Cretan *Heterostegina*, have been "correlated with the middle part of the type Tortonian". Thus, it seems very unlikely that Cretan heterosteginas belong to the lower Pliocene, but they probably are of early Messinian age (see Meulenkamp, 1985). Recently, *Heterostegina* has been recorded also from the pre-evaporitic Messinian of southeastern Spain (Michalzik, 1997).

In summary, the population of *Heterostegina papyracea* Seguenza, collected at Cessaniti (Cava Brunia), represents one of the youngest heterosteginas in the Mediterranean. In other words, in the Mediterranean *H. papyracea* is the latest species of the *H. complanata* lineage, whereas the contemporaneous *H. gomezangulensis* represents the last species of the *H. costata* lineage.

The age determined by means of planktonic foraminifera and ostracods allows us to specify the stratigraphic position of the mandible of *Stegotetrahelodon syrticus* Petrocchi found some four meters below the *H. papyracea* level.

The type specimen of *S. syrticus* (Petrocchi, 1954) was recently dated by Mein (1990) as Turolian in age (=MN 13), that means Messinian (Steininger *et al.*, 1990). Other specimens referred to the very close species *S. orbis*, found in Kenya and Ethiopia (Maglio, 1970; Kalb & Mebrate, 1993), have been dated between 7 and 5 Ma (Tassy, 1979; Kalb *et al.*, 1982), that is latest Tortonian-Messinian. So, the age attributed to the specimen from Cessaniti is in accordance with previous data from the literature, but it suggests that the MN 13 Zone (until now considered only as Messinian) could span also the uppermost part of the Tortonian.

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Cesare A. PAPAZZONI
Achille SIROTTI

Dipartimento di Scienze della Terra
Via Università 4, 41100 Modena, Italy
E-mail: sirotti@unimo.it