

TAPHONOMIC ASPECTS OF THE RADIAL BACKFILL OF ASTEROSOMIDS IN OLIGO-MIOCENE TURBIDITES OF CENTRAL ITALY (NORTHERN APENNINES)

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Abstract. One hundred asterosomid specimens from 24 sections of several flysch facies of the Northern (Tuscan-Romagna-Umbrian) Apennines have been analysed to study their radial backfill using taphonomic characteristics. These characteristics include the stratigraphic position in the bed, the shape and morphology of concave or convex tunnels, the type of subhorizontal crossing, the disposition and shape of wrinkles and cracks, and newly recognized fan-shaped, micro-debris flow deposits in the sides of tunnels induced by the radial backfilling compression causing shock in mud. Many types of preservation have been found in *Halopoa* ichnospecies while other preservational aspects (*Asterosoma* and *Lennea in primis*, while the *Fucusopsis* preservation and aspect has been included in ichnogenus *Halopoa*). This comparative taphonomic study enhances, for the first time in the turbidites of Apennines, the role of radial backfill as a type of deposit-feeding in deep-sea firmgrounds and softgrounds, produced by soft-bodied organisms (probably worms).

Introduction

The asterosomids represent a particular category of burrowing, rather than a distinct taxonomic category (Seilacher 2007). They are known in the geological record from Palaeozoic to Miocene, with many forms locally described as ichnogenus, ichnospecies, ichnosubspecies, preservational forms and many morphological variants. *Asterophycus* Lesequereaux usually is considered as a junior synonym of *Asterosoma*. They include *Halopoa* (essentially with three species), *Asterosoma* (with numerous species), *Fucusopsis* (now included in *Halopoa* and not recommended for further use by Uchman 1998), *Lennea* (essentially a type of preservation in Seilacher 2007), and the “Tatzelwurm” from the Jurassic of Italy. For description of these forms see Książkiewicz

(1977), Uchman (1998), Seilacher (2007), Baucon & Neto de Carvalho (2008), Monaco & Trecci (2014). Some very long traces from the Lower Jurassic of Italy (up to 7 m in length and 50 cm wide) with a regular alternation of ovoid structures were plausibly ascribed to *Asterosoma ludvigae*, and indicated with the term “Tatzelwurm” (Seilacher 2007, pl. 46). Others are simple but structured tunnels (*Halopoa imbricata* Torell, 1870). This explains the great variation in the preservation aspect of asterosomids. The burrow system is complex, with many external, structured forms, often branched to radiating, with or without many elongate parts (e.g. *Halopoa*) that in *Asterosoma* are oval or very wide and short. In this latter ichnogenus which gives its name to the group of asterosomids, the burrow is produced by expelling waste material forming a radial backfill (Seilacher 2007, pl. 37), that widens outward, and produces tree bark with a micro-faulted pattern at the point of maximum expansion (Seilacher 2007, pl. 37 and pl. 46). The radial backfill means that the organism deposited its waste sediment in the wall of its tunnel and then pressed it radially out, maintaining or changing the original diameter of tunnel (Seilacher 2007).

The taphonomy of asterosomids has been little studied in the flysch, although this group of trace fossils is very characteristic of turbidites, due to its preservation and abundance, producing burrows mainly at the sand-mud interface of pelitic arenaceous facies (Wetzel & Uchman 2001; Uchman 1998; Seilacher 2007; Milighetti et al. 2009; Monaco & Trecci 2014). In general, this form is rarely considered in the flysch literature, probably because when occurs it usually is rare and associated with many other known trace fossils that are more important for ichnofacies and ichnosubfacies

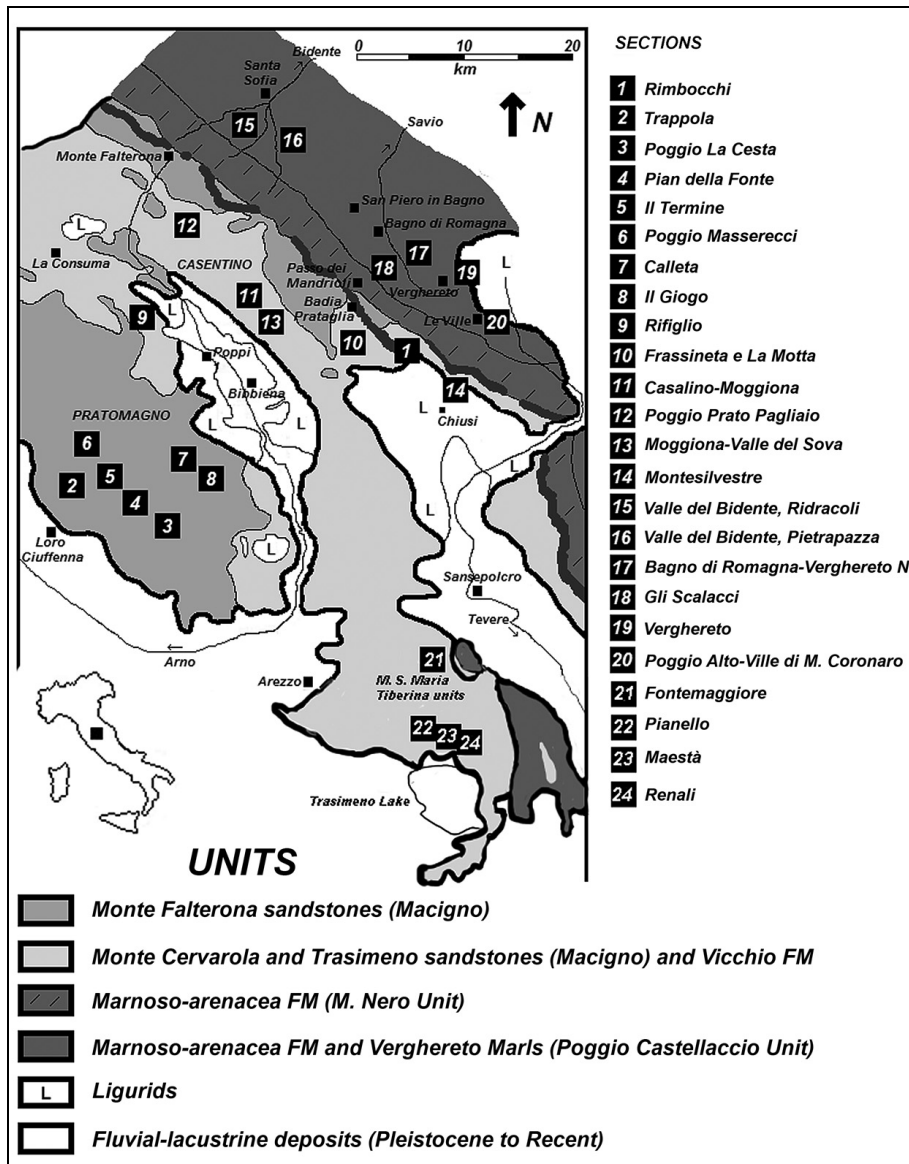


Fig. 1 - Geological setting and studied 24 sections containing the radial backfill of astero-somids.

characterization in deep water environments, such as *Ophiomorpha*, *Nereites* and *Paleodictyon* (Uchman 2007; Monaco 2008). The most common among astero-somids, the ichnogenus *Halopoa*, has usually been listed in ichnoassemblages together with many other trace fossils without analysis of their differences in preservation (Uchman 1998; Wetzel & Uchman 2001; Tchoumatchenco & Uchman 2001; Monaco & Checconi 2008). In the Upper Jurassic–Lower Cretaceous deep-water turbidite deposits of SW Bulgaria, *Halopoa* occurs in proximal facies and consists of endichnial (and exichnial), cylindrical (8–9 mm wide and at least 17 cm long), simple trace fossils preserved in full relief, covered with longitudinal and thin subparallel wrinkles that are irregular and discontinuous. Usually there are 3–4 wrinkles on the visible part of hyporelief (Tchoumatchenco & Uchman 2001, pl. 4 C). Ichnospecies are few but differ in their wrinkles which are long and anastomosing in *H. imbricata* Torell, whereas in *H. annulata*

(Książkiewicz) they appear as short cylinders segmented by transverse grooves (Uchman 2001, pl. 4.1– 4.2; Tchoumatchenco & Uchman 2001, pl. 4); in *H. storeana* (Uchman) they are inclined along the main axis at an angle of 10–20°, arranged in plait-like, oriented fashion (Uchman 2001, pl. 3). For a detailed description of taxonomic characteristics see also Książkiewicz (1977), Uchman (1998) and Monaco & Checconi (2008). In the muddy turbidites of the Beloveža Formation Wetzel & Uchman (2001) found that *Halopoa* producers reworked the sandy parts of turbidites and some mud below them, back-filling their tubes. These authors did not observe *Halopoa* crosscut by *Scolicia*, although this might be due to the sparse occurrence of *Halopoa*. In the northern Apennines the occurrence of *Halopoa* differs from Beloveža Formation because it is not sparse but may be very abundant in some levels of Frassineta and Maestà-Renali-Carapagli section (Fig. 1). This form has been simply listed but not fully described by Mo-

naco (2008), Monaco & Checconi (2008) and Monaco et al. (2010).

The present study analyzes 100 specimens observed *in situ* or collected and stored in the Biosedlab of the Perugia University, from Oligo-Miocene turbiditic deposits of the northern Apennines (Fig. 1). The aim is to characterize all variations in shape, stratigraphic position, and taphonomic aspects (wrinkles, cracks, micro-debris flow), focusing on significance of variation in preservation with in fine-grained turbiditic facies.

Material and methods

The material for this study comes from 24 sections of upper Oligocene to Miocene deposits in the central Apennines, from eastern Tuscany, to Romagna and Umbria (Fig. 1). The specimens consist of slabs of siliciclastic to mixed siliciclastic/carbonatic turbidites, locally very rich in plant debris and other organic matter. Grains of asterosomid burrows show a prevalence of quartz, feldspars and mica flakes and rocks that contain these trace fossils are litharenites, arkoses, micaceous graywackes and silty to clay (mud) turbidites. Sedimentologically, beds are gravity flow deposits (mainly debris flow deposits and turbidites s.l.). In distal zones (e.g. Frassineta and Verghereto) mixed distal thin-bedded turbidites (usually 3 to 10 cm thick) were reworked by bottom current flows (Mutti 1992; Shanmugam 2002; Muzzi Magalhaes & Tinterri 2010). All gravity-flow facies belong to flysch deposits deposited in different basins of NW-SE-oriented foredeep system, producing different formations as Modino-Cervarola-Falterona-Trasimeno sandstones (Macigno s.l.), Marnoso-arenacea, Vicchio and Verghereto Marls formations (Fig. 1). These units, individually, exceed 2500 meters in thickness (Milighetti et al. 2009). All these formations and associated facies have been previously described in many geological, sedimentological and ichnological papers and thus are not described here. For detailed geological aspects see Mutti & Ricci-Lucchi (1972), Ricci Lucchi (1981; 1986), Bruni et al. (1994), Costa et al. (1997), Brozzetti et al. (2002), Centamore et al. (2002), Monaco (2008), Monaco & Checconi (2008), Conti et al. (2008), Milighetti et al. (2009), Muzzi Magalhaes & Tinterri (2010), Monaco et al. (2010), Trecci & Monaco (2011), and Monaco & Trecci (2014), among many others.

The taphonomic study consists of analysis of morphological variations of asterosomids. The most interesting specimens derive mainly from the Macigno of Trasimeno, central Umbria (sections 22, 23, 24 of Fig. 1) and from the Vicchio Marls formation of the southern Casentino area in eastern Tuscany (Fig. 1) (sections 10, 11, 12, 13 and 14). Other forms (usually *Halopoa imbricata* Torell) are from the Marnoso-arenacea Formation of the Romagna Apennines (Fig. 1) (sections 15, 16, 17, 18 and 19) and the Verghereto Marls formation (section 20). For stratigraphy the works of Monaco (2008); Monaco & Checconi (2010a; b); Monaco et al. (2010); Monaco (2011) are recommended. The specimens' repository is the Biosedlab of the Earth Science Department of Perugia University. Further observations in field of asterosomids were made adjacent to the base of fine-grained turbidites of cited above formations, in cases where large blocks could not be sampled. Asterosomids are preserved mainly as hypichnia and evolve to endichnia close to the base of calcarenite beds. In the case of *Asterosoma* the characteristic sand-filled inner core, and the diagnostic target-like appearance of concentric rings are poorly preserved for the coarser grains at base of sandy turbidites. The surrounding mud balls figured in shallow-water *Asterosoma* by Howell (C. D. Howell, Jr. 2001-2013, <http://www.clastics.com/asterosoma.htm>) were rare due to the poor preservation of many specimens. In *Halopoa* on the contrary, the preservation is better in hypichnial specimens, where taphonomic features can be easily observed and described. Thin section analysis was made

with the Dino-Lite microscope camera. This camera obtains a continuous spectrum of photographs from 5 to 100 × magnifications, and can be very useful in cases of microstructures produced by displacement of sand grains induced by the makers of asterosomids. The image contrast and other settings were corrected in Adobe® Photoshop®. To study endichnial deformation, several thin sections were analysed transversally and longitudinally.

Taphonomic characteristics

The taphonomic analysis requires crucial characteristics (“clinos tafonómicos” of Fernández López 1997), in order to quantify morphological variations of this strange and variable technique of burrowing (Fig. 2). Analyses have been applied to those structures that are convex to concave reliefs in the sand medium (Savrda 2007, fig. 6.6).

A) Asterosomid tunnels and their morphological variations

Three types of preservation have been found: hypichnia, endichnia and rare epichnia. Asterosomids are unknown as exichnia or crossichnia (Monaco & Caracul 2007; Monaco & Checconi 2008).

A1) Hypichnial preservation. The specimens in this study are preserved as i) concave or ii) convex tunnels, with convex prevailing (Fig. 2). Transitions of both types in a same specimen are rare (Fig. 2). Both are horizontal or subhorizontal. Less frequent are those obliquely arranged inside the bedding plane.

i. **Concave hypichnia.** Concavities exhibit an empty nucleus and wall 0.5 to 1 cm thick. These preservations are rare (Pl. 1, A arrows). The nucleus is usually smooth, short up to 2.5 cm (CEV238, CEV323 specimens) and radiating (CEV323, CEV273, CEV241 specimens). Concavities are similar to many concave structures of *Rutichnus rutis* found in thin-bedded calcarenites of the Verghereto Marls formation (Monaco 2011).

ii. **Convex hypichnia.** Convexity is the dominant morphology on the sole of beds (Pl. 1, C), and forms isolated or singular tunnels (about 35%, Fig. 2), usually rectilinear or slightly curved in the horizontal plane (Pl. 1, C). Tunnels frequently evolve to complex and branched systems (Pl. 2, A) (CEV147, CEV387), locally diverging (about 30%, Fig. 2; e.g. CEV275), or producing groups of tunnels arranged in tufts, departing from a central main tunnel (CEV236, CEV322, CEV387, CEV273 specimens, e.g. Pl. 2, A). These groups can be termed as *Halopoa* and *Lennea* preservational aspects (Seilacher 2007, pl. 46). Diameter is inconstant, ranging from 1 to 2.5 cm within individuals (about 50% of specimens of the Marnoso-arenacea are single with bulges, MA59, Pl. 2, B). Some wide *Asterosoma*-like specimens of the Macigno and Marne di Vicchio formations are 35 mm wide and structured

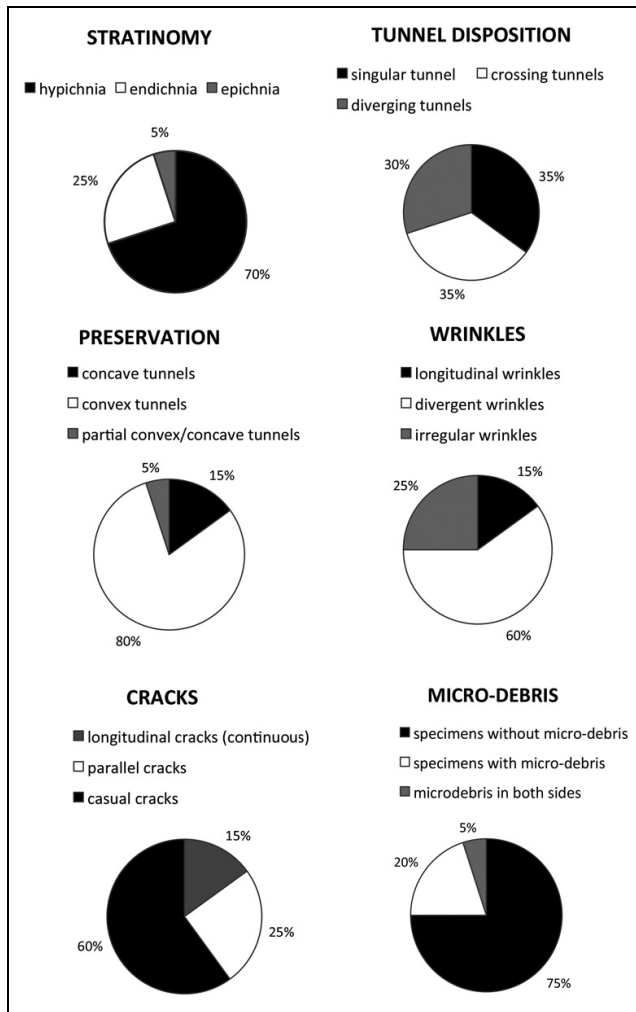


Fig. 2 - Taphonomic characteristics of the asteromid burrows in 100 studied specimens from 24 stratigraphic sections.

(CEV390, CEV153, Pl. 2, C-D). Enlargement of *Halopoa* tunnels is very common and narrowing may occur repeatedly with in a trace fossil. Short bulges can produce widening after narrowing with a sharp, rhythmically disposed enlargement (five bulges in CEV391, CEV152 specimens, Pl. 2, E); in other cases bulges may enlarge abruptly, forming rectangular and thick rings (up 2 cm, Pl. 2, F). Length of horizontal tunnels is extremely variable, from a few centimetres (usually depending on the hypichnial to endichnial preservation at the sole of turbidites), to about 50 cm (exceptionally 60 cm) in the case of hypichnia. Crosscut is another characteristic (Pl. 1, E); crosscut is different between hypichnial and shallow endichnial specimens of *Halopoa* (in Trasimeno and Casentino areas). In these specimens ichnodensity of asterosomids is very high in thin-bedded sands (up to 30 specimens for a square meter, see Frassineta beds). Crosscut in *Halopoa* has been figured also by Seilacher (2007, pl. 46) and is present in many sections in Tuscany and Romagna. Horizontal crossing, at the same level, varies from 45° to 90° (Pl. 1, D-E).

Crossing at different levels, on the contrary, is often accompanied by superposition of many different styles of preservation (CEV321, Pl. 1, F); this arrangement is reminiscent of the meshes of a typical net. The overlapping occurs at the point of the maximum narrowing of the lower tunnel (Pl. 1, F). In one sample (CEV392 specimen) an asterosomid crosses another larger hypichnial trace fossil, such as *Spirophycus* cf. *bicornis*, producing orthogonal fractures and cracks in the latter trace fossil at the point of intersection, indicating successive burrowing by the asterosomid (Pl. 3, B). A similar trend has been found in the Macigno of the Trasimeno area where *Halopoa* crosses both pre-depositional *Spirorhappe*, post-depositional *Spirophycus bicornis* and *Spongeliomorpha* (see the *Halopoa-Spirophycus-Spirorhappe* ichnocoenosis of Monaco & Trecci 2014).

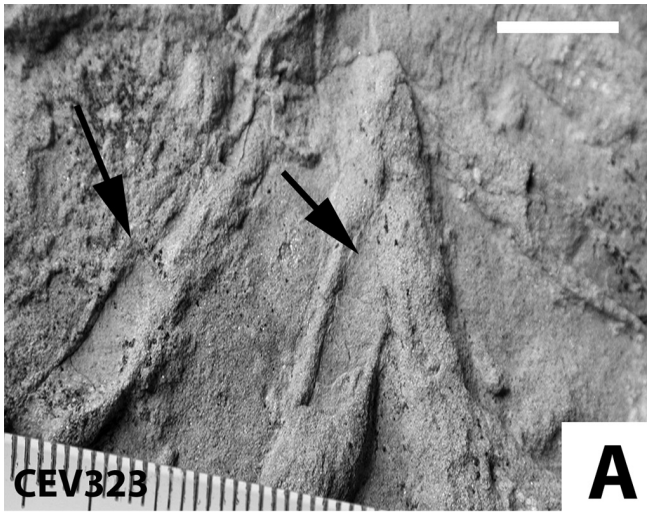
A2) *Endichnial preservation*. Endichnial preservation is less common than hypichnial (Fig. 2) but occurs frequently in Frassineta and in the Carapagli-Maestà-Pianello sections (Fig. 1; Pl. 1, G). It is more frequent where in the sandstone deposits a group of asterosomid tracemakers burrowed in depth (e.g. CEV273, CEV275, CEV322, CEV387 specimens). In some cases (CEV274, CEV275) these trace fossils can be confused with *Ophiomorpha*, where this trace is vertically developed (Monaco & Trecci 2014), but asterosomids differ in their horizontal arrangement and in their smooth, concave inner surface (Pl. 1, A, E). The outer part never shows the typical pelletoidal outer wall of endichnial *Ophiomorpha rudis* (Monaco & Caracuel 2007; Uchman 2009) or organized pellets (in rows) on the outer wall as in the recently described hypichnial/endichnial *Rutichnus rutis* (Monaco 2011).

A3) *Epichnial preservation*. This type is very rare; it is observed at the top of muddy deposits where *Halopoa imbricata* and *Halopoa storeana* occur. The central tunnel is poorly developed because these trace fos-

PLATE 1

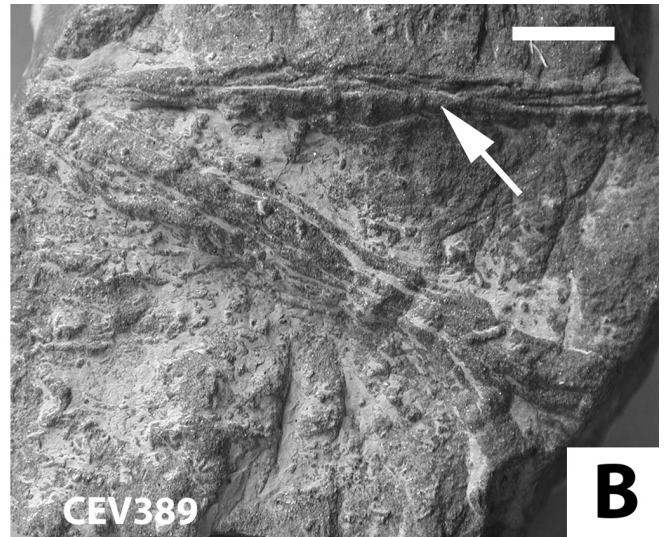
Examples of preservational features of asterosomids.

A) Concave hypichnia exposition (arrows) in some specimens, CEV323 Casalino section, scale bar: 10 mm; B) The *Halopoa*-like preservation with many longitudinal furrows and wrinkles, CEV389 Frassineta section, scale bar: 10 mm; C) Convex hypichnial specimens with longitudinal wrinkles at the base of sandy turbidite, CEV401 Maestà section, scale handle of the chisel: 100 mm; D) Horizontal crossing of different specimens of *Halopoa* preservation, CEV322 Casalino, scale bar: 10 mm; E) Concave to convex hypichnial/endichnial *Halopoa* specimens crossing each other in a fine-grained turbidite, CEV275 Frassineta section, scale bar: 10 mm; F) Hypichnial *Halopoa imbricata* specimens with overlapping at the point of the maximum narrowing of the tunnel, CEV321 Casalino section, scale bar: 20 mm; G) endichnial horizontal specimen, MV275 Frassineta area, scale bar: 10 mm.



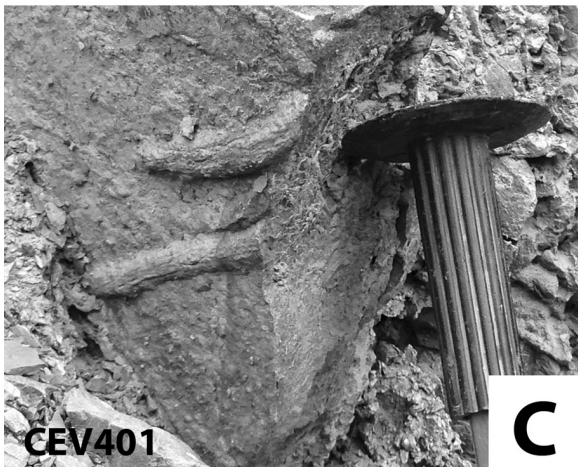
CEV323

A



CEV389

B



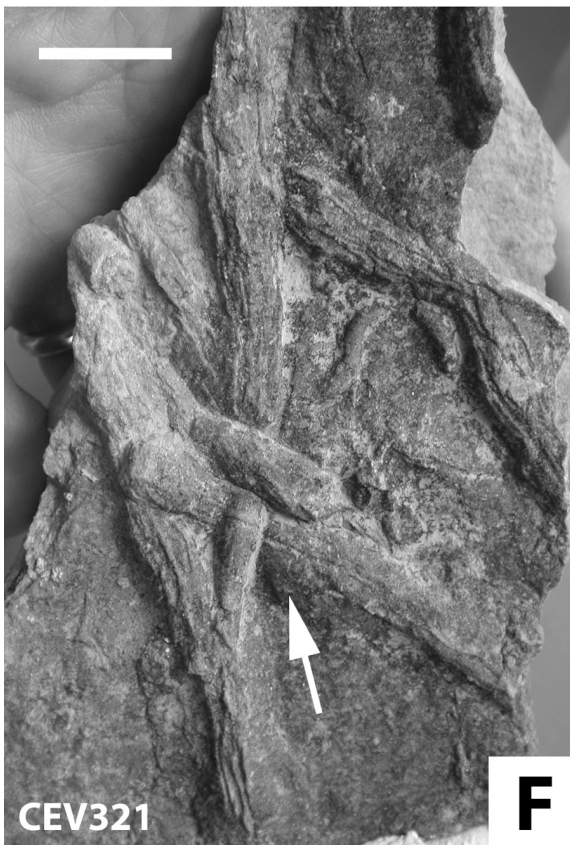
CEV401

C



CEV322

D



CEV321

F



MV275

E



CEV275

G

sils penetrate only shallowly into the mud and are never preserved on bedding planes.

B. Wrinkles and fractures (cracks)

Two interesting features are typical of asterosomid: wrinkles and fractures.

B1) Wrinkles. These are elongated convex structures, 0.5 to 1 mm thick and up to 10 cm long (e.g. CEV387, CEV146 specimens, Pl. 2, A and 3, A arrow), which usually appear as clumps diverging from the central axis of the tunnel (Pl. 3, C). Many are sinusoidal, where a master tunnel crosses previous ones. In some specimens wrinkles are irregularly disposed (CEV147 specimen, Pl. 3, C), long and anastomosing as observed for *Halopoa imbricata* (Uchman, 1998). Wrinkles are often short and wide, forming round micro-bulges up to 2 mm wide (CEV152 specimen, Pl. 3, D arrow). Usually wrinkles tend to shrink and converge towards a narrowing of the tunnel (CEV153, CEV238, CEV287, CEV391 specimens). In some specimens (e.g. CEV392, Pl. 3, B black arrow) wrinkles are parallel to fractures and disposed longitudinally to the tunnel. In this case the organism pressed the sediment, maintaining the original diameter of the tunnel.

B2) Fractures. A very typical feature of asterosomids is the presence of fractures (cracks). Longitudinal fractures are common; transversal cracks are rare. In the *Halopoa* longitudinal fractures are usually shallow and reflect the trend of wrinkles, widening close to the diameter of the tunnel (Pl. 3, E). Usually the cracks are deep (up to 1 mm), wide (normally 1 mm, exceptionally up to 2 mm) and continuous in longitudinal tunnels (e.g. CEV275, CEV320 specimens, Pl. 3, E). Some cracks and wrinkles in *Halopoa* preservation (e.g. CEV387 specimen) resemble, in micro scale, the braided channels of rivers in continental environments. Cracks in Frassineta deposits of Casentino are more developed than elsewhere (Umbria or Romagna), probably due to the composition of material of Vicchio Marls that are richer in clay.

B3) Micro-debris flows of mud (MDFM). A strange features but typical of a radial compression by the organisms has been observed in many specimens from Casalino-Moggiona, Frassineta and Montesilvestre (e.g. CEV272, Pl. 3, F arrows). It consists of a micro-debris flow that produces different micro-deltaic structures, side by side, each up to 3-5 cm wide and up to 10 cm long (Pl. 3, F upper arrows) that develop transversal to the sides of the tunnel. The saturated sediment seems flowed from the central part of the tunnel departing from unstable points of tunnel and expanded for gravity after an internal compression of the worm-like organism. In the opposite side of the same tunnel, smaller micro debris flows are present, producing MDFM structures (Pl. 3, F lower arrow). These strange struc-

tures look exactly like as the micro-deltas produced by rivers or slopes.

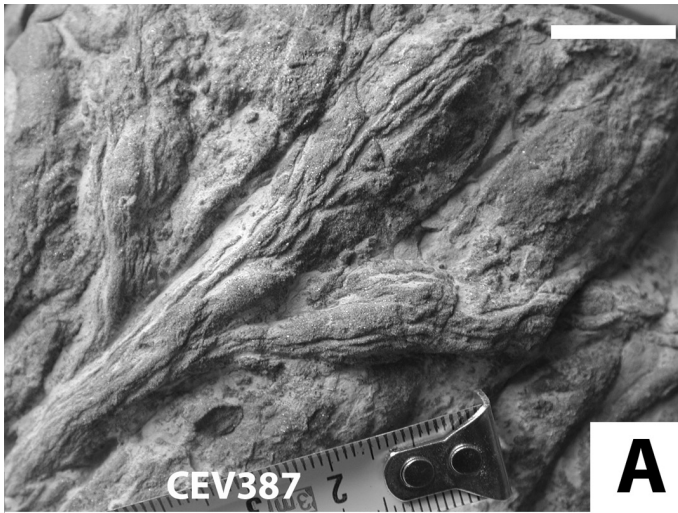
Discussion

In this study the typical features observed in asterosomids (summarized in Fig. 2) indicate a strong variation in shape and morphology of tunnel disposition and outer structures such as wrinkles, cracks and micro-debris. All these structures may be ascribed to radial backfill (Seilacher 2007, pages 108-109), which changes the sediment disposition. He described some types of backfill structures as terminal, marginal and transversal, with their geopetal potential accretion produced by sediment feeders with rejection of coarser and ingestion of finer fractions rich in edible detritus (Seilacher 2007, pl. 37). The intermittently released faecal material could produce finer-grained backfill lamellae with geopetal trend, where the lesser cohesive sand portion tend to gravitationally slide towards the bottom part than mud enhancing backfill. Regarding the description of the radial backfill, Seilacher (2007, pl. 46) did not dwell the description of this structure, providing instead a very short explanation of genesis of radial structures. He indicated that the asterosomid organism (not indicated, maybe a worm-like animal or a crustacean) forms radial backfills depositing the finest material on the wall of its tunnel and pressed it radially outward, maintaining the original diameter of the inner tunnel. The result is an abnormal thickening of radial accretion, forming wide burrows as in the case of the genus *Asterosoma* and their numerous ichnospecies (Seilacher 2007, pl. 46 bottom). In other preservational types (e.g. *Halopoa*) the central furrows may be long and longitudinal, while in *Fucusopsis* (now *Halopoa*) or *Lennea* wrinkles and cracks dominate the outer surface, often with a change of the tunnel arrangement, but the radial accretion is not so developed as for *Asterosoma*. In many specimens

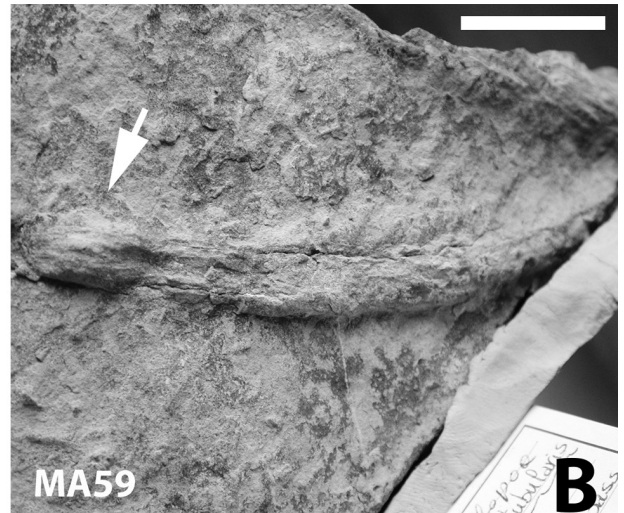
PLATE 2

Examples of asterosomid preservation.

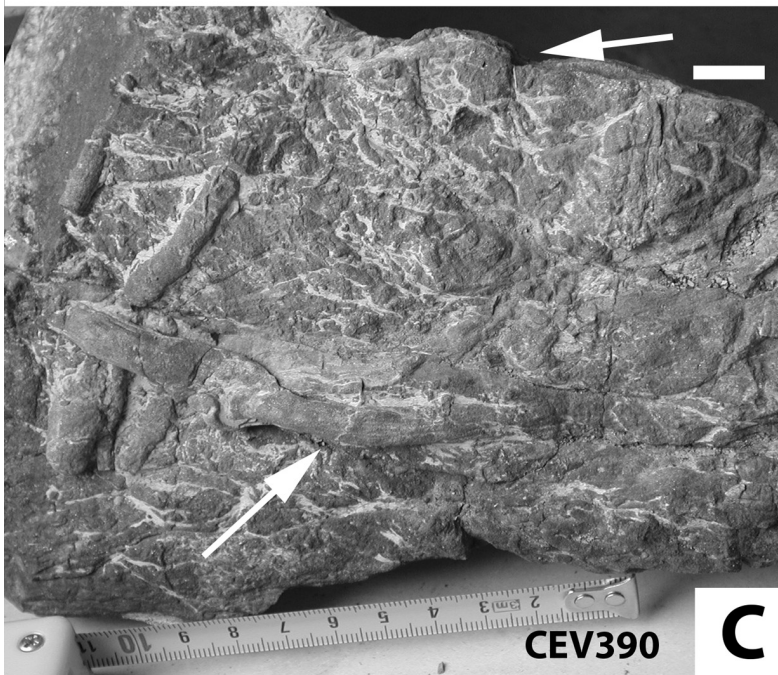
A) Longitudinal set of wrinkles and cracks in *Halopoa* specimens with divergent arrangement, CEV387 Frassineta section, scale bar: 13 mm; B) Hypichnial *Halopoa*-like preservation with terminal bulge (arrow) and longitudinal cracks and oblique wrinkles, MA59 Gli Scalacci section, scale bar: 10 mm; C) multiple crossing specimens of hypichnial *Halopoa/Asterosoma?* preservation, CEV390 Frassineta section, scale bar: 10 mm; D) Hypichnial *Asterosoma*-like specimen with wrinkles and cracks in tunnel, CEV153 Pianello section, scale bar: 10 mm; E) hypichnial *Halopoa* specimens with narrowing of tunnel and diverging wrinkles (arrow), CEV391 Valle del Bidente, scale bar: 10 mm; F) peculiar preservation with an enlarged ring (arrow) and different tunnels (right), CEV390 Bagno di Romagna-Verghereto N section, scale bar in mm.



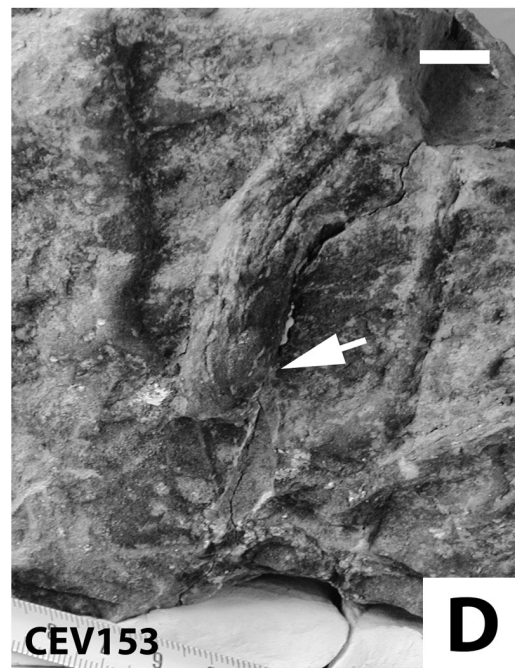
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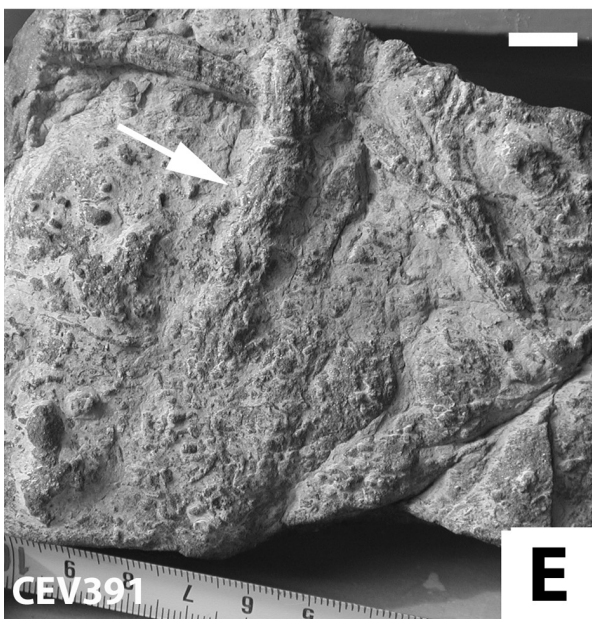
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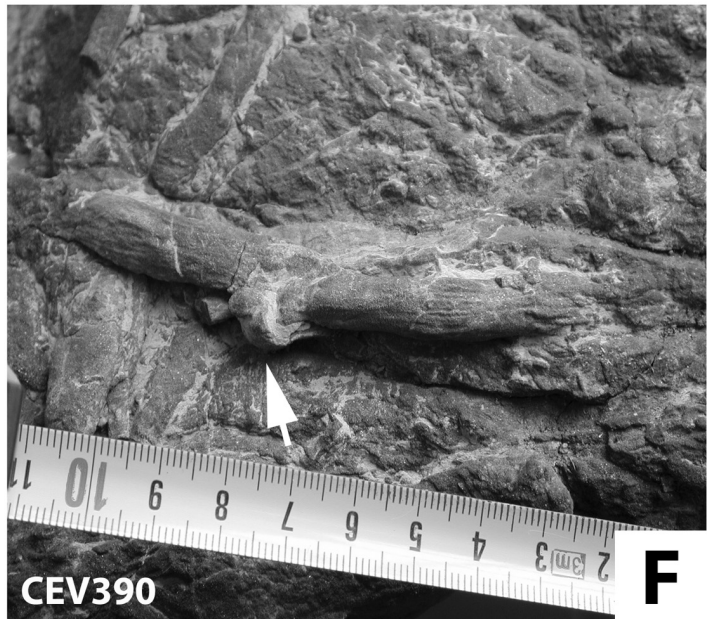
C



D



E



F

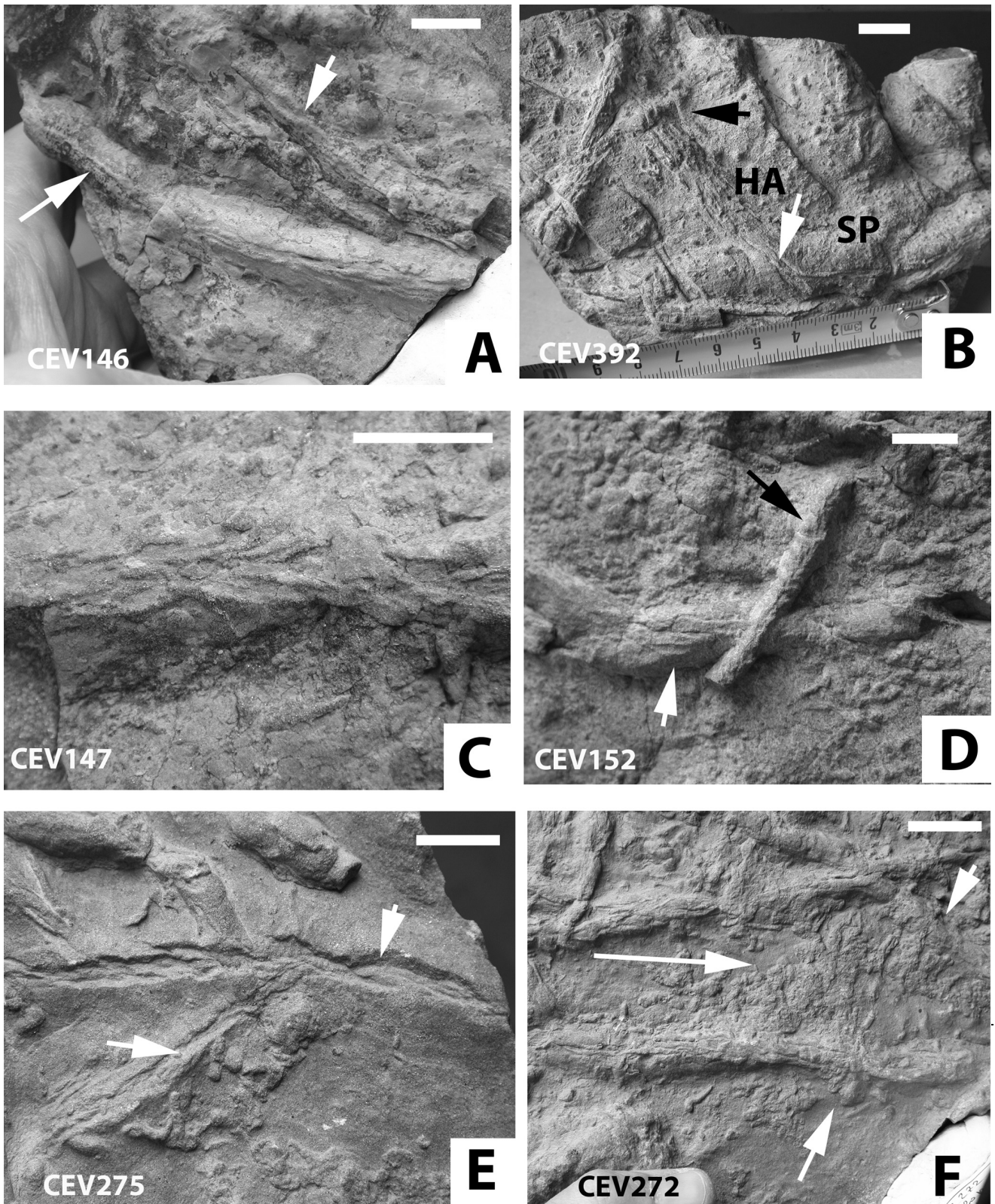


PLATE 3

Examples of asterosomid preservation.

A) Longitudinal wrinkle and axial cracks in *Halopoa* specimens (arrows), CEV146 Renali section, scale bar: 10 mm; B) Perpendicular crosscut of some *Halopoa* (Ha) specimens on *Spirophycus* cf. *bicornis*, CEV392 Maestà section, scale bar: 10 mm; C) wrinkles inclined along the main axis at an angle of 10-20°, arranged in plait-like, oriented fashion (*Halopoa storeana*), CEV147 Renali section, scale bar: 10 mm; D) wrinkles and bulges (arrows) in two specimens of *Halopoa*, CEV152 Pianello section, scale bar: 10 mm; E) cracks are deep (up to 1 mm), wide (normally 1 mm, exceptionally up to 2 mm) and continuous in longitudinal tunnels (arrows), CEV275 Frassineta section, scale bar: 10 mm; F) micro debris flow of mud that produces side by side micro-deltaic structures, each up to 3-5 cm wide and up to 10 cm long, at both sides of tunnels (arrows), CEV272 Frassineta section, scale bar: 15 mm.

from the Tuscan Apennines (Frassineta-Moiano, Casalino-Moggiona, Poggio Prato Pagliaio of southern Casentino area) the wrinkles and cracks are irregularly disposed (anastomosing forms), while in specimens from northern Umbria (Marnoso-arenacea and Verghereto Marls Formations) bulges and narrowing of tunnels are common. The sharp widening of some specimens resemble the outer subrectangular chambers of *Halimedes annulata* in Cretaceous firmgrounds of Southern Alps (Puez Formation, (Lukeneder et al. 2012, pl. 4A, D); those chambers were probably produced by the activity of small crustaceans (Gaillard & Olivero 2009). The analysis of Apennine asterosomids confirms a very strong variability into preservation due to the substrate characteristics. In finer sediments such mud, cracks and micro-debris dominate, while in slightly coarser ones such fine sand and medium sand there are more wrinkles (see also the outer surface with aligned rows of pellets of *Rutichnus rutis*, Monaco 2011). It is not yet clear what the exact role of water saturation of the sediment was, nor their stiff cohesion / cohesiveness / coherence / consistency in order to preserve these types of structures with respect to one another.

Conclusions

The study of the radial backfill technique of 100 different asterosomids specimens from many turbidite facies of the Northern Apennines (Italy), confirms the

model proposed by Seilacher (2007) in his study. In fact, as Seilacher indicated, a microfault pattern increases from inner to outer surface of tunnels where microfaults occur, increasing in abundance and depth. This model is convincing in asterosomids of the Northern Apennines by smooth inner concave surfaces, where the soft-body organism lived and produced the radial backfill, and by the outer cracked convex level fragmented progressively. The arrangement of wrinkles, cracks and micro-debris flow indicates a soupy to soft substrate although stiff – firmgrounds cannot be excluded. The feeding action in hypichnia/endichnia of a soft-bodied, worm-like organism preferred a water-saturated, mud/silt sediment very rich in organic matter that may be typical of fine-grained, turbidites (e.g. levee and overbank deposits). The consistency of the outer part of burrowed sediment preserved longitudinal cracks and also micro-debris flow deposits along both sides of tunnels. The change in diameter of tunnels reflects the change of volume of the body of the worm during their peristaltic contractions during the feeding activity into sediment.

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