

First record of the ichnofossil *Atollites* from the Late Cretaceous of the Northern Apennines, Italy

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A new radial trace fossil, *Atollites italicum* ichnosp. nov., is reported from Upper Cretaceous sediments of the Northern Apennines (Italy). It is made up of several cylinder-club systems, which are interpreted as radiating in a possible faint spiral pattern from a central shaft. The pre-diagenetic reconstruction of the *Atollites* structure is attempted for the first time. The trace fossil may be attributed to small crustaceans or, less probably, it represents a feeding burrow of other deposit feeders.

Key words: Radial trace fossil, Cretaceous, Apennines, Italy.

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Introduction

It is well known that Italy was one of the cradles of invertebrate paleoichnology. In fact, some of the most popular and famous ichnogenera, like *Paleodictyon* Meneghini, 1850 (in Murchison), *Zoophycos* Massalongo, 1855, *Paleomeandron* Peruzzi, 1881, *Taphrhelminthopsis* Sacco, 1888, *Urohelminthoida* Sacco, 1888, and *Lorenzinia* Gabelli, 1900 were established in this country by Italian paleontologists more than a century ago.

The flysch units are among the best sediments for preserving ichnofossils. In the Northern Apennine chain, such turbiditic complexes are several hundreds of metres thick, spanning from the Late Cretaceous to the late Miocene. Although trace fossils are quite abundant in such units, radial structures are very rare.

As regards their interpretation, there are several “medusoid” ichnogenera like *Asterichnus*, *Atollites*, *Capodistria*, *Gyrophyllites*, *Kirklandia*, *Lorenzinia*, that need clarification. The names “Traces en rosette” (Lucas and Rech-Frollo 1965), “star shaped problematica” (Ślączka 1965), “rosetted trails” (Książkiewicz 1970), “rosetted trace fossils” (Grubic 1970), “star-like trace fossils” (Häntzschel 1970; Karaszewski 1973), “rosetted structures” (Książkiewicz 1977; Schlirf 2000), “rosette-shaped trace fossils” (Fürsich and Bromley 1985) and “radial structures” (Uchman 1995) have been used for these kinds of ichnofossils. Furthermore, in the last available edition of the *Treatise on Invertebrate Paleontology* part W this group of traces is discussed under “Trace fossils or medusae incertae sedis” (Häntzschel 1975). However, with only one specimen available, it is impossible to make any contribution to such “clarification” at present.

Institutional abbreviation.—CMV, City Museum of Vigonola, Modena District, Italy.

Geological setting

The specimen described herein was collected by an amateur paleontologist from the red clay quarry of Cava Castelletta situated in the territory of Prignano (Modena district) close to the road running along the valley-bottom to the village of Gombola on the left bank of the River Rossenna (Fig. 1).

The quarry is placed in a large, displaced olistostrome of Argille varicolori di Cassio, included in the chaotic complex named Complesso di Rio Cargnone, possibly late Paleocene–middle Eocene in age (Bettelli et al. 2002). However, the original age of the Argille varicolori di Cassio unit, established in the Serramazzoni area on the basis of planktic foraminifera (Serpagli 1964a) as late Cenomanian–Turonian, was later expanded up to late Campanian on the basis of nannoplankton (Rio and Villa 1987; Fioroni et al. 2002). Therefore, the age of the ichnospecimen under discussion is considered here as Late Cretaceous.

The olistostrome of Argille varicolori di Cassio consists of varicoloured, mostly red, clays, about 100 m thick, deposited on a submarine plain below the Carbonate Compensation Depth, CCD (Bettelli et al. 2002). Its original stratigraphic position is at the base of the turbiditic flysch complex of Serramazzoni belonging to the upper Campanian–upper Maastrichtian Monte Cassio Formation.

The fossil record from the Argille varicolori di Cassio cropping out in Modena Province is very poor and, besides a few foraminifers and nannoplankton, is restricted to twenty species of dinoflagellates (Serpagli 1964b), and to ichthyosaur remains, discovered in the same quarry, consisting of two caudal centra of *Platypterygius* sp. (Rompianesi and Sirotti 1994; Sirotti and Papazzoni 2002) and to one pliosaurid tooth reported from another quarry just a few kilometres NNE of Cava Castelletta (Papazzoni 2003).

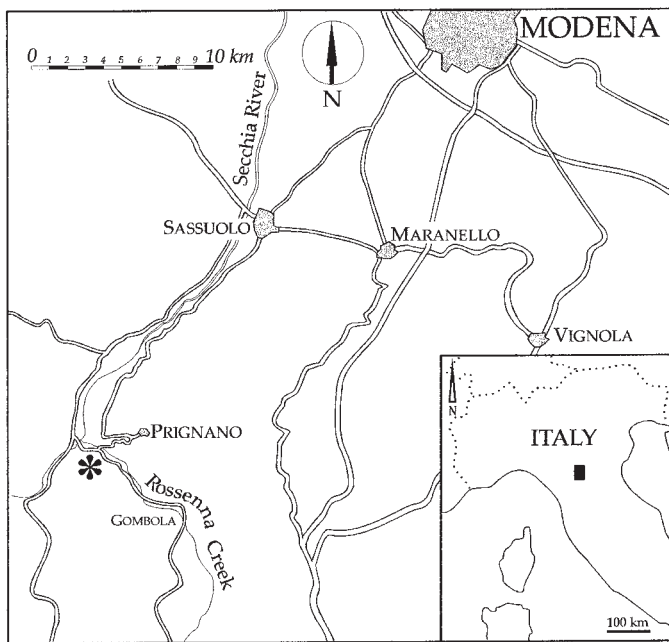


Fig. 1. Location map of the site (asterisk) where the specimen was collected.

Former record of “star-like trace fossils” in the Northern Apennines

The specimens recorded so far are almost all assignable to the ichnogenus *Lorenzina* and were studied mostly by former authors. Gabelli (1900) was the first to describe this kind of trace fossil from Cretaceous–Eocene flysch deposits (chaotic-“argille scagliose”) of the Northern Apennines. He established the ichnogenus *Lorenzina* (type species *L. apenninica*). Simonelli (1905) referred two specimens to *Lorenzina*, possibly *L. apenninica* (later identified as *L. apenninica* by Gortani 1920) which were found in a Tertiary? flysch unit of the Northern Apennines and envisaged the possibility that *Lorenzina* might be impressions of holothurian tentacles. Although these two specimens were found very close together in the same slab, they are apparently quite different. Fucini (1908) figured a trace fossil “very close” to *L. apenninica* from Pania di Corfino (Eocene?) and four years later (Fucini 1912: 21) recorded (but not figured) several traces fossils possibly close to *Lorenzina* from the “Verrucano” formation of the Monte Argentario area. Gortani (1920) provided a revision of the former specimens when he figured a slab with five specimens of *L. carpatica* (Zuber, 1910) from the Pania di Corfino area and, after exploring several hypotheses on the affinities of *Lorenzina*, concluded that the *Lorenzina* specimens must be referred to medusae. Uchman (1995) quite recently reported *Lorenzina pustulosa* (Książkiewicz, 1977) and *Capodistria vettersi* Vyalov, 1968 from turbiditic beds of the Marnoso-arenacea Formation (Miocene, Northern Apennines).

Besides the finds in the Northern Apennines, radial structures have been recognised only in two places of north-eastern Italy, both in Tertiary flysch deposits of Eocene age. Tunis and Uchman (1998) record *Lorenzina* and *Glockerichnus* in the Carnian pre-Alps and Malaroda (1947) referred to *Medusina tezgestina* Malaroda, 1947 radial traces discovered not far from Trieste.

Systematic palaeontology

Ichnogenus *Atollites* Maas, 1902

Type ichnospecies: *Atollites zitteli* Maas, 1902, by subsequent designation (Kieslinger, 1939).

Diagnosis.—Body discoidal, of circular outline; mid-field with small, circular, smooth depression, encircled by slightly convex annular zone crossed by 12 to 14 raised, narrow radial bands; external zone with 12 to 14 pyriform lobes, wider and thicker at periphery, sharply separated by deep radial sulci, some partly split by supplementary radial grooves.

Seilacher (1954: fig. 2) was the first to classify rosetted structures like *Lorenzina* (and *Atollites*) as feeding burrows abandoning the idea that they were imprints of medusae. As will be demonstrated below, *Atollites* represents a complex burrow system, which has nothing to do with medusoid-like body fossils owing to the presence of a vertical shaft connecting the cells (clubs) via lateral tunnels (cylinders).

Atollites has been regarded as synonymous with *Lorenzina* Gabelli, 1900 (not Da Gabelli) by several authors (Kieslinger 1939). I believe that *Atollites* is not only different from *Lorenzina*, as pointed out also by Seilacher (1977: 317), but also that these two trace fossils possibly belong to different ethological groups.

Atollites italicum ichnosp. nov.

Fig. 2A, B.

Holotype: Fig. 2. CMV 240787.

Type locality: Castelletta Quarry located in the territory of Prignano (Modena District).

Derivation of the name: The species name refers to the occurrence of the new taxon in Italy.

Diagnosis.—Rossetted (star-shaped) circular body having a central field with a circular area (bearing a small hole at the centre) encircled by a sharp, narrow, raised ridge-like collar, surrounded by an intermediate depressed zone radially crossed by numerous, narrow ray-like cylinders each connecting globular-subglobular knob-like clubs of the external zone. The boundary between the intermediate and external zones is not very well defined owing to the partial overlapping of some “clubs”. On the other hand, the boundary between the trace and the “housing” rock is well defined.

Description.—The diameter of the whole rosetted specimen varies from 60 to 65 mm and its thickness from 4 to 7 mm. It occurs inside a sediment rich in iron, black in colour, made

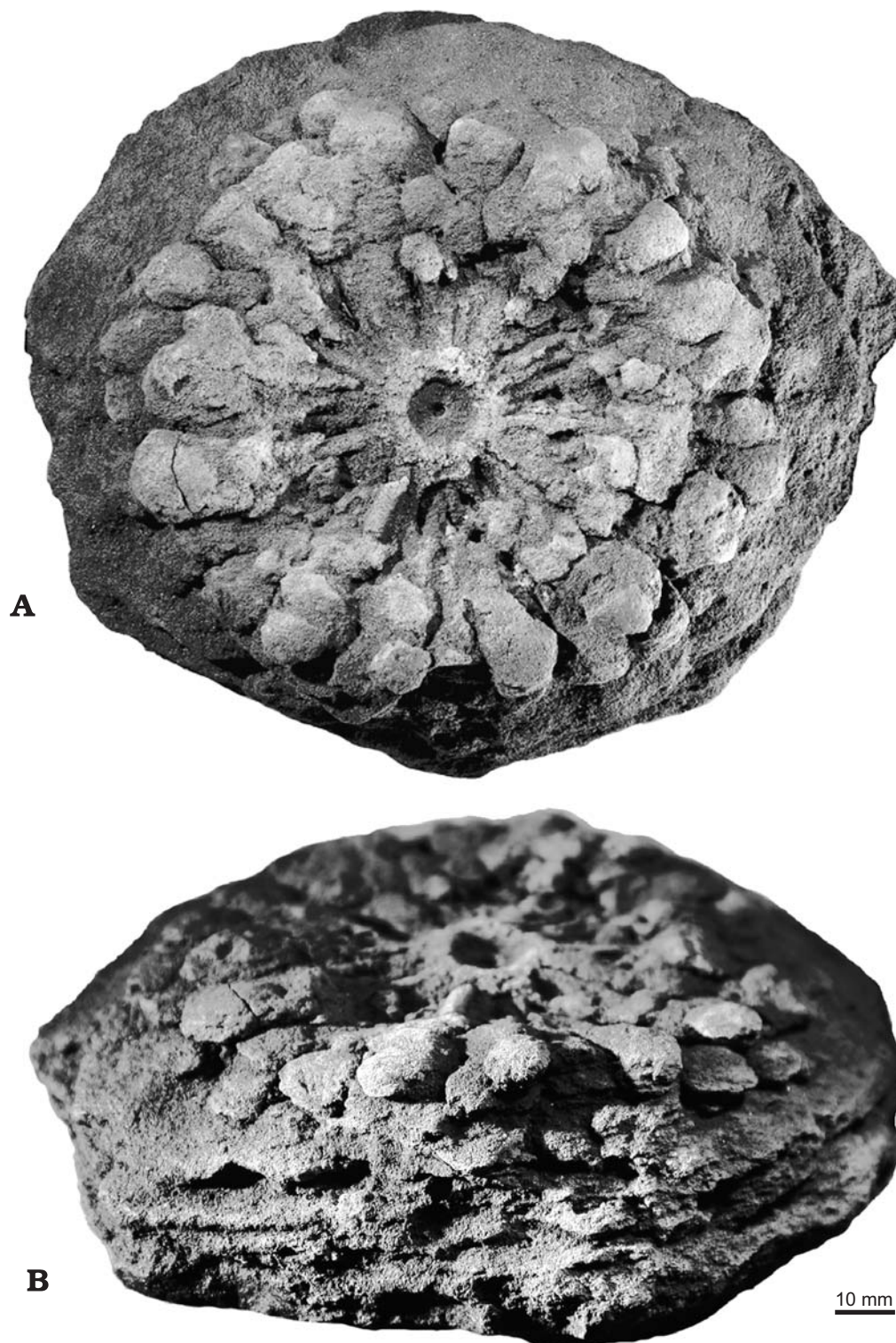


Fig. 2. *Atollites italicum* ichnosp. nov., CMV 240787, holotype in upper (A) and oblique (B) views.

by fine spherulites of dolomite which have substituted the original pelitic sediment.

The central circular area, including the encircling ridge-like collar, ranges from 10 to 11 mm in diameter. Inside the 2 mm thick ridge, there is a flat area (6 mm in diameter) with a narrow central hole (1–1.5 mm in diameter) producing a

neck-like constriction. The intermediate area is mostly occupied by the densely packed ray-like cylinders whose length ranges from 7 to 12 mm whereas the diameter seems to be more constant being about 1–1.5 mm. Locally, near the axis of the system, the cylinders overlap leaving only a small area of substrate undisturbed in the vicinity of the ridge. This also

prevents the exact number of cylinders from being established, but, owing to obliteration, they are apparently less in number than the clubs.

The clubs, 30–35 in number, are very close together and variable in shape (globular or subglobular) and size, ranging from 4×5 mm (for the smallest, mostly globular) to 8×11 mm (for the largest, mostly subglobular). The two groups of clubs are randomly distributed even if wider clubs are apparently more common at the periphery of the body. Whereas the clubs are in groups of two sizes, the ray-like cylinders have more or less the same diameter which corresponds to the diameter of the hole in the central area.

All the structures (cylinders and clubs) are in the form of internal moulds.

Reconstruction.—No attempt to identify the trace-maker can be made without restoration of the structure before it was affected by diagenesis and/or tectonics.

The specimen appears to be approximately planar owing to compaction, but it is nevertheless three-dimensional having a residual thickness between 4 and 7 mm. I have not been able to determine the precise degree of compaction affecting the specimen but reduction by 90% is probably consistent. Because of that, I interpret the pre-diagenetic situation as being very close to the idealised reconstruction showed in Fig. 3A, whereas in the Fig. 3B–D a computer visualization of the gradual compaction affecting the structure is illustrated. In all the figures the number of lateral clubs and cylinders has been deliberately and markedly reduced in order to produce clear, light and intelligible drawings. A conical reconstruction of the whole building is favoured because wider clubs are apparently more common at the periphery of the body.

In the structure three main elements can be recognised: a vertical, axial shaft, about 30–35 lateral clubs and as many connecting cylinders.

From the axial shaft, whose entrance is clearly visible in the centre of the specimen, about 30–35 clubs radiate sub-horizontally via narrow cylinders. In fact, the pre-compaction angle formed by the cylinders and the central shaft was probably close to 90° or so. The club-cylinder systems may follow a slight helical arrangement (faint spiral pattern) and in most cases they are arranged in closely packed whorls.

Discussion.—The trace fossil described has no equivalent, at least in literature known to the author, and therefore the establishing of a new species is proposed. *Atollites zitteli* Maas, 1902 and *A. minor* Maas, 1902 are apparently the only valid species of the ichnogenus. Other ichnotaxa originally referred to *Atollites* like *A. carpathicus* Zuber, 1910 and *A. caucasicus* Sobolev, 1957 have been subsequently placed in *Lorenzina* Gabelli, 1900 and *Kirklandia* Caster, 1945 respectively (Nowak 1957; Ślaczka 1964), whereas validity of *A. kulczinskii* Kuźniar, 1911 needs verification.

This ichnospecies shows important diagnostic characters that distinguish it from other species of the genus: (a) the clubs are of different sizes with the largest mostly at the periphery of the crown whereas either in *Atollites minor* or in *A.*

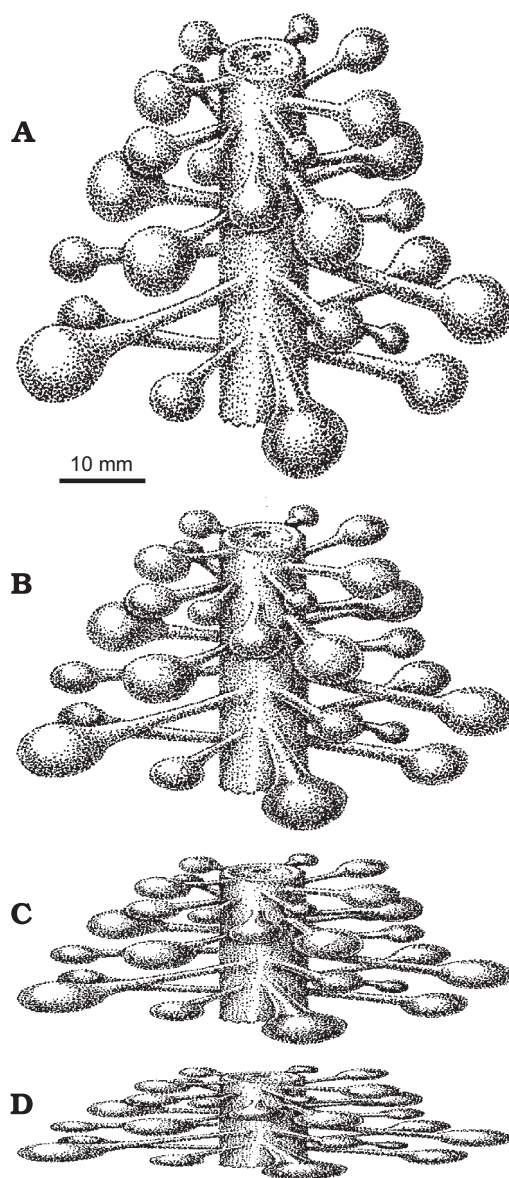


Fig. 3. A. Schematic and simplified pre-diagenetic reconstruction of the whole architecture of *Atollites italicum* ichnosp. nov.,. For drawing purposes, the number of lateral cylinders and clubs has been reduced to less than half of those actually present. B–D. Computer visualization of gradual compaction of the structure.

zitteli they are more or less the same size; (b) furthermore, *A. italicum* has at least a three times as many chambers as the former two species.

The possible helical arrangement of the clubs evidenced by our specimen confirms also a hypothetical link between *Atollites* and *Gyrophyllites* Glocker, 1841 (Seilacher 1977) and not between *Atollites* and *Lorenzina* as previously supposed (Kieslinger 1939).

There are similarities between the central area of the structure encircling the entrance of the shaft, and the same area of *Palaeosemaeastoma geryonides* (Huene, 1901) where a raised narrow collar is also present. Faint architectural similarities exist with elements of the ichnogenus *Celli-*

calichnus Genise, 2000 erected for fossil bee cells which is one of the most common traces in palaeosols.

Interpretation of the trace fossil

Very few attempts have been made to interpret the origin of “rosetted structures”.

Nowak (1957) tentatively explains *Lorenzina*-type trace fossils as feeding burrows made by crabs which accumulated their processed material in a star-shaped trace. Trace-makers have also been searched for among annelids (Häntzschel 1970; Książkiewicz 1977) and sipunculoids (Heezen and Hollister 1971). Vonderbank (1970: figs. 28, 29) attempted a spatial reconstruction of *Gyrophyllites kwassizensis* Glocker, 1841. Fürsich and Kennedy (1975) interpreted *Kirklandia* part as feeding trace of *Gyrophyllites* type and part as faecal-pellet-lined burrows. Seilacher (1977: 317) focuses his interpretation on *Atollites* stressing similarities with “faecal-stuffed burrows of sediment feeders such as *Gyrophyllites*”. Plička (1984) showed that “medusa-like” impressions were actually impressions of cudgel-shaped spines of echinoids probably of the *Cidaroida* group. Fürsich and Bromley (1985) interpreted the rosetted trace *Dactyloidies ottoi* (Geinitz, 1849) as a fodinichnion whose radial elements were protusive sprite made by a worm-like organism.

A building like that of *A. italicum* (Fig. 2) could have been produced by an organism burrowing vertically through the sediment and periodically changing its direction (behaviour?) to produce lateral chambers (clubs). There are, however, difficulties involved in identifying the trace-maker and it cannot be easily decided what kind of animal made *Atollites*. The presumed burrower could have been a worm-like animal or crustacean, able to move not only within the central shaft but also within the subhorizontal, narrow tunnels (cylinders) connecting the several lateral chambers of the system. Nevertheless, the reduced diameter of the lateral tunnels in comparison to that of the main vertical shaft and to the chambers is very difficult to explain just as it is also difficult to explain the existence of two kind of chambers (small and large).

For the moment two hypotheses can be suggested.

Hypothesis 1.—The construction could have been built by small, slim crustaceans, as long as the diameter of the vertical axial shaft and as wide as the diameter of the tunnels. Such crustaceans, possibly amphipod- or isopod-like, would be living together as in a colony, each individual perforating the wall of the shaft to excavate the tunnel and the chamber at its end. The chambers could have been used to rest or to store food (living chambers), to deposit or brood on eggs until hatching occurred (breeding chambers). The inhabitants of the building could have been of two sizes, male and female, or moulted and unmoulted individuals; this would explain the existence of cells of two sizes. In such an interpretation *A. italicum* could be classified among “callichnia” *sensu* Genise and Bown (1994).

Simple (U- or I-shaped) constructions below the sea-floor made by small living crustaceans like *Corophium* were shown by Seilacher (1953: 429) and the hypothesis of crustaceans producing “star-like” traces was favoured by Altevogt (1968) for *Asterosoma* Otto, 1854 and supposed by Schlirf (2000: 166) for *Asterichnus* Bandel, 1967.

Hypothesis 2.—The chamber-tunnel systems could suggest that the construction be interpreted as the feeding burrow of a deposit-feeder. The worm-like animal(s) could have possibly started to feed at higher levels (probably at the sea floor) as is suggested by the presence of a rim around the entrance. The outline and the existence of a vertical shaft connecting the chambers via sub-horizontal tunnels, leads me to assume that *A. italicum* could be classified as a possible fodinichnion. If *Atollites* was a feeding structure, the high complexity of the burrow system demonstrates a very well-specialised trophic adaptation and an efficient program for organic matter exploitation.

Stating first that both interpretations are largely speculative, I am inclined to favour hypothesis 1 because a deposit feeder systematically mining the sediment for food (hypothesis 2) does not usually produce chambers at the ends of tunnels. Furthermore, the lithology of the “bearing” rock and the massive fill of the tunnels and chambers is exactly the same. If the animal was a sediment-feeder, it must have first extracted food particles from the sediment and then refilled part of the feeding burrow with waste sediment, which should be slightly different from the main rock housing the burrow.

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