Fossil Gastropods (*?Aclis aenigmaticus* n. sp.) on a fish from the Pesciara of Bolca Lagerstätte (Eocene, Northern Italy): an enigmatic association

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Abstract

In the present life there are plenty of organisms associated with the integument of fishes; they can be commensals, mutualists or parasites (durable interactions). In the fossil record, it is very rare to find such associations although the fishes' integument is often very well preserved in exceptional conservation sites (Konservat - Lagerstätten). The observation of several thousands of fossil fishes from the collections of Munich, Paris and Verona museums enabled us to describe two snails of the species ?Aclis aenigmatica *Merle nov. sp. They seem to be fixed to the integument of a specimen of* Eoplatax papilio *(Volta, 1796), a fossil fish from the Pesciara di Bolca (Eocene, Northern Italy), deposited at the Paris National Museum of Natural History. It is difficult to specify the nature of the association and to determine if it happened while the fish was alive or after its death; some hypotheses are considered.*
Key Words: *Gastropods, fishes, durable interactions, Eocene, Pesciara di Bolca, Lagerstätte, paleoenvironment, paleoparasitology.*

Riassunto

Gli organismi associati all'apparato tegumentario dei pesci sono incredibilmente diversi e numerosi, e possono avere una relazione di commensalismo, mutualismo o parrassitismo. D'altra parte, nel registro fossile questo tipo d'associazione é stata documentata raramente, anche se nei siti a fossilizzazione eccezionale (Konservat-Lagerstätten) il tegumento dei pesci può essere ben conservato. L'osservazione di migliaia di pesci fossili nelle collezioni paleontologiche di Monaco, Parigi e Verona ha permesso di descrivere una nuova specie di gasteropode ?*Aclis aenigmatica* Merle nov. sp., che sembra essere fissata al tegumento di un esemplare di *Eoplatax papillo* (Volta, 1769), pesce fossile presente nella collezione di Bolca (Eocene, Italia Settentrionale) del Museo Nazionale di Storia Naturale di Parigi. Resta in ogni modo difficile precisare la natura dell'associazione e se la stessa sia avvenuta durante la vita del pesce, o dopo la sua morte; alcune ipotesi sono discusse.
Parole chiave: Gasteropodi, pesci, interazioni durevoli, Eocene, Pesciara di Bolca, Lagerstätte, paleoambiente, paleoparassitologia.

Introduction

Soft body structures in fossils from exceptional conservation sites (Konservat-Lagerstätte) are very well preserved and, in particular, the integument of some fishes can be in a perfect state of conservation. For several years we have been looking for organisms attached to or inside the integument of fossil fishes.

When this relationship is established during the fish life, the presence of these organisms may correspond to different types of associations: durable interactions (Combes, 1995) such as commensalism, mutualism and parasitism or ephemeral relations, without benefit or negative effect for both species. When the relationship is established after the fish death, it is necessarily short-lived. Some species will be there by hazard without gaining anything in particular, while others are represented by organisms feeding on the remains of the fish (scavengers, saprophytes).

During our examination of the museum collections in Munich (Bayerische Staatssammlung für Paläontologie und Geologie), Paris (Muséum national d'Histoire naturelle, collection de Paléontologie) and Verona (Museo Civico di Storia Naturale di Verona), more than 5000 fossil fishes were observed. Only skin tumors showing an internal pathology have been described in several fossil fishes from the Pesciara di Bolca (Eocene, Northern Italy) (Petit, 2010) and in a fish from the Solnhofen Plattenkalke (Upper Jurassic, southern Germany) (Petit and Khalloufi, 2012). To our knowledge, no description of an organism associated with the integument of a fish has been made to date from the fossil record.

The presence of two adult specimens of gastropods (new species) on the integument of a fossil fish from

the Pesciara di Bolca is an original observation. We will propose several hypotheses trying to explain the relationship between the gastropod and the fish.

The Gastropods

The two specimens observed correspond to a new species described below in a short systematic part. The first one (holotype G1, Fig. 1) is placed on the fish (BOL 92) and the second one (paratype G2, Fig. 2) is placed on the imprint of the fish (BOL 93). Each gastropod is also represented by its imprint (E1, Fig. 2C for the holotype and E2, Fig. 1C for the paratype). The two gastropods have the same parallel alignment, with the aperture directed towards the dorsal side of the fish. They are located behind the opercle, at the level of the pectoral fin. It is difficult to conclude if they adhere to the fin or to the integument below the fin, in reason of the artefacts of compression and fossilisation.

Class Gastropoda Cuvier, 1797
Order Neotaenioglossa Haller, 1882
"Group" Ptenoglossa Gray, 1853
Superfamily Eulimoidea, Philippi 1853
Family Aclididae Sars, 1878
Genus *Aclis* Lovén, 1846
Type species - *Alvania supranitida* Wood S.V., 1842 by monotypy.

?Aclis aenigmatica Merle nov. sp.
Figg. 1 and 2

Etymology
From the latin *aenigmaticus* (= enigmatic).

Type locality
Late Ypresian from Monte-Bolca, northern Italy (Pesciara di Bolca).

Type specimens
Holotype MNHN.F.A49912; paratype MNHN.F.A49913. Both specimens are housed in the collection of Paléontologie of the Muséum national d'Histoire naturelle, Paris. They are stored in the fish collection because they are preserved on the holotype of *Eoplatax papilio* (Volta, 1796).

Description of the holotype
Turriculate-pupoid shell of 3.5 mm in height and of 1.5 mm in width. Six convex teleoconch whorls. Suture linear. Protoconch and first teleoconch whorl missing. First preserved teleoconch whorl damaged, poorly visible. Last whorl occupying 37% of the total height. From the second to the third whorl, spiral sculpture made by fine threads more marked abapically than adapically. Eight spiral cords on the penultimate whorl, and twelve cords on the last whorl. No collabral sculpture. Aperture apparently holostomous or weakly siphonostomous.

The shell, presumably in living position, is visible in dorsal view.

Description of the paratype
The second gastropod is less well preserved than the first one, because its aperture is damaged and because the teleoconch whorls are partially covered by sedimentary matrix. Nevertheless, the shape is similar to that of the holotype (height 3-4 mm, width 1.5 mm, turriculate-pupoid shell, aperture holostomous or weakly siphonostomous) and the spiral sculpture displays also fine threads.

This shell is visible in dorsal view, too.

Comments and comparisons
As the characters of the protoconchs and of the ventral face of the teleoconch are unknown, it is difficult to give a generic or familial attribution with a high degree of certainty. The shape of these two shells suggests similarities with the Cerithioidea or the Eulimoidea, both being known during the Eocene. Among the Cerithioidea, several cerithids, such as members of the genus *Bittium* Gray, 1847, display a similar shape. However, they usually bear an axial sculpture that is lacking in the specimens from the Pesciara di Bolca. Juveniles of the turritellid genus *Sigmesalia* Finlay and Marwick, 1937 can also resemble these specimens, but they are usually larger in size. Among the Eulimoidea, aclids of the genus *Aclis* Lovén 1846 share more similarities with the gastropods here described and they are known from the Middle Eocene. The new species is therefore ascribed dubitatively to this genus. ?*Aclis aenigmaticus* has many characters in common (small size, 4-5 teleoconch whorls, spiral sculpture, holostomous or weakly siphonostomous aperture) with *Aclis tenuilirata* Cossmann, 1900 from the Middle Eocene of the Bois-Gouët (Western France) but it differs in having only five spiral cords on the penultimate whorls and eight on the last whorl. The spiral cords are stronger in *A. tenuilirata*. In addition, they are missing on the base of the shell of *A. tenuilirata* whereas they are present in ?*A aenigmaticus*.

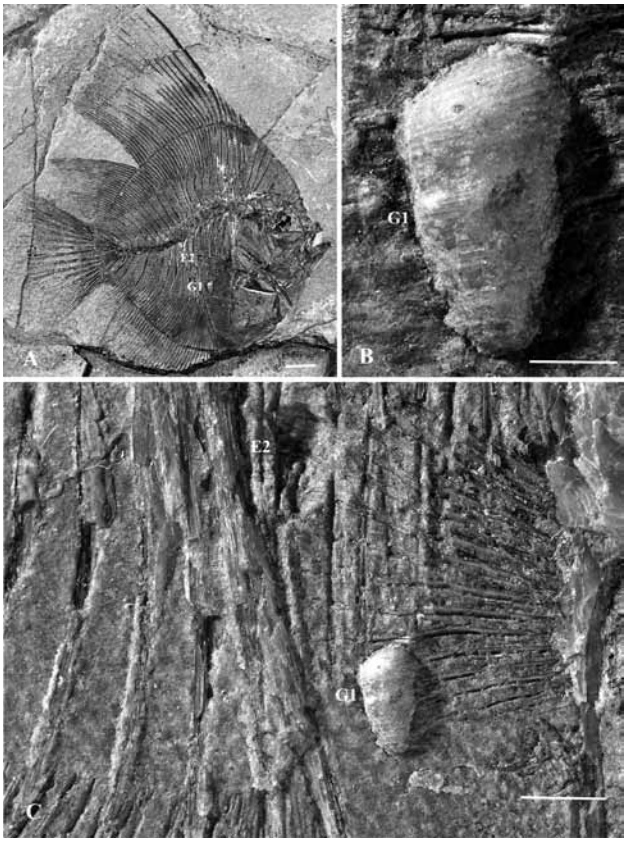

Fig 1 - *A*, General view of the part (bol 92), G1: gastropod G1 (holotype), E2: imprint of the gastropod G2 (paratype), scale bar 1cm. *B*, Details of the gastropod G1 (Bol 92), scale bar 1mm. *C*, View of the gastropod G1 and the imprint E2 behind the operculum (bol 92), scale bar 3mm.

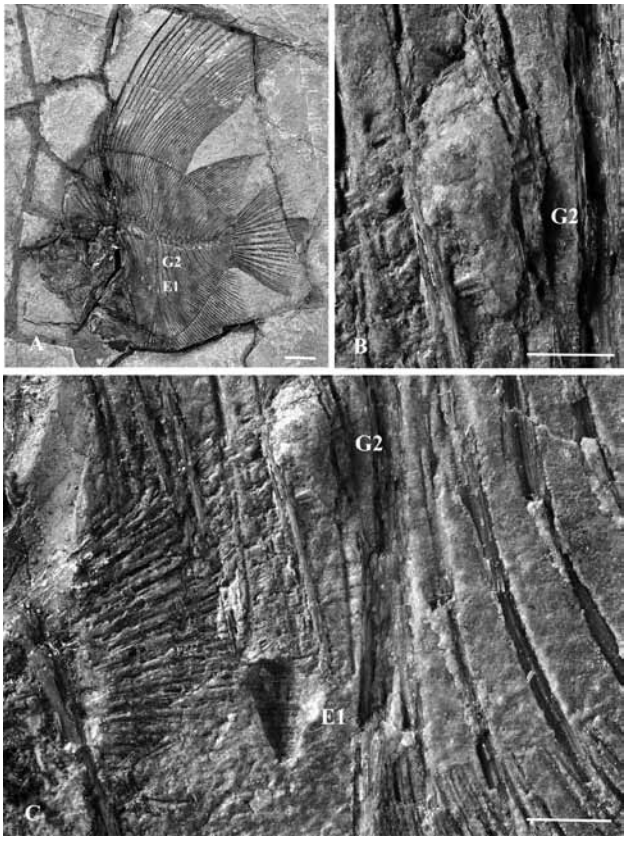

Fig 2 - *A*, General view of the counterpart (bol 93), G2 (paratype), E1: imprint of the holotype, scale bar 1cm. *B*, Details of the gastropod G2, scale bar 1mm. *C*: View of the gastropod G2 and the imprint E2, behind the operculum (bol 93), scale bar 3mm.

The Fish

The fossil fish is the holotype of *Eoplatax papilio* (Volta, 1796) deposited at the MNHN (Paris) and represented by a part (Bol 92, Fig. 1A) and a counterpart (Bol 93, Fig. 2C). It comes from the Gazola collection. This fish is particularly well preserved. The full description provided by Blot (1969) does not mention the presence of the gastropods, although they are very evident on the photographic plate LXVI. This fish belongs to the family Ephippidae and his normal living environment appears to be coral reefs (Landini and Sorbini, 1996; Bellwood, 1996) or a transition between coral reefs and pelagic systems (Papazzoni and Trevisani, 2006).

Five other specimens of *E. papilio* without any epibiont were observed at the Museum of Verona.

Palaeoenvironment of the Pesciara di Bolca

The locality of Bolca includes different fossiliferous sites, the fishes coming mainly from the «Pesciara di Bolca».

The stratigraphical succession of the Pesciara was reconsidered by Papazzoni & Trevisani (2006), who distinguished five 1 meter-thick layers of grey, fine-grained limestone. These layers with fishes and plants are intercalated by coarse-grained biocalcarenite-biocalcirudite layers, 1 to 3 meters-thick, with molluscs and foraminifers. Using paleontological and sedimentological data, the authors indicated a late Ypresian age for the site (between 49 and 50 Ma) and reconstructed the paleoenvironment as a basin or sub-tropical lagoon, close to land and in relation to rivers and wetlands. From time to time, this basin showed phases of opening to the sea and phases of isolation. When the basin was closed, conditions of weak oxygena-

tion and low disturbance of the sediment was established at the bottom. These circumstances explain the exceptional conditions of fossilization. More recently Schwark et al. (2009) confirm this model and describe, in the lagoon, a water column "higly stratified with anoxic saline bottom and fresh water surface". High salinity is not demonstrated. Dalla Vecchia et al. (2005) and Zorzin (2011) have assumed that the fishes death occurred from natural causes.

Discussion

A wide variety of organisms may be more or less closely related to the integument of current fishes. Most are parasites (see Paperna, 1996; Groff, 2001). They belong to the group of viruses, Bacteria, fungi (Microsporidia), Ciliata, Myxozoa, Plathyhelminthes (Turbellaria, Trematoda, Monogenea), Annelida (leeches), Mollusca (larvae of bivalves, gastropods), Crustacean (Branchiura, Isopoda, Copepoda), Vertebrata (lamprey). Depending on the group, they form tumours or skin cysts or are simply attached to the integument by specific structures (hooks, suckers, haptors, etc.). Other organisms are difficult to classify among commensals, mutualists or parasites because costs or benefits for each partner of the association are not well known: the teleostean fish from the Echeneidae family that attaches itself to a large variety of fish thanks to suckers (see Brunnschweiler and Sazima, 2008); the sessile hydroid colonies (Gudger, 1928) that attach to fish skin and fin and seem to form a camouflage; the chironomid larvae (see Henriques-Oliveira and Nessimian, 2009) that attach to fish skin or fin by their parapods and build up a pupa for their development.

Regarding molluscs, parasitism is common in freshwater fish: larvae of bivalve (Unionoida) have to encapsulate themselves inside the integument of the scales, gills and body of the fish in order to develop the juvenile stage (Graf et al., 2007; Kat, 2007). This interspecific relation also allows for the dispersal of the parasite. Some species of gastropods are bloodsucking ectoparasites of fish. They belong to the taxa Marginellidae (Kosuge, 1986; Bouchet, 1989), Cancellariidae (O'Sullivan et al., 1987) and Colubrariidae (Johnson et al., 1995; Bouchet and Perrine, 1996).

To explain the association between the two gastropods and the fish, some hypotheses are proposed here, which take into consideration the palaeoenvironment of the Pesciara di Bolca.

Association of the gastropods after the fish death

Benthic fauna is rare in fish levels. It is conceivable that two scavenging gastropods coming from outside the lagoon (storms, rising sea level) were attracted by the dead fish. To understand the fossilization of both species simultaneously, we must imagine that under anoxic conditions at the bottom of the lagoon, gastropods remain attached to their support, in a state of slow life, before dying. Experiments currently performed with a marine gastropod scavenger in hypoxic conditions show a slowed metabolism that may precede death (Cheung et al., 2008).

Association of the gastropods with the living fish

-Phoresy / Mutualism

Even if transportation of a gastropod by a fish has never been described in recent life, it is possible to imagine that this way of life may have existed in the past. Adult or larval stage of the gastropod can be installed when the fish passes through fields of algae, for example, or when it is in sleep phase. The relationship can evolve towards mutualism if the gastropod is feeding on algae and microorganisms adhered to the fish skin.

After death, the fish falls on the bottom and the same process illustrated above can occur.

-Parasitism

The gastropod ectoparasites of fish (see above) insert their proboscis into the tissues of a sleeping fish to pump blood and body fluids from it. Bouchet (1989) observed this type of association in vivo, in coral reefs of Noumea. Snails belonging to the Marginellidae "appeared to be firmly attached, and would not move after several minutes of illumination". We can assume that the two snails here have the same lifestyle. They are attracted by the fish dying on the bottom (behaviour similar to sleeping fish?), but they cannot finish their blood meal due to anoxic conditions. After that, they stick to the integument in a state of slow life before dying.

The aclidids belong to the Ptenoglossa which includes ectoparasites, but their hosts are cnidarians for the epitonids and echinoids for the eulimids (see Bouchet and Waren, 1986; McClain and Crouse, 2006). The presence of examples of parasitism in gastropods taxonomically close to the aclidids is an argument in favour of parasitism but this behaviour has not been reported until now for this group.

Conclusion

Despite this wide range of associations between fishes and their commensals, mutualists, or parasites, very few of them have been described in relation to fossils. The association between the snail and the fish remains enigmatic and many hypotheses are possible. In order to specify its nature, it would be necessary to obtain more material with the aim of validating the repeatability of the observation, of confirming the taxonomic identification of the gastropods and of knowing better the process of fossilization involved in this unusual association.

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