Skin nodules in fossil fishes from Monte Bolca (Eocene, Northern Italy)

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Petit G. 2010. — Skin nodules in fossil fishes from Monte Bolca (Eocene, Northern Italy). *Geodiversitas* 32 (1): 157-163.

ABSTRACT
The collection of fossil fishes from Monte Bolca (Eocene of Northern Italy), deposited at the Muséum national d'Histoire naturelle, Paris, was examined for the detection of parasites or traces of their activity. Of the 349 fishes studied, 62 showed a fairly well-preserved integument for the observation of skin nodules. Of these, all teleosts, six specimen exhibited skin nodules.The percentage of diseased fish is therefore 9.7%. The concerned species were *Exellia* (= *Semiophorus*) *velifer* (Volta, 1796), *Abromasta* (= *Pagellus*) *microdon* (Agassiz, 1839), *Pseudosparnodus microstomus* (Agassiz, 1839), *Eozanclus brevirostris* (Agassiz, 1833-1844) and *Cyclopoma gigas* Agassiz, 1833-1844. These pathologies of the integument are morphologically similar to those that can be observed in extant taxa. The causes of fish nodules are diverse (toxins, infectious agents, physical causes, imunological causes, nutritional and metabolic perturbations), but a pathogen among the group of viruses, bacteria, myxozoa, microporidia, ciliata, trematoda or turbellaria is generally involved. Their presence reflects an unbalanced palaeoenvironment in the basin where the fishes of the "Pesciara di Bolca" fossilized.

KEY WORDS
Teleostei,
skin nodules,
paleopathology,
paleoparasitology,
palaeoenvironnement,
Monte Bolca,
Eocene.

RÉSUMÉ
Nodules cutanés chez les poissons fossiles du Monte Bolca (Éocène, Italie du Nord).
La collection de poissons fossiles du Monte Bolca (Éocène, Italie du Nord), déposée au Muséum national d'Histoire naturelle, Paris, a été observée pour la recherche de parasites ou de traces de leur activité. Sur les 349 poissons étudiés, 62 présentaient un tégument assez bien conservé pour permettre l'observation de nodules cutanés. Parmi ces derniers, tous téléostéens, six poissons présentaient des nodules cutanés. Le pourcentage de poissons malades est donc de 9,7%. Les espèces concernées sont *Exellia* (= *Semiophorus*) *velifer* (Volta, 1796), *Abromasta* (= *Pagellus*) *microdon* (Agassiz, 1839), *Pseudosparnodus microstomus* (Agassiz, 1839), *Eozanclus brevirostris* (Agassiz, 1833-1844), *Cyclopoma gigas* Agassiz, 1833-1844. Ces pathologies du tégument sont semblables morphologiquement à ce que l'on peut observer chez les poissons actuels. Leur origine est variée (toxines, agents infectieux, causes physiques, causes immunologiques, perturbations nutritionnelles et métaboliques), mais elles font intervenir le plus souvent un pathogène parmi les virus, bactéries, myxozoaires, microsporidies, ciliés, trématodes ou turbellariés. Leur présence témoigne généralement d'un environnement déséquilibré comme celui qui s'est établi à certaines périodes dans le bassin où se sont fossilisés les poissons de la « Pesciara di Bolca ».

MOTS CLÉS
Teleostei,
nodules cutanés,
paléopathologie,
paléoparasitologie,
paléoenvironnement,
Monte Bolca,
Éocène.

INTRODUCTION

The search for fossil zooparasites or traces of their activity can be done in different types of samples: coprolithes (Bouchet *et al*. 2003; Poinard & Boucot 2006); cololithes (Zangerl & Case 1976); animals in amber (Poinar & Poinar 2005; Poinar & Buckley 2006; Poinar *et al*. 2006); bones and shells showing growth alterations and perforations (Littlewood & Donovan 2003); ectoparasites preserved with feathers or in the sediment (Wappler *et al*. 2004).

In search of ectoparasites that could have been fossilized with the tegument of their host, I focused on the fossil fishes from Monte Bolca (Verona, Italy), which are well known for a fossilization that allowed to preserve soft tissues. The tegument is often kept with the scales in place and even some elements of pigmentation.

I undertook the systematic inspection of the tegument from the entire collection of fossil fishes from Monte Bolca (Bol), deposited at the Muséum national d'Histoire naturelle, Paris (MNHN) and found evidence of skin nodules from different species.

These pathologies were comparable to what can be observed in fishes today.

MATERIAL AND METHODS

The fossil site of Monte Bolca

The locality of Bolca includes different fossil sites, the fishes mainly come from the "Pesciara di Bolca": an Eocene *Fossil-Lagerstätte*.

The stratigraphical succession of the Pesciara was recently reconsidered by Papazonni & Trevisani (2006), who distinguished five grey fine-grained limestone layers of a thickness of one meter. These layers of well-preserved fishes and plants fossils are intercalated by coarse-grained biocalcarenite-biocalcidurite layers of one to three meters thick, with molluscs and foraminifers.

Using paleontological and sedimentological data, the authors indicate a late Ypresian age for the site (between 49 and 50 Ma).

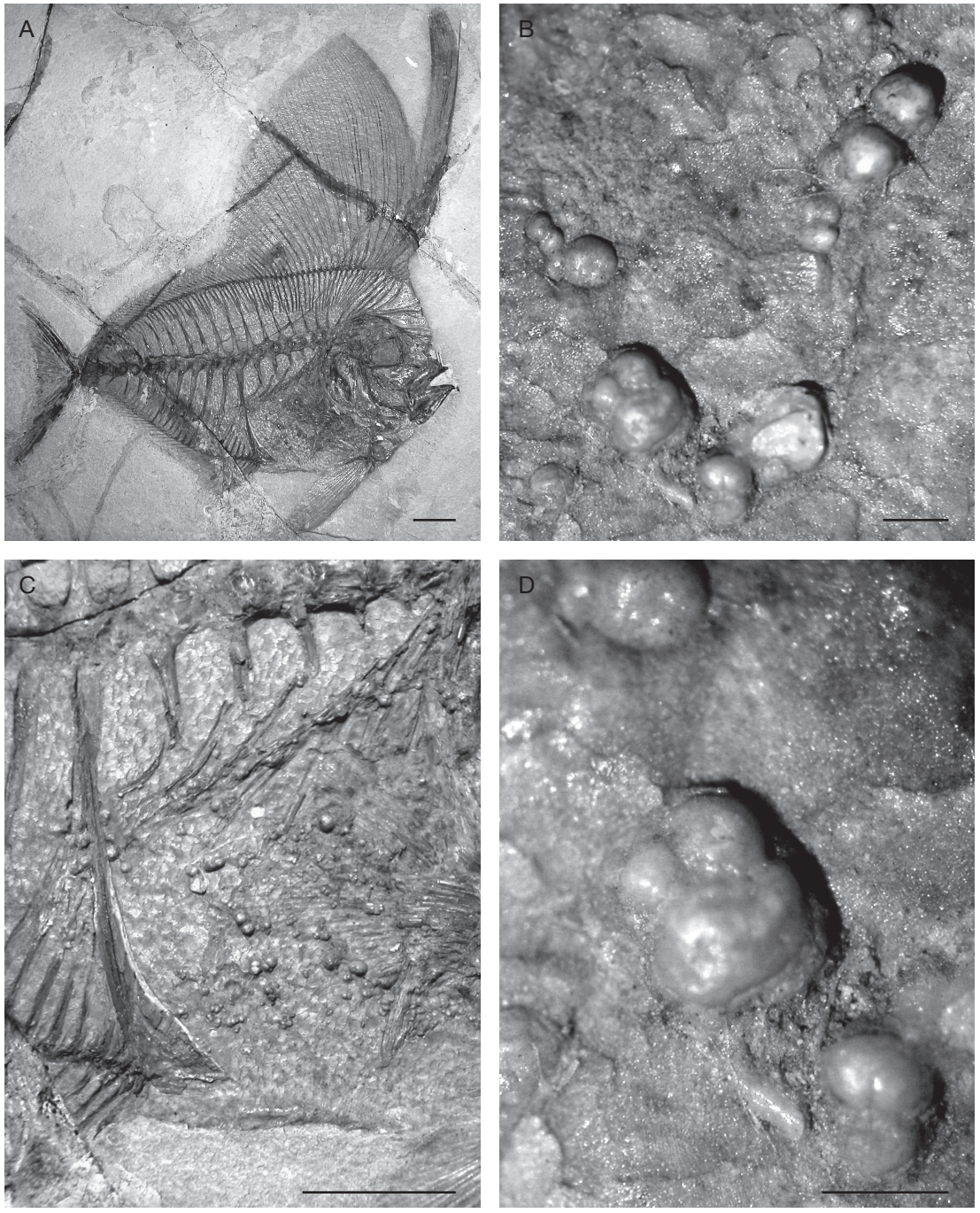

FIG. 1. — Skin nodules in *Exellia* (= *Semiophorus*) *velifer* (Volta, 1796) (Bol 81): **A**, general view; **B**-**D**, details. Scale bars: A, C, 1 cm; B, D, 1 mm.

Taxonomic status of the fishes

The taxonomic status of the fishes with skin pathology was determined from the work of Blot (1980) and the most recent changes by Bannikov (2006) and Tyler & Bannikov (2005).

Number of studied fishes

The collection of Monte Bolca (Eocene) at Paris has been largely studied: it comprises 349 fishes inclunding 128 fishes represented by a part and a counterpart. Only the fishes with well-preseved tegument and scales are usable.

RESULTS

Of the 349 fishes studied, 62 showed a well-preserved tegument suitable for the observation of skin nodules. In this sample, only constitued of teleostans, six fishes (9.7%) showed skin nodules.

Taxonomic status of fishes and distribution of skin nodules

Family Ephippidae

Exellia **(=** ***Semiophorus*****)** ***velifer*** **(Volta, 1796).** Bol 81 and 82, type specimen with counterpart.

About 40 nodules were visible on the ventral part of the abdominal region (Bol 81), behind the opercle (Fig. 1). The same nodules were preserved as imprints on the counterpart (Bol 82).

Family Sparidae

Abromasta **(=** ***Pagellus*****)** ***microdon*** **(Agassiz, 1839).** Bol 46 and 47, type specimen with counterpart (Fig. 2A).

About 30 ventral nodules were visible in the ventral part of the abdominal region, behind the opercle on Bol 46, the biggest nodules induced imprints in the integument of the counterpart (Bol 47) which also presented some small nodules.

Pseudosparnodus microstomus **(Agassiz, 1839).** Bol 269.

A dozen of ventral nodules were observed behind the opercle.

Family Zanclidae

Eozanclus brevirostris **(Agassiz, 1833-1844).** Bol 4 and Bol 5, type specimen with counterpart.

Five nodules were observed on Bol 4 and one in Bol 5, they were located in the ventral part of the abdominal region, behind the opercle.

Family Centropomidae

Cyclopoma gigas **Agassiz, 1833-1844.** 2 spécimens, Bol 368 and Bol 64.

The specimen Bol 368 showed about 80 nodules in the ventral part of the abdominal region, behind the opercle.

The specimen Bol 64 exhibited the highest number of nodules (over 200). They did create dense clumps in the ventral part of the abdominal region, but some were also present dorsally, as well as in the ventral part of the abdominal peduncle.

Description of skin nodules

Skin nodules were almost exclusively located in the ventral part of the abdominal region, sometimes isolated or in clumps. Their size varies between 100 µm and 3 mm. The damages looked like warts forming a hem at their base.

This appearance was fairly uniform regardless of the species. *Abromasta microdon* showed the greatest nodules. Some nodules were accidentally broken; the fractured surface was crystallized, white in the center and more transparent in the periphery (Fig. 2C).

For comparison, a similar pathology in an extant form is shown in Figure 2B.

In contrast to the latter, I did not find nodules on the opercles of the fossils which is probably due to insufficient fossilization of the respective body region.

DISCUSSION

The term "nodule" is the most general term to describe any pathological expansion of the vertebrate integument. It is preferred over other terms like tumor, cyst, blister, wart, pustule, papule, papilloma, granuloma which imply a pathological way difficult to determine even in extant fish.

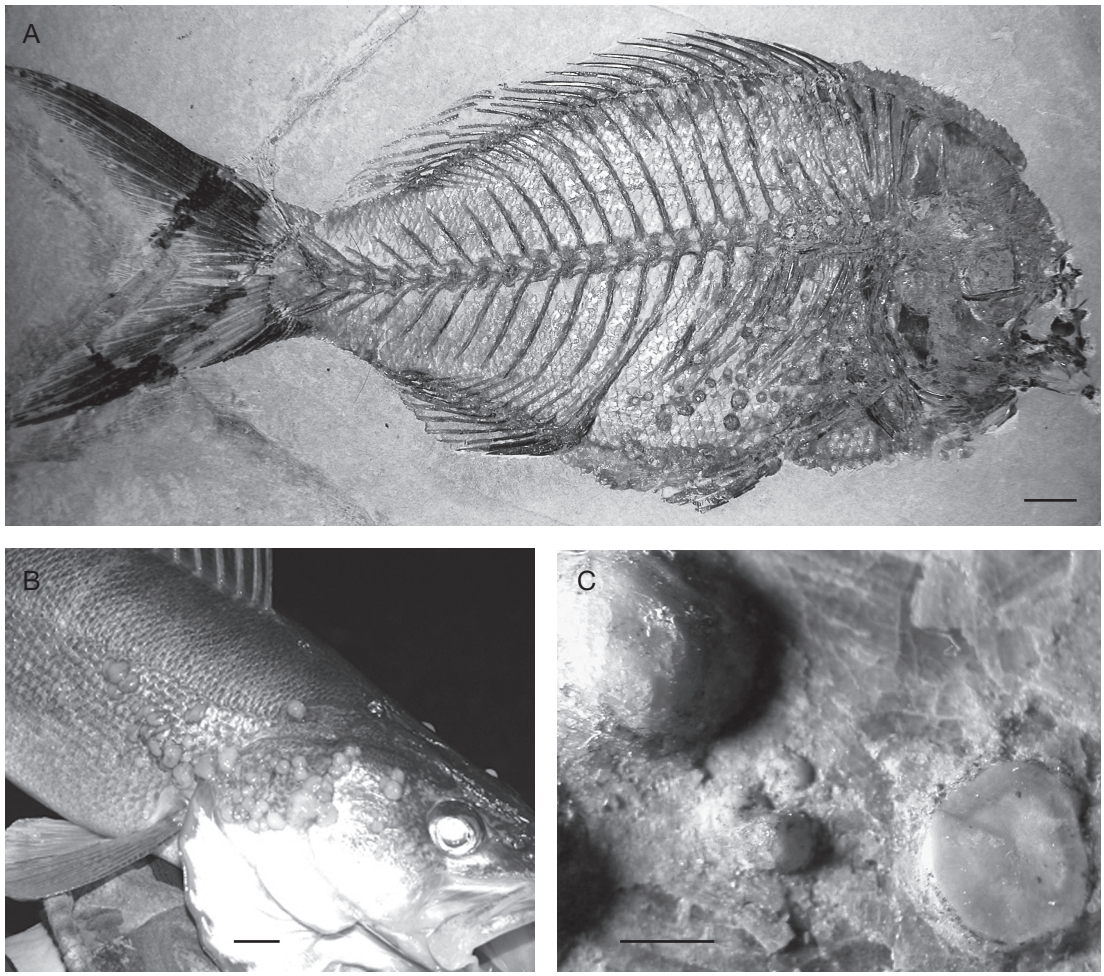

FIG. 2. — Skin nodules: **A**, in *Abromasta* (= *Pagellus*) *microdon* (Agassiz, 1839); **B**, in a Teleostean fish today (undetermined pathology); **C**, in *Cyclopoma gigas* Agassiz, 1833-1844; on the right, fracture surface of a broken nodule; on the left: normal nodule. Scale bars: A, B, 1 cm; C, 1 mm.

ORIGIN OF SKIN NODULES IN EXTANT SPECIES

Cutaneous lesions are generally nonspecific and may indicate a disease that is restricted to the integument or a manifestation of systemic disease (Groff 2001).

Skin nodules can have many differents origins, including infectious agents, toxins, physical factors, immunological factors, nutritional and metabolic perturbations (Paperna 1996; Vethaak *et al.* 1996; Nowak & LaPatra 2006; Korkea-aho *et al.* 2008). The infectious agents were often involved and facilited by the other factors (Williams & Mackenzie 2003; Bagge *et al.* 2004; Kan 2007).

Many pathogens can cause skin nodules in fish, both in freshwater and seawater; they belong to the groups of viruses (lymphocystis), bacteria (epitheliocystis), myxozoa, microsporidia, ciliata (ichthyophthiriasis or white spot disease), trematoda (black spot disease) and turbellaria.

The origin of skin nodules is often complex and multifactorial and understanding of the disease requires the implementation of histological, im-

munological and biochemical methods. With fossils it is of course impossible to make an accurate diagnosis, however it is likely that a high proportion of individuals with nodules in a fish population reflects a skewed environment.

Relationships between the pathology of fish and the palaeoenvironment of the Monte Bolca

According to Papazzoni & Trevisani (2006), the paleoenvironment of the "Pesciara di Bolca" was reconstructed as a basin or a sub-tropical lagoon, close to land and connected to rivers and wetlands.

This basin showed phases of opening to the sea and phases of enclosure and isolation. When it was closed, the conditions of high salinity and low oxygenation in the bottom explained the exceptional conditions of fossilization and the absence of benthic fauna and scavengers. Variations in the sea level allowed the colonisation of new fish into the lagoon. It is difficult to say if a pelagic fauna was able to live at the top of the anoxic zone (Papazzoni & Trevisani 2006).

If we compare with the current existing data, the percentage of fish from the Monte Bolca exhibiting nodules happens not to be very high. For example, tumor prevalence varies from 0.01% to 58% among flatfish and eels population (Stich *et al.* 1977). Additionally, seasonal prevalence of skin tumors from Walleye can reach up to 36% in Oneida lake (New York).

The skin nodules in fishes have been currently observed in many aquatic systems but rarely mentioned in the reef systems which was probably the living environment of the fishes from Monte Bolca (Bellwood 1996; Landini & Sorbini 1996). In the great barrier reef, turbellarian worms were found in the skin of Scaridae but the lesions look similar to those of the black spot disease (Cannon & Lester 1988) and very different from our fossil nodules.

If we take into account these considerations, it is possible that the upper portion of the lagoon in Monte Bolca was a viable environment in the period of the open lagoon. In contrast, skin nodules were probably promoted by bad environmental conditions during periods of isolation.

CONCLUSION

The study of pathological evidences in fossils can be used as a new methodology to improve the understanding of the palaeoenvironnements. More attention should be put on studies of the integuments of vertebrates when they are well preserved as in the fishes from the "Pesciara di Bolca". More generally, the sedimentary rocks generated under the same conditions of fossilization can be examined for the conservation of body structures and soft organisms.

Acknowledgements

Many thanks to Monette Véran (MNHN) who guided me through the collections of the MNHN and in particular for directing me towards the collection of Monte Bolca. I also thank Hervé Lelièvre (MNHN) for his advices and Bouziane Khalloufi for his assistance on the systematic of fossil fish. I thank Régine Vignes (UPMC), Jean Broutin (UPMC), Sevket Sen (CNRS) and Philippe Janvier (CNRS) who allowed me to study paleoparasitology within UMR CNRS 5143.

I am much indebted to Dr Isabella Cattadori, for valuable comments and corrections of my English.

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Submitted on 16 June 2008;
accepted on 7 November 2008.