

Description of the ophiuroid (Echinodermata) records in the Palaeontological Collection of the Museo di Storia Naturale “Antonio Stoppani” (Venegono Inferiore, Varese, Italy)

Luca JASELLI

L. Jaselli, Museo di Storia Naturale “Antonio Stoppani”, via Papa Pio XI 32, I-21040 Venegono Inferiore (VA), Italy; luca.jaselli@yahoo.it

KEY WORDS - *Ophiuroidea, Museum Collection, Stoppani, morphology, taxonomy.*

ABSTRACT - *The Palaeontological Collection of the Museo di Storia Naturale “Antonio Stoppani” (Venegono Inferiore, Varese, Italy), consists of more than 4000 specimens that are housed in its store and partially on display to the public. The ophiuroid series is represented by a considerable number of specimens of extant and fossil ophiuroids. The aim of the present study is to provide a catalogue of these ophiuroids together with their taxonomic assignment and illustrations of their anatomical features.*

RIASSUNTO - [Descrizione degli esemplari di ofiuroidi presenti nella Collezione Paleontologica del Museo di Storia Naturale “Antonio Stoppani” (Venegono Inferiore, Varese, Italia)] - *La Collezione Paleontologica del Museo di Storia Naturale “Antonio Stoppani” di Venegono Inferiore, in provincia di Varese, conta più di quattromila esemplari custoditi nel suo deposito e parzialmente esposti al pubblico. Fra questi reperti si annoverano, nelle serie zoologiche e paleontologiche, alcuni esemplari di ofiuroidi, sia attuali che fossili. Lo scopo del presente studio è quello di fornire un catalogo degli esemplari facenti parte di questa classe di echinodermi, assegnarli alla categoria tassonomica di riferimento e di illustrarne le particolarità anatomiche.*

INTRODUCTION

The collections of the Museo di Storia Naturale “Antonio Stoppani” located in Venegono Inferiore, Varese, Italy, consist of more than 4000 specimens distributed in the palaeontological, mineralogical and zoological series, stored in their respective archives and partially exposed to the public. The Palaeontological Collection consists of fifteen hundred fossil specimens, where the most relevant among them are the samples of the Antonio Stoppani Collection (to whom the Museum is dedicated).

Antonio Stoppani (1824-1891) was above all one of the founding fathers of the Italian geology. He was born in Lecco (Lombardy) and soon became an eminent geologist and palaeontologist, dedicating a considerable part of his studies to the places and to the territory in which he was born, grew up and where his academic career began: the Lecco mountain range known as *Le Grigne*. He went beyond this, exploring extensively the subalpine foothills area of Lombardy. He focused on the faunal remains of the Esino petrifacts (Esino Limestone) and in 1858 he published a monograph on the Esino Limestone, *Les pétrifications d'Esino et de Lenna*, in which he described 317 species of fossils he had discovered and catalogued (ammonoids, gastropods and bivalves), defining 214 new species and reporting 92 other species already described by other authors (Stoppani, 1858).

The young Stoppani kept his Collection where he lived and undertook his philosophical studies: the seminary high school in Monza. In 1891 Stoppani died, and the fossil specimens still remained in this place at least until 1930, when this venue of the seminary was closed. In connection with this event, the findings were packed and transferred, without too much care, to the brand new

seminary venue located in Venegono Inferiore, Varese province, deliberately built far from the noise of the big city to get not disturbed in studies and prayers.

Unfortunately, this transfer was not managed in an accurate way and some fossils were lost during the move and, once the Collection reached the new location, it was not immediately arranged, but for a certain amount of time it remained stored in a warehouse before to be newly organized and catalogued (Gentili & Pieroni, 2011).

It is also true that some of the fossils he collected in his life were donated to different institutions and, among them, the most important was the Museo Civico di Storia Naturale di Milano, of which Stoppani was the Director from 1882 until his death. Stoppani donated most of his Collection (about 400 specimens) to this museum, but unfortunately in 1943, during the Second World War, the building was seriously damaged by bombing, and his collections were lost. Only 88 specimens related to 45 different species (fossil molluscs of the Esino Limestone), which had been transferred to the University of Milan for study, escaped this disaster (Garassino, 1992).

In the meantime, the fossil Collection located in the seminary of Venegono was catalogued, settled and exhibited in the new Museum housed inside the seminary building.

In 1952 a Museum of Natural History dedicated to the memory of Antonio Stoppani was officially inaugurated into the complex of the Seminary of Venegono Inferiore. Here, 422 specimens of the original Stoppani Collection are currently housed and exhibited. Further donations and acquisitions occurred along all these years, enriching and enhancing the original series with samples belonging to different taxonomic units and distributed from the Palaeozoic to the present. Among them, several significant

specimens of ophiuroids (Echinodermata, Ophiuroidea) have to be mentioned.

Ophiuroids are the largest clade of modern echinoderms, with 2064 described species (Stöhr et al., 2012). Globally distributed from the equator to the poles, they adapted to several differentiated marine habitats and depths, ranging from the intertidal zone, inhabiting the shallow water environments, to the hadopelagic zone where in certain case they are dominant on the bottom of the deepest oceans (Stöhr et al., 2012; Thuy et al., 2013).

Ophiuroids are even generally known as “brittle stars”. They could resemble sea stars (Asteroidea) at a first sight but, taking a closer look, it can be observed that they are characterized by a different set of anatomical features (Stöhr et al., 2012).

The morphology of their body includes five (but even more) almost-cylindrical arms that sharply radiate from a clearly differentiated, round or pentagonal shape central disc. These arms are thin, flexible and sinuous and can get coiled, like snakes do. This last feature probably was distinctive for their etymology, and ophiuroids take advantage of this for their locomotion, walking and/or swimming purpose (Stöhr et al., 2012).

Ophiuroids are assumed to have originated in the Early Ordovician as the earliest *Pradesura jacobii* Thorall, 1935, was discovered in Southern France and appeared in the late Tremadocian (Dean Shackelton, 2005). According to O'Hara et al. (2014), their phylogeny, based on transcriptome evidence, shed a new light on ophiuroid evolution and taxonomy, refuting the traditional classification scheme based on a limited set of general skeletal characters. A major radiation of the ophiuroid crown-group occurred in the mid-Permian and brittle stars significantly diversified during the Early Triassic,

although the decline of the end-Permian mass extinction event, and the diversification pursued over the Mesozoic and the Cenozoic too (Jaselli, 2015).

The small ophiuroid Collection housed in the Museo di Storia Naturale “Antonio Stoppani” consists of eleven fossil specimens and an extant one, referring to seven systematic units. The aim of the present work is to provide a catalogue of this Collection where all these ophiuroid specimens are taxonomically assessed and properly figured as only selected specimens were previously studied by Jaselli (2014, 2015).

MATERIALS AND METHODS

The catalogue of the Palaeontological Collection of the Museo di Storia Naturale “Antonio Stoppani” referenced 11 ophiuroid-related specimens (Tab. 1). Inventory numbers of this institution are indicated by the acronym MSNVI. This whole material, studied in the present paper, is made up by ten fossil brittle star samples which document a Upper Ordovician-Upper Cretaceous distribution. Two of these records (MSNVI 038/032 - MSNVI 038/037) are represented by a couple of ichnofossil samples considered ophiuroids as well, according to Seilacher (2007), where *Asteriacites lumbricalis* (Seilacher, 1953) can be interpreted as undertraces left by this clade of echinoderms. Extant brittle stars are currently represented by a single specimen.

These samples do not originate from the historical Stoppani Collection, but they have become part of the series through acquisitions, collection or donation made to this institution over the years. Among them, some significant Italian specimens were studied in detail and

MSNVI-Ref.	Description	Period	Age (Subage)	Locality
034/015	<i>Protaster</i> sp. (Forbes, 1849)	Late Ordovician	Sandbian	El Kaid Errami, Maroc
038/032	<i>Asteriacites lumbricalis</i> (von Schlotheim, 1820)	Early Triassic	Olenekian (Smithian)	Val Venegia, Italy
038/037	<i>Asteriacites lumbricalis</i> (von Schlotheim, 1820)	Early Triassic	Olenekian (Smithian)	Forni di Zoldo, Italy
038/035	Ophiurinae ophiuroids	Early Triassic	Olenekian (Spathian)	Passo San Marco, Italy
038/036	Ophiurinae ophiuroids	Early Triassic	Olenekian (Spathian)	Passo San Marco, Italy
038/034	Ophiurinae ophiuroids	Early Triassic	Olenekian (Spathian)	Passo San Marco, Italy
038/033	Ophiurinae ophiuroids	Early Triassic	Olenekian (Spathian)	Passo San Marco, Italy
044/017	<i>Palaeocoma milleri</i> (Philips, 1829)	Early Jurassic	Sinemurian	M. Campo dei Fiori, Italy
048/056	<i>Geocoma carinata</i> (v. Münster in Goldfuss, 1833)	Late Jurassic	Late Tithonian	Hienheim, Germany
055/028	<i>Geocoma libanotica</i> (König, 1825)	Late Cretaceous	Cenomanian	El Hakel, Lebanon
010/016	<i>Ophioderma longicauda</i> (Bruzellius, 1805)	Holocene	Subatlantic	Arma di Taggia, Italy

Tab. 1 - Ophiuroid records in the Palaeontological Collection of the Museo di Storia Naturale “Antonio Stoppani” (MSNVI).

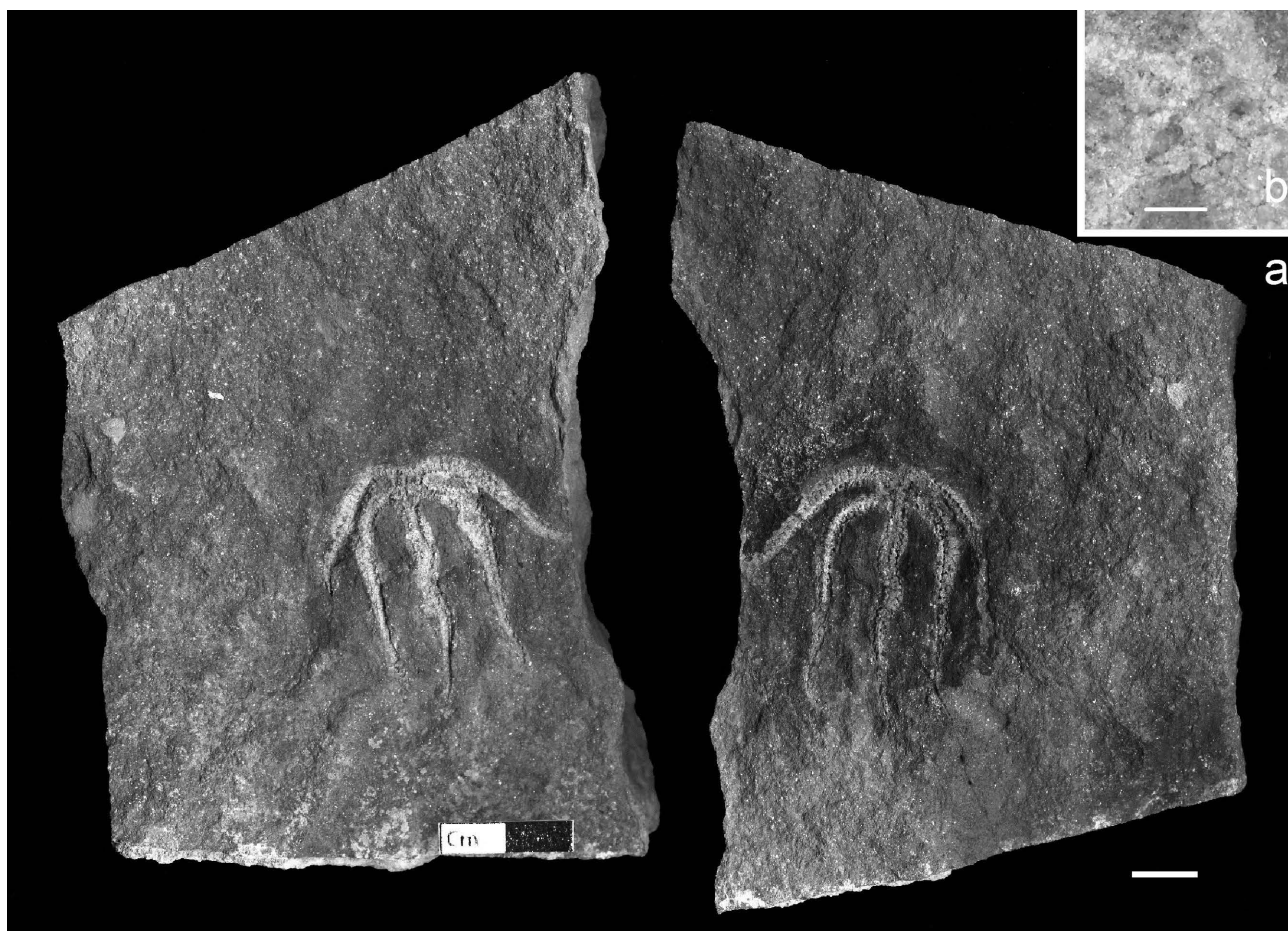


Fig. 1 - *Protaster* sp. (Forbes, 1849) from the starfish beds of the Lower Ktaoua Formation, Upper Ordovician (Sandbian) of El Kaid Errami region, Eastern Anti-Atlas (Maroc). a) Specimen MSNVI 034/015, imprint and counter-imprint; scale bar corresponds to 10 mm. b) Same specimen, detailed view of the mouth region; scale bar corresponds to 3 mm.

published. This is the case of records MSNVI 038/033, MSNVI 038/034, MSNVI 038/035, MSNVI 038/036 and MSNVI 044/017 (see Jaselli 2014, 2015).

Each sample mentioned herein has been measured, illustrated and taxonomically assessed. Specimen details and features registered in the inventory record as well as on the associated tag were updated if appropriate.

For a detailed morphological analysis and taxonomic identification, ophiuroids were examined with a Dino-Lite Digital Microscope AM4113TL-M40. Morphological terminology follows Stöhr et al. (2012). Higher-level classification was adopted from Smith et al. (1995). Additional resources were Paleobiology Database, Post-Palaeozoic Asterozoans (Villier, 2015) and WoRMS: World Register of Marine Species (Stöhr et al., 2015). The whole material studied and illustrated herein belongs and is housed in the Palaeontological Collection of the Museo di Storia Naturale "Antonio Stoppani" located in Venegono Inferiore (VA), Italy.

SYSTEMATIC PALAEONTOLOGY

Class OPHIUROIDEA Gray, 1840
Order OEGOPHIURIDA Matsumoto, 1915
Family PROTASTERIDAE Miller, 1889

Genus *Protaster* Forbes, 1849
Type species *Protaster sedgwickii* Forbes, 1849

Protaster sp.
(Fig. 1)

1849 *Protaster sedgwickii* FORBES, Pl. 4.

2009 *Protaster* sp. Forbes - HUNTER et al., p. 8, fig. 11i-j.

Material - Specimen MSNVI 034/015 is made up of two rock blocks (imprint and counter-imprint) with ophiuroid remains preserved in place. Dimensions are 80x120 mm each.

Age and provenance - This sample was collected from the starfish beds of the silty-sandy alternated deposit of the Lower Ktaoua Formation, Upper Ordovician (Sandbian) of the El Kaid Errami region, Eastern Anti-Atlas (Maroc). According to Hunter et al. (2009) and Lefebvre et al. (2010), several echinoderm Lagerstätten from the Upper Ordovician of the East of Anti-Atlas have been recently discovered. These Palaeozoic outcrops are dominated by rich echinoderm assemblages, characterized by well preserved and articulated specimens. Their taphonomy suggested a rapid in situ burial of these specimens in their environment (Hunter et al., 2009).

Description - The specimen is not well preserved. Partially subjected to erosion, some of its anatomical features are not clearly discernible. The central disc is somewhat circular, 6.5 mm in diameter, small mouth region compared to the disc size, jaw in spear shape with stout and elongated oral plates. Five equidistant, long arms which taper gradually, five times the disc diameter long, all bent in the same direction. Ventrally, a straight median suture line separates two rows of alternate (offset by half their length) and almost quadrate ambulacral ossicles. These ambulacrals originate from the oral plate and their sides are indented distally, laterally paddle shaped, spines not discernible.

Remarks - During the Ordovician, *Stenaster* and *Protaster* were dominant among the ophiuroids (Lefebvre, 2013) and the protasterid family included several species mainly differentiated by the morphology of the adambulacral spine, size of the disc and ambulacral characters (Dean Shackleton, 2005). However, the poor status of preservation prevents the detailed analysis of these morphological features, and a more precise determination.

Unranked clade Ichnofossils Häntzschel, 1975

Genus *Asteriacites* von Schlotheim, 1820

Type species *Asteriacites lumbricalis* Seilacher, 1953

Asteriacites lumbricalis (Seilacher, 1953)
(Figs 2-3)

2007 *Asteriacites lumbricalis* SEILACHER, p. 71, Pl. 24.

Material - Specimen MSNVI 038/037 (Fig. 2), dimensions 115x225 mm, and specimen MSNVI 038/032 (Fig. 3), dimensions 90x80 mm.

Age and provenance - Both samples were collected from the Werfen Formation, Campil Member of the Dolomites region (Italy), and referred in age to the Lower Triassic (Smithian). In detail, MSNVI 038/037 (Fig. 2) is from Forni di Zoldo (Belluno province), and MSNVI 038/032 (Fig. 3) is from Val Venegia, Passo Rolle (Trento province).



Fig. 2 - *Asteriacites lumbricalis* (Seilacher, 1953) from the Campil Member of the Werfen Formation, Lower Triassic (Smithian). Specimen MSNVI 038/037 from Forni di Zoldo, Belluno province (Italy). Scale bar corresponds to 10 mm.

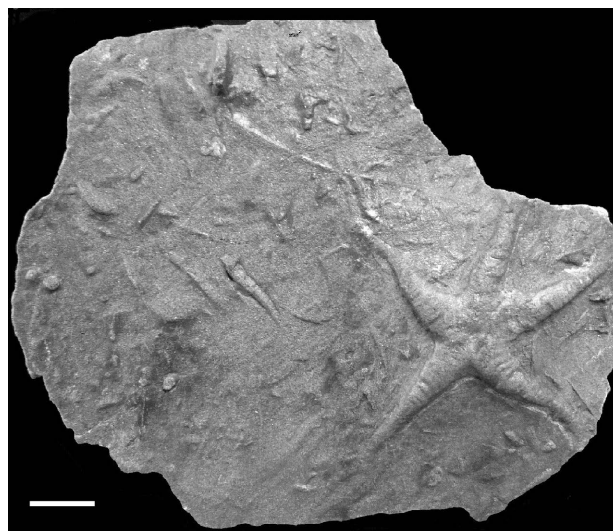


Fig. 3 - *Asteriacites lumbricalis* (Seilacher, 1953) from the Campil Member of the Werfen Formation, Lower Triassic (Smithian). Specimen MSNVI 038/032 from Val Venegia, Passo Rolle, Trento province (Italy). Scale bar corresponds to 10 mm.

Description - MSNVI 038/037 (Fig. 2) is a greyish calcareous slab with five almost complete undertraces of *Asteriacites lumbricalis* preserved. Their structure is recognizable in the same way as the previous sample even if in this case only a partial impression of the entire length of the arms is preserved. The size of these five trace impressions is respectively 40, 35, 30, 50 and 30 mm in diameter, with an arm length almost three times the central body. This slab documents an ophiuroid community that inhabited the Early Triassic shallow water environment of the Dolomites.

MSNVI 038/032 (Fig. 3) is a reddish sandstone samples and the typical *Asteriacites lumbricalis* (Seilacher, 1953) morphology is well recognizable. This ophiuroid resting trace structure here is well identified by the impressions of five separate arms that originate from a central body. This trace is 55 mm wide in diameter (tip to tip), with swollen arms almost three times the disc long.

Remarks - The *Asteriacites lumbricalis* ichnofacies is well known and widespread in the Campil Member of the Werfen Formation and represents a mixed carbonate-siliciclastic, shallow marine setting, above storm wave base (Twitchett et al., 2005). Fine red sandstones and mudstones are intercalated by grey intra-basinal carbonate beds and ophiuroid undertraces samples are yielded from several localities among the Dolomites. *Asteriacites lumbricalis* has been interpreted by several authors as an ophiuroid resting trace (Seilacher, 1953, 2007; Mikuláš, 1990; West & Ward, 1990; Mángano et al., 1999).

Order OPHIURIDA Müller & Troschel, 1840

Family OPHIURIDAE Lyman, 1865

Subfamily OPHIURINAE Lyman, 1865

Gen. et sp. indet.

(Fig. 4)

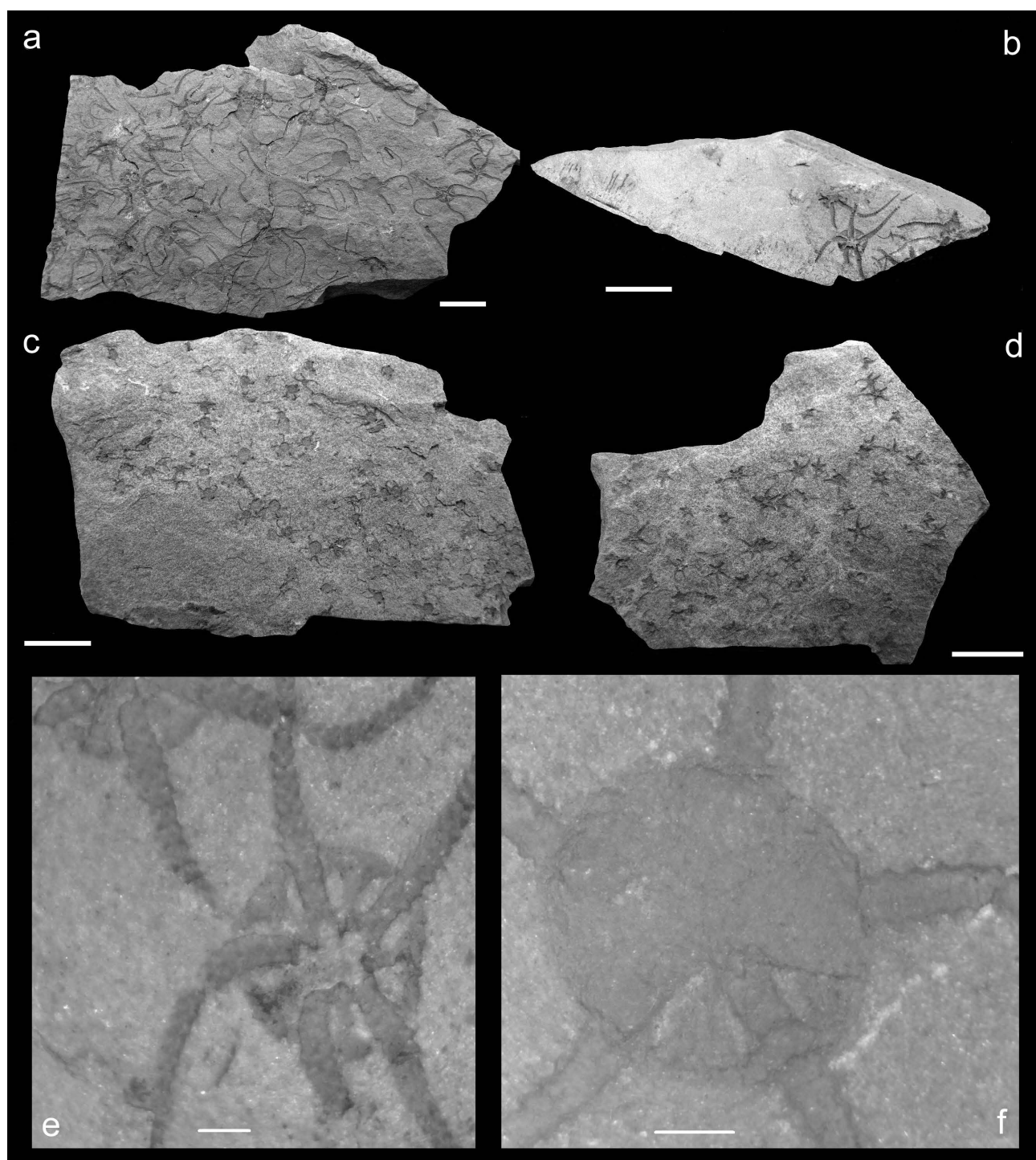


Fig. 4 - Ophiuroids (Ophiurinae) from the Myophoria beds of the Servino Formation, Lower Triassic (Spathian) of Passo San Marco, Bergamo province (Italy). a) Specimen MSNVI 035/038. b) Specimen MSNVI 036/038. c) Specimen MSNVI 034/038. d) Specimen MSNVI 033/038. e) Detailed view of specimen MSNVI 036/038, an ophiuroid individual ventrally oriented. f) Detailed view of specimen MSNVI 035/038, an ophiuroid individual dorsally oriented. a-d: scale bar corresponds to 10 mm; e-f: scale bar corresponds to 1 mm.

Material - MSNVI 035/038 (Fig. 4a) is a 100x65 mm brown-greenish slab of dolomitic marl with brownish iron oxides inclusion, probably siderite. Ophiuroids are light brown in color and they are represented by no less than 35 articulated specimens (9 dorsal, 26 ventral). MSNVI 036/038 (Fig. 4b) is a 70x27 mm slab. Ophiuroids are represented by four articulated and ventrally oriented specimens. MSNVI 034/038 (Fig. 4c) is a 70x50 mm slab.

Ophiuroids densely carpet the area of 35 cm² with almost 65 articulated specimens (61 dorsal, 4 ventral). MSNVI 033/038 (Fig. 4d) is a 55x45 slab. Ophiuroids densely carpet an area of 25 cm² with almost 50 articulated specimens (about 17 in dorsal position and 33 in ventral position).

All this material was widely described and figured in the previous work of Jaselli (2014) and this work can be referenced for further detail and explanations. However,

as the present study has the aim to provide a catalogue of each ophiuroid sample housed in the Palaeontological Collection of the Museo di Storia Naturale “Antonio Stoppani”, the author chose to provide here a short description of these specimens.

Age and provenance - All these samples originate from the Myophoria beds of the Servino Formation, Lower Triassic (Spathian) outcropping in the surroundings of Passo San Marco, Bergamo province (Italy).

Description - Slabs MSNVI 035/038 (Fig. 4a) and MSNVI 036/038 (Fig. 4b) are the best representatives of the set of four and show preserved ophiuroid remains with the following characters (Fig. 4e-f); central disc clearly differentiated from the five sinuous arms, average diameter 4 mm, subpentagonal in shape, dorsally covered by granules. Radial shields are eroded, moderately large, and subtriangular in shape, equaling the radius length and slightly overlapped proximally. Distally convex, they hide the most proximal portion of the arms, disc interradius depressed. On the ventral side the preservation is remarkably poor, especially in the mouth region where oral papillae and teeth are heavily weathered and indeterminable. Interradii with scattered granules, oral shields with the distalmost edge slightly flat and overlapping proximally the interradiial scales, concave lateral edges arrow-shaped. Two genital slits for each interradii, close to the arms, long and slender. Five arms, long and slender, three times the disc diameter, fused with the disc, composed of 30-35 segments, the most proximal three or four segments are under the disc. Segments appear to be wider than long on the proximal arm and then longer than wide on the distal arm. Arms taper slowly and gradually, distalwards. Ventrally large round tentacle pores, narrow ventral plates, with convex distalmost edge. Lateral plates are quite swollen, with arm spines, longer than a segment, strong and divergent.

Slabs MSNVI 034/038 (Fig. 4c) and MSNVI 033/038 (Fig. 4d) preserved very small ophiuroids, a third or a quarter the size of MSNVI 035/038 (Fig. 4a) and MSNVI 036/038 (Fig. 4b), about 3-4 mm as a whole (disc and arms), almost incomplete, especially distally. Discs are small in diameter and arms are short, one or two times the disc diameter. Both these slabs show juvenile individuals of the same taxon, in a poor status of preservation.

Remarks - It is remarkable that high weathering and poor preservation prevented to identify these specimens at the genus level and this is especially true for the mouth region, the eroded lateral arm plates and the dorsal side where granulation of the disc is slightly notable. On the base of these observations the samples described herein were assigned to Ophiurinae subfamily of Ophiuridae, with affinities to the genera *Preaplocoma* and *Aspiduriella*.

Suborder OPHIURINA Müller & Troschel, 1840
Infraorder OPHIODERMATINA Smith et al., 1995
Family OPHIODERMATIDAE Ljungman, 1867

Genus *Palaeocoma* d'Orbigny, 1850
Type species *Ophiura milleri* Philips, 1829

Palaeocoma milleri (Philips, 1829) (Fig. 5)

- 1829 *Ophiura milleri* PHILLIPS, p. 169, Pl. 13, fig. 20.
1837 *Ophiura egertoni* BRODERIP, p. 173, Pl. 12, figs 5-6, 6*.
1854 *Ophioderma gaveyi* WRIGHT, p. 376, Pl. 13, fig. 1a-c.
1866 *Ophioderma carinata* WRIGHT, p. 148, Pl. 16, fig. 1.
1960 *Palaeocoma milleri* HESS, p. 774, figs 14-16, 19a-21.

Material - MSNVI 044/017 is a 160x130 mm light grey calcarenite block with two ophiuroid individuals preserved in place: a complete and articulated ophiuroid, oriented with the ventral side up with a pentagonal disc. A second ophiuroid, close to the former, shows a near complete subpentagonal disc, 15 mm wide, dorsally oriented, articulated with the proximal fragments of three of its arms, the fourth arm has only the mid-distal portion preserved and the fifth one is missing.

Age and provenance - These specimens originated from the Lower Jurassic (Lower Sinemurian) light grey fine limestone of the Saltrio beds, exposed on the eastern side of M. Campo dei Fiori (Varese province), Italy.

Description - The genus *Palaeocoma* is distributed from the Middle Triassic (Ladinian) to the Lower Jurassic (Toarcian) with occurrences reported from France (De Brun & Vedel, 1919; Thuy, 2011; Thuy et al., 2011), Germany (Kutscher, 1988; Haude, 2004), Luxembourg (Kutscher & Hary, 1991), Serbia and Montenegro (Bachmayer & Kollmann, 1968), Switzerland (Hess, 1960, 1962), the United Kingdom (Hess, 1964; Negus, 1983; Kutscher, 1996).

Specimen MSNVI 044/017 (Fig. 5) represents the first record of the genus *Palaeocoma* ever found in Italy. This important sample was widely described and figured in Jaselli (2015) and this work can be referenced for further detail and explanations.



Fig. 5 - *Palaeocoma milleri* (Philips, 1829) from the Saltrio beds, Lower Sinemurian (Lower Jurassic) of M. Campo dei Fiori, Varese province (Italy). Specimen MSNVI 044/017. Scale bar corresponds to 2 mm.

Remarks - MSNVI 044/017 (Fig. 5) is fully compatible with the description of Hess (1960, 1964) and according with the morphological characters here described it was assigned to *Palaeocoma milleri* (Jaselli, 2015).

Infraorder CHILOPHIURINA Matsumoto, 1915

Family APLOCOMIDAE Hess, 1965

Subfamily APLOCOMINAE Hess & Meyer, 2008

Genus *Geocoma* d'Orbigny, 1850

Type species *Ophiura carinata* Münster in Goldfuss, 1826-33

Geocoma carinata (Goldfuss, 1833)

(Fig. 6)

1826-1833 *Ophiura carinata* (v. MÜNSTER in GOLDFUSS), Pl. 62, fig. 5.

1997 *Sinosura kelheimense* (Boehm) - KUTSCHER, Pl. 1, figs 3-4; Pl. 2, figs 2-5.

1997 *Geocoma carinata* (v. Münster in Goldfuss) - KUTSCHER, Pl. 1, figs 1-2; Pl. 2, fig. 1.

Material - Sample MSNVI 048/056 is a 150x125 mm light yellow fine-grained limestone slab with the imprint of two ophiuroid individuals preserved in place, both with the ventral side up.

Age and provenance - This specimen originated from the Marly Plattenkalk of the Lower Hienheim beds outcropping in the Quarry of the Stieberberg, north of Hienheim, Germany. The Upper Jurassic (Lower Tithonian) Fossil-Lagerstätte of Hienheim is well known due to its rich faunal content, mainly represented by benthic specimens and among them, mass occurrence of ophiuroid individuals buried in their environment.

Description - Small sub-circular disc, respectively 3 mm and 2 mm wide. Arm length is seven times the

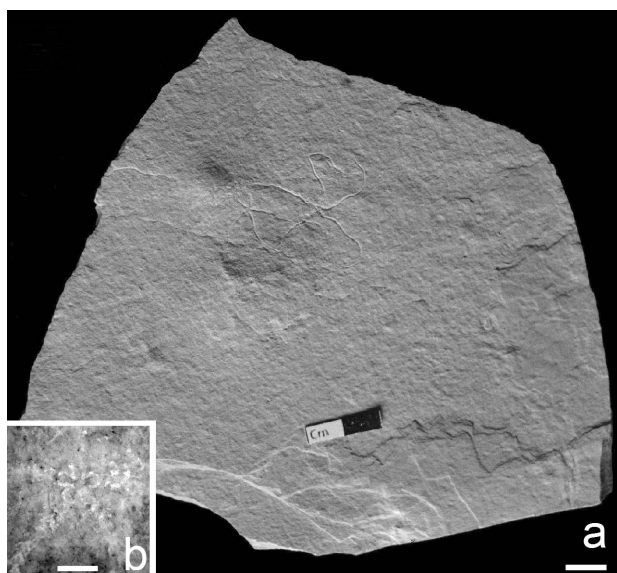


Fig. 6 - *Geocoma carinata* (Goldfuss, 1833) from the Lower Hienheim beds, Upper Jurassic (Lower Tithonian) of Hienheim (Germany). Specimen MSNVI 048/056; scale bar corresponds to 10 mm. b) Same specimen, detailed view of the mouth region; scale bar corresponds to 1 mm.

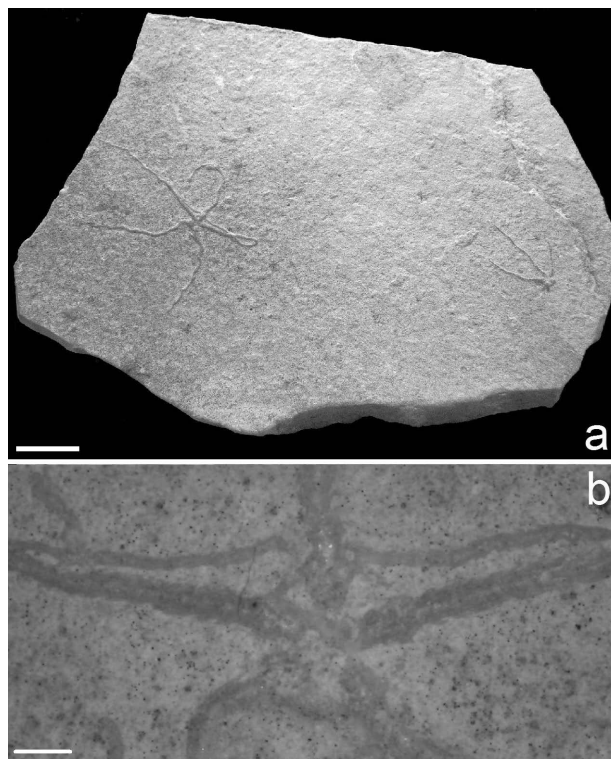


Fig. 7 - *Geocoma libanotica* (König, 1825) from the Plattenkalk of the El Hakel Formation, Upper Cretaceous (Cenomanian) of El Hakel (Lebanon). a) Specimen MSNVI 055/028; scale bar corresponds to 10 mm. b) Same specimen, detailed view of the ventral side; scale bar corresponds to 1 mm.

disc diameter (on the first individual, but this cannot be ascertained on the second one due to poor preservation), very long in proportion to the disc size. Oral skeleton with adoral shields that meets proximally. Arms are thin, sinuous, they taper very smoothly, with more than 50 segments each, where visible. Ventral arm plates broad on proximal arm and contiguous, rapidly narrowing. Lateral arm plates flat, do not meet dorsally, large tentacle pore that can be observed over the entire length of the arms, short spines which barely reach a segment length.

Subfamily APLOCOMINAE Hess & Meyer, 2008

Genus *Geocoma* d'Orbigny, 1850

Type species *Ophiura carinata* Goldfuss, 1826-33

Geocoma libanotica (König, 1825)

(Fig. 7)

1825 *Ophiura libanotica* KÖNIG, Pl. 2, fig. 26.

1858 *Geocoma libanotica* (König) - HELLER, Pl. 4, figs 1-3.

Material - Specimen MSNVI 055/028 is a 95x65 mm light yellow fine-grained (micritic) slab with two ophiuroid individuals preserved in place; the former complete and articulated and the latter only partially complete, both dorsally oriented.

Age and provenance - This sample was collected from the well stratified and finely laminated limestone

(Plattenkalk) of the El Hakel (=Haqel) Formation, exposed in the quarry of the Lebanese village with the same name and located in north west Lebanon, 57 km away from Beirut. The famous fossiliferous deposit of Hakel is considered a Konservat-lagerstätten with a rich fauna dominated by fish and crustaceans and aged to the Late Cretaceous (Cenomanian) (Dalla Vecchia et al., 2002).

Description - Small sub-circular disc, 2.5 mm wide, dorsal surface eroded so that only the large radial shields are preserved within the disc edge. Arm length is six times the disc diameter, very long in proportion to the disc size. Arms are thin, sinuous and slightly keeled in mid arm, they taper very smoothly. Lateral arm plates flat, do not meet dorsally, with short adpressed spines which barely reach a segment length.

Genus *Ophioderma* Müller & Troschel, 1840

Type species *Ophioderma longicauda* Bruzelius, 1805

Ophioderma longicauda (Bruzelius, 1805)
(Fig. 8)

1733 *Stella lumbricalis longicauda* LINCK, Pl. 11, fig. 17.

1805 *Asterias longicauda* BRUZELIUS, p. 28.

2009 *Ophioderma longicauda* (Bruzelius) - STÖHR, BOISSIN & CHENUIL, figs 2, 5.

Material - Sample 010/016 is a dried preserved (ventrally glued on a stand) complete ophiuroid individual, belonging to the species *Ophioderma longicauda*.

Age and provenance - This extant specimen, according to the inventory information, was collected in the Ligurian

Sea (part of the Mediterranean Sea) off the coast of Arma di Taggia (Imperia province), located in northwestern Italy. *Ophioderma longicauda* is a common and widespread large ophiuroid of the Mediterranean Sea (Boissin et al., 2011; Weber et al., 2013, 2014).

Description - Large ophiuroid, evenly brown in color, disc pentagonal in shape, 25 mm in diameter, covered by fine granules. Radial shields completely covered too. Five slender, thin and cylindrical arms, tip tapered, 110-120 mm long (4.5 times the disc size), all bent in the same direction and with the same color of the disc. Dorsal arm plate are almost rectangular, naked, wider than long and slightly overlapping. Mid-proximally they are sometimes irregularly fragmented in two or three parts. Lateral arm plate semi-lunate, with six large conical and adpressed arm spines.

Remarks - This extant sample, unlike the fossils described herein, belongs to the zoological collections of the Museo di Storia Naturale "Antonio Stoppani".

CONCLUSIONS

The main purpose of the present study is to describe, figure and provide a taxonomic assessment of the ophiuroid specimens housed in the Museo di Storia Naturale "Antonio Stoppani". This small but significant Collection consists of several interesting samples of fossil and extant brittle stars, distributed from the Palaeozoic to the actual, and they were collected in the Italian territory and abroad as well.

In this collection, *Protaster* sp. MSNVI 034/015 (Fig. 1) represents the only one Palaeozoic sample. It was collected in the El Kaid Errami region of Maroc, where

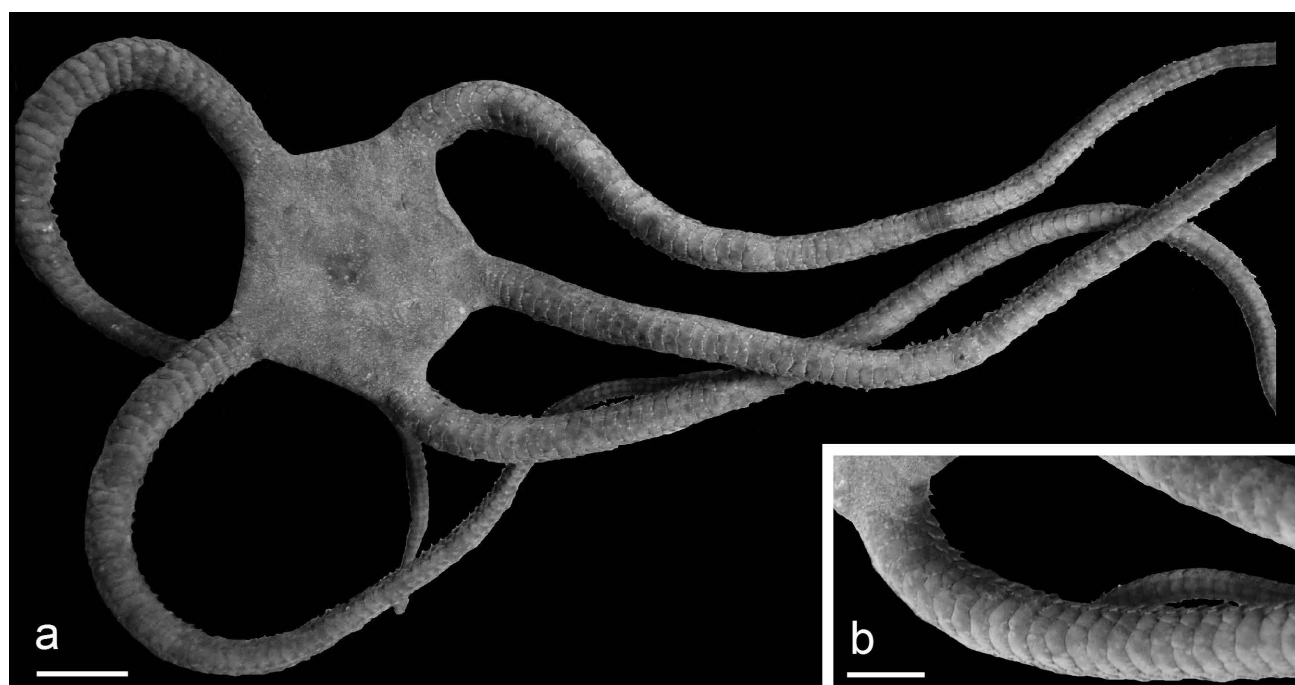


Fig. 8 - *Ophioderma longicauda* (Bruzelius, 1805). Extant species from the Ligurian Sea, off the coast of Arma di Taggia, Imperia province (Italy). a) Specimen MSNVI 010/016; scale bar corresponds to 10 mm. b) Same specimen, dorsal arm plate detailed view; scale bar corresponds to 5 mm.

several echinoderm Lagerstätten are known and this species is quite diffused.

Post-Palaeozoic ophiuroids are represented by the Lower Triassic trace fossil *Asteriacites lumbricalis*, diffused in the Werfen Formation of the Dolomites where samples MSNVI 038/032 (Fig. 3) and MSNVI 038/037 (Fig. 2) were collected in two different localities of Northern Italy.

Slabs MSNVI 035/038 (Fig. 4a), MSNVI 036/038 (Fig. 4b), MSNVI 034/038 (Fig. 4c) and MSNVI 033/038 (Fig. 4d) are one of the two most important and significant records of this ophiuroid Collection. These Lower Triassic slabs show a dense ophiuroids assemblage of individuals referred to the Ophiurinae subfamily. They are particularly rare and represent the first occurrence of ophiuroids in the Lower Triassic of Lombardy (Northern Italy) ever recorded.

Jurassic brittle stars are firstly represented by another important specimen; *Palaeocoma milleri* MSNVI 044/017 (Fig. 5) from the Sinemurian sediments of M. Campo dei Fiori, Lombardy. This sample, quite rare and well preserved, represents the first record of the genus *Palaeocoma* ever found in Italy and should be considered an exceptional discovery.

The genus *Geocoma* is documented by two specimens. The Upper Jurassic *Geocoma carinata* MSNVI 048/056 (Fig. 6) was sampled in the type locality of Hienheim, Germany, a well known Echinoderm Fossil-Lagerstätte. Instead the Upper Cretaceous *Geocoma libanotica* MSNVI 055/028 (Fig. 7) was sampled in the Fossil-Lagerstätte of El Hakel, Lebanon.

Last sample of this series is the extant *Ophioderma longicauda* MSNVI 010/016 (Fig. 8) sampled in the Ligurian sea, Northwestern Italy.

All these specimens, part of the small but significant ophiuroid Collection of the Museo di Storia Naturale "Antonio Stoppani" are here illustrated and described in details, as useful reference for future research to come.

ACKNOWLEDGEMENTS

I would like to thank the helpful and valuable comments of the reviewers Sabine Stöhr and Muhammad Akbar Khan to whom I am indebted. I also thank the BSPI editorial board for guidance and assistance, in particular Maria Rose Petrizzo for her constructive suggestions that greatly improved an early version of the manuscript. Finally, I am grateful to Prof. Elio Gentili, Director of Museo di Storia Naturale "Antonio Stoppani" in Venegono Inferiore (VA) for his constant support and for giving me the opportunity to study the specimens in his care.

REFERENCES

- Bachmayer F. & Kollmann H.A. (1968). Ein Ophiure aus der Trias Jugoslawiens. *Annalen des Naturhistorischen Museums in Wien*, 72: 645-648.
- Boehm G. (1889). Ein Beitrag zur Kenntnis fossiler Ophiuren. *Bericht der Naturforschenden Gesellschaft zu Freiburg*, 4: 232-287.
- Boissin E., Stöhr S. & Chenuil A. (2011). Did vicariance and adaptation drive cryptic speciation and evolution of brooding in *Ophioderma longicauda* (Echinodermata: Ophiuroidea), a common Atlanto-Mediterranean ophiuroid? *Molecular Ecology*, 20: 4737-4755.
- Broderip W.J. (1837). Description of Some Fossil Crustacea and Radiata, found at Lyme Regis, in Dorsetshire. *Transactions of the Geological Society of London*, 2: 5.
- Brun P. de & Vedel L. (1919). Etude géologique et paléontologique des environs de St-Ambroix (Gard). Première partie (Houiller, Trias, Infraalias). *Bulletin de la Société d'Etudes des Sciences Naturelles de Nîmes*. Imprimerie Générale: 1-220.
- Bruzeliuss N. (1805). Dissertatio, sistens species cognitatas Asteriarum, quam, consentiente ampliss. Ord. Philos. sub praesidio D.M. And. J. Retzii, pro laurea modeste exhibet Nicolaus Bruzeliuss. 37 pp. Lund.
- Dalla Vecchia F.M., Venturini S. & Tentor M. (2002). The Cenomanian (Late Cretaceous) Konservat-lagerstätte of en Nammoûra (Kesrouâne Province), Northern Lebanon. *Bollettino della Società Paleontologica Italiana*, 41: 51-68.
- Dean Shackleton J. (2005). Skeletal homologies, phylogeny and classification of the earliest asterozoan echinoderms. *Journal of Systematic Palaeontology*, 3: 29-114.
- Forbes E. (1849). Figures and descriptions illustrative of British Organic Remains. *Memoirs of the Geological Survey of the United Kingdom*, Decade 1:1-64.
- Garassino A. (1992). Catalogo dei tipi del Museo Civico di Storia Naturale di Milano. *Atti della Società italiana di scienze naturali e del Museo Civico di Storia Naturale di Milano*, 133: 245-260.
- Gentili E. & Pieroni V. (2011). Memorie di Antonio Stoppani nel seminario di Venegono. *La scuola cattolica*, 3: 431-454.
- Goldfuss G.A. (1826-1833). Petrefacta Germaniae tam ea, quae in Museo Universitatis Regiae, Borussiae Fridericiae Wilhelmae Rhenanae servantur quam alia quaecunque in Museis Hoeninghusiano, Muensteriano aliisque extant, iconibus et descriptionibus illustrata. Abbildungen und Beschreibungen der Petrefacten Deutschlands und der Angränzende Länder, unter Mitwirkung des Hrn Grafen Georg zu Münster, herausgegeben von August Goldfuss. v. 1, Divisio secunda, Radiariorum reliquiae [Echinodermata]. Arnz & Co., Düsseldorf: 115-221.
- Gray J.E. (1840). Synopsis of the Contents of the British Museum. 42nd ed. 370 pp. British Museum, London.
- Häntzschel W. (1975). Trace fossils and problematica. In Teichert C. (ed.), Treatise on Invertebrate Paleontology. Part W, Miscellaneous, Supplement I. Geological Society of America and University of Kansas Press, Colorado, Boulder: W1-269.
- Haude R. (2004). 'Worm holothurians' from the Lower Jurassic of Göttingen, Germany. In Heinzeller T. & Nebelsick J.H. (eds), Echinoderm: München: Proceedings of the 11th International Echinoderm Conference, 6-10 October 2003, Taylor & Francis Group: 421-423.
- Heller C. (1858). Über neue fossile Stelleriden. *Sitzungsberichte der Akademie der Wissenschaften mathematisch-naturwissenschaftliche*, Klasse 28: 155-170.
- Hess H. (1960). *Ophioderma escheri* Heer aus dem unteren Lias der Schambelen (Kt. Aargau) und verwandete Lias-Ophiuren aus England und Deutschland. *Eclogae Geologicae Helveticae*, 53: 757-793.
- Hess H. (1962). Mikropaläontologische Untersuchungen an Ophiuren II. Die Ophiuren aus dem Lias (Pliensbachien-Toarcien) von Seewen (Kt. Solothurn). *Bericht der schweizerischen palaeontologischen Gesellschaft*, 55: 609-656.
- Hess H. (1964). Die Ophiuren des englischen Jura. *Eclogae Geologicae Helveticae*, 57: 755-821.
- Hess H. (1965). Trias-Ophiuren aus Deutschland, England, Italien und Spanien. *Mitteilungen Bayerische Staatssammlung Paläontologie Historische Geologie*, 5: 151-177.
- Hess H. & Meyer C.A. (2008). A new ophiuroid (*Geocoma schoentalensis* sp. nov.) from the Middle Jurassic of northwestern Switzerland and remarks on the family Aplocomididae HESS, 1965. *Swiss Journal of Geosciences*, 101: 29-40.
- Hunter A.W., Lefebvre B., Nardin E., Van Roy P., Zamora S. & Régnault S. (2009). Preliminary report on new echinoderm Lagerstätten from the Upper Ordovician of the eastern Anti-Atlas, Morocco. In Harris L.G., Böttger S.A., Walker C.W. & Lesser M.P. (eds), Echinoderms: Proceedings of the 12th International Echinoderm Conference, 7-11 August 2006, Durham, New Hampshire, U.S.A. CRC Press: 23-30.

- Jaselli L. (2014). The First Occurrence of Ophiuroids (Ophiuroidea, Echinodermata) In the Early Triassic of Lombardy (Northern Italy). *Atti Società Toscana Scienze Naturali, Memorie, Serie A*, 121: 47-54.
- Jaselli L. (2015). The Lower Jurassic (Early Sinemurian) ophiuroid *Palaeocoma milleri* in the palaeontological collection of the Museo di Storia Naturale "Antonio Stoppani" (Italy). *Bollettino della Società Paleontologica Italiana*, 54: 187-195.
- König C.D.E. (1825). *Icones fossilium sectiles*. London: 1-44.
- Kutscher M. (1988). Zur Invertebratenfauna und Stratigraphie des oberen Pliensbachien von Grimmen (DDR), Echinodermata. *Freiberger Forschungsheft*, C419: 62-70.
- Kutscher M. (1996). Echinodermata aus dem Ober-Toarcium und Aalenium Deutschlands II: Ophiuroidea. *Stuttgarter Beiträge zur Naturkunde, serie B, Geologie und Paläontologie*, 242: 1-33.
- Kutscher M. & Hary A. (1991). Echinodermen im Unteren Lias (bucklandi-und semicostatum-zone) zwischen Ellange und Elvange (SE-Luxemburg). *Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen*, 182: 37-72.
- Lefebvre B., Noailles F., Franzin B., Régnault S., Nardin E., Hunter A.W., Zamora S., Van Roy P., El Hariri K. & Lazreq N. (2010). Les gisements à échinodermes de l'Ordovicien supérieur de l'Anti-Atlas oriental (Maroc): un patrimoine scientifique exceptionnel à préserver. *Bulletin de l'Institut Scientifique, Rabat, section Sciences de la Terre*, 32: 1-17.
- Lefebvre B., Sumrall C.D., Shroat-Lewis R.A., Reich M., Webster G.D., Hunter A.W., Nardin E., Rozhnov S.V., Guensburg T.E., Touzeau A., Noailles F. & Sprinkle J. (2013). Palaeobiogeography of Ordovician echinoderms. In Harper D. & Servais T. (eds), *Early Palaeozoic Biogeography and Palaeogeography*. Geological Society of London, 173-198.
- Linck J.H. (1733). *De stellis marinis liber singularis*. 107 pp. Lipsia.
- Ljungman A.V. (1867). Ophiuroidea viventia huc usque cognita enumerat. Öfversigt af Kongliga Vetenskaps-Akademien's Förhandlingar, 23: 303-336.
- Lyman T. (1865). Ophiuridae and Astrophytidae. Illustrated catalogue of the Museum of comparative zoology, Harvard College, 1: 1-200.
- Mángano M.G., Buatois L.A., West R.R. & Maples C.G. (1999). The origin and paleoecologic significance of the trace fossil *Asteriacites* in the Pennsylvanian of Kansas and Missouri. *Lethaia*, 32: 17-30.
- Matsumoto H. (1915). New Classification of the Ophiuroidea: With Descriptions of New Genera and Species. *Proceedings Academy of Natural Science Philadelphia*, 67: 43-92.
- Mikuláš R. (1990). The ophiuroid *Taeniasteras* a tracemaker of *Asteriacites*, Ordovician of Czechoslovakia. *Ichnos*, 1: 133-137.
- Miller S.A. (1889). North American Geology and Palaeontology for the Use of Amateurs, Students and Scientists. 664 pp. Published by the author.
- Müller J. & Troschel F.H. (1840). Über die Gattungen der Ophiuren. *Archiv für Naturgeschichte*, Berlin, 6: 327-330.
- Negus P.E. (1983). Distribution of the British Jurassic corals. *Proceedings of the Geologists Association*, 94: 251-257.
- O'Hara T.D., Hugall A.F., Thuy B. & Moussalli A. (2014). Phylogenomic resolution of the class Ophiuroidea unlocks a global microfossil record. *Current Biology*, 24: 1874-1879.
- Orbigny A.D. d' (1850). Prodrome du paléontologie stratigraphique universelle des animaux mollusques et rayonnés faisant suite au cours élémentaire de paléontologie et de géologie stratigraphique, 2: 1-428.
- Phillips J. (1829). Illustrations of the Geology of Yorkshire; or a description of the strata and organic remains of the Yorkshire Coast. Part 1. 192 pp. York.
- Pieroni V. (2014). I fossili raccolti da Antonio Stoppani conservati nel museo del Seminario Pio XI di Venegono Inferiore. 49 pp. Published by the author.
- Schlotheim E.F. von (1820). Die Petrefactenkunde auf ihrem jetzigen Standpunkte durch die Beschreibung seiner Sammlung versteinerter und fossiler Überreste des Thier- und Pflanzenreichs der Vorwelt erläutert. 432 pp. Becker'sche Buchhandlung, Gotha.
- Seilacher A. (1953). Studien zur Palichnologie. 11. Die fossilen Ruhespuren (Cubichnia). *Neues Jahrbuch für Geologie und Paläontologie - Abhandlungen*, 98: 87-124.
- Seilacher A. (2007). Trace fossil analysis. 226 pp. Springer, Berlin.
- Smith A.B., Paterson G.L.J. & Lafay B. (1995). Ophiuroid phylogeny and higher taxonomy: morphological, molecular and palaeontological perspectives. *Zoological Journal of the Linnean Society*, 114: 213-243.
- Stoppani A. (1857). *Studii geologici e paleontologici sulla Lombardia*. 461 pp. Turati, Milano.
- Stoppani A. (1858). Paléontologie Lombarde ou description des fossiles de Lombardie, première série, Les Pétrifications d'Esino ou description des fossiles appartenant au dépôt triasique supérieur des environs d'Esino en Lombardie, divisés en quatre monographies, comprenant les gastéropodes, les acéphales, les brachiopodes, les céphalopodes, les crinoïdes, les zoophytes et les amorphozoaires. 152 pp. Tipografia Bernardoni, Milano.
- Stöhr S. (2015). Ophiuroidea. In Stöhr S., O'Hara T. & Thuy B. (eds), World Ophiuroidea database. Accessed through: World Register of Marine Species at <http://www.marinespecies.org/aphia.php?p=taxdetails&id=123084> on 2015-08-03
- Stöhr S., Boissin E. & Chenuil A. (2009). Potential cryptic speciation in Mediterranean populations of *Ophioderma* (Echinodermata: Ophiuroidea). *Zootaxa*, 2071: 1-20.
- Stöhr S., O'Hara T.D. & Thuy B. (2012). Global diversity of brittle stars (Echinodermata: Ophiuroidea). *PLoS ONE*, 7, e31940. <http://dx.doi.org/10.1371/journal.pone.0031940>
- Thoral M. (1935). Contribution à l'étude paléontologique de l'Ordovicien inférieur de la Montagne Noire et révision sommaire de la faune cambrienne de la Montagne Noire. Imprimerie de la Charité, Montpellier: 1-362.
- Thuy B. (2011). Exceptionally well-preserved brittle stars from the Pliensbachian (Early Jurassic) of the French Ardennes. *Palaeontology*, 54: 215-233.
- Thuy B., Gale A.S. & Reich M. (2011). A new echinoderm Lagerstätte from the Pliensbachian (Early Jurassic) of the French Ardennes. *Swiss Journal of Palaeontology*, 130: 173-185.
- Thuy B., Marty D. & Comment G. (2013). A remarkable example of a Late Jurassic shallow-water ophiuroid assemblage from the Swiss Jura Mountains. *Swiss Journal of Geosciences*, 106: 409-426.
- Twitchett R.J., Feinberg J.M., O'Connor D.D., Alvarez W. & McCollum L. (2005). Early Triassic Ophiuroids: Their Paleocology, Taphonomy, and Distribution. *Palaos*, 20: 213-223.
- Villier L. (2015). Post-Paleozoic Asterozoans. Paleobiology Database. http://paleobiodb.org/cgi-bin/bridge.pl?page=OSA_12_Asterozoans
- Weber A.A.-T., Dupont S. & Chenuil A. (2013). Thermotolerance and regeneration in the brittle star species complex *Ophioderma longicauda*: A preliminary study comparing lineages and Mediterranean basins. *Comptes Rendus Biologies*, 336: 572-581.
- Weber A.A.-T., Stöhr S. & Chenuil A. (2014). Genetic data, reproduction season and reproductive strategy data support the existence of biological species in *Ophioderma longicauda*. *Comptes Rendus Biologies*, 337: 553-560.
- West R.R. & Ward E.L. (1990). *Asteriacites lumbricalis* and a protasterid ophiuroid. In Boucot A.J. (ed.), *Evolutionary Paleobiology of Behavior and Coevolution, Elsevier*: 321-327.
- Wright T. (1854). Contributions to the Palaeontology of Gloucestershire: a description, with figures of some new species of Echinodermata from the Lias and Oolites. *The Annals and Magazine of Natural History*, 2: 376-383.
- Wright T. (1866). A Monograph on the British fossil Echinodermata from the Oolitic Formations. Volume second. Part 2. On the Ophiuroidea. *The Palaeontographical Society*: 132-154.

Manuscript received 1 March 2016

Revised manuscript accepted 4 December 2016

Published online 28 December 2016

Editor Maria Rose Petrizzo