

# OLIGOCENE DIGESTICHNIA IN THE LOWER PART OF THE VALEA CASELOR FACIES FROM FIE NI (ROMANIA) – A PRELIMINARY REPORT

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**Abstract.** The paleoichthyological site located in the Fieni City has been the source of knowledge for more than 120 years of fossil fish associations, provided by the samples extracted from the Valea Caselor Facies. However, despite the long time span, the presence of coprolites and regurgitalites (Digestichnia *sensu* Vallon, 2012) was never discussed before. Therefore, this paper reports the first findings of such fossil traces of fish, belonging to the lower limb of dysodilic schist with menilite of Rupelian age. For the regurgitalites, a classification based on the mucus (m)/figurative elements (fe) ratio is proposed:  $m < fe = decapsulate$  type;  $m > fe = capsule$  type. The reported observations are intended to open new chapters in the paleoichnological investigations that needs in the series of bitumolites with fossil fish from the Oligocene formation scattered in different parts of Romania, using modern research approaches, both in the field and the laboratory.

**Key words:** trace fossils, Digestichnia, Oligocene, Valea Caselor Facies, Fieni, Romania

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## 1. INTRODUCTION

More than 120 years have passed since the first publication (Priem, 1899) dedicated to a fossil fish from Muntenia – *Scorpaenoides popovicii* – with material collected from a flysch sequence from the Valea Caselor, near Fieni locality, by Popovici (1898, p. 151)\*. The research of Oligocene fossil fish from the surroundings of this locality is later resumed by Paucă, at Moțăeni (1929), Valea Mare (1934a), Bezdead (1935) and Ulmetu (1938). Later, out of 11 outcrops of the Lower Oligocene from Fieni City and surroundings, Constantin (1975) determines 17 species of fish, a crab (*Portunus oligocenicus*) and two species of *Sequoia*, a characteristic ensemble of the neritic-pelagic zone.

If for the knowledge of the Oligocene fossil ichthyofauna remarkable results were obtained from a taxonomic, paleobiological and paleogeographical point of view (e.g., Paucă, 1934; Jonet, 1958; Ciobanu, 1977, and others), in none of the mentioned works, but also of many others undertaken in the flysch of the Eastern Carpathians, presented from the perspective of historical knowledge (Grigorescu, 2003; Grigorescu & Csiki-Sava, 2018; Grădianu, 2018), fish coprolites are not mentioned. Explicit references to the fish coprolites can be found only in the doctoral thesis of Pauca M. (1934). Specifically, only two types of coprolites, discovered at Suslănești, Arges County (located at ~26km NE from Fieni) were described - without figures - (Paucă, 1934, p. 667): some round, with a diameter of 5-8 mm, consisting of a mass of bone fragments and others, formed from strings of round, fine and homogeneous bodies, with a diameter of 2-3 mm.

\*The PhD thesis (Série A, no.311, No d'Ordre 968), signed by V. Popovici, was defended at the Faculty of Sciences in Paris, on June 30, 1898, before the commission chaired by Prof. Yves Delage, examiners Prof. Gaston Bonnier and Prof. Ernest Munier-Chalmas. In the Geological Bibliography of Romania (vol. I, 1926, p. 101) the thesis is reported to Valer Popovici-Hatzeg.

The state of art of coprolites and other digestive residues of vertebrates research, that started more than 200 years ago, was concisely summarized by Hunt *et al.* (2012). Hunt (1992) integrates the products of the digestive system previously known in the major category of bromalites, which includes three groups of trace fossils, with different origins (Hunt *et al.*, 1994, p. 222): **regurgitalite** (evacuated through the oral cavity), **cololite** (retained in the intestinal tract) and **coprolite** (evacuated through the anus). Hunt & Lucas (1992, 2012a) laid the foundations of the classification, and Hunt *et al.* (2012b) descriptive terminology of bromalites. For those interested, the volume "Vertebrate Coprolites" (44 articles, 387 pages) includes the topics in the field, with case studies from the Paleozoic, Mesozoic and Cenozoic.

The Digestichnia class, defined by Vialov in 1972 and forgotten for 40 years, was amended and brought to the rank of ethological category by Vallon (2012). It contains all the fossil remains made by digestive processes. According to Vallon *et al.* (2015), coprolites usually consist of a fecal mass that can be phosphatic, calcitic, organic or a mixture of these types; regurgitalites (produced mainly by reptiles, birds and some fish), devoid of a fecal mass, consist exclusively of remnants of hard body parts of the prey or of accidentally ingested sediment particles; cololites is fecal matter preserved in the intestinal tract inside the body cavity, the term can also be used for fecal matter in the form of intestines isolated from the body, as opposed to coprolites; geogastrolites are pebbles and sand swallowed deliberately or accidentally, with surfaces modified by stomach digestive processes. Digestichnia (except geogastrolites) is preserved as complete reliefs and frequently contains the remains of the hard parts of the prey consumed by the tracemaker.

In Romania, the stage of investigations regarding the coprolites of invertebrates (Crustacea, Isopoda) and vertebrates (Pisces, Carnivora) until the 2000s, is made known by Brustur *et al.* (1999, p. 35-38) and Brustur *et al.* (2001, p. 57-58). In a brief note, Costea & Brustur (2001) refer to the ultrastructure and chemistry of the microcoprolites of the ichnogenus *Zoophycos*. To these are added the research of human coprolites from some archaeological sites in Banat (Cârciumaru, 1973) and Dobrogea (Tomescu *et al.*, 2003; Le Bailly *et al.*, 2006). In this preliminary work, we include the physiological traces from Fieni outcrops, included in the ethological category Digestichnia (*sensu* Vallon, 2012), thus honoring the memory of the paleontologist Oleg S. Vialov\*\*.

## 2. GEOLOGICAL SETTING

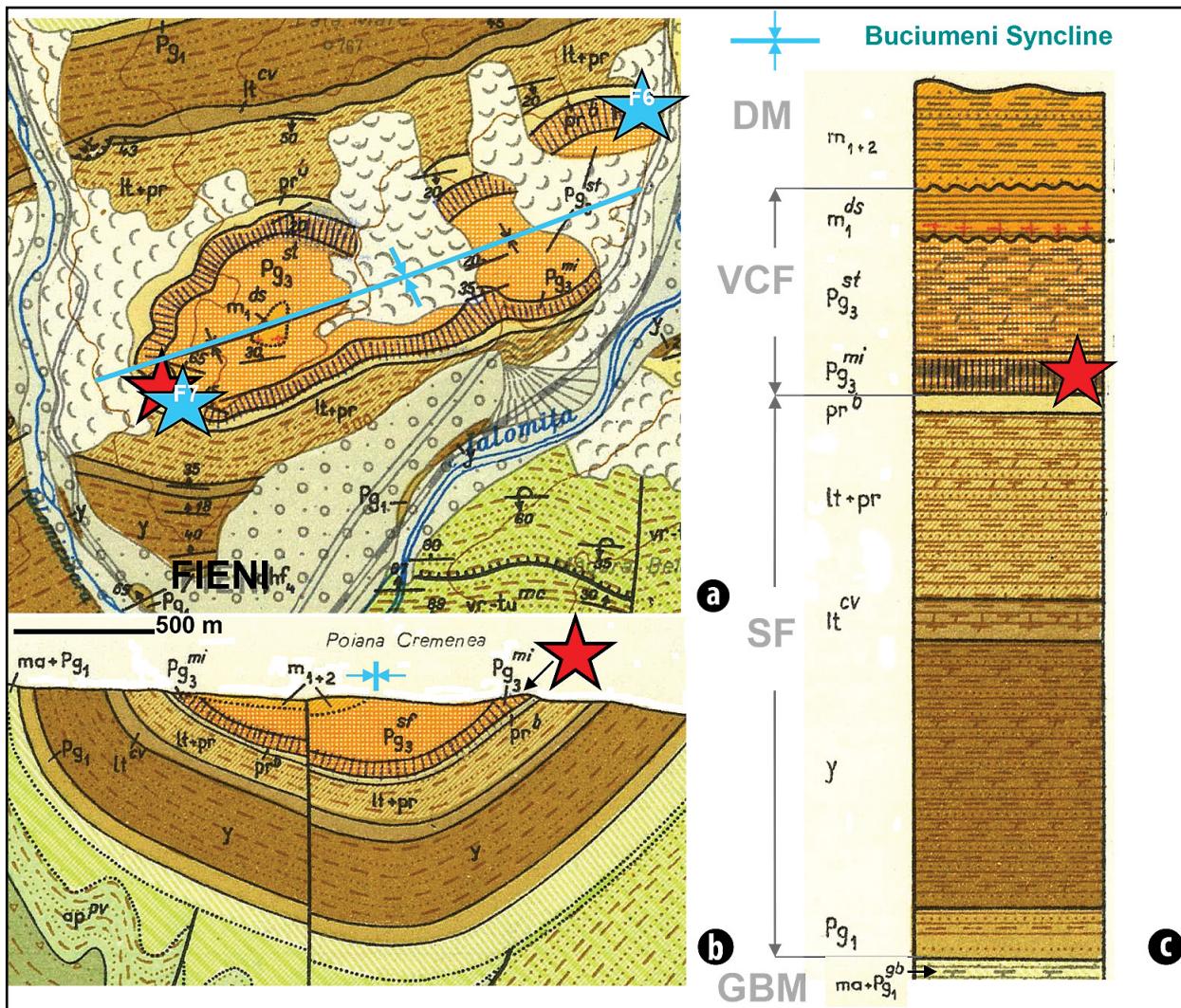
Located on the crossing interfluve between the Ialomița valley and the Ialomicioara valley, the Fieni fossiliferous

sector (Fig. 1a) belongs to the southwestern termination of the Eastern Carpathians, with a complex geological structure (Băncilă, 1958), characterized by strong spatial reduction of tectonic units. According to Săndulescu (1984), in this sector, the internal flank of the Buciumeni Syncline covers the forehead of Ceahlău Nappe. The intensely deformed post-tectonic deposits that participate in the composition of the Buciumeni Syncline (Fig. 1b) mostly cover the tectonic contacts between the Teleajen Nappe, Macla Nappe and Variegated Clays Nappe (Ştefănescu, 1995).

According to Ştefănescu (1995), the deposits of the Teleajen Nappe are represented by the *Fieni Series*, made up of gray-yellow calcareous sandstones (sometimes convolute), gray marls, sideritic marls and lenticular sedimentary breccias, which was deposited in the Vraconian-Turonian interval. The Macla Nappe comprises the *Macla Series*, with three members: lower with purplish pellets, medium with gray and black pellets, upper with feldspar sandstones, deposited in the Vraconian-Turonian stratigraphic interval. The Variegated Clays Nappe consists of the *Variegated Clays Series*, intensely wrinkled and with a very complicated internal structure, of Vraconian-Senonian age, it is composed of red, gray and green clays, limestone with cement sandstones with granodiorite fragments, followed by massive sandstone packages with muscovite and biotite.

From the lithostratigraphic point of view (Fig. 1c), the Buciumeni Syncline is composed, according to Ştefănescu *et al.* (1988) and Ştefănescu (1995), of deposits whose age begins in the Upper Senonian (Gura Beliei Marls), ascends into the Paleogene (Facies of Şotriile and Facies of Valea Caselor) and ends in the basal Miocene (Upper Member of Disodilic Shales from Valea Caselor Facies). The first term of this stack of deposits – Gura Beliei Marls – is arranged discordantly over all the tectonic units of the Cretaceous flysch. After the deposition, the formations of this syncline were refolded and fractured together with those of the nappes over which they are discordant. The first movement manifested itself after the deposition of the second member of the Valea Caselor Facies, at the Oligocene-Miocene boundary. According to Ştefănescu (1995, p. 20), the correlation of the lithological entities attributed to the Facies of Valea Caselor with those of the Pucioasa – Fusaru Facies (PFF) indicates the synchronism of these facies. According to Melinte (1995), the age of the PFF lower Dysodilic with menilite member belongs to the Rupelian (NP22, NP23 and lowermost part of the NP24 nannofossil zones). According to "The ICS International Chronostratigraphic Chart" (Cohen *et al.*, 2013), the Rupelian has a duration of 5.8 Ma, between 33.9-28.1 Ma. The ichnofauna belonging to the Digestichnia category, comes from the lower limb of the dysodile shales with menilites, open which outcrops on the southern flank of the Buciumeni Syncline (Fig. 1a).

\*\*Oleg S. Vialov was one of the first soviet paleontologist who appreciated the value of trace fossils and the promoted the progress of paleo- and actuoichnology research (Palij, 1990, p. 53). He proposed a first classification and nomenclature of traces, a system adopted and substantially improved by Romanian researchers of footprints of birds and mammals in the Subcarpathians Miocene molasses (e.g., Panin & Avram, 1962, p. 457).



**Fig. 1.** Geological map (a), Buciumeni Syncline cross-section (b), and lithostratigraphical column (c) of the Fieni sector (acc. to Ștefănescu *et al.*, 1988). Legend: **GBM** = Gura Beliei Marls (Maastrichtian+Paleocene – ma+Pg<sub>1</sub><sup>gb</sup>); **SF** = Sotriile Facies (Paleocene-Eocene – Pg<sub>1</sub> = Violaceous Clay Member; y = Lower Flysch Member; Lt<sup>cv</sup> = Crevedia Calcareous Marls Member; Lt+pr = Upper Flysch Member; pr<sup>b</sup> = Buciumeni Calcareous Marls Member), **VCF** = Valea Caselor Facies (Oligocene – Pg<sub>3</sub><sup>mi</sup> = Lower Member of the Dysodile Shales with menilites; Pg<sub>3</sub><sup>st</sup> = Shaly Member with Marly-limestones; Lower Miocene – m<sub>1+2</sub><sup>ds</sup> = Upper Member of the Dysodile Shales); **DM** = Doftana Molasse (Lower-Middle Miocene = m<sub>1+2</sub>); Green color = Cretaceous deposits; Blue star = Outcrop F<sub>6</sub> and F<sub>7</sub> (after Țicleanu & Constantin, 2002); Red star = Fossiliferous site (present article)

### 3. MATERIAL AND METHODS

The fossil material, collected by one of the authors (F.C.) with the occasion of recently geophysical research (Chitea & Nuțu-Dragomir, 2019; Nuțu-Dragomir & Chitea, 2019), comes from under the peak „La Plantăție” (629 m). It was extracted from several outcrops of the Lower Member of the Dysodile Shales with menilites from the perisynclinal end of the Buciumeni Syncline, located in the vicinity of the F7 fossiliferous point („Băcanu Brook”), identified and studied previously by Grigorescu & Constantin (1997), Constantin (1999, 2000), and Țicleanu & Constantin (2001) (Fig. 1a). A number of 65 fragments of dysodilic shale, contain impressions of fish in different stages of fossilization, fish scales, crabs (*Portunus oligocenicus*), rare pieces of chelonian and bromalite (coprolite and regurgitalite) (Figs. 2-5). All the

collected materials were photographed in the field and in the laboratory with a NIKON D5 camera. The photo frames, automatically numbered, are registered in the collection of the Romanian Society of Applied Geophysics (RSAG). The measurement of the dimensions (length, diameter), expressed in mm, was performed with Electronic digital calliper PowerFix. For studying the morphological details was used the binocular magnifier as well as the negative images and color corrections light (from computer). For the analysis of coprolites, the criteria recommended by Hunt & Lucas (2012a, Figs. 1, 5, 6, and Table 1) regarding the morphological classification and descriptive terminology were used. For regurgitalite, the works of Zangerl & Richardson (1963), Schweigert & Dietl (2012), Vallon (2012), Klug & Vallon (2019), Hoffmann *et al.* (2020) were used.

## 4. RESULTS

### 4.1. FAUNA AND FLORA FROM FIENI

In several works regarding the Oligocene ichthyofauna from the southern Eastern Carpathians (Grigorescu & Constantin, 1997; Constantin, 1999; Constantin & Baciu, 1998) and in the doctoral thesis of Constantin (2000), 29 species of fish are recorded, including the new species *Holosteus fienensis* (Constantin, 2001; recently, Přikryl *et al.* [2016, p. 434] proposed a revision of this species) and *Polyipnus anteasteroides* (Baciu & Constantin, 2006), found in the Fieni paleontological site, located between the Ialomița and Ialomicioara valleys.

According to Grigorescu & Constantin (2001) and Constantin (2001a), the dominant species of this biocenosis belong to the families Serranidae, Argentinidae, Gadiidae and Clupeidae of small feature, to which are added *Capros*, *Ammodytes*, *Hemiramphus*, *Syngnathus*, *Scorpaena*, *Scorpaenoides*, *Aulostomus*, *Bregmaceros* which characterizes the sublittoral-neritic area. Sporadic, meso-pelagic predatory fish *Scomber*, *Holosteus* and *Lepidopus* also appear. This fauna has many affinities with other Oligocene ichthyological faunas from the Carpathians and the Caucasus, *Palaeogadus simionescui* (SIM.) and *Glossanodon musceli* (PAUCA) representing index fossils for the Rupelian ichthyofaunal zone IPM2, established in the Polish Carpathians.

The list of the paleoflora from Fieni is documented by Ticleanu & Constantin (2002), the synthesis of paleoichthyological research being given in Table 1. Some examples of the fossil material recently discovered in Fieni are illustrated in figure 2.

### 4.2. COPROLITE VS REGURGITALITE – GENERAL DATA

In most coprolites, the main component is represented by a phosphate, calcite or carbonate mass, and iron sulfides or oxides can also occur (Klug & Vallon, 2019). They can also be of a purely organic nature or a mixture of these types (Vallon *et al.*, 2015). This fossil fecal mass has a homogeneous macroscopic appearance, being more or less elongated in a cylindrical shape, some having shaped the spiral of the intestine through which they passed. Large coprolites, produced by vertebrates, may contain determinable prey residues and sometimes intestinal parasites. Hunt & Lucas (2012a, p. 156-159) recognize 27 morphotypes of coprolites and recent fecal vertebrates in 11 main categories: A – elongated cylinder (length =>5x diameter), with 6 subtypes; B – short cylinder (length =<5x diameter), with 5 subtypes; C – subround, with 3 subtypes; D – flattened rounded plates accumulated in circular piles; E – reniform, with 2 subtypes; F – spiral, with 5 subtypes; G – elongated cylinder wound; H – thin and ovoid; I – thin and linear; J – strap; K – irregular shape.

To identify a regurgitalite, the first step is to verify its biogenic nature (Hoffmann *et al.*, 2020, p. 83). Regurgitalites

may have a mineralogical composition similar to coprolites, but without a dominant mass. They often contain visible remains of prey organisms, such as hard-to-digest hard parts. The main differences are the more irregular contour and the often almost flat appearance, with parts of the prey macroscopically visible (e.g., Vallon 2012). An important role in the grouped maintenance of undigested residues (= figurative elements) is played by stomach fluids and mucus, the latter ensuring cohesion and preventing the disintegration of regurgitalites, ultimately facilitating regurgitation (Vallon, 2012).

Given this particularity, for the regurgitalites identified from the Fieni site, at the moment only single specimens, two types can be distinguished, based on the ratio between the mucus envelope and the figurative elements: the first, with the mucus envelope subordinated to the figurative elements (= *decapsulated* type – Fig. 3a), and the second, with the figurative elements embedded in the mucus envelope (= *encapsulated* type – Fig. 3b), taphonomic reality noticed by other researchers, (e.g., Cueille *et al.*, 2020, p. 707), but without assigning appropriate terminology.

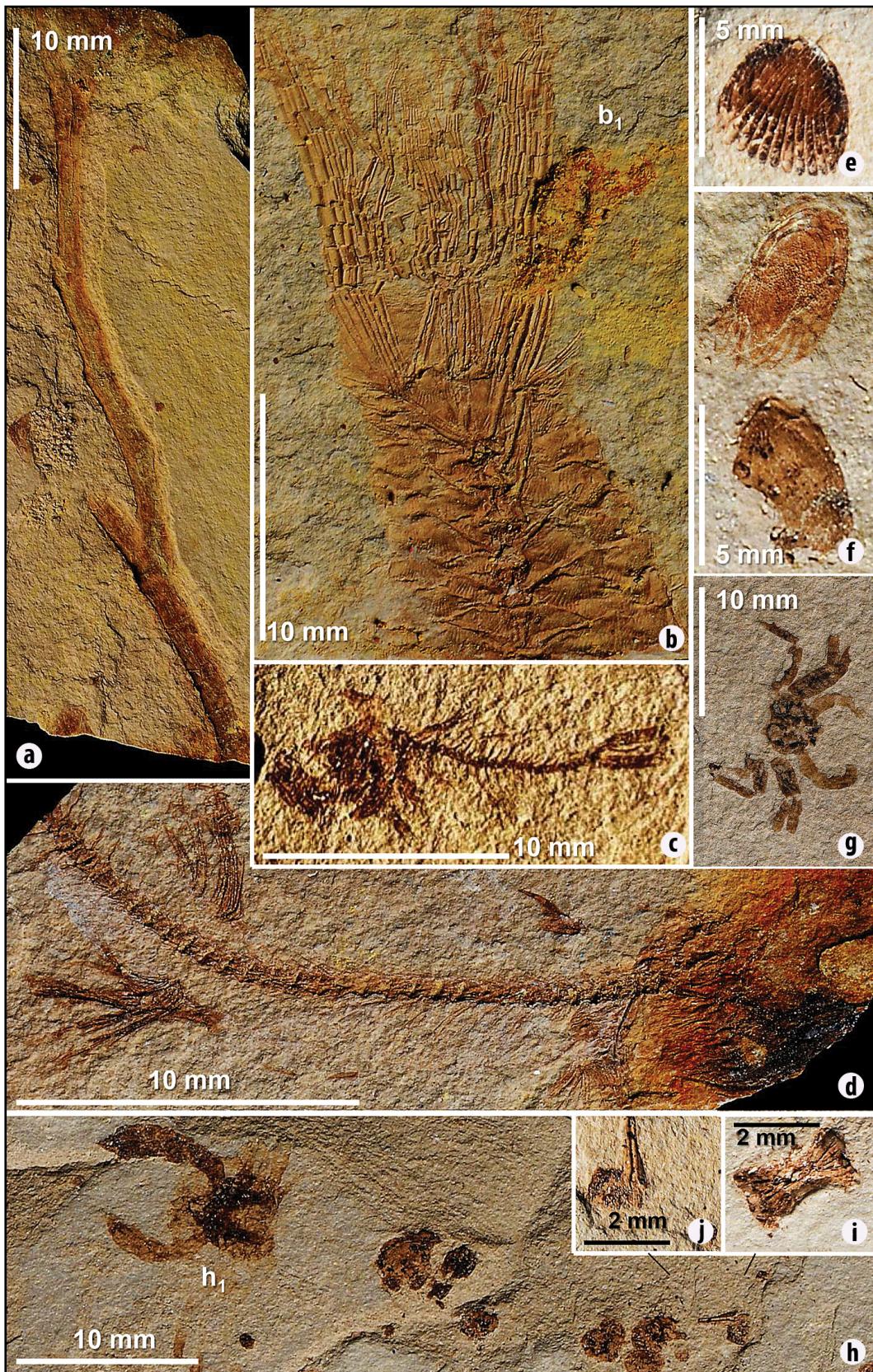
The characteristics of regurgitalites, compiled from several sources by Klug & Vallon (2019, p. 92-93) and Hoffmann *et al.* (2020, p. 83), are the following: 1) dominates the undigested remains belonging to at least one prey individual; 2) non-existence or minimal presence of the fine-grained matrix between the skeletal elements; 3) hard parts (e.g., bones) may be totally or partially fractured due to chewing or biting; 4) the fractured or non-fractured contents may have signs of the action of stomach acids (hollows, corrosion, rounded edges); 5) elongated remains can be oriented parallel or grouped; 6) the presence of skeletal elements that can be lost through taphonomic processes; 7) in regurgitalitis, unlike those in coprolites, the articulated parts of the hard body are more frequent and have larger dimensions; 8) the indigestible parts can be exfoliated, polished or colored by digestive enzymes and stomach acids; 9) the undigested parts, more or less free, are bound together by stomach fluids and excess mucus; 10) the accumulations of undigested organic material have an irregular contour, with a clear limit in relation to the surrounding sediment; 11) skeletal materials that can easily dissolve (e.g., eggshells, shells, aptychi) when passing through the digestive tract of the predator, are kept in regurgitation; 12) are recognized mainly from environments with calm waters or caves.

#### 4.2.1. Coprolite

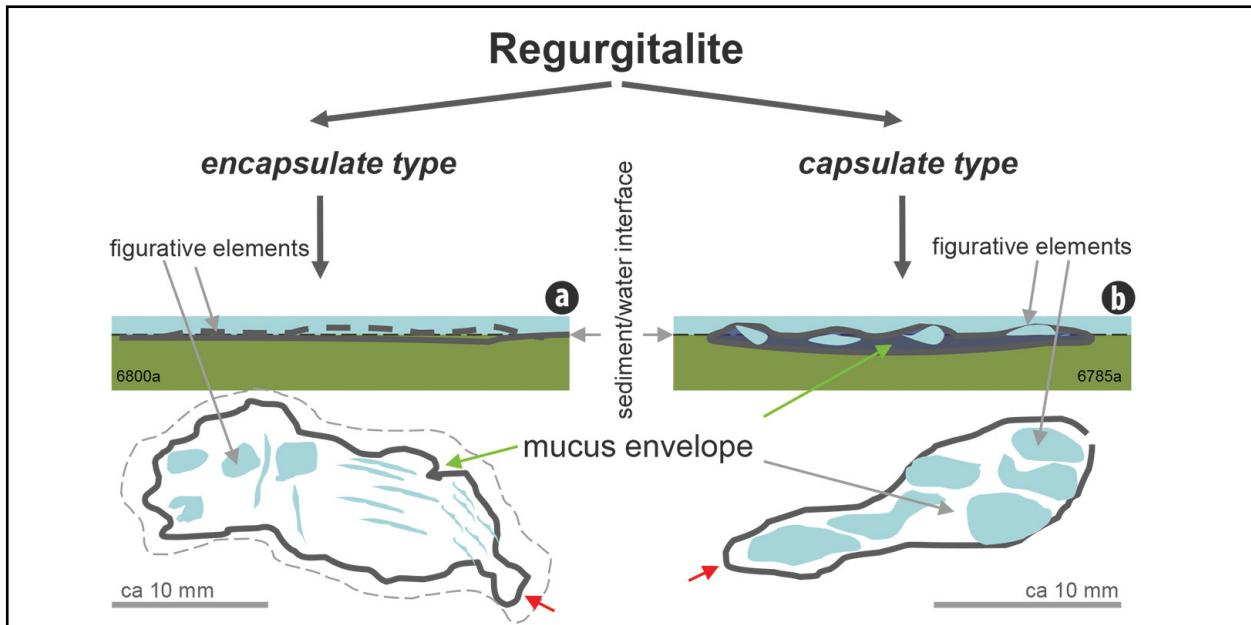
Due to the flattened appearance of Fieni coprolites (except for the morphotypes Fig. 4f and Fig. 4g-h), similar to Luoping-type Triassic coprolites (cf. Luo *et al.*, 2017), but difficult to attribute to a particular ichnotaxon, so as in the Mesozoic (e.g., Hunt *et al.*, 2007), we prefer the use of informal terms of coprolite classification (with adaptations), following the models proposed by Hunt & Lucas (2012a) for vertebrates in general and by Cueille *et al.* (2020) for fish in particular.

**Table 1.** Fossil ichthyofauna and plants from Fieni (acc. to Constantin, 1999; Ticleanu & Constantin, 2002)

Fossil ichthyofauna				
No.	Family	Species	Outcrops (acc. to T & C, 2002)	
1	Clupeidae	<i>Clupea longimanus</i> (HECKEL, 1850)	F6	
2		<i>Clupea sardinites</i> (HECKEL, 1850)	F6	
3		<i>Clupea</i> sp.		F7
4	Argentinidae	<i>Glossanodon musceli</i> (PAUCA, 1929)	F6	F7
5		<i>Glossanodon</i> sp.		
6	Sternopychidae	<i>Polyipnus anteasteroides</i> (CIOBANU, 1977)		
7	Paralepididae	<i>Holosteus fienensis</i> (CONSTANTIN, 2000)	F6	
8	Bregmacerotidae	<i>Bregmaceros</i> sp.		
9	Gadidae	<i>Palaeogadus athanasiui</i> (PAUCA, 1929)	F6	
10		<i>Palaeogadus simionescui</i> (SIMIONESCU, 1905)		F7
11		<i>Palaeogadus</i> sp.		
12	Merlucciidae	<i>Merluccius romanicus</i> (PAUCA, 1929)		
13	Hemiramphidae	<i>Hemiramphus georgii</i> (JERZMANSKA, 1968)		F7
14	Caproidae	<i>Capros radobojanus</i> (KRAMBERGER, 1882)		F7
15		<i>Capros longirostris</i> (KRAMBERGER, 1882)		
16		<i>Capros</i> sp.		
17	Aulostomidae	<i>Aulostomus</i> sp.		
18	Syngnathidae	<i>Syngnathus</i> sp.1		
19	Scorpaenidae	<i>Scorpaenoides popovicii</i> (PRIEM, 1899)		
20	Serranidae	<i>Serranus budensis</i> (HECKEL, 1856)	F6	F7
21		<i>Serranus simionescui</i> (PAUCA, 1929)		
22		<i>Serranus</i> sp.	F6	
23		<i>Properca sabbai</i> (PAUCA, 1929)	F6	
24		<i>Properca</i> sp.	F6	
25	Carangidae	<i>Caranx</i> sp.		
26	Ammodytidae	<i>Ammodytes antipai</i> (PAUCA, 1929)		F7
27	Trichiuridae	<i>Lepidopus caudatus</i> (EUPHRASEN, 1788)		
28		<i>Lepidopus</i> sp.		
29	Scombridae	<i>Scomber</i> sp.		
Fossil plants				
1	Cupressaceae	<i>Chamaecyparis argensiensis</i> (GIVULESCU)	F6	
2		<i>Cupressus</i> sp.	F6	
3	Taxodiaceae	<i>Sequoia abietina</i> (BROGNIARD)		F7
4	Fagaceae	<i>Quercus apocynophyllum</i> (ETTINGSHAUSEN)	F6	
5	Rhamnaceae	<i>Zizyphus ziziphoides</i> (UNGER) WEYLAND	F6	
6	Classe Liliatae	<i>Monocotylephyllum</i> sp.	F6	



**Fig. 2.** Example of the flora and fauna from Fieni (natural light) – (a) ?*Ephedra* sp. (cf. Denk et al., 2017); (b) caudal appendix of ?*Serranus* sp. (b<sub>1</sub> ?coprolite); (c) *Scorpaenoides popovicii* Priem; (d) *Glossanodon musceli* (Pauca); (e, f) fish cycloid scales; (g) *Portunus oligocenicus* Pauca; (h) fish ?cycloid scales (h<sub>1</sub> ?juvenile *Portunus oligocenicus* Pauca); (i, j) fish amphycelic vertebrae (photos Florina Chitea)



**Fig. 3.** The regurgitalite from Fieni: (a) Encapsulate type with free figurative elements; (b) Capsule type with captive figurative elements in mucus envelope (posterior ends indicated by red arrows) (original)

According to the descriptive terminology used by Hunt & Lucas (2012a, p. 155), some coprolites analyzed in this paper are anisopolar type (*sensu* Thulborn, 1991, in Hunt & Lucas, 2012a), in which the cylinder ends are different: the previous one (proximal) is rounded, leaving the first anus and the posterior (distal) conical to sharp, marked by the constriction of the anal sphincter as it closes (Fig. 4a-e; Fig. 4f). In addition, for discrete longitudinal elements of such coprolites, Hunt & Lucas (2012a) propose the term segments.

#### **"Cylindrical flattened coprolite"**

**Fig. 4a-e**

Group of five flattened cylindrical coprolites, located on the surface layer, of the anisopolar type, with a sharp posterior end and a rounded anterior end. One of the specimens (Fig. 4a), probably composed of reddish-brown organic substance, apparently structured towards the anterior end, has a crack on one of the sides (dimensions: 18.07 mm long; average diameter 2.60 mm). Consisting of a homogeneous, blackish-brown, microgranular-looking organic substance, the specimen in figures 4b shows 6-7 unequal segments in length and diameter, very similar to the A1 sub-morphotype, described by Luo *et al.* (2017, Fig. 3A, p. 236) (dimensions: 28.06 mm length; average diameter approx. 4.40 mm); two other specimens, segmented and with a total length almost equal (28.95 mm and 29.37 mm, respectively) (Fig. 4c, d), have a content distributed approximately evenly along the flattened cylinder: relatively homogeneous in the anterior half (well macerated in the case of coprolite of figure 4c and with prismatic remains of undigested material in the coprolite of figure 4d) and inhomogeneous in the posterior half, with undigested remains of scales and small bones in the specimen of figure 4c and whole scales and granular

packets, in the specimen of figure 4d. The segments of both specimens are unequal in length (3.72-9.46 mm, respectively 2.38-7.63 mm), their average width having values of 2.40 mm and 2.04 mm, respectively.

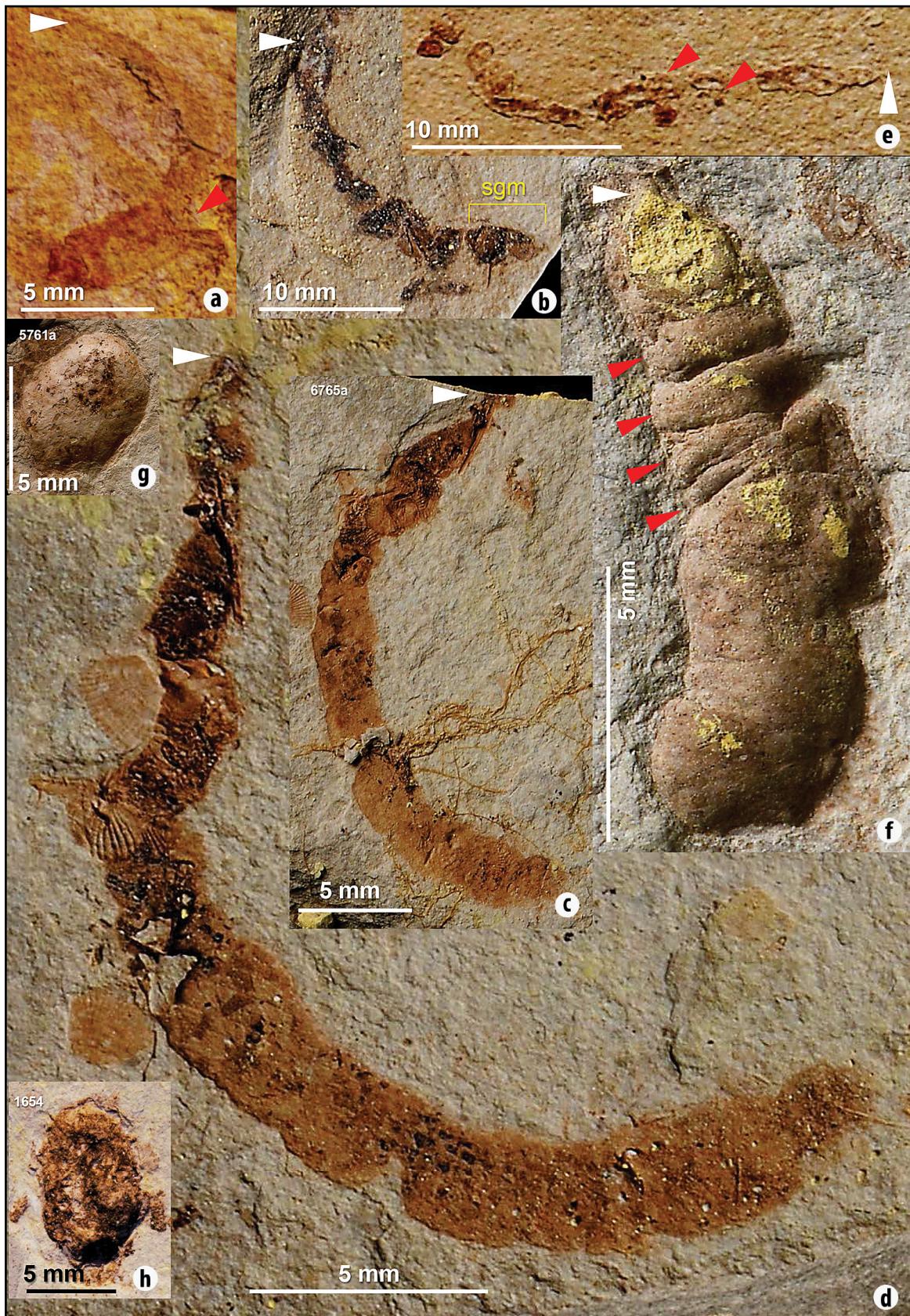
A special specimen, vaguely segmented and with parallel edges in the form of rounded ridges, resulting from the compression of the elongated cylindrical body, is represented in figure 4e. Although we initially attributed it to a possible cololith, it bears similarities to the coprolites of the A2 sub-morphotype, described and represented by Luo *et al.* (2017, Figs. 3d, e, p. 236) (dimensions: 23.5 mm length, average diameter approx. 2.35 mm). According to the morphological classification of Hunt & Lucas (2012a, Fig. 6, p. 158-159), all these coprolites belong to category A Cylindrical elongate (= length >5x diameter), subtype A1 tapered at one end with distinct rounded segments.

#### **"Cylindrical spiral coprolite"**

**Fig. 4f**

Singular specimen (Fig. 4f), representing the positive replica of a coprolite with heteropolar-microspiral morphology (*sensu* Hunt *et al.*, 2007, fig. 6B-D; = F4 in the classification of Hunt & Lucas, 2012a, Fig. 6), with four turns on the posterior half ending in an obvious mucrone. The filling, probably of a phosphatic nature, as long as it has been preserved, has a powdery, dirty yellow appearance.

Locally, submillimeter circular pits can be seen on the surface of the coprolite, resulting from bioerosion probably produced by parasites. „Points“ of this kind are cited by Cueille *et al.* (2020, p. 712) due to bacterial activity (dimensions: 13.19 mm length, average diameter approx. 3.36 mm).



**Fig. 4.** Digestichnia (natural light) – (a-e) *Cylindrical flattened coprolite*: (a) with break margin (red headarrow); (b) with segments (sgm); (c, d) segmented coprolite; (e) with lateral ridges (red headarrows); (f) *Cylindrical spiral coprolite* – pozitive relief with four coils (red headarrows) (all posterior ends = white headarrows); (g, h) *Ovoid coprolite* – positive relief (photos Florina Chitea)

#### **"Ovoid coprolite"**

##### **Fig. 4g-h**

In figures 4g and 4h are illustrated two specimens of ovoid coprolites, positive replicas of depressions created in the fine granular sediment, at the sediment / water interface. The specimen in figure 4g has an oval outline, slightly elongated, with semicircular ends. The surface is devoid of ornamentation (dimensions: 7.77 mm long; 6.13 mm wide). The second specimen (Fig. 4h) has an irregular oval contour, with one end rounded and the other slightly pointed. It consists of two unevenly developed tubers, separated by a shallow ditch. Filiform inclusions can be observed, two of which are probably very thin bone fragments (dimensions: 10.2 mm long, 6.55 mm wide).

Remarks: Spherical coprolites have been described by van Regenmorter *et al.* (2008, Fig. 5, p. 27) from the Lower Carboniferous in the USA, with dimensions of 6.1-7.2 mm length / 5-5.4 mm diameter. From Bear Gulch Lagerstätte of Central Montana (USA), Hunt *et al.* (2012b, Fig. 2B), describe ovoid bromalites composed of a dense phosphate mass (13 mm long and 8 mm wide). Brinites from Tinajas Lagerstätte (Upper Carboniferous, USA), striated and with rounded ends (31 mm long, 18 mm in diameter) are described by Hunt *et al.* (2012c, Fig. 3A) which attributes them to fish. From Nusplinger lithographic limestones (Upper Jurassic, Germany), phosphate coprolites with oval contours are cited, probably from sea crocodiles (Dietl & Schweigert, 2001, Fig. 119, p. 68), as well as elongated oval coprolites (40-50 mm long) attributed to a fish similar to *Caturus furcatus* (Schweigert & Dietl, 2012, Fig. 3, p. 216). A coprolite similar to the specimen we figured, but with larger dimensions (20.7 mm long, 14.3 mm wide), reports El Hajj *et al.* (2021, Fig. 11E, p. 14) in the dysodiles of the Lower Barremian of Lebanon.

#### **4.2.2. Regurgitalite**

Based on specimens from carbonaceous bituminous shales in the USA, interpreted as regurgitated prey, Zangerl & Richardson (1963, p. 130-144) distinguish two groups: expelled prey and gastric residues. The expelled prey consists of whole or partial skeletons in a disarticulated and disoriented state, with parts of the body still articulated and with rare signs of engraving due to the action of gastric juices. Gastric residues consist of completely mixed bone material, more or less scattered or tightly packed in the form of pellets, accompanied by varying amounts of brown, fecal-like material; intermediate gastric residues are also common.

Fulfilling half of the 12 criteria mentioned above (1, 3-5, 10, 12 - see above), the two specimens of regurgitation identified in the Fieni material belong to the decapsulated (Figs. 5a, b; 5e) and encapsulated types (Fig. 5c, d).

#### **Regurgitalite A – encapsulate (amalgamated) type**

##### **Fig. 5a,b**

According to the Zangerl & Richardson (1963) classification, this morphotype corresponds to gastric waste consisting of bone material, tightly packed (amalgamated), surrounded by a brown tire that contrasts with the host rock (Fig. 5a), much more evident in the color corrected negative image (Fig. 5b). The entire trapezoidal bone content has a length of 19.64 mm and an average width of 7.40 mm. It is bordered by the ovoid-shaped mucus (?), 23.06 mm long and 11.95 mm wide. Short, thin, differently oriented bone debris, long parallel-oriented bones, vertebrae, scales, and parts of the head (e.g., square bone, operculum) can be recognized.

Remarks: The specimen described and figured is similar to the gastric rest cited by Huber (1992, p. 43, Fig. 4) from the Wild Cow Formation (Upper Carboniferous, New Mexico, USA), which contains disarticulated elements of the skull bones, ribs and scales of actinopterygian fish.

#### **Regurgitalite A – encapsulate (serpentiforme) type**

##### **Fig. 5e**

A special specimen with a serpentine appearance is the one represented in figure 5e. With a discrete mucus envelope, it contains granular inclusions, relatively evenly distributed, and two remnants of fine bones, located near the posterior end of the trace. Dimensions: length = 16.55 mm, average width = 2.55 mm.

#### **Regurgitalite B – capsulate type**

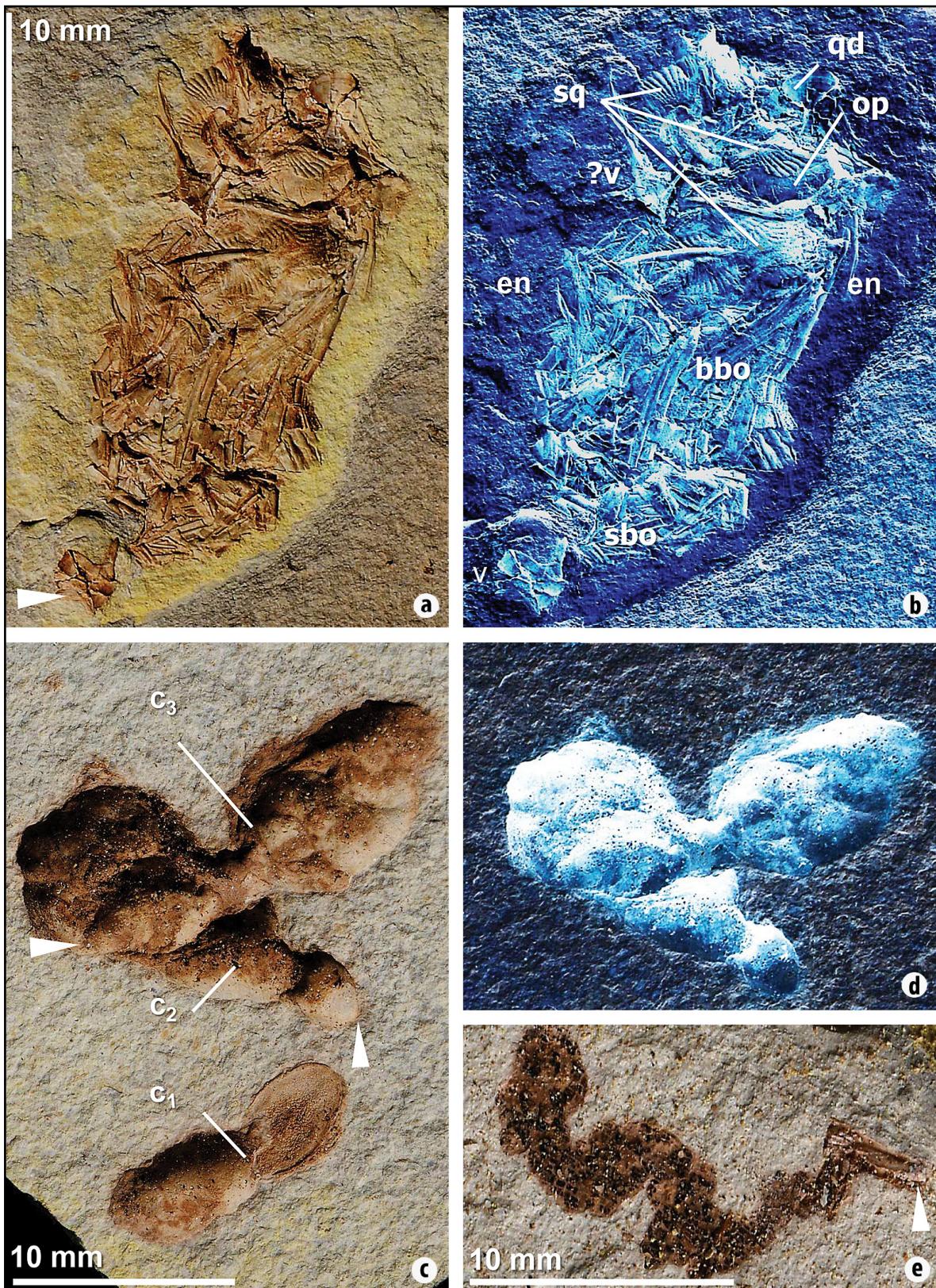
##### **Fig. 5c,d**

This morphotype corresponds to three specimens (Fig. 5c), one small (length = 5.56 mm, width = 3.12 mm), ovoid, with a broken end through which a cycloid scale was expelled (Fig. 5c<sub>1</sub>). Two others (Fig. 5c<sub>2</sub>, c<sub>3</sub>), with similar dimensions (length = 13.55 mm, respectively 14.59 mm; width = 4.86 mm, respectively 9.38 mm), have a fan-like shape, with the front end widened or slightly elongated. The inclusions (as the case may be, mono- or polituberculated elements), are masked by the abundant mucus, sufficiently highlighted in the color-corrected negative image (Fig. 5d).

## **5. DISCUSSION AND FINAL REMARKS**

The progress in knowing the fossil ichthyological inventory from geological formations of different ages (from Paleozoic to Tertiary) in Romania, was published in the studies elaborated by Paucă (1956, 1957, 1973), Ciobanu (1977), Paucă & Ciobanu (1986), and Constantin (1999).

Although very rich in fish genera and species, from almost all ecological categories (benthic, pelagic, batipelagic), the only author who cared about their conservation status was Paucă (1956, 1957). The author considers the biological conditions on the Oligocene seabed as favorable as possible for mummification, due to lack of oxygen and high salinity, fish appear laterally compressed, their flesh and skeleton being transformed into an unstable carbonaceous substance (Paucă, 1956, p. 23).



**Fig. 5. *Regurgitalite A* – encapsulate type:** (a) Natural light; (b) Negative and color corrections light (*v* = vertebrae; *?v* = probable vertebrae; *bbo* = big bones; *sbo* = small bones; *sq* = cycloid scales; skull bones [*op* operculum; *qd* quadratum]; *en* = probable gastric liquid envelope); (e) *Regurgitalite A* – encapsulate type; ***Regurgitalite B* – capsulate type:** (c) Natural light (*c<sub>1</sub>* = “monotuberculated” element with scale expulsion; *c<sub>2</sub>*, *c<sub>3</sub>* = “polituberculated” element); (d) Negative and color corrections light; (all posterior ends = white headarrows) (photos in natural light Florina Chitea)

Detailling later this taphonomic concept, Paucă & Ciobanu (1986, p. 177-178) adds to the two conditions the total lack of necrophagous benthic species and the bituminous organic substance on the dead bottom, with euxinic character, particularly favorable to mummification as the first phase of the complete conservation of fossil fish (Paucă & Lubenescu, 1982, p. 275), produced in a long period of time in which all these factors acted. The interception of levels with mummified fossils by erosion and the action of water and air initiates the phase of decomposition of the mummy, leaving the skeleton and finally only the impression. In this way, "frequent death by asphyxiation and mummification represent conservation states typical for very fine sediments of different ages deposited in a deep-water environment intoxicated with gases, generated in the initial stage of bituminization of the organic substance" (Paucă & Ciobanu, 1986, p. 178).

An important issue brought up by Paucă (1957) is the almost exclusive presence of fish and, we add, of bromalites, in rocks deposited under the facies of menilites and dysodilic schists, noting that, however varied they may be from a petrographically point of view, these rocks are pelitic in nature and originally with a mud aspect. From this point of view, the main mineralogical components of dysodile are clay minerals (chlorite, montmorillonite and kaolinite ± chlorite-illite, and montmorillonite-illite), followed by epiclastic and autogenic minerals, of chemical and biochemical precipitation (Grasu *et al.*, 1988, p. 172). For example, the average mineralogical composition of the bituminous rocks from Tarcău Nappe is in menilite: illit = 16.6%; smectite = 3.4%; chlorite = 1.4%; in dysodile: illit = 31.88%; smectite = 3.41%; chlorite = 2.70%; kaolinite = 8.57% (cf. Grasu *et al.*, 2007).

Noticing the connection between the changes of the lithological composition, existing at different levels of the Oligocene bitumolites, and some changes of the faunal composition, Paucă & Ciobanu (1986, p. 176) report for the Susalnești site the presence of large Clupeids on sandstone plates, with centimeters thick and irregular surfaces, the result of at least two causes: increased sedimentation rate and, implicitly, seafloor oxygenation and temporary changes in the composition of migratory fauna. This finding showed that the movements of the foundation blocks contributed to the frequent lithological facies changes of the bituminous sedimentary deposits and, depending on them, of the ichthyofaunal associations. Recently, this reality has been confirmed in the Polish Carpathians by Kotlarczyk & Uchman (2012) in the menilites of the Skole and Subsilesian Nappes by integrating ichnological, ichthyological and benthic foraminiferal data. The authors conclude that the presence of the trace fossil suite *Trichichnus - Palaeophycus - (Multina, Halimedides) - Rhizocorallium* indicates an increase in sediment oxygenation, the absence or reduction of batipelagic fish marks anoxia in the water column and total anoxia at the bottom of the sea and (due to the action between thermostratification and very high organic productivity), it occupied entirely the IPM2 ichthyofaunal zone in the middle part of the

NP23 Zone (Kotlarczyk & Uchman, 2012, p. 116). To mention that the IPM2 Zone corresponds to the Rupelian to which the member with dysodilic and menilite schists from Fieni was assigned (Ştefanescu, 1995), with the ichthyofossils index *Palaeogadus simonescui* (SIM.) and *Glossanodon musceli* (PAUCA) (cf. Grigorescu & Constantin, 2001a).

Although Paucă & Ciobanu (1986, p. 165) considered that there is no  $\text{CaCO}_3$  in the dysodilic shales from the Carpathians, the presence of calcareous deposits is demonstrated, in the form of laminitic limestones (e.g., Tylawa, Jaslo, Zagórz) widespread, from The Polish Carpathians to the south of the Eastern Carpathians in Romania (e.g., Haczewski, 1989; Alexandrescu & Brustur, 1985; Ionesi, 1986; Grasu *et al.*, 1988; Brustur & Alexandrescu, 1989; Melinte-Dobrinescu & Brustur, 2008). For example, referring to the taphonomy of teleost fish in the Polish Outer Carpathians, Bienkowska-Wasiluk (2010) mentions two fish assemblages in Tylawa Limestone, unusually well preserved due to the penetration of  $\text{CaCO}_3$  into the soft tissues of corpses buried in sediment.

As for the non-spiral coprolites of the Rupelian menilites of the Polish Western Carpathians, Bajdek & Bienkowska-Wasiluk (2020) consider them probably produced by teleost fish. They are elongated, linear, more or less sinuous, with a diameter between 1.25 and 10 mm. They appear to have a morphological continuum, rather than more morphotypes, with a phosphate matrix composed of fossilized bacteria. Over 80% of them contain fish remains (bones, scales, teeth), being attributed to predatory fish (e.g., *Palimphyes*, *Oligophus*). The authors interpret coprolites as products of pelagic fish that lived in the oxygenated parts of the water column, their fecal matter sinking and depositing in the anoxic environment on the seabed.

Regarding the conservation status of coprolites, Bajdek & Bienkowska-Wasiluk (2020) discuss this process based on information from various sources from which the following aspects can be deduced: the fecal matter produced by fish is considered to be particularly fragile and easily decomposed, sometimes quite liquid; fecal mineralization is possible due to the mineral constituents they contain (e.g., phosphates from bones and meat); the soft consistency of the feces may reflect the low mineralization potential of some fish droppings; the presence of fragile morphological details may be an indication of a low energy environment; it is admitted that the mineralization process can be mediated microbially, as the development of microbial films on the seabed can be crucial for the preservation of feces in environments with low sedimentation rates in which they cannot be buried quickly; the anaerobic environment is favorable for the fossilization of fecal matter, protecting it from disturbance by bioturbation.

Rediscovering the state of conservation by mummification summarized above, we consider it necessary to resume this issue in terms of new hypotheses on the role of sediment mineralogy in the genesis and conservation of flattened non-mineralized fossils. This is the case of the famous Burgess

Shale (BST) fauna from the Lower Paleozoic of the USA. Thus, according to Gaines *et al.* (2005), the Cambrian sites Conservat-Lagerstätten type of Wheeler Formation contain non-mineralized fossils preserved in the form of kerogenized carbon films under conditions of domination of the siliciclastic fraction with clay-size particles, the flow of mixed carbonate-clay sediments from a carbonate platform, the minimum level of oxygen to block benthic colonization and the relative vicinity of the oxic bottom water to allow the movement of organisms from a habitable environment to one favorable to their conservation. It is assumed that the intimate mechanism of preservation of non-mineralized bodies could be the result of a combination of factors that reduced the permeability that decreased the oxidative flow, by deflocculating clay mineral aggregates. Moreover, by experimentally burying polychaete (*Nereis*) and crustacean (*Crangon*) carcasses in kaolinite, calcite, quartz and montmorillonite, Wilson & Butterfield (2014) demonstrated the effect of sediment mineralogy on non-biomineralized skin, as the first phase in the production of compressed carbonaceous fossils of the BTS type. The complex system of interaction between the original histology and the mineralogy of sediments controls the pH, oxygen content and major ion concentrations, all of which control the conservation potential of certain substrates in certain environments.

Such an approach in the future could bring new data on the particular conservation of laterally compressed fish and flattened coprolites, such as the case of the "cylindrical flattened coprolite" morphotype (see Fig. 4a-e), based on the results of systematic analyzes of clay minerals from the Oligocene fossiliferous bituminous suite.

Because the research of ichnofossils in the Digestichnia category does not stagnate, relatively recently Myhrvold (2012, p. 510) proposes the term *emetolite* for fossilized gastric pellets produced by *routine emesis*. Although emetolites (often with keratin inclusions) are confused to the point of regurgitation, it is difficult to admit that the sum of

arguments based on phylogeny, anatomy, and biomechanics may suggest that many extinct species, including crocodilians and pterosaurs, may have produced gastric pellets. They can and should be in the attention of researchers, as much as the appeal of the inspired title of the paper, signed by this author.

The signaling of the coprolites and – for the first time – of the regurgitalites from the Dysodilic Shale Member with menilites from Fieni, offers the opportunity to continue the paleoichnological study of these metabolic ichnofossils, as Gautier (1993, p. 514) calls them so inspired. The present note, of a preliminary nature, was limited only to the brief description and figuration of some particularly well-preserved specimens. It remains that in the future, the new generation of geologists and paleontologists will use the entire arsenal of field investigations (*bed-by-bed* stratigraphy, systematic collection, etc.) and analytical (optical and electron microscopy, thermo-differential determinations, X-rays, cathodoluminescence, etc.) for the detection of as many details as possible is necessary to understand the nature, origin and role of these fossil traces, important testimonies of the food chains established between the organisms of the Oligocene Mediterranean Sea. According to Hunt (1992), bromalites have numerous uses in biochronology, biostratigraphy, sedimentology, paleoecology, taphonomy and economic geology.

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