THE PALAEO-ICHNOLOGY OF THE MIOCENE DEPOSITS IN THE ROMANIAN CARPATHIANS

A short overview of existing data referring to the uncovered footprints of vertebrates in the Miocene deposits, their taxonomy, a hypothesis regarding the paleo-environmental condition within the region and the genesis of these deposits

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Abstract. The paper refers to the paleo-ichnology of the Miocene Molasse deposits in the Romanian Carpathians. The principles of systematics and nomenclature of the vertebrate traces from these deposits are briefly presented. Follows a review of the ichno-fossiliferous points in the Carpathians, with a complete inventory of the traces discovered in each ichno-fossiliferous region. In the next chapter, the vertebrate tracks are described and each ichno-species is illustrated. In the end, the article presents a hypothesis regarding the formation of the flish-like Miocene Molasse deposits having footprints of vertebrates coexisting with mechanical traces generated by strong currents (scour - and tool-marks) but also with wave ripple-marks and traces of rain drops. The present article is actually a synthesis of the papers published in 1961, 1962, 1964, 1965, 1966 and 1968 by N. Panin and N. Panin in collaboration with other researchers.

Key words: Paleo-ichnology, Miocene Molasse, taxonomy, paleo-environmental conditions, turbidity flood currents

1. INTRODUCTION

The Palaeo-ichnology appeared as a domain of interest for geological sciences since the 19th century, but only after the middle of the 20th century, with the studies of Seilacher (1953, 1954), it became a well-defined discipline. The Paleo-ichnology of the Miocene deposits in the Carpathian Mountains has a special significance due to the abundance and variety of vertebrate traces found in these deposits. For the first time footprints of birds in the Lower Miocene deposits of Romania have been found by Grozescu in 1914. Then in 1927, Popescu-Voiteşti cited traces of artiodactyl mammals and later, in 1942, Pauca found birds' footprints (Larus, Sterna) in the Lower Miocene of Vrancea Mountains.

The most important Miocene ichnofossiliferous regions in the Romanian Carpathians (Fig. 1) are the Vrancea and the Piatra Neamt areas, but they are not the only ones – the vertebrates traces have been found also in the Brebu zone, in the Doftana area, etc. The Miocene deposits with footprints of vertebrates are of Burdigalian age and are placed in the Romanian Sub-Carpathians (Outer Moldavides Unit). The footprints occur in the Red and in the Grey Horizons. The Red Horizon is composed of a package of red and green sandstones and marls, in a flysch type alternation, with intercalation of conglomerates as alluvial fans (for example the Bârsesti conglomerates in the Vrancea region and the Upper Conglomerates of Almaşu in the Piatra Neamt area) covered by a new thinner package of sandstones, micro-conglomerates and green marls, while the Grey (or Dark)

Horizon is formed of a quite thick alternation of layers of grey sandstones and marls. The Aquitanian Lower Salt Formation, comprising the salt "breccia", with deposits of rock salt and potassium salt, as well as some intercalations of conglomerates (as the Lower Conglomerates of Almaşu in the Piatra Neamt region) underlie the Red Horizon. The Langhian deposits succeed the Burdigalian ones.

The variety and frequency of traces in some packages are impressive: footprints in addition to traces of birds, of paricopitates, of proboscides and rhynoceratides, felines and canines have been found. In some packages the traces (especially of birds) are found on almost every sandstone layer. On some of layers there are also, on the upper side of layers, wave ripple marks and rain drops marks, and on the lower side, mecanoglyphes as current and tools casts and marks.

The present article represents a synthesis of the works published by N. Panin and by N. Panin in collaboration with E. Avram or other researchers (V. Lazarescu, C. Grujinski or M. Stefanescu) from 1961 to 1968. The paper will briefly present the principles of nomenclature and taxonomy of vertebrate traces as proposed by Vialov (1960-1961) and then developed by Panin and Avram (1962) and Panin (1965).

Then a description of traces found and of the hypothesis on palaeo-environmental conditions and of the ways of described deposits formation will follow.

2. ON THE NOMENCLATURE AND SYSTEMATICS OF VERTEBRATE TRACES

The problem of nomenclature and classification of fossil traces of biological activity found on the surfaces of geological strata has been the subject of many scientific papers.

Traces of vertebrates from Miocene deposits have been studied with great attention by O.S. Vialov in the 60th, who proposed the main principles of nomenclature and systematics of these traces. These Vialov's principles *(ex literis, 1961),* are the following (cited from Panin and Avram, 1962):

"The nomenclature must be Latin, binomial and have an exclusively conventional character. This nomenclature must be Latin, binomial and have an exclusively conventional character. When forming the name of a new „genus" of traces, one of the following stereotype suffixes can be used on a case-by-case basis: *-ites, -ichnites, -ichnis, -pus, -pes, -peda*.

The generic and specific denominations of traces of vital activity (including vertebrate foot-prints) have a purely nomenclatural and by no means taxonomic value and do not represent the units of a natural biological classification, but of a conventional one. O.S. Vialov developed, in accordance with the above, a classification and a system of nomenclature of traces. Thus, he proposes the name of *Vivichnia* for all traces of vital activity.

Fig. 1. The ichno-fossiliferous regions of the Romanian Carpathians (after Brustur, 2012; geological map after the Geological Institute of Romania map).
Legend: (**1**) Piatra Neamt; (**2**) Vrancea; (**3**) Teleajen; (**4**) Doftana-Brebu

The *Vivichnia* comprises two large groups: *Invertebratichnia* and *Vertebratichnia*. Traces of vertebrates can be divided into: *Avipedia, Mammalipedia* etc. The last type of traces can be subdivided into: *Carnivoripedae, Perissodactipedae, Artiodactipedae* etc."

To these basic principles, the works of Panin and Avram (1962) and Panin (1965) brought some remarks, clarifications and additions. These additional principles could be expressed as follows (Panin and Avram, 1962):

The paleoichnological studies are based mainly on the principle of actualism. Having in mind this principle, the

determination of fossil traces can be done only by comparing them with the traces of the present-day animals. Therefore one can consider that the studied fossil traces belong to animals from the geological past, which are part of the same taxonomic group as those of today whose traces most closely resemble the fossils ones.

The following steps have been proposed as being the safest and least risky method for determining the traces of vertebrates from the Miocene: one compare the fossil trace with the traces of present-day animals finding the closest resemblance, going as far as the today species; one return to the higher taxonomic group - order, family; one verifies if the systematic this group existed in the respective geological epoch; one proceeds to denominate the fossil trace. The nomenclature of the traces must be suggestive to reflect the relationship between the trace and the animal to which they are due.

To form the names of the traces Panin and Avram have proposed to attach to the roots of the various taxonomic categories of animals, corresponding suffixes: for the ichnological „order", the suffix -*ipedia*, for the „family" -*ipedidae*[2], for the „subfamily" -*ipedinae*, and for the „genus" -*ipeda*. For generic names, the root of the nearest higher taxonomic group up to which the identification of animals based on their traces has been pushed should be taken. The specific name must specify the animal or highlight the characteristic features of the tracks.

For example, the resemblance between a fossil trace and a current one of *Recurvirostra* have been established. The generic name of the fossil trace will be formed by attaching to the root of the category immediately above the genus *Recurvirostra* the suffix -ipeda. This taxonomic category is the family *Charadriidae* and its root *Charadri*. This will give the name of the ichno-genus – *Chardriipeda*. For obtaining the specific name it will be taken into account to which animal of the family the respective trace belongs or, alternatively, some characteristic features of this trace. In this way the specific name of the considered trace will be *Charadriipeda recurvirostra*. The genus *Charadriipeda* belongs to the ichno-family *Charadriipedidae* of the order *Avipedia*.

Haubold (1971) proposed a nomenclature system for bird footprints based on osteology. Such a system would allow a more reliable recognition of the bird that left the trace, but for the traces from the Miocene deposits, it is very difficult to recognize the osteological structure of the leg that left the trace. W.A.S. Sarjeant *et al.*, in their works of 1994 and 2001, accepted in principle the system proposed by Panin and Avram, but having not all the works published by these authors up to 1994 and having difficulties translating from the Romanian language, they made observations and amendments to the initial descriptions, which in fact, were mostly contained in the works of 1961, 1962, 1964, 1965, 1966 and 1968 published by Panin *et al.* and consequently they should not be taken into consideration.

In the present work, the traces discovered in Romania will be presented in the initial description, nomenclature and systematics from the mentioned works of Panin *et al.*

3. INVENTORY OF THE TRACES DISCOVERED IN THE MIOCENE DEPOSITS FROM THE ROMANIAN SUB-CARPATHIANS

The inventory below presents mainly the traces discovered and described in the papers of Panin, 1961, Panin and Avram, 1962 and Panin, 1965. Additionally will be presented the traces mentioned by Panin *et al.*, 1966 and Panin and Ştefănescu, 1968.

3.1. The traces found in Vrancea county of Romania, near the confluence of Putna and Zăbala rivers, are listed below:

I. Order AVIPEDIA Vialov, 1961

1. Family **ARDEIPEDIDAE** Panin, 2021
(= **ARDEIPEDAE** Panin et Avram, 1962)
Genus **Ardeipeda** Panin et Avram, 1962
Ardeipeda egretta Panin et Avram, 1962 – Gray Horizon.
Ardeipeda gigantea Panin et Avram, 1962 – Gray Horizon.
Ardeipeda incerta Panin et Avram, 1962 – Gray Horizon.

2. Family **ANATIPEDIDAE** Panin, 1964
(= **ANATIPEDAE** Panin et Avram, 1962)
Genus **Anatipeda** Panin et Avram, 1962
Anatipeda anas Panin et Avram, 1962 – Gray Horizon.

3. Family **CHARADRIIPEDIDAE** Panin, 1964
(= **CHARADRIIPEDAE** Panin et Avram, 1962)
Genus **Charadriipeda** Panin et Avram, 1962
Charadriipeda recurvirostra Panin, 1964 (= **Charadriipeda recurvirostrioidea** Panin et Avram, 1962) – Gray Horizon.
Charadriipeda minima Panin et Avram, 1962 – Gray Horizon.
Charadriipeda disjuncta Panin et Avram, 1962 – Gray Horizon.
Charadriipeda becassi Panin et Avram, 1962 – Red Horizon.

4. Fam. **GRUIPEDIDAE** Panin, 1964
(= **GRUIPEDAE** Panin et Avram, 1962)
Genus **Gruipeda** Panin et Avram, 1962
Gruipeda maxima Panin, 1964 – Gray Horizon, Vindobonian.

II. Order MAMMALIPEDIA Vialov, 1961

1. Family **PROBOSCIPEDIDAE** Panin, 2021
(= **PROBOSCIPEDAE** Panin et Avram, 1962).
Genus **Proboscipeda** Panin et Avram, 1962
Proboscipeda enigmatica Panin et Avram, 1962 – Red Horizon.

2. Family **CARNIVORIPEDIDAE** Panin 1964
(= **CARNIVORIPEDAE** Vialov, 1961)
a) Subfamily **Canipedinae** Panin et Avram, 1962
Genus **Canipeda** Panin et Avram, 1962
Canipeda longigriffa Panin et Avram, 1962 – Red Horizon.
b) Subfamily **Felipedinae** Panin et Avram, 1962.
Genus **Felipeda** Panin et Avram, 1962
Felipeda lynxi Panin et Avram, 1962 – Red Horizon.

3. Family **ARTIODACTYPEDIDAE** Panin, 1964
(= **ARTIODACTYPEDAE** Vialov, 1961)
a) Subfamily **Pecoripedinae** Panin et Avram, 1962
Genus **Pecoripeda** Panin et Avram, 1962
(= **Pecorapeda** Vialov, 1961)
Pecoripeda gazella Vialov, 1961 – Gray Horizon.
Pecoripeda amalphea Vialov, 1961 – Red Horizon.

3.2. In the Miocene ichno-fossiliferous region of Piatra Neamț the following types of vertebrate footprints have been found:

III. Order AVIPEDIA Vialov, 1961

1. Family **CHARADRIIPEDIDAE** Panin, 1964
(= **CHARADRIIPEDAE** Panin et Avram, 1962)
Genus **Charadriipeda** Panin et Avram, 1962
Charadriipeda minima Panin et Avram, 1962
Charadriipeda recurvirostra Panin, 1964
(= **Charadriipeda recurvirostrioidea** Panin et Avram, 1962)
Charadriipeda becassi Panin et Avram, 1962
Charadriipeda disjuncta Panin et Avram, 1962
Charadriipeda minor Panin, 1965

2. Family **GRUIPEDIDAE** Panin, 1964 (= **GRUIPEDAE** Panin et Avram, 1962)
Genus **Gruipeda** Panin et Avram, 1962
Gruipeda intermedia Panin, 1965

3. Family **ANATIPEDIDAE** Panin, 1964 (= **ANATIPEDAE** Panin et Avram, 1962)
Genus **Anatipeda** Panin et Avram, 1962
Anatipeda sp.

IV. Order mammalipedia Vialov, 1961

1. Family **CARNIVORIPEDIDAE** Panin 1964
(= **CARNIVORIPEDAE** Panin et Avram, 1962)
Subfamily **Felipedinae** Panin et Avram, 1962
Felipeda felis Panin, 1964

2. Family **ARTIODACTYPEDIDAE** Panin, 1964
(= **ARTIODACTYPEDAE** Vialov, 1961)
Subfamily **Pecoripedinae** Panin et Avram, 1962
Genus **Pecoripeda** Vialov, 1961
Pecoripeda gazella Vialov, 1961
Pecoripeda amalphea Vialov, 1961

3.3. In the Teleajen ichno-fossiliferous zone, the following fossil traces of vertebrate footsteps were identified:

I. Order AVIPEDIA Vialov, 1961

1. Family **CHARADRIIPEDIDAE** Panin 1964
(= **CHARADRIIPEDAE** Panin et Avram, 1962)
Genus **Charadriipeda** Panin et Avram, 1962
Charadriipeda becassi Panin et Avram, 1962
Charadriipeda minor Panin, 1964

2. Family **GRUIPEDIDAE** Panin, 1964
(= **GRUIPEDAE** Panin et Avram, 1962)
Genus **Gruipeda** Panin et Avram, 1962
Gruipeda grus Panin, Lăzărescu et Grujinski, 1966

II. Order MAMMALIPEDIA Vialov, 1961

1. Family **CARNIVORIPEDIDAE** Panin, 1964
(= **CARNIVORIPEDAE** Vialov, 1961)
a) Subfamily **Felipedinae** Panin et Aram, 1962
Genus **Felipeda** Panin et Avram, 1962
Felipeda minor Panin, Lăzărescu et Grujinski, 1966

2. Family **ARTIODACTYPEDIDAE** Panin, 1964
(= **ARTIODACTYPEDAE** Vialov, 1961)
a) Subfamily **Pecoripedinae** Panin et Avram, 1962
Genus **Pecoripeda** Vialov, 1961
Pecoripeda gazella Vialov, 1961
Pecoripeda amalphea Vialov, 1961

3.4. In the Miocene ichno-fossiliferous region of Brebu – Doftana the following types of vertebrate footprints have been found:

1. Family **ARTIODACTYPEDIDAE** Panin, 1964
(= **ARTIODACTYPEDAE** Vialov, 1961)
a) Subfamily **Pecoripedinae** Panin et Avram, 1962
Genus **Pecoripeda** Vialov, 1961
Pecoripeda gazella Vialov, 1961
Pecoripeda amalphea Vialov, 1961

2. Family **PERISSODACTYPEDIDAE** Panin et Stefanescu, 1968
Subfamily **Rhinoceropedinae** Panin et Stefanescu, 1968
Genus **Rhinoceropeda** Panin et Stefanescu, 1968
Rhinoceropeda problematica Panin et Stefanescu, 1968

4. DESCRIPTION OF TRACES (CHARACTERISTICS FOR DETERMINING SPECIES)

Order AVIPEDIA Vialov, 1961

Family **ARDEIPEDIDAE** Panin, 2021
(=**ARDEIPEDAE** Panin et Avram, 1962)
Genus **Ardeipeda** Panin et Avram, 1962

Ardeipeda egretta Panin et Avram, 1962

Localization: Gray Horizon, Vrancea county, Prisaca – Putna, Râpa Porcului.

The species *Ardeipeda egretta* (Fig. 3) was described from bas-relief traces of bird steps having the following characteristics:

- Dimensions of fingers: d1 (posterior) 28 mm; d2 (internal) 35 - 42 mm; d3 (median anterior) 50-54 mm; d4 (external) 38 - 40 mm;
- Total length of the track: 80 - 85 mm;
- Total width: 60 - 65 mm.
- Angles between fingers: between fingers 2 and 3 (α_{2-3}), about 50°, between fingers 3 and 4 (α_{3-4}), 60°.
- Finger impressions are thin, with no trace of interdigital membrane.

Comparing this type of traces with those of the present-day birds, the greatest resemblance is with the footprints of *Ardea* (Fig. 2). The maximum size (total length) of *Ardea*'s traces can reach about 175 mm. The fossil traces described above are smaller, but the conformation of the foot is identical.

Fig. 3. *Ardeipeda egretta* Panin et Avram, 1962

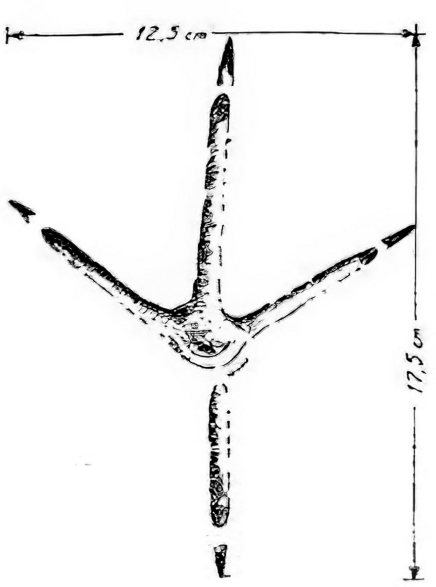

Fig. 2. Footprint of the present-day *Ardea cinerea* (after Formosov, 1952)

Ardeipeda gigantea Panin et Avram, 1962

Localization: Gray Horizon, Vrancea county, Prisaca – Putna, Râpa Porcului.

Characteristics:

- Dimensions of fingers: d1, 87 mm; d2, 95 mm; d3, 145 mm; d4, 90 mm.
- Total length of the track: 230 mm
- Total width: 163 mm.
- Angles between fingers: between fingers 2 and 3 (α_{2-3}), approx. 70°, between fingers 3 and 4 (α_{3-4}), 75°.

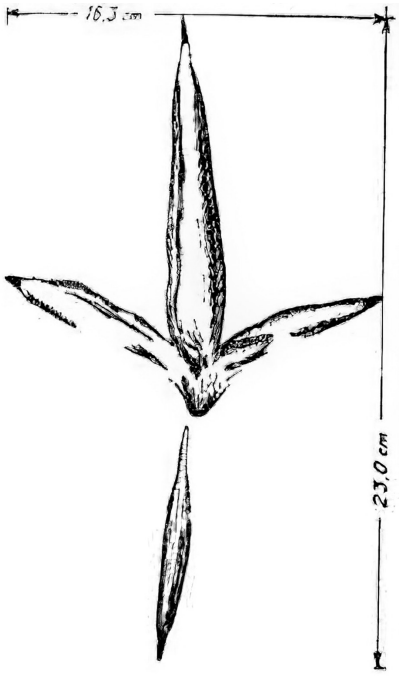

Fig. 4. *Ardeipeda gigantea* Panin et Avram, 1962

The described footprint *Ardeipeda gigantea* (Fig. 4) is of the bird's right leg and resembles the footprints of Ardea's legs, but it is larger.

Ardeipeda incerta Panin et Avram, 1962

Localization: Gray Horizon, Vrancea county, Prisaca – Putna, Bozului brook.

The foot-print described below represent an imprint of the bird's right paw (Fig. 5).

Fig. 5. *Ardeipeda incerta* Panin et Avram, 1962

Characteristics:

- Dimensions of fingers: d1, 30 mm; d2, 42 mm; d3, 58 mm, d4, 34 - 40 mm.
- Total length of the track: 88 mm
- Total width: 68 mm.
- Angles between fingers: $\alpha_{2-3} = 60°$, $\alpha_{3-4} = 50°$.
- Length of the bird's step: approx. 17 - 20 cm.
- Possible small inter-digital membrane between the fingers.

The trace shape brings it closer to the *Ardeipeda* type described above; however, the possibility of existence of a membrane between the fingers obliges to certain reserves to assign it to *Ardeipeda* type. Therefore, these traces are named *Ardeipeda incerta*.

Family **ANATIPEDIDAE** Panin, 1964
(= **ANATIPEDAE** Panin et Avram, 1962)
Genus **Anatipeda** Panin et Avram, 1962

Anatipeda anas Panin et Avram, 1962 – Gray Horizon.

Localization: Gray Horizon, Vrancea county, Prisaca – Putna, Râpa Porcului

Characteristics (Fig. 6, 7):

- Dimensions of fingers: d1, 5 -10 mm (sometimes the imprint of d1 is missing); d2, 48 - 51 mm; d3, 50 – 58 mm; d4, 48 - 51 mm;
- The inter-digital membrane is highly developed, comprising entirely all three front fingers;
- The angle formed by the anterior margin of the interdigital membrane, having the finger d3 as bisector, is approximately equal to 90^0.

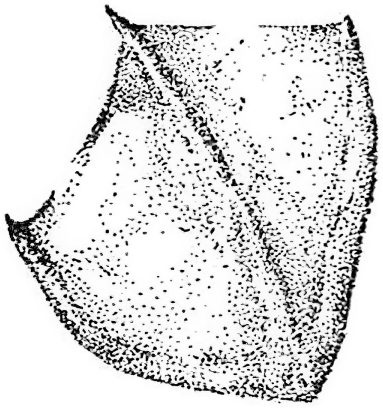

Fig. 6. Foot-print of present-day *Anas platyrhynchos*

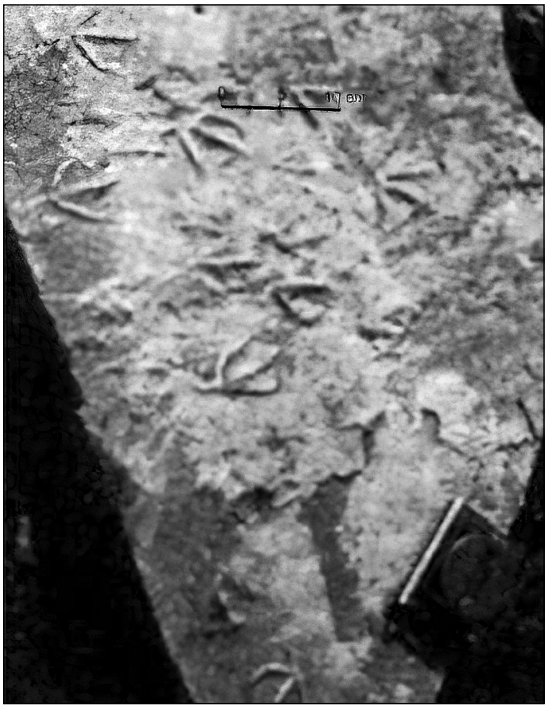

Fig. 7. *Anatipeda anas* Panin et Avram, 1962

Family **CHARADRIIPEDIDAE** Panin, 1964
(= **CHARADRIIPEDAE** Panin et Avram, 1962)
Genus **Charadriipeda** Panin et Avram, 1962

Charadriipeda recurvirostra Panin, 1964
(= **Charadriipeda recurvirostrioidea** Panin et Avram, 1962)

Localization: Gray Horizon, Vrancea county, Prisaca – Putna, Rîpa Porcului; Piatra Neamt county, Cuejdiu valley.

Characteristics:

- Dimensions of fingers: d1, 5 - 7 mm (sometimes the imprint of d1 is missing); d2, 18 - 24 mm; d3, 25 - 35 mm; d4, 23 - 28 mm.

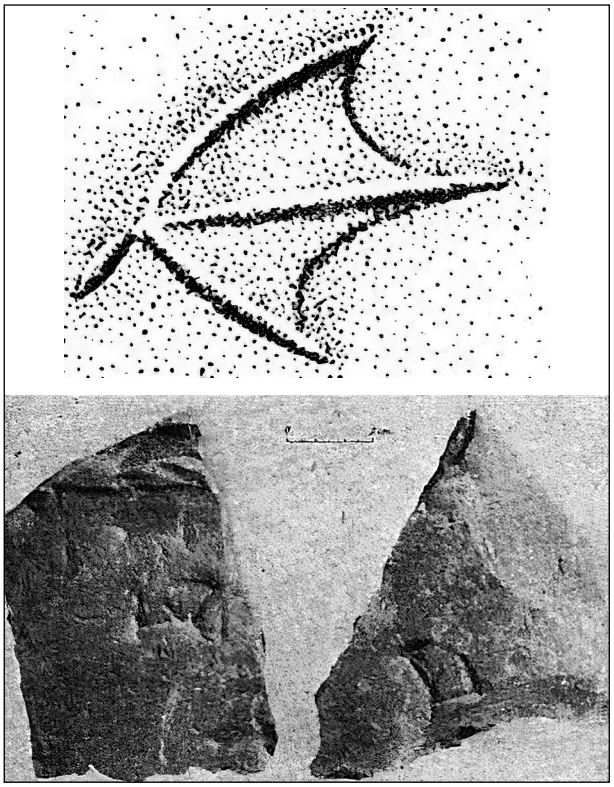

Fig. 8. *Charadriipeda recurvirostra* Panin 1964

- Angles between fingers: $\alpha_{2-3} = 42^0$; $\alpha_{3-4} = 40^0$
- The inter-digital membrane is well developed, comprising entirely the fingers d2 and d4 and the middle finger d3 for more than 2/3 of its length.
- The distance between two consecutive tracks is 12 - 14 cm.
- The middle fingers of the tracks are oriented inward.

The *Charadriipeda recurvirostra* (Fig. 8) – traces resemble the present-day *Recurvirostra*'s fingerprints.

Charadriipeda minima Panin et Avram, 1962

Localization: Gray Horizon, Vrancea county, Prisaca – Putna, Rîpa Porcului; Piatra Neamt county, Cuejdiu valley.

Characteristics:

- Dimensions of fingers: d1, 7 - 8 mm (sometimes the fingerprint of d1 is not complete, being of only of about 3 mm); d2, 14 - 16 mm; d3, 17 - 20 mm; d4, 15 - 17 mm.
- Angles between fingers: $\alpha_{2-3} = 60 - 70^0$; $\alpha_{3-4} = 50 - 65^0$; $\alpha_{2-4} = 120 - 130^0$
- The distance between two consecutive tracks: 4.0 to 7.5 and even 11.0 cm.

The *Charadriipeda minima* (Fig. 9) traces resemble the footprints of present-day culics.

Fig. 9. *Charadriipeda minima* Panin et Avram, 1962

Charadriipeda disjuncta Panin et Avram, 1962

Localisation: Gray Horizon, Vrancea county, Prisaca – Putna, Rîpa Porcului; Piatra Neamt county, Cuejdiu valley.

Characteristics:

- The fingerprints do not join together;
- Dimensions of fingers: d2, 20 - 25 mm; d3, 25 - 35 mm; d4, 20 - 25 mm
- Dimensions of fingerprints: d2 print, 12 - 18 mm; d3 print, 17 - 23 mm; d4 print, 12 - 18 mm
- Angles between fingers: $\alpha_{2-3} = 60 - 70^0$; $\alpha_{3-4} = 60 - 75^0$
- The posterior finger d1 does not reach the surface of the ground or, in other cases, the imprint is like a dot

The *Charadriipeda disjuncta* (Fig. 10) traces resemble the footprints of sandy culics.

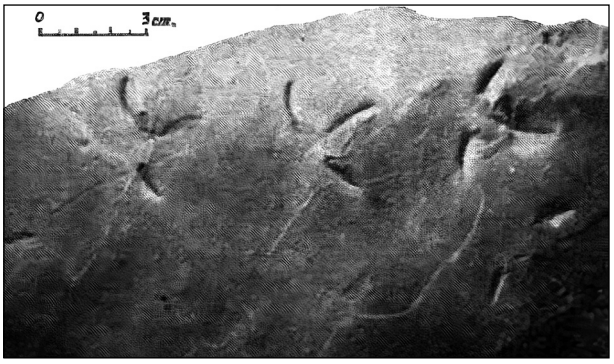

Fig. 10. *Charadriipeda disjuncta* Panin et Avram, 1962

Charadriipeda becassi Panin et Avram, 1962 – Red Horizon.

Localisation: Red Horizon, Vrancea county, Prisaca – Putna, Rîpa Porcului; Gray Horizon, Piatra Neamt county, Cuejdiu valley.

Characteristics:

- Dimensions of fingers: d1, 5 - 10 mm (sometimes the impression d1 reaches 30 mm); d2, 25 - 30 mm; d3, 30 - 45 mm; d4, 25-35 mm
- Angles between fingers: $\alpha_{2\text{-}3} = 55 - 75^0$; $\alpha_{3\text{-}4} = 55 - 75^0$
- The distance between two consecutive tracks: 6.5-14.0 cm (depending of the bird's walking speed

The *Charadriipeda becassi* (Fig. 11) traces resemble the footprints of present-day snipe.

Charadriipeda minor Panin, 1964.

Localisation: Gray Horizon, Piatra Neamt county, Cuejdiu valley.

Characteristics (Fig. 12):

- Dimensions of fingers: d2, 12 - 13 mm; d3, 19 - 20 mm; d4, 12 - 13 mm
- Angles between fingers: $\alpha_{2\text{-}3} = 50 - 60^0$; $\alpha_{3\text{-}4} = 50 - 70^0$

The general aspect of this trace recalls *Charadriipeda minima*. There are some differences as: at *C. minor* the imprint of the posterior finger is always missing; the outer and inner fingers (d2 and d4) are roughly equal and smaller than the same fingers at *C. minima*; the finger d3 (anterior), compared to d2 and d4, at *C. minor*, is considerably longer; the anterior fingerprint at *C. minor* is larger than at *C. minima*, which is probably due to a partial interdigital membrane.

Family **GRUIPEDIDAE** Panin, 1964
(= **GRUIPEDAE** Panin et Avram, 1962) (footprint of Gruide)
Genus **Gruipeda** Panin et Avram, 1962

Gruipeda grus Panin, Lăzărescu et Grujinski, 1966

Localisation: Gray Horizon, Teleajenului Valley

Characteristics:

- Finger sizes: d1 = 10 - 11 mm; d2 = 56 - 58 mm; d3 = 7 - 68 mm; d4 = 56 - 58 mm;

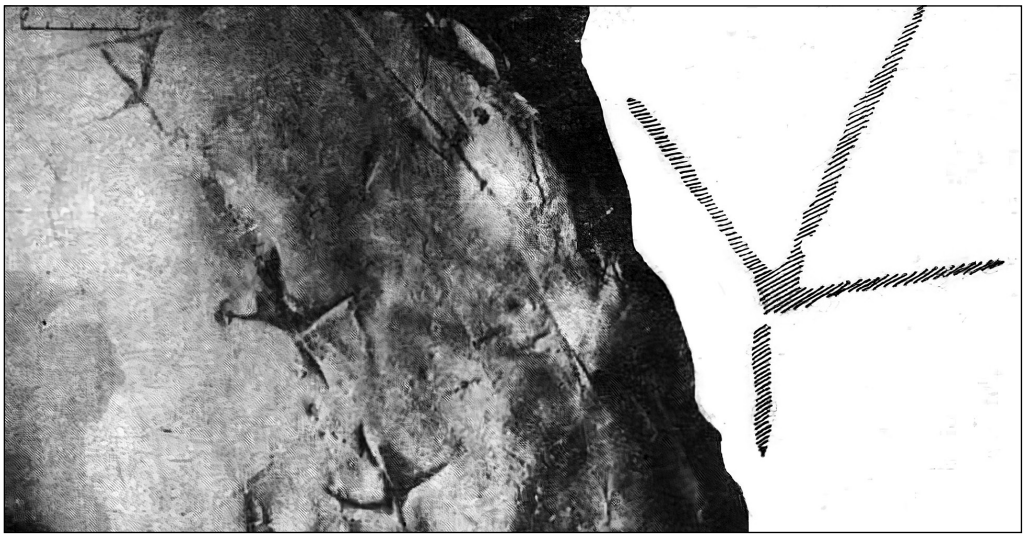

Fig. 11. *Charadriipeda becassi* Panin et Avram, 1962

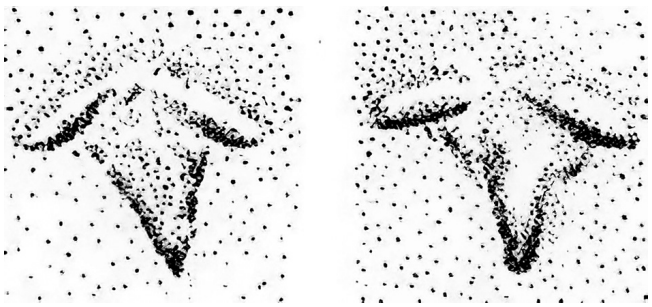

Fig. 12. *Charadriipeda minor*, Panin, 1964

- Angles between fingers: $\alpha_{2-3} = 70^{o}$; $\alpha_{3-4} = 76^{o}$;
- Total length = 87 mm;
- Total width = 114 mm.

The trace found in the level of the Brebu conglomerates represents a trace of the bird's left foot. The bird slipped a bit as a small bulge of sand formed in front of the track.

Order MAMMALIPEDIA Vialov, 1961

Family **PROBOSCIPEDIDAE** Panin, 2021
(= **PROBOSCIPEDAE** Panin et Avram, 1962).
Genus **Proboscipeda** Panin et Avram, 1962

Proboscipeda enigmatica Panin et Avram, 1962

Localisation: Red Horizon, Vrancea county, Prisaca – Putna, Bozului brook.

Characteristics: Dimensions and shape of traces: oval shape, dimensions varying between (40 x 30) cm and (25 x 19) cm; traces have large flat surface, without any special relief of the sole; in the vast majority of traces the fingers were not imprinted at all, but on some of them three small impressions can be observed in the anterior part and two laterally on sides of the trace; the traces are quite deep (10 - 12 cm) with small ridges of sediment (pads) on the sides. The traces are very similar to those of the present-day elephants (Fig. 13). In the Miocene the Proboscides were represented by *Mastodons* and *Deinotherides* and because these traces cannot be assigned to one of the mentioned groups they are named *Proboscipeda enigmatica* (Fig. 14, 15).

In the 1980s, a landslide almost completely destroyed the layer with the *Proboscipeda enigmatica* Panin & Avram, 1962.

Family **PERISSODACTYPEDIDAE** Panin et Stefanescu, 1968
Subfamily **Rhinoceropedinae** Panin et Stefanescu, 1968
Gen **Rhinoceropeda** Panin et Stefanescu, 1968

Rhinoceropeda problematica Panin et Stefanescu, 1968

Localization: Gray Horizon, Doftana valley.

The poor degree of conservation, as well as the fact that only one trace of this kind had been found did not allow a more definite determination.

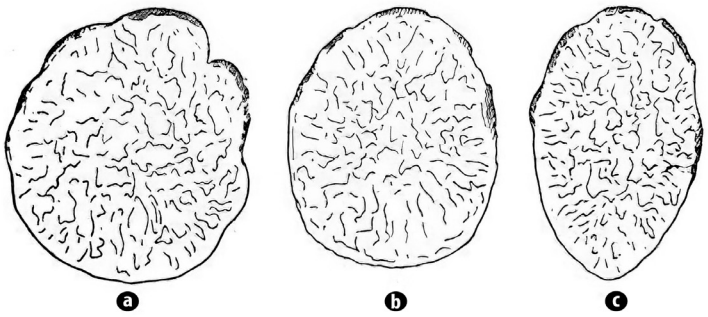

Fig. 13. Traces of African elephants (after Gromier, 1936). (**a**) anterior right leg (life size 44 x 37 cm); (**b**) anterior right leg (life size 42 x 34 cm); (**c**) right posterior leg (life size 45 x 29 cm).

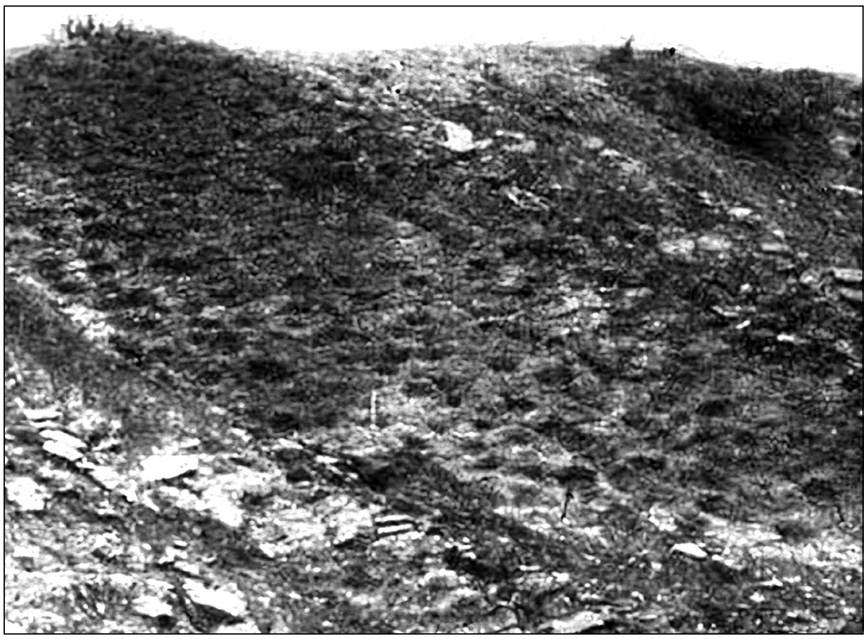

Fig. 14. The bed with *Proboscipeda enigmatica* – Red Horizon, Bozului brook

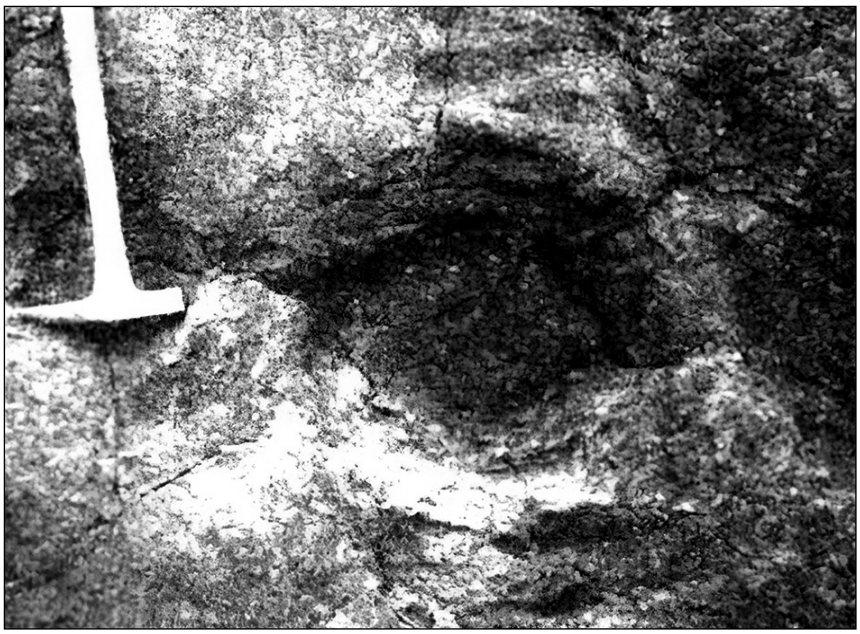

Fig. 15. *Proboscipeda enigmatica* Panin et Avram, 1962 – Red Horizon, Bozului brook

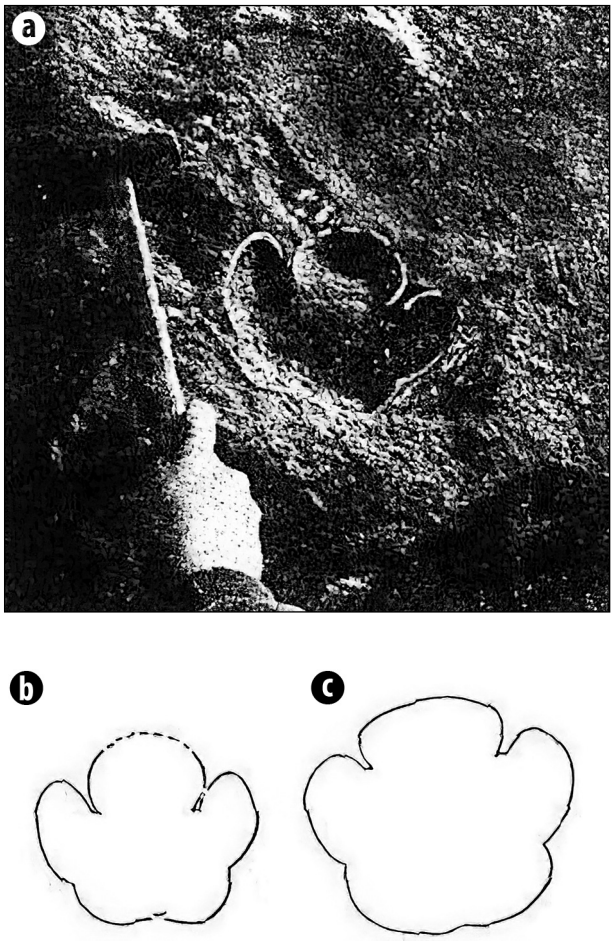

Fig.16. (a) *Rhinoceropeda problematica* Panin et Stefanescu, 1968 – Gray Horizon, Doftana valley; (**b**) *Rhinoceropeda problematica*; (**c**) trace of present-day rhinoceros, anterior right leg (after Gromier, 1936).

The general shape, the ratio between the total length and the total width, the slightly accentuated relief of the trace (which denotes the fact that the animal stepped on a sort of elastic pillow), as well as the dimensions of the middle finger (length Lm = 7 cm, width lm = 9 cm), plead that this fossil trace resemble the traces of current Rhinoceros. Consequently it was called *Rhinoceropeda problematica* (Fig. 16).

Family **CARNIVORIPEDIDAE** Panin 1964
(= **CARNIVORIPEDAE** Vialov, 1961)
Subfamily **Canipedinae** Panin et Avram, 1962
Genus **Canipeda** Panin et Avram, 1962

Canipeda longigriffa Panin et Avram, 1962

Localization: Red Horizon, Vrancea county, Prisaca – Putna, Bozului brook.

Characteristics:

- Total length of the track: 61 mm;
- Maximum width: 32 mm
- Dimensions and shape of traces: four prints of digital cushions, oval, close one to another, around 13 - 14 mm in length, and 8 - 9 mm in width; the length and width of the heel cushion are both 27 mm each; the distance between the heel and the toes 2 and 3 is 8 - 9 mm; four traces of strong, non-retractable claws, 8 - 11 mm in length.

The trace *Canipeda longigriffa* (Fig. 17) resembles the footprint of a present-day fox.

Subfamily **Felipedinae** Panin et Avram, 1962
Genus **Felipeda** Panin et Avram, 1962

Felipeda lynxi Panin et Avram, 1962

Localization: Red Horizon, Vrancea county, Prisaca – Putna, Bozului brook.

Fig. 17. *Canipeda longigriffa* Panin et Avram, 1962

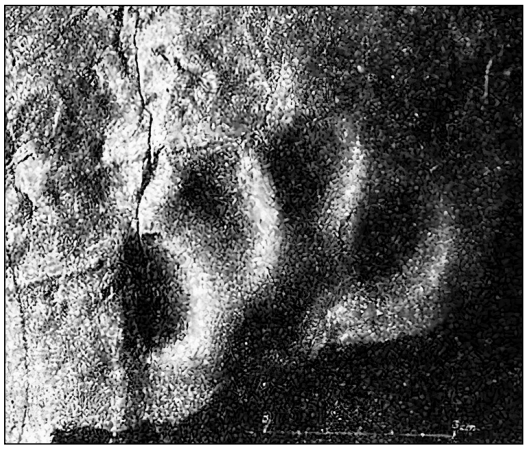

Fig. 18. *Felipeda lynxi* Panin et Avram, 1962

Fig. 19. *Felipeda felis* Panin, 1964

Characteristics (Fig. 18):

- Width: 52 mm
- Length: the trace is not complete
- Oval fingerprints of four digital cushions of 17×12 mm and partially of the heel cushion.
- Fingers 2 and 3 closer to each other and in a more advanced position than the fingers 1 and 4. A distance of 6 mm
- Between the toes 2 and 3 and the heel cushion – 6 mm.
- Between the finger 4 and finger 3 - 4 mm.
- Between the finger 1 and finger 2 – 2 - 3 mm.
- There are no traces of claws, these being retractable.

The *Felipeda lynxi* trace is particularly similar, both in size and shape, to that described by Vialov and Flerov, 1952 in the Dobrotov strata. The closest analogies with the present day animals traces are with those of *Felis chaus* and *Lynx caracal*; therefore they were named *Felipeda lynxi* (Fig. 18).

Felipeda felis Panin, 1964

Localization: Gray Horizon, Piatra Neamt county,Cuejdiu valley.

Characteristics (Fig. 19):

- Total length: L 30 - 31mm;
- Maximum width: I 23 mm;
- Heel length: Lc 11 - 12 mm
- Fingerprint dimensions: 9 - 10 × 5 - 6 mm.
- The distance between two consecutive tracks: 21 - 22 cm.

The *Felipeda felis* track (Fig. 20) is of the "in line" type, in other words the tracks are located exactly in the direction of travel, being as if strung on a straight line.

The trace of the hind leg is almost perfectly superimposed on that of the front leg.

As dimensions *F. felis* looks like the trace of a present-day wild cat *Felis silvestris*. The difference is that the *Felipeda felis* traces are of "in line" type, while those of the wild cat is closer to the type "in zigzag".

Family **ARTIODACTYPEDIDAE** Panin, 1964
(= **ARTIODACTYPEDAE** Vialov, 1961)
Subfamily **Pecoripedinae** Panin et Avram, 1962
Genus **Pecoripeda** Panin et Avram, 1962
(= **Pecorapeda** Vialov, 1961)

Pecoripeda gazella Vialov, 1961

Vialov and Flerov (1952), p.84; Vialov (1963), III / 2, p.310; Panin and Avram (1962), p.462.

Localization: Red Horizon, Vrancea county, Bozului brook; Gray Horizon, Vrancea county, Bozului brook, Râpa Porcului.

Characteristics:

- Maximum length L = 33 - 55 mm
- Maximum width I = 22 - 37 mm
- The front angle $\alpha = 40 - 50^{o}$

Fig. 20. *Felipeda felis* track

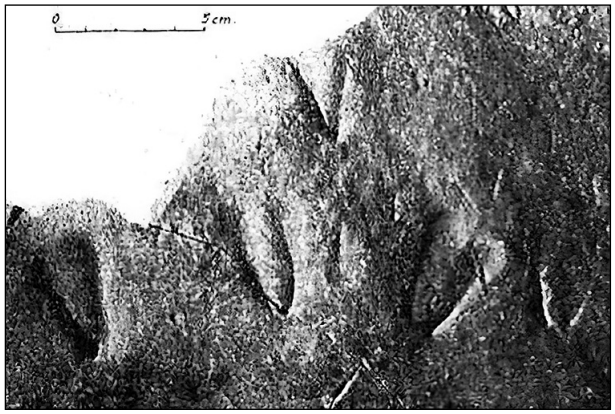

Fig. 21. *Pecoripeda gazella* Vialov, 1961

The maximum width is in the posterior third or quarter of the trace. When the traces are well conserved, they have straight margin and the heel very clearly printed.

Pecoripeda gazella (Fig. 21) is characterized by an anteriorly pointed (acuminate) shape and by the length / width ratio approximately of 1.3-1.6.

Pecoripeda amalphea Vialov, 1961

Vialov and Flerov (1952), p.84; Vialov (1963), III / 2, p.310; Panin et Avram (1962), p. 462.

Localization: Red Horizon, Vrancea county, Bozului brook; Gray Horizon, Vrancea county, Bozului brook, Râpa Porcului; Piatra Neamt county, Cuejdiu valley.

Characteristics (Fig. 22):

- Total length L = 42 - 43 mm
- Total width l = 37 - 40 mm
- The front angle α = 56 - 70^0

Unlike *P. gazella*, *P. amalphea* (Fig. 22) is less pointed (acuminée) anteriorly, the angles are more rounded, the margin of the hooves is less straight and the heel less clear. The length / width ratio is 1.1-1.3.

5. A HYPOTHESIS REGARDING THE ENVIRONMENTAL CONDITIONS DURING THE FORMATION OF MIOCENE MOLASSE DEPOSITS.

A hypothesis regarding the paleo-geographic and environmental conditions during the formation of Miocene molasse deposits of Burdigalian age (Red and Grey Horizons) in the Romanian Carpathians was presented in the 1965 paper "Coexistence of vertebrate footprints and mechano-glyphs in the Molasse Miocene of the Eastern Carpathians". The Miocene time in the Carpathians corresponded to a Climatic Optimum with average temperatures higher than 20^0 C, that explained the red colour of rocks. The hypothesis was based on the very special characteristics of Miocene molasse deposits: they (mainly those of the Piatra Neamț and Vrancea counties) present, at first glance, an aspect of flysch. There is a rhythmic alternation of sandstones and marls/ clays, with graded-bedding. There are in these deposits many textures very widespread in the flysch: cross bedding, all kinds of sole-markings (scour-marks – Fig. 23 and tool-marks – Fig. 24).

However, the main characteristic of these deposits is the presence of typical wave ripple marks (Fig. 25), traces of raindrops (Fig. 26), traces of ice crystals, salt and gypsum crystals and especially traces of animal footprints that coexist with the mechanical traces.

Sometimes these traces are on the same layer of sandstone – wave ripple-marks, animal foot prints, raindrops traces on the upper side of the layer, and scour and tool marks on the lower side of it.

These characteristics, especially the coexistence of vertebrates' traces and ripple-marks with mechanical traces due to strong currents, demonstrate that such deposits cannot be considered as flysch deposits in the general sense. Their flysch-like aspect is, probably, due to the fact that one of the main factors generating this rhythmic succession is represented by currents loaded with clastic material in suspension similar to turbidity currents that are responsible with flysch deposits formation but flowing in very shallow environment - turbid surface currents.

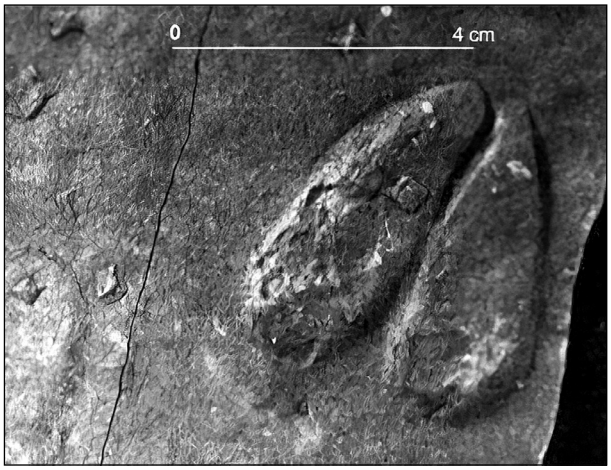

Fig. 22. *Pecoripeda amalphea* Vialov, 1961

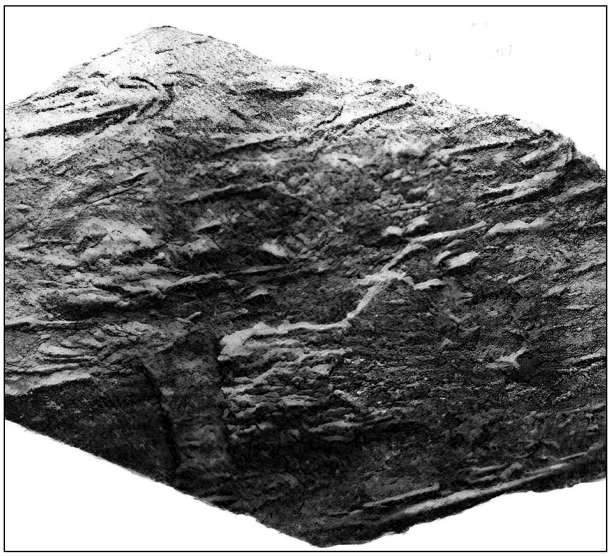

Fig. 24. Tool casts

Fig. 23. Scour casts

Fig. 25. Wave ripple-marks

Close to the flysch-like Miocene molasse deposits there are local intercalations of conglomerates (the Bârseşti conglomerates in the Vrancea County, the Almaşu conglomerates in the Piatra Neamț County) that were a sort of fan-deltas of young hydrographic networks that had a considerable erosive force and were flowing directly into the sea.

The presence of green schist pebbles shows that they come from a land located to the East, probably from the East-European Platform. These conglomeratic fan-deltas pass laterally to the sandstone-marl/clay alternations described above.

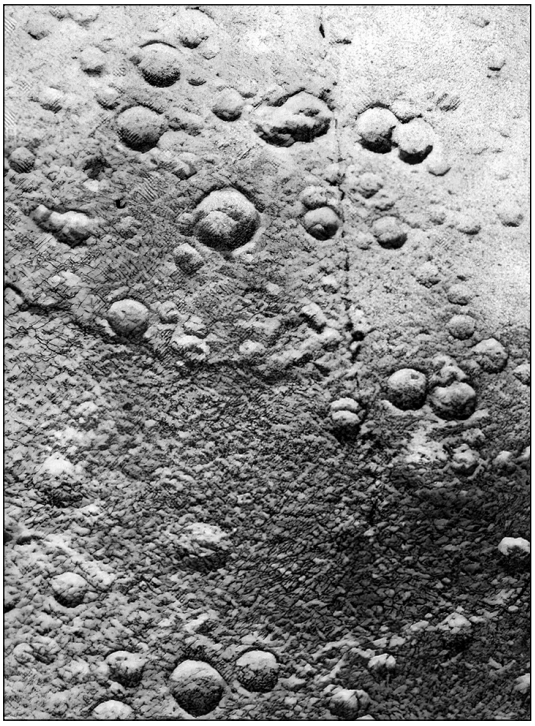

Fig. 26. Traces of raindrops

At the river mouth, the flood currents, "the turbid surface currents" or "turbidity flood currents", spread, probably, on an alluvial-deltaic area, partly exposed, partly covered with very shallow water.During the intervals between floods, the coastal alluvial fields were visited by various animals as the rivers were fresh water sources, traces of raindrops were imprinted and, in the submerged places, wave ripple marks were formed.

The picture presented above represents only a hypothesis which could explain, at least in part, the genesis of the Miocene rhythmic Molasse deposits with flysch aspect and the association of vertebrates' footprints, wave ripple-marks and raindrops with the mechanical traces due to strong currents (scour and tool marks).

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