7

THE STAGES OF PALEOICHNOLOGICAL STUDIES IN ROMANIA

Titus BRUSTUR

National Institute of Geology and Marine Geoecology (GEOECOMAR)
Str. Dimitrie Onciul No. 23-25, Bucharest 70318, P.O.Box 34-51

Abstract: The paper synthetises the Romanian and foreign researchers' contribution made to the paleoichnological studies in Romania. These studies may be divided into the following stages: the stage of "fucoids" (1910-1955), the stage of vertebrate footprints (1960-1970) and the stage of paleoichnological study revival (after 1980). One hundered and seventy-nine invertebrate and vertebrate ichnospecies belonging mostly to the Cretaceous, Paleogene and Miocene have been mentioned for the geological formations in Romania so far. Of this number, more than 100 ichnospecies represent new forms for Romania, most of them referred to after 1980.

Key words: geological history, stages of the paleoichnological studies, Romania.

1. Introduction

Having been considered as curiosities for a long time, sometimes bizarre and having a mysterious origin, the biogene sedimentary structures (BSS) known as "bioglyphs" not long ago, have drawn the extraordinary attention of paleontologists and sedimentologists all over the world in the last 35-40 years. This short but particularly efficient period coincides, in fact, with the development of the paleoichnology as an independent branch of knowledge. The progress made in the study of BSS and the elucidation of their significance has been possible due to the accurate definition of the main concepts, terminology and classification. This effort has been supported by a large number of famous learned geologists such as Richter (1928), Abel (1935) Lessertisseur (1935), Seilacher (1953,1964, 1964,1986), Häntzschel (1962,1975), if we mention only some of them.

Ignored for a long time by paleontologists or considered as "ludus naturae", more and more BSS produced both by invertebrates and vertebrates are nowadays used in biostratigraphy (ichnostratigraphical marks, correlation by means of the index of ichnofossils, paleogeographical and retrotectonical reconstruction), paleontology (proofs of the evolution of the metazoans and of their behaviour especially at the Precambrian/Cambrian boundary), *paleoecology* (biotic and paleoenviron-mental features) and *sedimentology* (indicators of depositional processes).

Attempting to review the contributions of Romanian and foreign researchers to paleoichnological knowledge of different geological formations in our country one can notice that these date back to the last century, the oldest specification of this kind belonging to Capellini who, in 1868, mentioned in the Eocene at Moinești ''macigne con fucoidi e *Paleodictyon*". In the same period, Coquand drew the attention to some "horizon with fucoids" at Târgu Ocna . Records of the information on the animal activity is found in about 100 papers published, showing the following stages in the paleoichnoloical research in Romania: the stage of " fucoids " (1910-1955); the stage of vertebrate footprints (1960-1970); and the stage of paleoichnological study revival (after1980) (Fig.1).

2. Stages of paleoichnological studies

2.1. The stage of "fucoids"

Most researchers who studied the flysch formations in the East Carpathians frequently mention different types of fucoids in the Inoceramian Beds (Macovei & Atanasiu, 1923,1926), some at the level of ichnospecies (*Chondrites intricatus*, *C. expansus*, *C. furcatus* -Ştefănescu, 1927) and *Zoophycos* (=*Taonurus*, = *Caulerpites* - Athanasiu et al 1927, Ştefănescu,1927). Of the same formation, Ştefănescu (1937) mentioned *Spirophyton* and *Cladichnus* (=Muensteria). Later on, Joja (1955) used the fucoids for separating the Senonian from the Outer Flysch in a "lower horizon with fucoids" and an "upper horizon" in which these are not to be found. A "marl level with fucoids" was found at the basis of "Nummulitic of the Sotrile type" by Protescu (1918).

Except for the Senonian deposits, fucoids were mentioned in the Sinaia Formation (Cernea,1952), the Comarnic Formation (Murgeanu, 1934), the Black Shale Formation (Ştefănescu,1937), the Tisaru Formation (Mateescu, 1930) as well as in the Eocene-Oligocene formations (Filipescu,1934; Ştefănescu,1937; Joja, 1952, 1955; Dumitrescu, 1952; Grigoraş, 1955). It is worth mentioning that Mateescu (1927) maintained the certain marine origin of the marls with fucoids, and the "hieroglyphs" in the Eocene are considered as "produced by animals".

Worth mentioning are the contributions made by Protescu (1912) and Mrazec (1927) to explaining some hieroglyphs in the flysch, by comparing them with the present-day traces produced by some insects (*Gryllotalpa*), by gastropoda respectively (i.g. *Pirenella* noticed by Mrazec in 1915 in the mud of the Yemsah lagoon in the Red Sea). The two Romanian researchers may thus be considered as initiators of neoichnological studies in Romania as well as forerunners of "actuopaleontology", a discipline whose basis was laid by Richter in 1929 when he explained the ways of formation and preservation of animal activity traces on the German coast of the North Sea and extrapolated the data obtained by studying the fossil traces in the Devonian Shales of Hunsrück.

Much in the same period, Ilie (1931) reported the first ichnospecies of *Paleodictyon* (*P. tellini, P. minimum* and *P. regulare*) in the Sotrile Facies in the East Carpathian Bend Area and the Neogene of Turda (*P.magnus*), and later on the same author, reviewing the assumptions regarding the formation of this structure, maintained its organic origin considering that this represents batrachian eggs (Ilie, 1937). This explanation was opposed by Joja (1952) who remarked, with good reason, that, if the hexagonal networks should represent frog eggs, then one cannot understand why they are not present in the Pliocene deposits. Paleodictyon had been mentioned

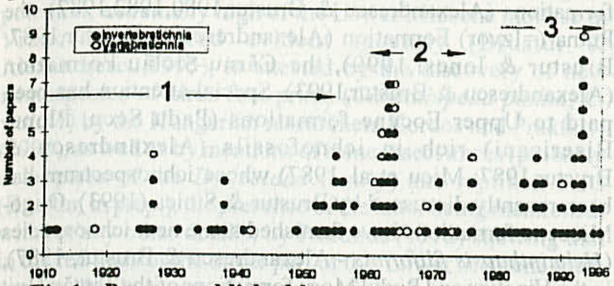

Fig.1 - Papers published between 1910 - 1996, with references to BSS

before in the Eocene by Filipescu (1934), Ştefănescu (1937), Olteanu (1953), Joja (1955) and Ilie & Mamulea (1952) use it for separating this stage in the Haţeg basin. Mention should be made that surprisingly present are the observations referring to this ichnogenus made by Filipescu (1934), who showed that its regular form excludes the hazard, and the hexagonal network represents "a system of burrows belonging to a vermidian species endowed with a very pronounced sense of direction". In Miocene deposits, *Paleodictyon* was found in the Dej Tuff Complex (Török, 1947; Fuchs,1961) and in the Hida Beds in the Transylvanian basin (Fuchs,1956).

The first footprints of birds in the Lower Miocene in Moldavia (Grozescu,1918) and mammals' footprints (*?Dicrocerus*) at Ocniţa (Popescu-Voiteşti,1927) were made known during the period studied, completed later on by Paucă (1942,1952) with numberless traces of *Palmipeda* and *Gruida* in the Vrancea county.

Some other types of BSS are better known for the Lower Paleozoic of the Moldavian Platform ("problematic traces" of the Atachi Sandstone and "worm traces" of the Molodova Sandstone - Văşcăuţanu,1931; "coal-like vermicular hieroglyphs" - Macarovici, 1956), the Permian of the Apuseni Mountains ("worm burrows" - Palfy & Rozlozsnik, 1938), considered as worm dejections by Arabu (1941), the Upper Cretaceous in the Haţeg basin ("worm traces and fucoids" - Laufer,1925), Eocene of the Getic Facies ("numerous traces of worms" and "great traces of Annelida" - Popescu-Voiteşti,1911; cylindrical burrows coming from "the digested and secreted material in the alimentary duct of some limnivorae Annelida" - Dragoş, 1953; *Scolicia* (=*Palaeobullia*) traces - Murgeanu,1941) and borings of *Teredo norvegica* in the Oligocene south of the Rodna Mountains (Kräutner,1938), the Borsa Sandstone in the Bârgăului Mountains (Semaka,1955) and the Miocene in Banat (Florei,1961).

Borings, considered by Cantuniari (1935) as being produced by *Teredo* in the fossil wood, are found in the Upper Cretaceous on the bank of the Prut River in Bessarabia. From the Cenomanian glauconitic deposits in Rădăuţi-Prut, the same type was mentioned later by Bâgu & Mocanu (1984). Borings in the wooden substratum are also those produced by *Martesia* revealed for the first time in Romania by Suraru & Suraru (1959) in the Almaşului Valley Beds. Later on, this bivalve was mentioned in the Dej Tuff (Meszaros & Clichici,1976) and also on the Corus Beds (Givulescu,1981). One should mention that the BSS resulting from the activity carried out by Martesia is assigned to the *Teredolites clavatus ichnospecies* characterising the marine *Teredolites* ichnofacies with *Teredolites* characteristic of the wooden substratum (Bromley et al., 1984).

Remaining in the same field of traces produced by perforating animals, it is worth mentioning the contribution made by Niţulescu (1936) to explain the bioerrosion of the calcareous substratum of the Stramberg Limestone type by the pholadidae and echinoderms during the Badenian, when this made up a submarine seamount situated near the water surface in the Petreşti area (Turda).

2 .2. The stage of vertebrates footprints

This stage generally corresponds to the concerns for sedimentology started in 1958 under the management and guidance of Academician G. Murgeanu. The first paleoichnological observations on the turbiditae in the Sotrile Facias (Contescu et al., 1963) were made on this occasion, and especially in the Lower Miocene molasse in the Subcarpathians, when numerous ichnospecies of birds footprints were described (Panin,1961,1965; Panin & Avram,1962; Panin et al.,1966; Grujinschi,1969; Ioniţă, 1964; Panin & Ştefănescu, 1968). As for birds and mammals footprints, some of which new for Romania (*Pecoripeda amalphaea*, *P. gazella*) and most of which new for science (*Ardeipeda egretta*, *A. gigantea*, *A. incerta*, *Gruipeda intermedia*, *G. grus*, *G. maxima*, *Anatipeda anas*, *Charadriipeda recurvirastra*, *C. minima*, *C. disjuncta*, *C. minor*, *C. becassi*, *Rhinoceropeda problematica*, *Proboscipeda enigmatica*, *Canipeda longigriffa*, *Felipeda lynxi*, *F. felis*, *F. minor*) we should mention the concern for imposing a new specific research methodology and for using a proper ichnotaxonomical terminology (Panin & Avram,1962; Panin,1965).

Paleoichnological observations on the Cretaceous and Paleogene Flysch were made on some other occasions too, when ichnogenus and even ichnospecies were mentioned in different formations (Săndulescu et al.,1962; Alexandrescu & Soigan,1963; Dimian & Dimian,1964). In that period, Pauliuc (1962) applied the terminology and the classification of superficial structures, devised by Vassoevici, on the Paleogene sandstone in the Buzău Valley basin. The petrogenetic role of the excrements of the crustacean decapoda was discussed by Patrulius (1964), when talking about the microcoprolite (*Favreina salevensis*) in the Neocomian limestones met at the borehole at Atârnaţi. Later on, one could notice (Drăgănescu, 1976) the wide spread of such limestones in the intertidal flats of the Lower Cretaceous in the Wallachian area of the Moesic Platform. Microcoprolite as *Favreina* and boring traces produced by lithofagous Mollusca were mentioned by Dragastan (1975), too, in the Bicaz Valley area, the Haghimaş Mountains.

In some other geological formations and areas, one mentioned *Paleodictyon* and "organic impressions of bilobated type" (which rather seem to belong to the *Nereites* ichnogenus) in the Silurian in Northern Dobrogea (Mutihac,1964), and on the basis of the *Arthrophycus alleghanensis* ichnospecies, Răileanu & Năstăseanu (1963) assigned the Silurian age to the argillaceous shales below the Ideg Limestone in Banat. In the Crystalline - Mesozoic Zone of the East Carpathians were frequently mentioned in the Triassic Werfen Beds in the Bucegi Mountains (Patrulius, 1969) and the Rarău Mountains (Turculeț,1971) as well as *Zoophycos* in the Anisian dolomites in the Haghimaș Mountains (Baltres,1976). The borings produced by lithofagous organisms on the indurate surface of Tithonian limestones in the Dâmbovicioara Pass mentioned by Patrulius (1963) are interesting and terribly resembling the galleries of the *Ophiomorpha bornensis* in the Miocene of the Borneo Island, a form indicating the coastal area.

The large fucoids were mentioned in the Cretaceous Flysch and the small ones in the Convolute Flysch and the Black Shale Formation (Ionesi,1962) and in the Transcarpathic Eocene (Petrova Beds), the same author fucoids mentioned a great size (Ionesi,1959).

In the Apuseni Mountains, the Upper Cretaceous deposits, in the Bozeș Beds, have a large number of *Paleodictyon*, *Helminthoida crassa*, *Spirophyton* and *Scolicia* (= *Palaeobullia*) traces mentioned by Antonescu et al. (1963), Dimian & Dimian (1963) and Mantea et al. (1971). In the Senonian deposits in Maramureș *Spirophyton* was mentioned in the Puchov Marl at Poiana Botizei (Bombiță,1972), ichnogenus which had been met before at Săcel, beside *Zoophycos* (Patrulius et al.,1955). Tubes of worms are also to be found in the Badenian in the Șimleu basin (Nicorici,1972). Macarovici (1969) made some observations on some lithofagous fossil bivalve and it is present in the East-European Miocene and the Black Sea. Bărbulescu (1974) mentioned borings of the *Clione* spongiae on belemnits rostrum in the Topalu area. Finally, worth mentioning are imprints and footprints left by the cave bear (*Ursus spelaeus*) on the walls and floor of some caves in the Apuseni Mountains, sometimes very numerous, as those in the Ciur-Izbuc Cave (Viehmann,1973) and footprints of the primitive man in the same cave represented by about 400 imprints (Rusu et al.,1969 ; Viehmann et al.,1970), more than 200 of which were studied from an anthropological point of view by Riscuția & Riscuția (1970). The determination of the age by radiometrical methods, carried out on a hominid footprint studied by Viehmann from the Ghețarul de la Vârtop Cave, indicates 22,400 years (Lauritzen & Onac,1995). Unfortunately, the human footprint impression left in the cave disappeared together with a part of the floor as a result of an act of vandalism (the "Flagrant" (a newspaper), no. 40/ 2-8, October 1995).

2.3. The stage of the paleoichcological study revival

The resumption of paleoichnological studies in Romania may be considered, on the one hand, as an answer to the need of continuing an activity already begun and resulting in important results and, on the other hand, as joining the common efforts of many foreign researchers, nowadays, practically not being any sedimentologic study or of a basin analysis which should not contain references to BSS associations as indicating the environmental deposition.

The paleoichnological study of the East Capathians Flysch which started about the '80s resulted in continuing the BSS inventory in such different geological formations as: the Bistra Formation (Dinu,1985), the Siriu Sandstone in which exceptional specimens of *Zoophycos* appear (Alexandrescu & Crăciun,1984), the Hangu and Horgazu formations (Alexandrescu & Brustur,1980,1982,1987), the Putna (=Izvor) Formation (Alexandrescu & Brustur,1987; Brustur & Ionesi,1990), the Cârnu-Șiclău Formation (Alexandrescu & Brustur,1993). Special attention has been paid to Upper Eocene formations (Padu Secu, Plopu, Bisericani) rich in ichnofossils (Alexandrescu & Brustur,1987; Micu et al.,1987) whose ichnospectrum has been recently discussed by Brustur & Stoica (1993). Oligo-Miocene formations have furnished some new ichnospecies (*Helminthopsis filiformis* - Alexandrescu & Brustur, 1987), in the Vinetisu and Podul Morii formations of the Tarcău Unit in Bucovina and from the East Carpathian Bend Area, rendering the paleoichnocenosis with Sabularia (Alexandrescu & Brustur, 1984; Alexandrescu, 1986) with a special paleoecological significance and being characterised as an excelent ichnostratigraphical marker (Alexandrescu et al.,1993). This paleoichnocenosis has recently also been noticed in the side in Vrancea to the dominant association of Sabularia and Mammillichnis (Brustur,1996). In the Tarcău Sandstone Formation one could identify, within the Giurgiu-Ghelința Beds in the Trotuș Valley (Alexandrescu & Brustur, 1990) and then in the Buzău Valley (Brustur,1995), paleoichnocenosis with *Subphyllochorda*, dominated by BSS produced by spatangoida echinoids (*Subphyllochorda*, *Cardioichnus*, *Taphrhelminthopsis*, see Plate). Within the same formation on the Buzău Valley at the Siriu dam one could identify a layer keeping a lot of traces of *Taphrhelminthopsis* which were studied from an ichnotaxonomical point of view (Brustur & Alexandrescu,1992) and an interesting association, if not unique, made up of graphoglyptides (*Paleodictyon*, *Cosmorhaphe*) and an extremelly well preserved impression of *Asteriacites stelliforme*, a new ichnofossil for the Paleogene Flysch in Romania (Brustur,1992).

The study of the Sotrile Facies in the Dâmbovița Valley revealed a new biodeformating structure produced by sea urchins (*Spatangoidichnus reinecki* - Brustur,1993), of the ichnogenus *Ophiomorpha* and *Teichichnus* (Brustur,1995), and from the Ialomița valley one could describe the "huge" ichnospecies *Paleodictyon gomezi*, known in the Eocene in Spain (Brustur,1995).

An important discovery is represented by noting a real population of the *Rhizocorallium* ichnogenus (see Plate) in the Kliwa Sandstone in Vrancea, significant for the shalow water conditions in which these deposits accumulated (Brustur et al.,1995). The good preservation state, the accessibility and the scarcity of this occurrence motivated the proposal to protect them by law (Brustur & Alexandrescu, 1993), especially the one within the Carpathian area. This ichnogenus was known only in Poland as isolated specimens in some places in the Măgura Unit (Ksiazkiewicz, 1977; Uchman,1992).

The research of the Lower Miocene mollase formations in Vrancea led to the identification of some new traces of isopoda (*Oniscoidichnus miocenicus* - Alexandrescu et al., 1986) and amphipoda (*Talitrichnus panini* - Brustur & Alexandrescu, 1993), also requiring the need for protecting the paleoichnologic heritage of this region (Brustur,1992) within the paleontological protected Prisaca-Bozului Brook area (Brustur & Alexandrescu,1991). The paleoichnological potential, extremelly high of the Lower Miocene mollase in Vrancea, rendered evident recently (Brustur & Alexandrescu,1993), is attested by the discovery of new ichnospecies of birds foot-prints (*Carpathipeda panini*, *C. vialovi*) by the Hungarian researchers Kordos and Prakfalvi (1990), as well as by mentions of some insect traces (probably coleoptera of the *Dytiscidae* family) and reptilian ones (Brustur, in prep.), the presence of the latter being mentioned, without any other details, by Patrulius (1976) showing that in the red beds of the upper part of the Lower Miocene there appear "birds traces, footprints of antelope, deer, horses, mastodonts and even crocodiles".

Except for the East Carpathians, cylindrical burrows were found and they proved to be BSS according to the SEM analytical method as well as traces of a jellyfish type (*Nemiana simplex*) which represent elements of the Ediacara fauna in the series of Green Schist in the Central Dobrogea (Oaie,1992), the same author describing a deep water association too (*Helminthoida*, *Nereites*, *Protopaleodictyon*, *Helminthopsis*, *Chondrites*) in the Bestepe Formation, mentioning the presence of *Planolites* in the Carapelit Formation (Oaie,1989). Burrows of *Thalassinoides* and *Ophiomorpha* (Brustur, in prep.) have also been noticed in Dobrogea in the Cenomanian in the Babadag basin, south of the village of Cerna. Two ichnospecies of *Planolites* (*P. beverleyensis* and *P. montanus*) of the Permian have been described, "Vermicular Sandstone Formation" in the Arieş Valley in the Apuseni Mountains (Brustur,1986). The same type has been distinguished in the Permian of the western part of the Codru Mountains (Istocescu,1971). Not long ago, Bordea & Bordea (1993), due to the presence of Planolites and to the characteristic lithology, arqued the presence of the "Vermicular" Sandstone Formation in the central part of the Highiş Mountains. The same ichnogenus, but as glauconitised burrows, was mentioned by Catană et al. (1992-1993) in the Lower Miocene deposits in the Argeş Valley.

Rădan & Brustur (1993) have recently for the first time described birds footprints (*Charadriipeda limosa* n.isp.) in the Upper Oligocene of the Dâlga-Uricani Formation in the Petroşani basin, where Culda (1984) mentioned borings of *Cliona* and *Polydora* on *Ostrea* shells in the Sălătruc Formation (Badenian). Grigorescu et al. (1983) mentioned vertical cyllindrical tunnels filled with sand, assigned to the detritus feeding worm activity in the Haţeg basin, in the upper part of the fluvio-lacustrine cyclotheme of the Sânpetru Beds with dinosaurian remains. Similar structures, but with calcitic filling were noticed in the Rona Limestone of the stratotype by Bombiţă & Baltres (1986). Ştefănescu et al. (1986) recognised frequent traces of *Scolicia* (=*Palaeobullia*) as well as *Laminites* (Brustur, in prep.) in the Eocene deposits of the Titeşti-Brezoi basin.

Special attention should be paid to paleopathological elements in the Upper Miocene (=Bosphorian, Dacic sense) fossil leaves of Chiuzbaia, described by Givulescu (1984). These are represented by sores due to crysomelidae, coleopters and the gastropodes and galleries (mines) produced by hymenopteres, lepidopteres and dipteres.

3. Final remarks

For Romanian geological formations, 179 ichnospecies of invertebrates and vertebrates belonging mostly to the Cretaceous, Paleogene and Miocene have been identified so far.

Together with the ichnofauna of Chiuzbaia represented by 15 ichnospecies and without the 8 ichnospecies present in same other geological formations of different ages, 171 ichnospecies remain, of which 142 invertebrates and 29 vertebrates forming the ichnospectrum of the leaf material in the Upper Miocene of Maramureş and the Outer Moldavides in the East Carpathians. Of this number over 100 ichnospecies represent new forms for Romania, most of them indicated after 1980, 13 of them being new for science (Table 1). 44 ichnospecies are described, of which 40 vertebrates and 4 invertebrates of the red and grey deposits of the Lower Miocene mollase in the Ukrainian and Romanian Subcarpathians. Worth mentioning is the fact that, of the vertebrates footprints, 26 ichnospecies come from the Romanian area, 20 of them being new for science (Table 2).

This points out the high paleoichnological potential of the Lower Miocene molasse as well as the interest paid to the study of it by Romanian geologists.

As to the ichnofauna of the Outer Flysch and of the Lower Miocene mollase in the East Carpathians, this has been recently synthesised in a doctor's degree thesis, when 108 ichnospecies and 4 ichnogenus were described and the significance of the ichnospectrum of the same formations of the Cretaceous-Lower Miocene interval was discussed (Brustur,1995).

Being entirely local, ichnofossils are closely connected to the change of environmental conditions, the reccurence of the ichnofacies showing the recurrence of biofacies in a given formation. The change of the BSS distribution with the depth increase and with the coast distance was considered a dogma of paleoichnology materialised in the famous Seilacher's bathymetric model (1964,1967). Nowadays the link between ichnofacies and bathymetry is considered as a *passive* connection (Frey et al., 1990), more and more researchers considering that environment local factors are the ones controlling the distribution of the ones producing traces. Recent investigations on the present-day sea and ocean bottoms show that the shapes of the trace and the ichnofacies do not depend on the depth, the morphology of the trace depending ultimetely on the biological interrelation between the ravaging one and the one being ravaged, independent of the food availability.

In the long term, one expects that the paleoichnology should make its contribution to stating the facial diversity of depositional systems, especially of the deltaic ones, lacustrian and fluvial ones which could enrich the content of *Scoyenia* ichnofacies (Bromley & Asgaard, 1979). The division into zones of this nonmarine ichnofacies, situated at the interference between land and sea, has recently shown the participation of the characteristic trace fossil association of the terrestrial sediments (*Termitichnus ichnofacies*), of the transition area between the land field and the nonmarine aquatic one (*Scoyenia* ichnofacies) and of nonmarine aquatic deposits (*Mermia* ichnofacies), the arthropoda tracks being dominant (Buatois & Mangano, 1995).

From this point of view, placing the vertebrate and invertebrate traces from Vrancea in the *Scoyenia* ichnofacies (Brustur & Alexandrescu, 1993) opens the way of continuing and deeply studying the systematic paleoichnology in the Red and Grey Formations which will certainly offer a spectacular ichnofaunal material.

References

Alexandrescu Gr. , Brustur T., 1987 - Structures sédimentaires biogènes (trace fossils) du flysch des Carpates Orientales (III-ème partie). D.S.Inst.geol.geofiz., 72-73/3, 5-20.

Alexandrescu Gr., Brustur T.,1990 - Paleoichnocenoza cu Subphyllochorda din formaţiunea gresiei de Tarcău din Valea Trotuşului (Carpaţii Orientali). D.S.Inst.geol. geofiz., 74, 5-26.

Alexandrescu Gr., Crăciun P.,1984 - Zoophycos brianteus din gresia de Siriu de la Covasna (Carpaţii Orientali). D.S.Inst.geol.geofiz., LXVIII/3, 5-15.

Bromley R.G., Pemberton S.G., Rahmani R.A.,1984 - A Cretaceous woodground: the Teredolites ichnofacies. J.of Palaeontology, 58/2, 488-498.

Brustur T.,1995 - Studiul paleoichnologic al formaţiunilor cretacic-miocene din Moldavidele externe. Ph.D. thesis (unpubl.), 286 p., Univ.Bucureşti.

Brustur T., Alexandrescu Gr.,1993 - Paleoichnological potential of the Lower Miocene molasse of Vrancea (East Carpathians). Rev. Roum. Géologie, 37, 77-94.

Brustur T., Ionesi L.,1990 - L'ichnofaune des formations de Plopu et de Izvor (le flysch paléogène - Carpates Orientales). Anal.st. Univ."Al.I.Cuza", XXXVI, 37-41.

Brustur T., Stoica M.,1993 - Asupra unor structuri sedimentare biogene din Formaţiunea de Plopu de la Grozeşti (Carpaţii Orientali). Stud. cerc.geol., 38, 57-70.

Filipescu M.G.,1934 - Cercetări geologice între valea Teleajenului şi valea Doftanei (jud. Prahova). 167p., Tipografia Curţii Regale, Bucureşti.

Givulescu R.,1984 - Pathological elements on fossil leaves of Chiuzbaia (galls, mines and insect traces). D.S.Inst.geol.geofiz., LXVIII/3, 123-133.

Grozescu H.,1918 - Géologie de la région sub-Carpatique de la partie septentrionale du district de Bacău. Ann.Inst.Géol.Roum., VIII, 46 p.

Ilie M.,1937 - Note sur l'origine du genre Palaeodictyon (Batracoides nidificans). C.R.Inst.Géol.Roum., XXI, 62-64.

Joja Th.,1955 - Structura geologică a flişului dintre Cracăul Alb şi Cracăul Negru. D.S.Com.Geol., XXXIX, 178-192.

Macarovici N.,1969 - Observations sur la présence de certains lamellibranches lithophages fossiles du miocène dans le sud-est de l'Europe et dans la Mer Noire. Am. Zoologist, 9, 721-724.

Mrazec L.,1927 - Les traces de reptation dans les vases des lagunes de la Mer Rouge. D.S.Inst. Géol.Roum., VI, 77-81.

Panin N.,1965 - Coexistenţa urmelor de paşi de vertebrate şi cu mecanoglife în molasa miocenă din Carpaţii Orientali. Rev.Roum.géol., géophys.,géogr., géologie, 9/2, 141-163.

Panin N., Avram E. ,1962 - Noi urme de vertebrate în miocenul sub-Carpaţilor româneşti. Stud.cerc.geol., VII/3-4, 455-484.

Paucă M.,1942 - Empreintes de pas de Palmipèdes dans l'Helvetien carpathique du dép. de Putna. Bul.Soc.Geol.Rom., V, 85-87.

Pauliuc S.,1962 - Contribuţii la studiul texturilor superficiale ale gresiilor paleogene din zona externă a flişului Carpaţilor Orientali. D.S.Com.Geol., XLVI, 305-316.

Popescu-Voiteşti I.,1927 - Contributions à la connaissance des Artiodactyles en Roumanie. Rev.Muz.Geol.Min.Univ.Cluj, 2/1, 27.

Protescu O.,1912 - Communication sur l'origine de certains grès à hiérogliphes. D.S.Inst.Geol.Rom., III, 76-82.

Rădan S., Brustur T. ,1993 - Urme de paşi de păsări în Oligocenul superior din bazinul Petroşani (Carpaţii Meridionali). Stud.cerc.geol., 38, 71-80.

Răileanu Gr., Năstăseanu S.,1963 - Asupra prezenţei formei Arthrophycus alleghanensis (Harlan) în Carpaţii Meridionali. Com.Acad.RPR, XIII/5, 439-443.

Table 1. Inveretebrate ichnofauna (invertebratichnia) in the Sotrile Facies, Outer Moldavide (East Carpathians) and Chiuzbaia (Maramures)

No.	Ichnospecies	CRETACEOUS			PALEOGENE			NEOGENE	
		Ne-Ap	V-Tu	Sn	Pc	E	O	M_1	M_2
1	*Acanthorhaphe cf. incerta*					+			
2	*Agrichnium incompositum*					+			
3	*Agrichnium isp.*					+			
4	*Ancorichnus horizontalis*					+			
5	*Arthrophycus cf. strictus*					+			
6	*Asteriacites stelliforme*					+			
7	*Asterichnus isp.*					+			
8	*Belorhaphe isp.*					+			
9	*Belorhaphe zickzack*					+			
10	*Bergaueria isp.*					+			
11	*Caloptilia roscipenella HB fossilis*								+
12	*Capodistria moldavica**					+			
13	*Cardioichnus ovalis*					+			
14	*Cardioichnus cf. planus*					+			
15	*Chondrites aequalis*					+			
16	*Chondrites affinis*	+	+						
17	*Chondrites arbuscula*		+			+			
18	*Chondrites expansus*		+	+					
19	*Chondrites filiformis*		+						
20	*Chondrites furcatus*		+	+		+			
21	*Chondrites granulatus*		+						
22	*Chondrites hoessii*			+					
23	*Chondrites intricatus*		+	+					
24	*Chondrites isp.1*		+						
25	*Chondrites isp.2*		+						
26	*Chondrites isp.3*	+							
27	*Circulichnis montanus*					+			
28	*Cladichnus fischeri*			+					
29	*Cladichnus isp.*			+					
30	*Cosmorhaphe cf. gracilis*					+			
31	*Cosmorhaphe sinuosa*			+		+			
32	*Cosmorhaphe helminthopsidea*					+			
33	*Cosmorhaphe isp.*					+			
34	*Cuniculonomus parallelus**								+
35	*Curvolithus isp.*					+			
36	*Cylindrichnus concentricus*							+	
37	*Cylindrichnus isp.*					+			
38	*Desmograpton cf. fuchsi*				+				
39	*Desmograpton geometricum*					+			
40	*Desmograpton isp.*			+					
41	*Fenusa ulmii SD fossilis*								+
42	*Fenusites betulacerum*								+
43	*Fenusites caryae**								+
44	*Fenusites fagi*								+
45	*Fenusites zelkovae*								+
46	*Glockerichnus aff. sparsicostata*					+			
47	*Glockerichnus aff. disordinata*					+			
48	*Granularia isp.*					+			
49	*Halymenidium oraviense*					+			
50	*Helicolithus sampelayoi*					+			
51	*Helminthopsis abeli*			+					
52	*Helminthopsis filiformis**						+		
53	*Helminthopsis aff. hieroglyphica*	+							
54	*Helminthopsis hieroglyphica*					+			
55	*Helminthopsis isp.1*						+		
56	*Helminthopsis isp. 2*						+		

No.	Ichnospecies	CRETACEOUS			PALEOGENE			NEOGENE	
		Ne-Ap	V-Tu	Sn	Pc	E	O	M1	M2
1	*Helminthopsis isp. 3*						+		
2	*Helminthoidea crassa*		+			+			
3	*Helminthoidea aff. crassa*			+					
4	*Helminthoidea cf. crassa*					+			
5	*Helminthoidea labyrinthica*		+	+					
6	*Isopodichnus isp.*					+			
7	*Laevicyclus isp.*					+			
8	*Laminites kaitiensis*					+			
9	*Lorenzinia isp.*								
10	*Mammillichnis aggeris*						+		
11	*Mammillichnis isp.*		+				+		
12	*Megagrapton irregulare*					+			
13	*Oniscoidichnus miocenicus**							+	
14	*Ophiomorpha cf. nodosa*					+			
15	*Ophiomorpha isp.*					+			
16	*Palaeophycus isp.*		+						
17	*Palaeophycus striatus*					+			
18	*Palaeophycus sulcatus*					+			
19	*Palaeophycus tubularis*		+						
20	*Paleodictyon carpathicum*					+			
21	*Paleodictyon gomezi*					+			
22	*Paleodictyon minimum*			+					
23	*Paleodictyon miocenicum*					+			
24	*P. miocenicum f.pleurodictyonoides*					+			
25	*Paleodictyon regulare*					+			
26	*Paleodictyon tellini*					+			
27	*Paleodictyon isp.*					+			
28	*Paleomeandron elegans*					+			
29	*Pelecypodichnus isp.*					+			
30	*Phagophytichnus circumsecans*								+
31	*Phagophytichnus gastropodinus**								+
32	*Phagophytichnus isp.1*								+
33	*Phagophytichnus isp. 2*								+
34	*Phagophytichnus marginis-folii*								+
35	*Phagophytichnus nervillos-reliquens*								+
36	*Phagophytichnus uvaeformis**								+
37	*Phycodes dentatus**					+			
38	*Phytomyzites querci**								+
39	*Planolites annularis*					+			
40	*Planolites beverleyensis*					+			
41	*Planolites isp.*		+			+	+		
42	*Planolites montanus*					+			
43	*Profenusa pigmaea KL fossilis*								+
44	*Protopaleodictyon incompositum*					+			
45	*Psammichnites cf. gigas*					+			
46	*Pseudogyrochorte burtani*					+			
47	*Pseudogyrochorte imbricata*					+			
48	*Rhabdochondrites hamatus**		+						
49	*Rhizocorallium cf. irregulare*						+		
50	*Rhizocorallium isp.*	+							
51	*Sabularia isp.*						+		
52	*Sabularia tenuis*						+		
53	*Scalarituba isp.*					+			
54	*Scolicia isp.*			+		+			
55	*Scolicia plana*					+			
56	*Spatangoidichnus reinecki**					+			
57	*Spirophyton isp.*			+		+			
58	*Spirophycus bicornis*	+				+			
59	*Spirorhaphe involuta*					+			
60	*Spirorhaphe isp.*					+			

No.	Ichnospecies	CRETACEOUS			PALEOGENE			NEOGENE	
		Ne-Ap	V-Tu	Sn	Pc	E	O	M_1	M_2
1	*Sublorenzinia cf. nowaki*			+		+			
2	*Sublorenzinia plana*					+			
3	*Subphyllochorda granulata*					+			
4	*Subphyllochorda striata*					+			
5	*Subphyllochorda cf. laevis*		+						
6	*Subphyllochorda isp.*			+					
7	*Strobilorhaphe cf. clavata*					+			
8	*Sustergichnus lenadumbratus*					+			
9	*Taenidium isp.*			+					
10	*Taenidium cf. satanassi*		+						
11	*"Muensteria" planicostata*			+	+	+			
12	*Talitrichnus panini**							+	
13	*Taphrhelminthopsis auricularis f."auricularis"*					+			
14	*T. auricularis f."convoluta"*			+		+			
15	*T. auricularis f."maeandriformis"*					+			
16	*T. auricularis f."plana"*					+			
17	*T. auricularis f."spiralis"*					+			
18	*Taphrhelminthopsis isp.*					+	+		
19	*Teichichnus isp.*					+			
20	*Thalassinoides isp.*					+			
21	*Tuberculichnus bulbosus*					+			
22	*Tuberculichnus punctiformis**					+			
23	*Urohelminthoida isp.*					+			
24	*Zapfella isp.*							+	
25	*Zoophycos brianteus*			+	+	+			
26	*Zoophycos isp.*		+			+			

Abreviations: Ne-Ap = Neocomian-Aptian; V-Tu = Vraconian-Turonian; Sn = Senonian; Pc = Paleocene; E = Eocene; O = Oligocene; M_1 = Lower Miocene; M_2 = Upper Miocene.
*** New ichnospecies for science.**

Table 2. Lower Miocene vertebrate ichnofauna (vertebratichnia) in the Subcarpathians

No.	Ichnospecies	Ukraine	Romania: Piatra Neamt	Romania: Tazlău	Romania: Vrancea	Romania: Teleajen	Romania: Doftana	Romania: Ocnita
1	*Aves indet.*			+				
2	*Anatipeda isp.*		+		+			
3	*Anatipeda anas**				+			
4	*Ardeipeda egretta**				+			
5	*Ardeipeda gigantea**				+			
6	*Ardeipeda incerta**				+			
7	*Avipedia filiportatis*	+						
8	*Avipedia phoenix*	+						
9	*Avipedia sirin*	+						
10	*Charadriipeda becassi**		+		+			
11	*Charadriipeda disjuncta**		+		+			
12	*Charadriipeda minima**		+		+			
13	*Charadriipeda minor**		+		+			
14	*Carpathipeda panini**				+			
15	*Charadriipeda recurvirostra**		+		+			
16	*Carpathipeda vialovi**				+			
17	*Gruipeda grus**					+		
18	*Gruipeda intermedia**		+					
19	*Gruipeda maxima**				+			
20	*Larus*				+			
21	*? Motacilla*				+			
22	*Sterna*				+			
23	*Bestiopeda bestia*	+						
24	*Bestiopeda gracilis*	+						
25	*Bestipoeda sanguiolenta*	+						
26	*Canipeda longigriffa**				+			
27	*? Dicrocerus*							+
28	*Felipeda felis**		+					
29	*Felipeda lynxi**				+			
30	*Felipeda minor**					+		
31	*Hippipeda indet. (?Hipparion)*				+			
32	*Hippipeda aurelianis*	+						
33	*Pecoripeda amalphaea*	+	+		+	+		
34	*Pecoripeda diaboli*	+						
35	*Pecoripeda djali*	+						
36	*Pecoripeda gazella*	+	+		+			
37	*Pecoripeda isp.*	+						
38	*Pecoripeda satyri*	+						
39	*Proboscipeda enigmatica**				+			
40	*Rhinoceropeda problematica**						+	

* New ichnospecies for Romania and science