UNIUNEA EUROPEANĂ
GUVERNUL ROMÂNIEI MINISTERUL MUNCII, FAMILIEI ŞI PROTECŢIEI SOCIALE AMPOSDRU
Fondul Social European POSDRU 2007-2013
Instrumente Structurale 2007-2013
OIPOSDRU
MINISTERUL EDUCAŢIEI CERCETĂRII TINERETULUI ŞI SPORTULUI
UNIVERSITATEA BABEŞ-BOLYAI CLUJ-NAPOCA

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UPPER CRETACEOUS CONTINENTAL VERTEBRATE ASSEMBLAGES FROM METALIFERI SEDIMENTARY AREA: SYSTEMATICS, PALEOECOLOGY AND PALEOBIOGEOGRAPHY

PhD THESIS

- ABSTRACT -

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2012

CLUJ-NAPOCA

SUMMARY

Keywords: Upper Cretaceous, Maastrichtian, Metaliferi area, macrovertebrates, microvertebrates, taphonomy, paleoecology, paleobiogeography.

Chapter 1 - Introduction

In Romania, the Upper Cretaceous continental formations containing vertebrate-bearing deposits are found within intra-Carpathian area, the most notably occurences being in Haţeg Basin and the Metaliferi area.

During last decades, geologists and paleontologists have investigated and monitored systematically Upper Cretaceous continental formations of Romania, pointing out a remarkable diversity of vertebrate fossils (e.g. Codrea et al., 2002a, 2009, 2010a,b,c; Codrea & Jipa, 2011; Grigorescu & Csiki, 2002; Smith et al., 2002; Therrien, 2005; Venczel & Csiki, 2003; Codrea & Godefroit, 2008; Godefroit et al., 2009; Vasile, 2008; Vremir, 2010; Martin et al, 2010; Wang et al., 2011a,b), attention was directed almost entirely to different localities from Haţeg Basin.

Recent research performed in Someş-Odorhei area (Sălaj county) enriched the fossil inventory with well preserved ornithopods remains (Codrea & Godefroit, 2008). Studies in other areas where Cretaceous deposits occur leaded to the first discovery of vertebrate fossils in Rusca Montana Basin (Codrea et al., 2009; Feigi et al., 2010; Vasile et al., 2011) thus extending the area of "Haţeg Island".

At the same time, the research made by a team from the University Babeş-Bolyai University (UBB), Faculty of Biology-Geology, revealed the outstanding potential for paleontological, sedimentological, stratigraphic and paleoenvironmental results of the sedimentary deposits exposed in the Metaliferi sedimentary area (Codrea et al., 2010a,b,c). A microvertebrates-bearing accumulation discovered at Oarda de Jos (Codrea et al., 2010a,b,c; Jipa et al., 2010) shows a remarkable diversity, enriching the taxa range. The paleontological inventory includes now fossil groups such as: dinosaurs, crocodilians, turtles, amphibians, lizards, small mammals, but also invertebrates or palinomorfs (Codrea et al., 2001a, 2002a, 2008, 2010a,b,c; Delphino et al., 2008; Jipa et al., 2010).

Detailed study of Cretaceous vertebrates assemblages from Alba-Iulia-Sebeş-Vurpăr area represents the topic of this Ph.D thesis. This thesis was realised with financial support provided from the programs cofinanced by The Sectorial Operational Program Human Resources Development, Contract POSDRU 6/1.5/S/3 -„Doctoral studies: through science towards society”.

Thesis objectives

The objectives of this thesis are: (a) the inventory and the taxonomic identification of previously collected fossil bones, now part of the Laboratory of Paleotheriology collection, and fossils collected during field campaigns to Maastrichtian vertebrate localitie from the studied area, (b) recovery of the micro-remains through Oarda de Jos sediment processing, and (c) their taxonomic classification, taphonomic interpretation (based on morphological features) and paleoecology analysis of faunal association through various statistical methods, for each studied locality and the whole area.

Materials and methods

A part of the studied macro-fossil remains was provided by the Laboratory of Paleotheriology (UBB) collections, while other part were collected during several field campaigns in the study area.

The micro-fossil material is exclusivelly the result of laboratory screen-washing of 2436 kg sediments, over 3.000 pieces belongs to several groups of vertebrates being recovered.

Macro-fossil remains were prepared by removing the sediment, both mechanically, using either a pneumatic hammer connected to the "AIRBAG HP1" compressor, or a hammer and a chisel (the “traditional” way), and chemically, through differentiated treat with acetic acid. To prevent fossil remains destruction during preparation, the material was reinforced by brushing with a solution of mowillit, rodopast or diluted glue.

The microvertebrates were collected exclusively from Oarda de Jos site. The collected sediment was stacked in bags, then transported and stored in the laboratory for further processing. Dry sediment was soaked in warm water and was washed using meshes of 0.3 mm and 0.5 mm. The resulted sediment, without fine fraction, was sorted under binocular.

The descriptions of the large remains was performed by direct observation, while for small fragments observation through a binocular was used. To identify and compare the material described in this thesis, papers and books were used, the authors being cited both in the body text and references chapter. Morphometric measurements for macro-remains were performed with a classic caliper, while for smaller fragments than 3 cm an electronic-display caliper was used.

Photographs for macroscopic remains were taken using an 8 Megapixel - Sony camera. Microscopic pieces were visualized by a SEM (scanning electron microscope) at the Royal Institute of Natural Sciences in Brussels (Belgium).

Drawings in text and plates were processed using Adobe Photoshop CS5. Maps digitization was performed using CorelDRAW X5. For tables and diagrams, Microsoft Office

Excel 2003 was involved. Diversity index values were determined using PAST program version 2.05 (Hammer et al., 2001).

Chapter 2 - Geological setting

The Romanian areas where vertebrates-bearing deposits within the Upper Cretaceous continental deposits crop out are Haţeg Basin, Rusca Montana Basin, the eastern border of the Apuseni Mountains (at its contact with the Transylvanian Basin) - on Alba and Cluj counties, and near Jibou at Someş-Odorhei (fig. 1).

From structural point of view, the sedimentary formations outcropping in Metaliferi area belong to Apuseni Mountains and Transylvanian Basin. In the first area, the sedimentary units, in a flysch facies, constitute the Bozeş Nappe, a component of Transylvanides (Bleahu et al., 1981; Săndulescu, 1984). It is covered by post-"Laramian" sedimentary deposits that marks the beginning of the Upper Cretaceous - Paleocene evolution in the Transylvanian Basin (Balintoni et al., 1998; Codrea et al., 2001a,b, 2003). The deposits from the base of the sequence are indicating a deltaic successions with short marine episodes, belonging to Vurpăr Formation, covered by the continental deposits bearing Cretaceous vertebrates, part of Şard Formation, both formations being recently defined by Codrea & Dica (2005).

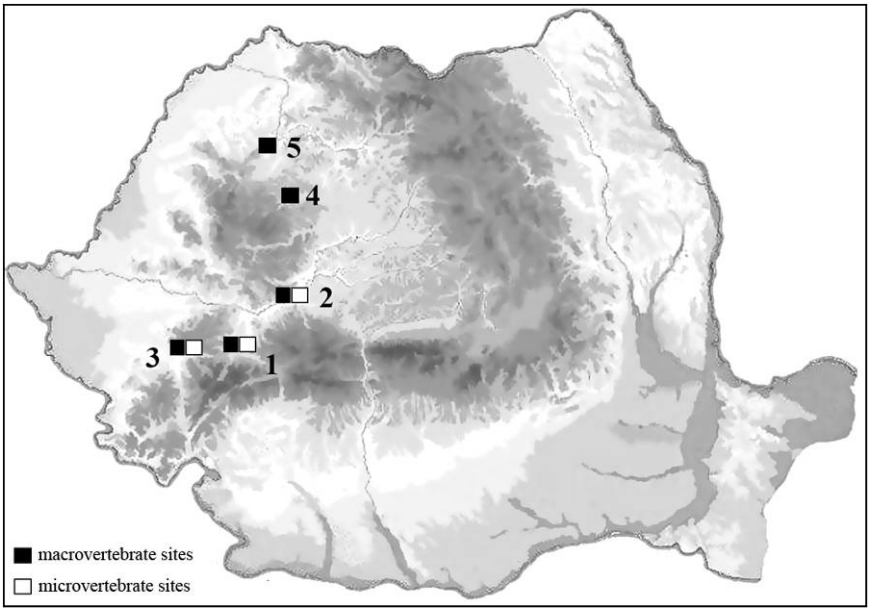

Figure 1 - Locations of major areas in Romania where Upper Cretaceous continental deposits crop out: 1 – Haţeg Bazinul; 2 - Sebeş-Vinţu de Jos-Alba Iulia area; 3 - Rusca Montană Basin; 4 – Ierii Valley (Cluj county); 5 - Someş Odorhei (Sălaj county).

In the study area, Maastrichtian continental deposits are delimited by the localities Vurpăr - Pâclişa - Ighiu - Bărăbanţ - Sântimbru on the right bank of the Mureş river and Teleac - Oarda de Jos - Lancrăm - Sebeş on the left bank of the it, and along the Sebeş riverbed (Codrea et al., 2001a, 2003, 2010a).

Structural units in the area were defined by Codrea & Dica (2005) and belong to Santonian-Aquitanian, the oldest being the Bozeş Formation while the youngest one is Sântimbru Formation.

Vertebrates-bearing Upper Cretaceous continental deposits in this area are assigned to Şard Formation, which consists of fluvial red beds, which channels infillings, alternating with flood plains deposits. Channel sediments are represented by sands and gravels, with a specific braided flows internal architecture, and numerous internal bars. Downstream migration of sand and gravel bars caused the dominance of oblique-concoid lamination. Also crevasse deposits, sand or silt levee and flood plain deposits represented by silty clay can be observed (Codrea et al., 2001a, 2003).

Maastrichtian is pointed out by very rich reptiles fauna, similar to that of Haţeg Basin: dinosaurs (theropods, sauropods, ornithopods, nodosaurids), crocodiles (*Allodaposuchus precedens*) and turtles (*Kallokibotion bajazidi*), but also by microfloristic elements represented by *Pseudopapillopollis praesubhercynicus*, *Normapolles*, *Postnormapolles* (Antonescu, 1973, Antonescu et al., 1983).

A special attention should be given to red beds exposed within Râpa Roşie and Râpa Lancrăm, which were assigned initially to ?Eggenburgian-Ottnangian “Sebeş Formation" (Codrea & Dica, 2005). The recently collected paleontological materials and micropaleontological analysis of several reworked Eocene limestone blocks (Vremir et al., 2009; Solomon et al., 2010; Solomon & Miclea, 2010) have indicated an Upper Cretaceous age for these deposits and their assignment to Şard Formation (Codrea et al., 2010b). Vremir (2010) included the Cretaceous deposits between Oarda de Jos-Lancrăm-Râpa Roşie-Petreşti to "Sebeş Formation" equivalent to Şard Formation.

The important localities with numerous collected Maastrichtian vertebrate remains are Vurpăr, Oarda de Jos, Lancrăm and Sebeş. Other sites such as Stăuinii Valley, Şard-Ampoi Valley, Teleac, Râpa Lancrăm and Râpa Roşie are characterized by a reduced bones frequency.

Vurpăr (VP) is situated on the road between Vurpăr and Alba-Iulia, on the right bank of the river Mureş, in a place called “Râpele din susul Dumbrăvii”. The large outcrop exposes red beds.

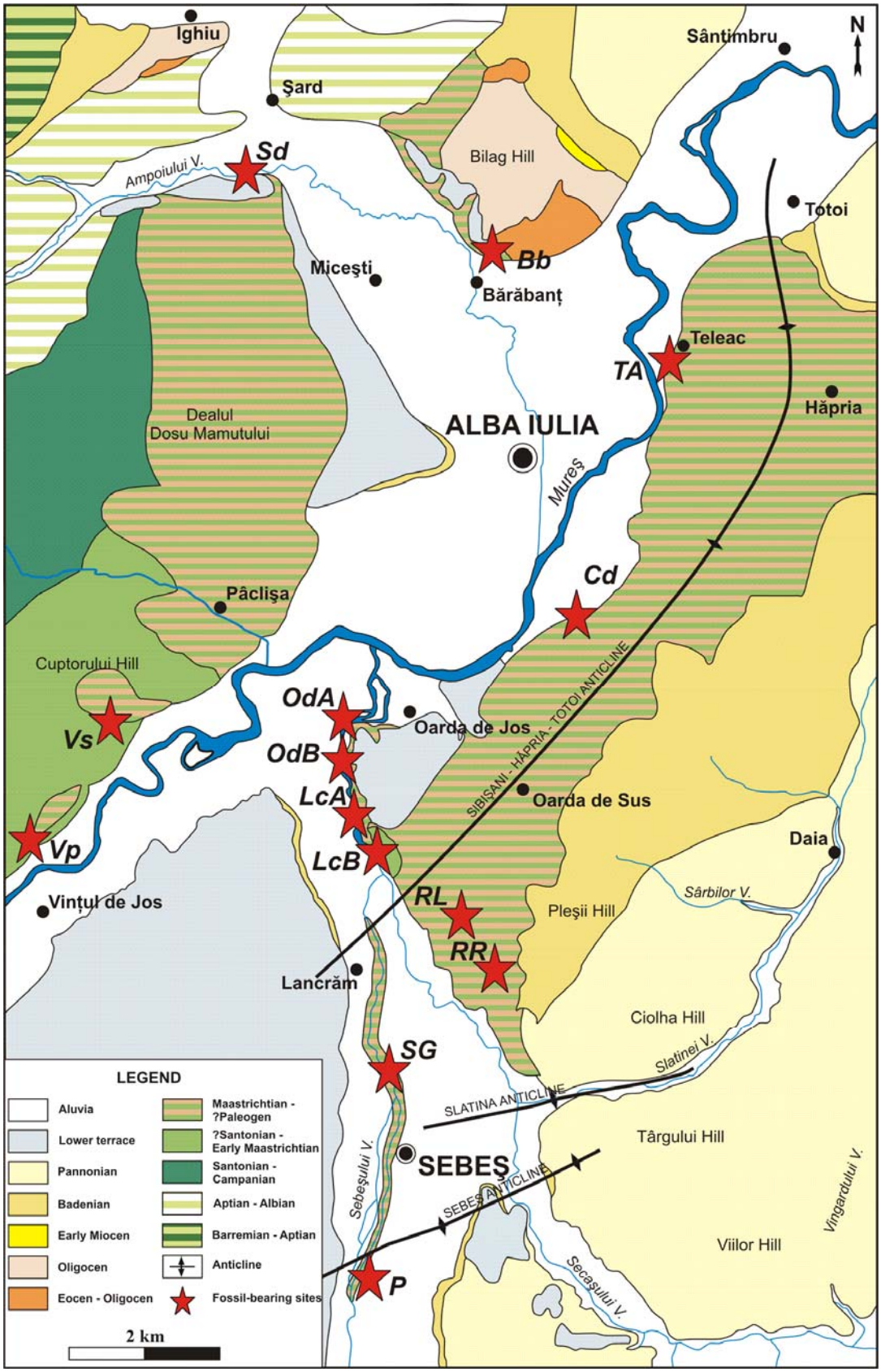

Figure 2 – The geological map of Alba area, with studied Cretaceous vertebrate localities (modified after Codrea & Dica, 2005). Abbreviations: VP-Vurpăr, Vs-Valea Stăuinii, Sd-Şard-Valea Ampoiului, TA-Teleac, OdA-Oarda outcrop A, OdB-Oarda outcrop B, LcA-Lancrăm outcrop A, LcB-Lancrăm outcrop B, RL-Râpa Lancrăm, RR-Râpa Roşie, SG-Sebeş-Glod, P-Petreşti, Bb-Bărăbanț, Cd-Ciugud.

Red beds are predominantly composed of red or reddish brown silt clay alternating with microconglomerates and sand represented by arenites or silts (Codrea et al., 2010a). In the basal part of red clay deposits, carbonate concretions and root-marks can be observed.

These deposits are bearing vertebrate remains belonging to crocodiles (*Allodaposuchus precedens*), theropods, ornithopods (*Zalmoxes*, *Struthiosaurus*) or turtles (*Kallokibotion bajazidi*) (Nopcsa, 1905; Codrea et al., 2002b; Weishampel et al., 2003; Codrea et al., 2010a). The recovered osteological material includes a large number of indeterminable small fragments.

Stăuinii Valley (Vs) is located about 3.5 km NE of locality Vinţu de Jos. The marine deposits croping out here belong to Vurpăr Formation, and are represented by conglomerates, sandstone, siltstone, marlstone and claystone with thin coal intercalations. These deposits indicate a coast environment, with fan delta successions and several interbedded invasive marine deposits. The upper section shows the transition to the continental domain represented by paleosols (Codrea & Dica, 2005; Codrea et al., 2010a).

Vertebrate remains are very rare and they belong to crocodiles, turtles and dinosaurs.

Şard-Ampoi Valley (Sd) is an outcrop located at the Sard entrance, near the bridge crossing the Ampoi valley. Deposits, consisting predominantly of conglomerates, microconglomerates and subordinate clays, belong to Şard Formation. These deposits probably indicate the presence of a braided river system with a medium to high energy, a dynamic environment given by high erosion and depositional processes (Codrea et al., 2010a).

Teleac (TA) is located at 5 km NE of Alba Iulia and it displays openings on several torrents. Exposed deposits are predominantly siliciclastic with alternating red clays, sandstones and conglomerates, similar to deposits from Râpa Roşie and Râpa Lancrăm. Vertebrate remains are very rare.

Oarda de Jos is located on the right side of the Sebeş valley, at 3 km S from Alba Iulia locality. Maastrichtian deposits are exposed in two sections marked as Oarda A (ODA) and Oarda B (ODB). The succession includes arenites and conglomerates deposits alternating with clay deposits. In the basal part of these deposits can be observed carbonized remains and very rare silicified trunks.

A micro- and macrovertebrates accumulation was discovered in 2007 by a team from the Faculty of Biology-Geology (UBB) led by prof. Dr. Vlad Codrea. Lens (named ODAN) is situated in the upper part of section OdA, and represent the only location with microvertebrates in the study area. By processing of 2400 kg sediment quantity, over 3000 pieces belonging to different groups of vertebrates and invertebrates (gastropods, charophytes

ostracoda) were collected. Also, from this lens, isolated crab chelipeds were recovered (Codrea et al., 2010a).

In the middle part of the sequence, a greenish-gray clays layer (noted ODAX) provided few turtle fragments, eggshells and a crocodile tooth.

The paleontological material from both Oarda de Jos sections include ornithopods (*Zalmoxes, Telmatosaurus transsylvanicus*), sauropods, crocodiles, turtles (*Kallokibotion bajazidi,* ?Dortokidae indet.), dinosaur tracks which belong to *Iguanodontichnus* group (Codrea et al., 2010a).

Lancrăm presents two exposures on the right bank of the Sebeş river on several hundred meters, downstream to Lancrăm locality. The deposits are similar with those from Oarda de Jos, covered by the red beds that occur also to Râpa Roşie, and represented by an alternance of fine clay deposits, arenites and conglomeratic layers, with lateraly variations.

The first section (LcA) is around 500m upstream from OdB and consists of sands, conglomerates, silty clay and arenites. The second section (LcB), with a length of about 120m, is to be found upstream of LcA and it is lithologically similar to LcA.

The osteological material collected from this site belongs to the appendicular skeleton and it can be assigned to sauropods and ornithopods (*Zalmoxes, Telmatosaurus transsylvanicus*).

Sebeş (SB), located on Sebeş riverbed, reveals a typical fluvial facies, with dominant red silty clays interbedded with high-energy channel deposits (conglomerates and arenites). The bone remains have a white colour, similar to those from Vurpăr, and belong to sauropods, ornithopods and turtles. A partial skeleton belonging to a theropod named *Balaur bondoc* was recently discovered (Csiki et al., 2010c).

Râpa Roşie (RR), located at 3km northeast of the locality Sebeş, is a natural reserve (Toniuc et al., 1992). The deposits are predominantly siliciclastic with finning-upward tendency. The lower part is typical of conglomeratic facies while the upper part includes alternating sandstone and clays.

Bone remains are dominated by small pieces, strongly rounded, while large pieces are rare. They have a white colour, indicator of a sub-aerial exposure, and belongs to theropods, turtles, sauropods, hadrosaurs and azdarchids (Grigorescu, 1987; Codrea & Vremir, 1997; Jianu et al., 1997a; Codrea et al., 2008; Vremir et al., 2009; Vremir, 2010).

Râpa Lancrăm (RL) is an outcrop similar in appearance to that from Râpa Roşie (which is situated 2km S). Channel deposits, represented by conglomerates, microconglomerate and arenites, alternate with plain alluvial deposits consisting of clay silt.

One exceptionally well-preserved caudal vertebra belongs to an ornithopod dinosaur was mentioned (Jianu et al., 1997).

Petreşti (P) is a section situated on the Sebeş riverbed between Sebeş and Petreşti localities. Here, red beds are exposed in a typical alluvial plain facies. The vertebrate remains are very rare and broken.

Two bones that belong to dinosaurs are mentioned from Bărăbanț and Ciugud and they are now in the custody of Natural Science Museum from Aiud (Codrea & Marginean, 2007; Codrea et al., 2010a).

Chapter 3 - Evolution of the knowledge on the Uppermost Cretaceous vertebrates in Romania

Garfish firstly reported Haţeg Basin from the Fântânele-Vălioara (Grigorescu et al., 1999) and Budurone-Vălioara (Csiki et al., 2008), the remains being represented by teeth and ganoid scales. Characiforms are reported by Grigorescu et al. (1985) from Haţeg Basin, but without any morphological description of the collected material. Recently, fossils belonging to lepisosteids and characiforms were collected from the Oarda de Jos lens and was reported preliminary by Codrea et al. (2010b) and Codrea & Jipa (2011).

Amphibians are mentioned from different localities from the Haţeg Basin, and are represented by fragmentary material belonging to albanerpetontids and anuras (e.g. Grigorescu et al., 1985, Smith et al., 2002; Codrea et al., 2002a, Folie & Codrea, 2005). Grigorescu et al. (1999) assigned some isolated remains to the family Albanerpetontidae, represented by two taxa: g.*Albanerpeton* and g.*Celtedens*. Based on dissociated skeletal elements, Venczel & Csiki (2003) described the first anurans species in Romania: *Hatzegobatrachus grigorescui* and *Paralatonia transylvanica*.

Turtles are reported by Nopcsa (1923a) from Cretaceous deposits from Sânpetru, describing a new genus with two species, but only *Kallokibotion bajazidi* is now valid. The revision and phylogenetic analysis of *Kallokibotion* is performed by Gaffney & Meylan (1992). Other remains are reported from Râpa Roşie, Someş-Odorhei and Rusca Montană (Codrea & Vremir, 1997; Codrea & Godefroit, 2008; Codrea et al., 2009). Mlynarski (1966) assigned a material discovered by Nopcsa (1915) to *Pleurosternon* genus with at least two species.

Vremir & Codrea (2009) indicates the presence of a new taxon in the Metaliferi area localities, called *Muehlbachia nopcsai*, currently considered *nomen nudum* (Rabi & Vremir,

2011). The presence of turtles in the Cretaceous deposits of the Haţeg Basin and Alba area is mentioned by Lapparent et al. (2009) based on new material.

Teiidae finds its representatives in Romania through the new species *Bicuspidon hatzegiensis* (Folie & Codrea, 2005). Lacertilia are represented by two species of the family Paramacellodidae, one of them being a distinct species called *Becklesius nopcsai* (Folie & Codrea, 2005). Based on different morphology of the jaws and teeth collected from Budurone, Csiki et al. (2008) suggests the presence of at least two types of lizards with scincomorph affinity.

From Maastrichtian deposits of Vălioara (Haţeg Basin) the first crocodilian from Romania, named *Allodaposuchus precedens* (Nopcsa, 1928) is reported, and recently from the same deposits one tooth assigned to *Doratodon* (Grigorescu et al., 1999) was collected. After a detailed analyses of a right jaw fragment with 7 teeth, collected from Tustea, a new taxon called *Theriosuchus sympiestodon* is described (Martin et al., 2010). A very well-preserved skull discovered in Cretaceous deposits from Oarda de Jos (Alba County) was assigned to *Allodaposuchus precedens* and considered as a non-crocodilian eusuchian based on morphological characters (Delfino et al., 2008).

Currently, three locations with remains belonging to the flying reptiles are known: Cornet (Bihor county), Haţeg Basin and recently in Alba county.

The pterosaurs from Cornet are Berriasian-Valanginian (Early Cretaceous) and include parts of the skull and limb bones (Dyke et al., 2010). The first mention of a pterosaur in Haţeg Basin belongs to Nopcsa (1914) based on a material which belongs to Ornithocheiridae indet., later reviewed by Jianu et al. (1997b). Based on associated cranial elements and a fragment of humerus, a new species of azdarchid pterosaur from Vălioara was described: *Hatzegopteryx thambema* (Buffetaut et al., 2002). Recently, a cervical vertebra was reported in Râpa Roşie (Alba county), belonging to a large azdarchid (Vremir et al., 2009; Vremir, 2010).

Nopcsa (1901, 1915) firstly mentioned the theropods in Romania, based on only one small isolated teeth collected from Borod Basin, named the species as *Megalosaurus hungaricus* (currently considered an indeterminate theropod). Andrews (1913) wrongly assigned one end of a femur and tibio-tarsus to pelenicaform *Elopteryx nopcsai*, which are now considered as belonging to a theropod. Harrison & Walker (1975) identifies three tibio-tarsal bones as the owls, named *Bradycneme draculae* and *Heptasteronis andrewsi*, but the material is reassigned to theropods by Csiki & Grigorescu (1998). Isolated teeth belonging to different groups of theropods are signaled at Sânpetru, Pui, Fântânele, Toteşti and Râpa Roşie (e.g. Grigorescu, 1987; Codrea et al., 2002a; Vasile, 2008). The most recent discovery is

made to Sebeş, where a partially postcranial skeleton, belonging to a theropod called *Balaur bondoc,* was excavated (Csiki et al., 2010c). From Cornet, two phalanges are reported as belonging to a theropod indet. (e.g. Benton et al., 1997).

Based on the collected material by Baron Nopcsa, Huene (1932) described the remains from Haţeg Basin, considering that they are enough characteristic to be assigned as a new titanosaur sauropod genus - *Magyarosaurus* different from *Titanosaurus*, known in India, Madagascar, South America and Europe, and refers to three different species in his oppinion: *Magyarosaurus dacus*, *M. transsylvanicus* and *M. hungaricus.* In a paper on the continental Cretaceous age deposits, Dincă et al. (1972) described a well preserved caudal vertebra discovered in Haţeg Basin, attributed to "*Titanosaurus dacus*". Along with an vertebrate faunas overview from Haţeg Basin, a description of a partial titanosaur skull from Pui was made (Weishampel et al., 1991). Jianu & Weishampel (1999) and Stein et al. (2010) discusses Nopcsa's hypothesis on *Magyarosaurus*, along with other taxa of Haţeg, as case of island dwarfism. First description of a dermal armor assigned to genus *Magyarosaurus* (Csiki, 1999) support the Titanosauridae family taxon membership since the presence of dermal armor is an important autapomorphy of titanosaurian sauropods. From Râpa Roşie, it is reported only one caudal vertebral centrum with a length of 105 mm (Codrea et al., 2008). Recently from Nălaţ-Vad more bone belonging to the same individual named *Paludititan nalatzensis* has been reported (Csiki et al., 2010b).

In Romania, studies concerning nodosaurids are very scarce primarily due to the limited number of fossils found in the latest Cretaceous deposits. Nopcsa (1915) based on a material found in Haţeg Basin assigned *Struthiosaurus transylvanicus*. A new material is discovered and published by Weishampel et al. (1991) and Pereda-Suberbiola & Galton (1997) published an overview on this species from Romania. The most recent remains belonging to ankylosaurs are reported preliminary by Codrea et al. (2010a) from Vurpăr, the material being included in the present thesis.

"*Rhabdodon priscus*" is reported firstly in the Haţeg Basin and it was initially assigned to another taxon, *Mochlodon suessi* (Nopcsa, 1915). Jianu (1994) described a jaw of "*Rhabdodon priscus*" found on Sibişel Valley near Sânpetru (Haţeg Basin). Jianu et al. (1997a) published an inventory including elements of the appendicular skeleton discovered at Râpa Roşie. New well-preserved bone remains were discovered in Haţeg Basin and Metaliferi area, and lead to review the old material and its assignement to a new genus with two species: *Zalmoxes robustus* and *Z. shqiperorum* (Weishampel et al., 2003). A material that include teeth, skull and postcranial elements is found at Budurone, Nălaţ-Vad, Someş-Odorhei and

Rusca Montană and assigned to *Zalmoxes* (Csiki et al., 2008; Godefroit et al., 2009; Codrea & Godefroit, 2008; Codrea et al., 2009). In Metaliferi area the ornithopods *Zalmoxes* are found at Vurpăr, Oarda de Jos, Lancrăm and Sebeş (Codrea et al., 2010a,b,c).

Hadrosaurs was reported firstly by Nopcsa (1900). He named it "*Limnosaurus transsylvanicus*", and few years later he changed it in *Telmatosaurus transsylvanicus* (Nopcsa, 1903). Other postcranial elements were described by Nopcsa (1915) and Weishampel et al. (1993). An overview of the species and other hadrosaurs from the European Cretaceous was made by Dalla Vecchia (2006, 2008, 2009).

The birds are reported from the Lower Cretaceous deposits of Cornet and they were assigned to *Archaeopteryx* and two species of neornithine: *Palaeocursornis biharicus* and *Eurolimnornis corneti* (Kessler 1984, Kessler & Jurcsák 1984a, b, 1986; Jurcsák & Kessler, 1985). Recent review of the material didn't confirm the *Archaeopteryx* presence and both of the neornithines species are considered *nomina dubia* (Dyke et al., 2010). The first clear mention of a material which can be assigned to birds is made by Wang et al. (2011a), which prove the presence of ornithurines from the Haţeg Basin, based on a fragment of a left tibio-tarsus, while the first report of an euenantiornithine bird is made based on an almost complete right humerus and on an end of a proximal left humerus (Wang et al., 2011b). In the Metaliferi area from Oarda de Jos, the presence of enanthiornite birds is reported by Vremir (2010).

The mammals are exclusively represented in Romania by multituberculates. Their presence was firstly reported based on an isolated upper incisor from Sânpetru (Haţeg Basin) (Grigorescu, 1984a). Rădulescu & Samson (1986) described the first species of multituberculate from Romania on the basis of an upper M1 found at Pui: *Barbatodon transylvanicum* and a new material that includes two incomplete mandibles which helped to reinterpret this species (Csiki et al., 2005). A broken skull from an outcrop of Tămăşel Hill in deposits of Sânpetru Formation was assigned to a new family and genus including a single species - *Kogaionon ungureanui* (Rădulescu & Samson, 1996). From Toteşti were collected 14 complete teeth and some fragments assigned to at least two taxa, predominantly being those of *Kogaionon* (Codrea et al., 2002a; Smith & Codrea, 2003).

Extending research outside Hateg Basin led to the discovery of new sites with multituberculate teeth. The first is located in Rusca Montana Basin (Codrea et al., 2009) and the second one in the Metaliferi area at Oarda de Jos (Codrea et al., 2010a,b).

The first nest with fossil eggs was reported at Tuştea (Haţeg Basin) (Grigorescu et al., 1990), assigned to Megaloolithidae (Grigorescu, 1993, Grigorescu et al., 1994). Also dinosaur

egg nests were found at Toteşti (ten nests with megaloolithid type eggs were collected) and in Nălaţ-Vad (Smith et al., 2002; Codrea et al., 2002a). Garcia et al. (2002) indicated the presence of egg fragments at Pui, assigned to 5 morphotypes: discretispherulitic, prolatospherulitic, prismatic, ratite and geckonoid. From Tuştea, Grigorescu (2003) assigned the megaloolithid egg shells to hadrosaur dinosaurs but based on scarce evidence.

Recently from the site from Oarda de Jos (Alba county) the presence of eggshell fragments, preliminary assigned to ?*Pseudogeckoolithus* and *Megaloolithidae* has been reported (Codrea et al., 2010a,b,c). Also, from Rusca Montana Basin some eggshell fragments were assigned to two morphotypes, one of which being geckonoid (Vasile et al., 2011).

Chapter 4 - Systematic paleontology

Maastrichtian deposits from Metaliferi area yielded a rich material belonging to vertebrates classified into 15 groups, 5 classes and 11 orders:

Class: Osteichthyes HUXLEY, 1880

Order: Lepisosteiformes BERG, 1840

Family: Lepisosteidae CUVIER, 1825

Occurrence: Oarda de Jos (ODAN).

Lepisosteids are represented by four morphotypes. The first is massive, cylindrical with rounded apex and could be related to ?*Lepidotes*. The second type is more robust, conical with numerous ridges on the enamel surface and the apex becoming suddenly narrows. It can be straight or curved. The third morphotype is dominated by an elongated conical form and numerous and parallel ridge on the surface enamel. Two types of teeth can be distinguished: pointed, typical for *Lepisosteus* (morphotype 3) and lanceolate, which can be attributed to genus *Atractosteus* (morphotype 4). Vertebrae are opisthocoelous, of different sizes and have grooves on lateral sides. Scales have a predominant rhomboidal or irregular morphology.

Order: Characiformes GOODRICH, 1909

Family: Characidae BLEEKER, 1859

Occurrence: Oarda de Jos (ODAN).

Only isolated teeth were collected and two morphotypes can be distinguished. First type bears two cusps, one higher, larger, flattened, while the second is conical and reduced in size. The second type has a triangular shape and symmetrical two secondary cusps disposed side by side of the main cusp.

Pisces indet.

The material includes an isolated tooth with flattened point like "spatulate", slightly curved and lingual concave, while the base presents in cross section a "tear" shape.

Class: Amphibia LINNAEUS, 1758

Order: Allocaudata FOX & NAYLOR, 1982

Family: Albanerpetontidae FOX & NAYLOR, 1982

Genus: Albanerpeton ESTES & HOFFSTETTER, 1976

***Albanerpeton* sp. A**

Occurrence: Oarda de Jos (ODAN).

Inventory refers to frontal, premaxilla, incomplete dentaries. The frontal has triangular outline, relative larger than occurs in *A. pannonicum* and Paskapoo species and relatively more elongate than frontals of *A. pannonicum* şi *A. inexpectatum*. Internasal process lacks dorsal ornament, being similar with *A. nexuosum*, *A. pannonicum*, *A. inexpectatum*, and Paskapoo species, but differs by his width. Premaxilla differs from *A. arthridion* through the location low of suprapalatal pit on lingual surface of pars dorsalis, moderate dimension vs. smaller to *A. arthridion* and larger to *A. galaktion*, dorsal boss present and which is different from that present in *A. inexpectatum* and Paskapoo species, and covers about dorsal one-half of pars dorsalis being ornamented with polygonal pits (Gardner, 1999a,c, 2000a).

***Albanerpeton* sp. B**

Occurrence: Oarda de Jos (ODAN).

Premaxilla ODAN-Pm.G is incomplete can be assigned to *Albanerpeton* based on features of the suprapalatal pit: low location of suprapalatal pit on lingual surface of pars dorsalis, and moderate dimension versus higher up on pars dorsalis and relatively smaller in *Anoualerpeton*, *Celtedens*, and basalmost species of *Albanerpeton*, for example *A. arthridion.* Other differences are the elliptical shape of the suprapalatal pit versus "fissure" of *A. cifellii* and *A. gracile* and moderate dimension of suprapalatal pit versus smaller of *A. arthridion* and larger to *A. galaktion* (Gardner, 1999a,c, 2000a)

***Albanerpeton* sp. indet**

Occurrence: Oarda de Jos (ODAN).

The inventory includes incomplete premaxilla, maxilla, dentals, quadrat, atlas, axis and humerus. Premaxilla are incomplete and preserved a different number of teeth. Teeth are highly pleurodont, close to each other, straight, non-pedicellate with the labio-lingually compressed crown, slightly tricupid and chisel-like. Vertebrae are amphicoelous and present a

general shape similar to a clepsidra. The humerus presents the shaft straight, elongate and in a line with semisferic humeral condil.

Order: Anura RAFINESQUE, 1815

Anura indet.

Ocurence: Oarda de Jos (ODAN).

The material includes skull, axial and appendicular skeleton remains. The morphology of some elements such as maxilla, iliums, urostyles and scapula indicates the presence of Discoglossidae. Ilium presents distinct morphological features to dorsal crest, the various dimension of acetabular and preacetabular fossa; these features indicate at least three taxa. The maxilla presents a smooth labial surface and does not preserve teeth. Urostyles are different in dimension and can be separated in two types based on presence/absence of a groove on dorsal crest.

Class: Reptilia LAURENTI, 1768

Order: Testudines BATSEH, 1788

Cryptodira indet.

Occurrence: Oarda de Jos (ODAN), Sebeş, Vurpăr.

There are several fragments from plastron and carapaces.

Pleurodira indet.

Occurrence: Vurpăr, Oarda de Jos (ODAN, OdA, ODAX), Sebeş.

The material includes fragments from plastron and carapace and several ilium and ischium.

Order: Squamata OPPEL, 1811

Suborder: Lacertilia OWEN, 1842

Lacertilia indet.

Occurrence: Oarda de Jos (ODAN).

Several elements belong to parietals, frontals, maxilla, dental, premaxilla, vertebrae and humerus were collected. The parietals represent the anterior part and are incomplete. Frontals are triangular outlined and to some specimens the fusion line between the two parts can be observed. In dorsal view most of the frontals presents ornamentation. Based on teeth morphology the maxilla and premaxilla can be divided in four morphotypes. First is represented by ODAN-Amf-4 with a single tooth well preserved which show a conical crown, slightly concave of lingual surface where can be observed 6 small and distinct ridges. This looks similar with *Biscuspidon* described from Haţeg Basin (Folie & Codrea, 2005). Second type, represented by three specimens (ODAN-Amf-5, Amf-11, Amf-13), show the teeth

highly pleurodont, elongate and relatively straight, with crown lingualy slightly curved. The apex bears low, mediodistally broad labial and lingual cusps. Below cusps the surface is ornamented with fine vertical ridges. The teeth resemble those of *Becklesius nopcsai* (Folie & Codrea, 2005). The third type presents the teeth recurved, canin-like, with the crown labio-lingualy compressed (ODAN-Amf-6). The fourth type presents the mesio-distaly bicuspid crown.

Order: Crocodylia GMELIN, 1789

Suborder: Eusuchia HUXLEY, 1875

***Allodaposuchus precedens* NOPCSA, 1928**

Occurrence: Vurpăr, Sebeş, Lancrăm, Oarda de Jos (ODAN, OdA, OdB, ODAX).

Numerous isolated teeth and a few vertebrae were collected. Depending on their morphology, teeth can be divided in two morphotypes: first is conical, slightly curved and sharp, while the second is shorter and robust, with a height-width ratio less than the previous. Vertebrae show the centrum with globular condyle while the cotyl is convex and circular in cross section. Neural channel is relatively large and circular.

Genus: *Acynodon* BUSCALIONI ET AL., 1997

Acynodon indet.

Occurrence: Oarda de Jos (ODAN).

Only isolated teeth were collected from Oarda de Jos lens. Teeth can be divided in two morphotypes: type 1 represented by spatulate teeth with marginal carena and asymmetrical, rounded tip which can be attributed to anterior part of maxillary/mandible and type 2 represented by molariform teeth having a width substantially greater than their height, with lateral carena continuing in apical side, forming a flattened ridge; this teeth can be assigned posterior part of maxillary/mandible.

Suborder: Mesoeucrocodylia WHETSTONE & WHYBROW, 1983

Genus: *Doratodon* SEELEY, 1881

Doratodon indet.

Occurrence: Oarda de Jos (ODAN).

Material includes only isolated teeth. These are triangular shaped, broader than higher and latero-medial compress with marginal carena. Based on width/height ratio can be separated two types of teeth. First are lateral compressed with a subtriangular to lanceolate shape, lateral faces relatively straight or slightly curved, pointed and presents small ridges on the edges of the faces ending with small mesial and distal denticles. The second form is subtriangular.

Crocodylia indet.

Occurrence: Vurpăr, Oarda de Jos (ODAN, OdA), Sebeş.

Frontals are incomplete and show on the dorsal surface an ornamentation with irregular ridges and concavities. Osteoderms are relatively squared with rounded corners, thin, with an ornamentation formed by round or oval concavities on dorsal surface.

Order: Pterosauria KAUP, 1834

Pterosauria indet.

Occurrence: Oarda de Jos (ODAN).

Fragments of mandible/maxillary are small and represent the anterior part that is fused. The cross section of the bone has a triangular outline. Occlusal surface is straight, slightly concave and has two rows of small foramina disposed parallel with oval shape.

Order: Saurischia SEELEY, 1887

Suborder: Theropoda MARSH, 1881

Genus: *Richardoestesia* CURRIE, RIGBY & SLOAN, 1990

***Richardoestesia* sp.**

Occurrence: Oarda de Jos (ODAN).

Teeth are more or less backward curved, with an oval cross section and most specimens with denticles on carena with a frequency range from 7.5 to 11 denticles/mm. The denticles present a rounded tip and the height approximately equal with the length. Teeth with similar morphology are reported from Haţeg Basin (Csiki & Grigorescu, 1998; Codrea et al., 2002a) or North America (Baszio, 1997; Sankey et al., 2005).

Dromaeosauridae indet.

Occurrence: Oarda de Jos (ODAN).

Teeth have relatively larger sizes than other theropods teeth collected. They are slightly curved backward, lateral compressed and present an oval to oval-flattened shaped cross section.

Genus: *Paronychodon* COPE, 1876

?*Paronychodon* sp.

Occurrence: Oarda de Jos (ODAN).

Teeth are relatively small, elongated, strong recurved and sharps. Teeth preserved only the crown. This is strongly convex in labial view while the lingual face is flat. The anterior and posterior carena has not serations. Lingual face presents two curved longitudinal grooves along the length of the tooth and the labial face presents six grooves separate by six ridges, the lateral being shorter.

Theropoda indet.

Occurrence**:** Oarda de Jos, Vurpăr.

The humerus is represented by a fragment of the proximal part preserving humeral head. Pubis preserves a part of the acetabular process. The articulations with the ilium and the ischium are broken. Ungual phalanx has a pronounced curvature to the distal end tapering to a point. On the lateral side is a curved groove along the length of phalanx body. Phalanx could be the phalanx 2 or 3 from the upper right member.

Suborder: Sauropodomorpha Huene, 1932

Infraorder: Sauropoda MARSH, 1878

Sauropoda indet.

Occurrence: Oarda de Jos (ODAN, OdA, OdB), Lancrăm, Sebeş.

Teeth are cylindrical, slightly to moderately curved in median shaft with a circular cross section and has the very slightly flattened tip. Maximum preserved length is 14.45 mm (UBB ODAN-Cr-252), while the maximum diameter is 4.03 mm (UBB ODAN-Cr-257). Teeth with similar morphology were assigned to *Lirainosaurus astibiae* (Sanz et al., 1999). The tooth of *Ampelosaurus atacis* presents the mesial and distal carena more pronounced and expanded than in Oarda specimens (Le Loeuff, 1995, 2005).

Inventory includes six caudal vertebrae from the front (ODA-18), antero-median (SB-3), mediano-back (SB-19; ODAN-32) and posterior (SB-23, ODA-20). The vertebrae have an elongated centrum and the neural arch is incomplete. Articular surfaces is typical to titanosaurids with a concave condyle and convex cotyl. Only a chevron is fully preserved and presents an "Y"-shaped forrm. Humerus does not preserve the distal and proximal end. Tibiae ODA-7 is the best-preserved specimen and presents the shaft straight with cnemial crest well developed in the proximal part. Femurs are straight in cranial view and show a slight arching of the back in side view. The fourth trochanter is located on the median-proximal part of shaft and is presented as a small and rounded ridge.

Order: Ornithischia SEELEY, 1888

Family: Nodosauridae MARSH, 1890

Genus: Struthiosaurus BUNZEL, 1870

***Struthiosaurus transylvanicus* NOPCSA, 1915**

Occurrence: Vurpăr, Oarda de Jos (ODAN).

Dorsal vertebra has a short centrum and a neural arch that preserved both lateral diapophysis T-shaped in cross section, prezygapophysis and postzygapophysis. Ribs are represented by different fragments sizes T-shaped in cross section. The caudal vertebrae are

from the distal part of tail, are of small size and are not preserving the neural arch. Humerus is the first such bone ever reported from Romania. It is a left humerus, preserving only the upper half. It is marked by a very long ridge and robust deltopectoral crest showing proximal a robust and rounded humeral head. The preserved shaft is more gracile than *Struthiosaurus* specimens reported from Austria and Spain (Pereda-Suberbiola, 1999; Pereda-Superbiola & Galton, 2001). Two femurs were collected: one left femur with the proximal part broken, robust and slightly arched of shaft and a distal end of one right femur. Ulna is severe damaged. Osteoderms have various sizes and can be classified into two categories: the first type has a height greater than width and can be related to the anterior tail and the second type with a relatively low ridge height in relation to its length, probably dorsal and/or tail osteoderms. The last has an oval ventral surface, suboval or subrounded.

Family: Rhabdodontidae WEISHAMPEL ET AL., 2003

Genus: *Zalmoxes* WEISHAMPEL ET AL., 2003

Occurrence: Vurpăr, Oarda de Jos, Sebeş, Lancrăm.

Vurpăr is representative for this taxon, 58 pieces being collected. Teeth have various sizes with labial surface furrowed by numerous, unequal and vertical slightly divergent ridges. Some specimens have proeminent main ridge. Most vertebra preserved only the centrum while the neural arch is broken. The vertebrae centrum is cross rounded in section and has anterior and posterior articular surfaces flattened and slightly concave. The ribs are curved and fragmented. Only two ribs conserved proximaly capitulum and tuberculum which are slightly rounded. Two ischium preserve a fragment from median and one from proximal part. Humerus is incomplete with a broken delto-pectoral crest being more robust than NVZ4 (Godefroit et al., 2009). A complete femur, a distal end and a shaft were collected from Vurpăr where *Zalmoxes* remains are dominant. VP-31 can be attributed to *Zalmoxes shqiperorum* species by the following characters: arching the body and the presence of a similar femoral elongated femoral head, narrow than that of *Zalmoxes robustus* species (Weishampel et al., 2003). Compared with NVZ29 (Godefroit et al., 2009) it presents the femoral head and neck elongation relatively gracile, while the great and anterior trochanter are similar in shape. The best preserved tibia is VP-10 which presents an arch of the shaft in anterior and posterior views.

Class: Aves LINNAEUS, 1758

?*Aves* indet.

Occurrence: Oarda de Jos (ODAN).

The material include teeth and one fragment. Teeth are represented by two morphotypes. First is pointed and presents posteriorly a small-size cusp. Second is curved backward. With lateral faces slightly concave and apex rounded. The fragment dispose two condils with the medial one slightly expanded and backward. It can be can be assigned to a tibio-tars.

Class: Mammalia LINNAEUS, 1858

Family: Kogaionidae RĂDULESCU & SAMSON, 1996

***Kogaionidae* indet.**

Occurrence: Oarda de Jos (ODAN).

The inventory consists of isolated teeth from maxilla and mandible. Among them the M1, represented by 9 pieces, presents a diagnostic value for Kogaionidae. The molars have a relatively rectangular shape and the cusp rows are separated by a V-shaped longitudinal valley. The cusps formula is 3:4:2, which differentiates them from g.*Kogaionon* whose formula is 3:4:3 (Rădulescu & Samson, 1996). The absence of one cusp on the lingual row may be an argument for a distinct species present in Metaliferi area.

Eggshells

Occurrence: Oarda de Jos (ODAN, ODAX).

Numerous fragments of eggshells were collected by screen-washing technique and do not exceed 1 cm in size. There were four morphotypes assigned. The first one shows columnar shaped crystalline units with tubocanaliculate pore system. The cross section displays a discretispherulitic microstructure. External and internal morphology indicates the dinosauroid tubosferulitic type. The second present the crystallin unit larger than type 1 with the top more expanded than the bottom and it can be asigned to dinosauroid prolatopherulitic type. The external surface of the third type presents pattern of craters and different sized tubers rarely being connected through a ridge. In the section, the eggshells presents two to three layers. This morphology indicate a geckonoid type. The fourth is similar to type three but the most craters are interconected with ridges.

Chapter 5 - Taphonomy

Facies types with vertebrate remains

The main sedimentary facies, in which remains of Cretaceous vertebrate fossils were found, at Vurpăr, Stăuinii Valley, Oarda de Jos and Sebeş is represented by silt and red clay or brownish-red deposits with frequent limestone concretions. These are interpreted as well drained alluvial plain deposits with pedogenetic changes (Therrien, 2005; the 5 category

described by Therrien et al., 2009). At Oarda de Jos the fossil remains also appear in silt and clayly greenish - gray deposits and are interpreted as poorly drained alluvial plain deposits with rare carbonate concretions interpreted as pond deposits or small abandoned channels (the 2 paleosol category - Therrien et al., 2009). In Vurpăr and Oarda de Jos sites fossil remains are also found in microconglomerates or sands with cross stratification which presents at bottom an erosion surface interpreted like a minor channel deposits whith low energy. Vertebrate remains appear at Lancram in massive coarse sand and conglomerates and cross stratification which could be interpreted as a major channel deposits and high-energy lags.

Descriptive and quantitative taphonomy

In the study area, the fossils were found in three taphonomical mode: partial skeletons were found in two accumulations in Vurpăr (Codrea et al., 2010a), isolated bones (the main mode) and accumulations lens-like microvertebrates at Oarda de Jos.

From the Metaliferi area, for the fossil record included in this thesis and for each site, the shape of the remains was considered. Thus, the total number of pieces under study is 2579.

Four sites (Sd, Vs, TA, RL) were excluded from this analysis due to the very small pieces. A predominance remains can be observed in six sites (OdA, OdB, ODAN, LcA, LcB, SB) with elongated shapes which comprise in majority appendicular skeleton parts preferentially oriented by the axis.

Compact shapes are mostly represented as vertebrae (mainly found in Vurpăr site) and followed by teeth (ODAN is typical for teeth). At Râpa Roşie the pieces exceed in compact shape but this is relatively because in this analisys the unidentified remains were also taken.

The flattened shapes are thin with a large surface and they are well represented in Oarda de Jos lens. These include in particular garfish scales and chelonian plate fragments.

The size of fossil remains

The first category in which the predominant bone remains are less than 0.5 cm (67.71%) considered mainly in Allocaudata, Anura indet. and Lacertilia indet. They are represented in one location at Oarda de Jos lens (ODAN). In fact, the most pieces at the Oarda de Jos lens (94.15%) preserve a size less than 1 cm, the remaining of the bones representing a proportion less than 2%. The second category contains elements ranging from 5-10 cm and include the following sites: Vurpăr (26.39%), Oarda (OdA: 31.58%) and Lancrăm (LcA: 42.86%). Remains with dimensions between 10 and 20 cm are in majority in Oarda (OdB: 37.50%), Lancrăm (45%) and Sebeş (24.39%). In these sites remains predominantly belong to the appendicular skeleton.

The largest fossil remains were collected from Vurpăr, Lancrăm, Sebeş and Oarda: UBB VP-26 - ankylosaur femur = 20.43 cm, UBB VP-31- sauropod femur = 34.74 cm, UBB VP-10- euornithopod tibia = 33.21 cm, UBB SB-5- euornithopod fibula = 28.66 cm, UBB LcB-5- sauropod femur = 44.35 cm, UBB LcB-18- sauropod femur = 47.55 cm şi UBB Oda-2- hadrosaur femur = 40.85 cm.

Abrasion. This analysis provided a qualitative measure of time and transport distance before burial. Categories considered in this study were defined by Fiorillo (1988).

For the analysis all the sites from where the fossils were collected were taken into account. Sites preserves predominantly fragments classified in abrasion class 1 reflecting subraerial exposure on the surface, followed by transportation to a certain distance excepting the Râpa Lancrăm.

The most representative locality in this point of view is Vurpăr. Some pieces show a very well preserved shaft, abrassion tracks but devoid distal or proximal parts. This can be interpreted as a result of transport or erosion due the high pneumaticity of articular surfaces, especially of long bones. Another causes could be the action of predators.

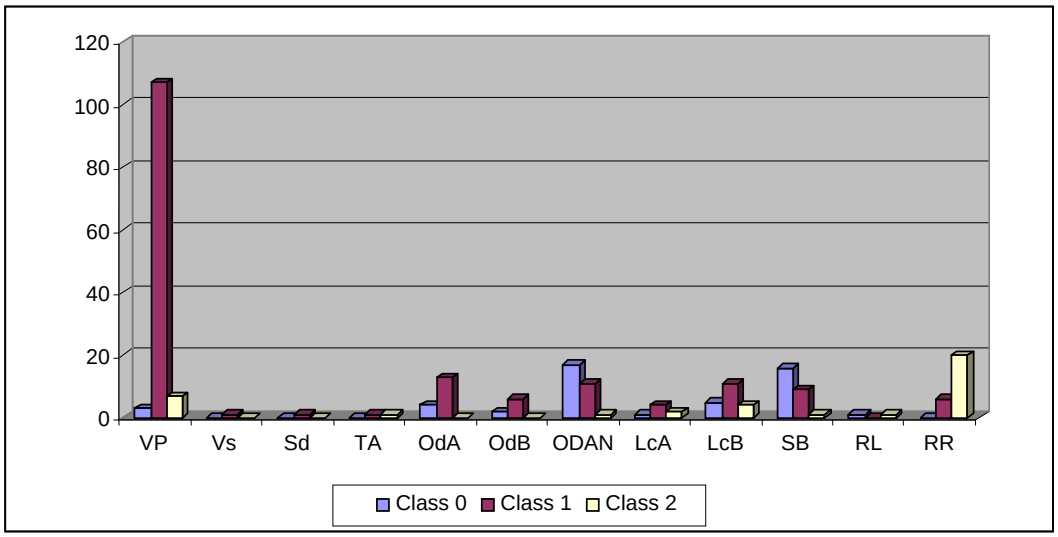

Figure 3 – Representation of abrasion classes in the Metaliferi area localities (n=256).

In Sebeş and Oarda de Jos lens (ODAN) most remains were slightly or not affected by abrasion (class 0), the alternative being the mild abrasive (class1). An exception is Râpa Roşie site where predominantly remains whith high abrasion are located (class 2; fig.3).

Fragmentation. Estimating the fragmentation degree is relatively subjective. Most collected remains from the Metaliferi sedimentary area shows a medium preservation, only a part of them is fully preserved (e.g. OdA-7, VP-31). Long bones, especially in the

appendicular skeleton ones (femurs, tibiae, ulnae, fibulae) shows the entire length of the median body and a variable number of cracks depending on piece's length and mostly the articular ends are broken. Another example is represented by turtle carapace which due to poor junction between plates can be very easily shattered if it didn't suffer a rapid burial. Also, due to rock overburden shattering can occur on long fragment remains or turtle plates, where cracks or fractures appearance are filled by sediment or calcite.

Macroperforations. Remains bearing any bite trace are rare in the Metaliferi area. Such traces were found on a *Telmatosaur* femur (UBB OdA-2) of site A from Oarda de Jos (Codrea et al., 2003; Codrea et al., 2010a). The "perforations", disposed in the proximal part, are circular and most probably were caused by a crocodile argumented by numerous remains found in this location, being the only large predator in the studied area. Also, bite traces were identified on two vertebrae at Vurpăr.

Weatherings. Cracks and flakings. To study the bone surface, different classes were used and proposed by Astibia et al. (1999). Analysis include 256 pieces of which 90% are classified as class 1 indicating a short period of subaerial exposure before burial. Vurpăr and Oarda outcrop A preserve the highest percentage of pieces affected by weather (class 2) indicating a longer subaerial exposure.

The most remains from Alba area preserved cracks and fissures, predominantly being the transverse and longitudinal ones. The most affected pieces are the limb bones which present fissures and transverse cracks on the shafts (femurs, tibiae, etc.).

Pieces with flat surfaces, such as the humerus, often present a network of mosaic like cracks. Another characteristic of fossil remains from Metaliferi area is the development of calcareous concretions on their surface. Recovered remains from Oarda, Lancrăm or some pieces from Vurpăr, included the first category, while the second category include some remains from Vurpăr and rarely from Oarda. This deposition is due to particular conditions occurring during fossilisation, when the burial and the decomposition of organic matter leads to the formation of an anoxic environment, especially in the alluvial plain deposits low or well drained (Allison & Pie, 1994; Varricchio et al., 2008).

Chapter 6 - Paleoecology

From twelve different localities, a variable number of Maastrichtian vertebrate remains was collected from the Metaliferi area (Fig. 4).

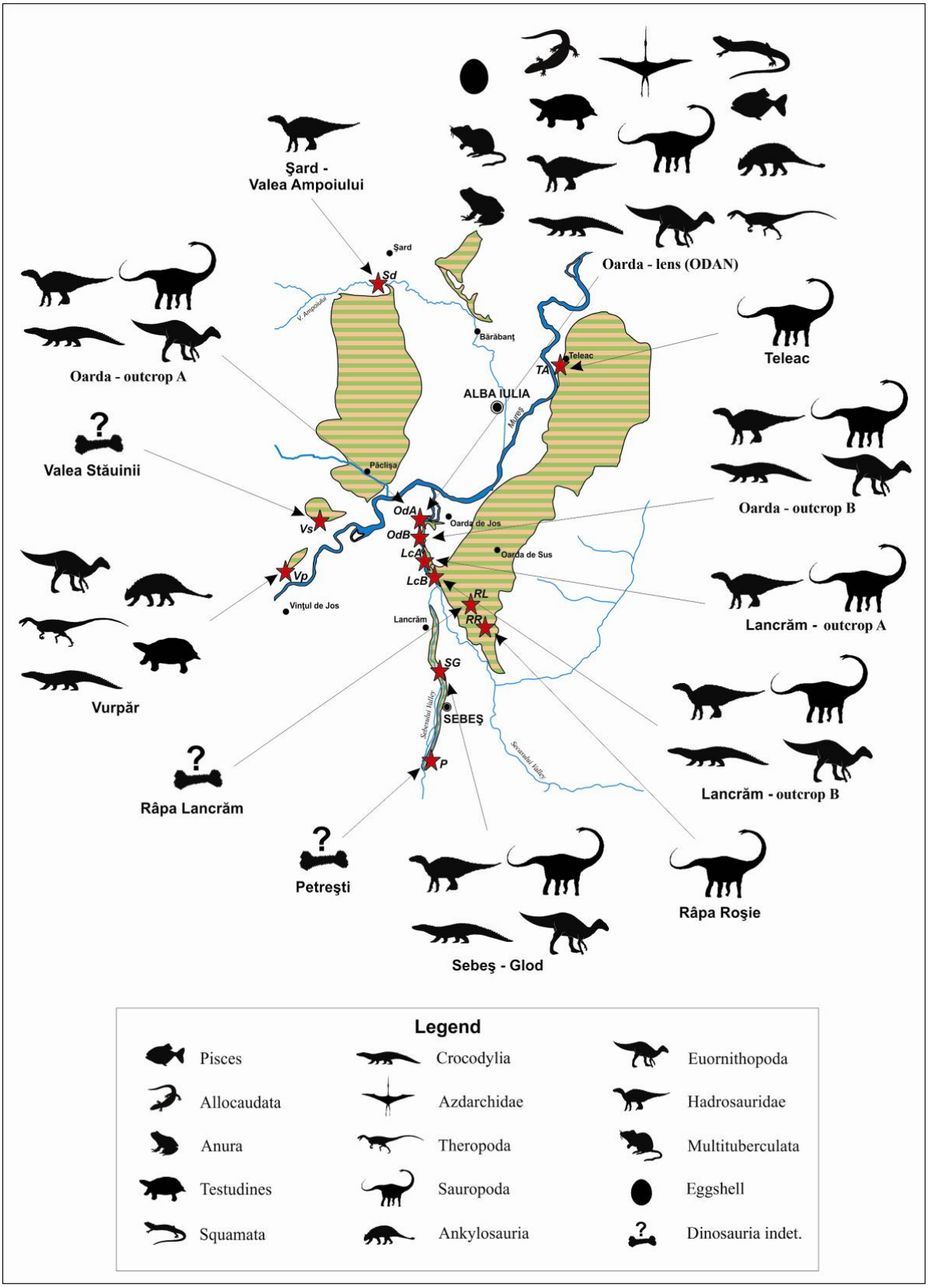

Figure 4 - Relative biodiversity of Upper Cretaceous vertebrates from Metaliferi area.

The discovery of Upper Cretaceous lens with microvertebrates at Oarda de Jos, representing the only location of this type from Metaliferi area, was an important factor in defining and modelling the assemblage of vertebrates in the study area. In the lens, larger elements appears with a relatively low frequency probably from decomposing carcasses around it.

Thus, the overall association is made of 14 groups of vertebrates represented by 2515 pieces, from which 2239 pieces were discovered in Oarda de Jos lens. To these are added the eggshells group. The diagrams were made by distinguishing sites in which macroremains appear - mainly dinosaurs and those with microremains represented by one location, the lens from Oarda de Jos lens (Fig. 5 and 6).

From several localitie such as Valea Stăuinii, Râpa Lancrăm and Petreşti, unidentifiable bone elements were recovered and assigned to Dinosauria indet. based on other reports (Codrea et al., 2010a; Vremir, 2010).

The vertebrates association from Şard, Teleac and Râpa Roşie has a low number of taxa compared to the one from Vurpăr, Oarda de Jos, Lancrăm and Sebeş which has a high number of taxa. The vertebrates include dinosaurs such as theropods, pterosaurs, sauropods, ankylosaurs, euornithopods and hadrosaurs being found in a varied proportion in different sites. Other groups of vertebrates are represented by crocodiles and turtles.

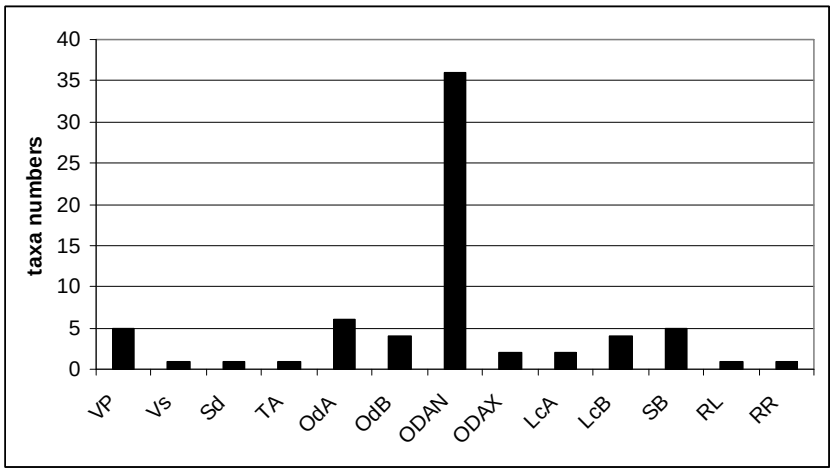

Figure 5 -Histogram representing the relative number of taxa on each site from the Metaliferi area.

The number of taxa present in sites is different, not being in relation with the number of remains collected. An example is the site from Oarda A (OdA) from which 7 pieces were

collected and assigned to 6 taxa, while in the site from Vurpăr 127 pieces belonged only to 5 taxa (Fig. 5).

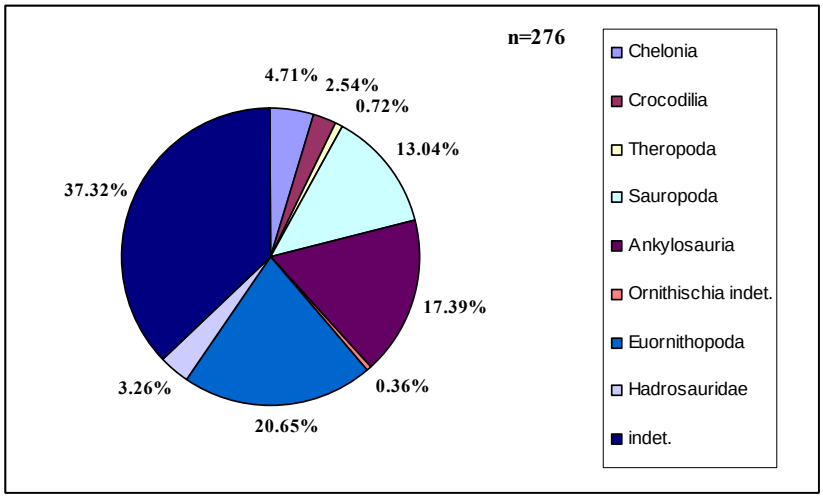

Figure 5 - Relative taxonomical frequency from Metaliferi area sites. The lens from Oarda de Jos is not included.

The largest relative number of taxa (36) is identified from Oarda de Jos lens (ODAN). One taxon is present in each site from Stăuinii Valley, Şard, Teleac, Râpa Lancrăm and Râpa Roşie. This difference between the number of taxa from sites reflect different paleoenvironmental conditions.

A remarkable vertebrates association is present in the Oarda de Jos lens where there is the largest diversity in the study area. This includes, besides the above mentioned vertebrates and pisces, amphibians, lizards, birds and small mammals (Fig. 6).

From microvertebrates the anurans represent 38.95% of total pieces collected and identified which include elements belonging mainly to appendicular and axial skeleton. Among dinosaurs a predominance of euornithopods (20.65%) and ankylosauri (17.39%) can be noticed especially in Vurpăr. Other euornithopods remains were collected from the Oarda A (1 piece), Oarda B (1 piece), Lancrăm A (1 piece) and Sebeş (2 pieces) sites. Using screen-washing technique 8 isolated teeth were recovered from Oarda de Joss lens. If we consider the number of pieces, it can be concluded that the remains of euornithopods (*Zalmoxes*) are the most abundant dinosaur in the whole Metaliferi area. Dinosaur fauna also includes a hadrosaur (*Telmatosaurus transsylvanicus*), belonging to a commonly group present in the Upper Cretaceous dinosaur assemblages from the entire world.

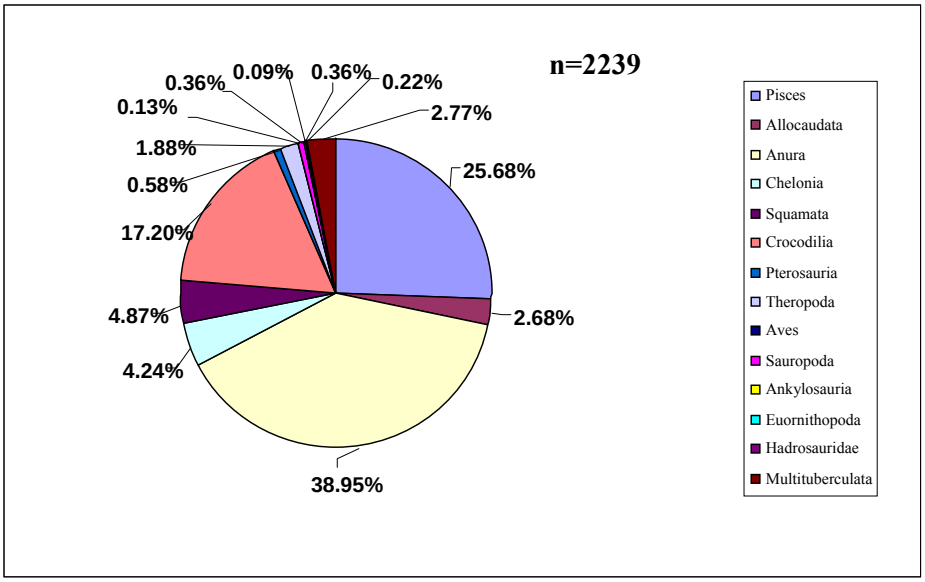

Figure 6 - Relative taxonomical frequency in Oarda de Jos lens.

Based on their habitats vertebrates are divided into: aquatic, semi-aquatic and terrestrial.

Aquatic vertebrates are represented by fishes and they are only found in Oarda de Jos lens. The recovered elements include teeth, scales and vertebrae assigned to Lepisosteidea and Characiformes.

Semi-aquatic vertebrates include frogs, lizards, turtles and a part of crocodiles which present an addiction to water courses or ponds areas. Semi-aquatic crocodiles are represented by two taxa: *Allodaposuchus precedens* and *Acynodon* sp. The first one, with a high frequency could reach large sizes and it was the largest predator in the whole Mealiferi area if we bear in mind the number osteological remains and their size.

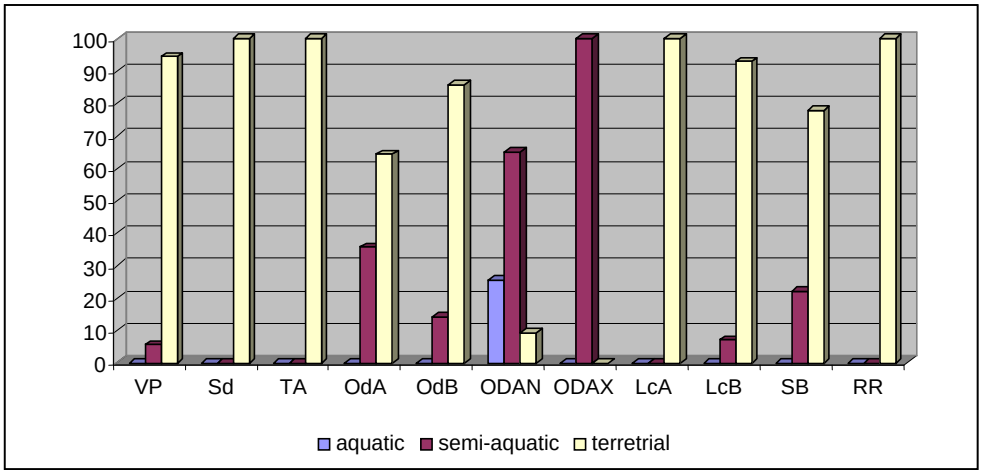

Figure 7 - The relative frequency of vertebrates on each site from Metaliferi area based on their habitat.

The most remains are collected from the Oarda de Jos site, where the most complete *Allodaposuchus* skull was found (Delfino et al., 2008).

Based on their diet the Cretaceous vertebrate groups present in the Metaliferi area are divided into: carnivores, herbivores, omnivores and invertivores. Terrestrial vertebrates are represented by dinosaurs, pterosaurs, birds and small mammals. Dinosaurs include sauropods, theropods, ornithopods and ankylosaurs and they are predominant vertebrates associations in the majority of Cretaceous sites from the Metaliferi area (Fig.7).

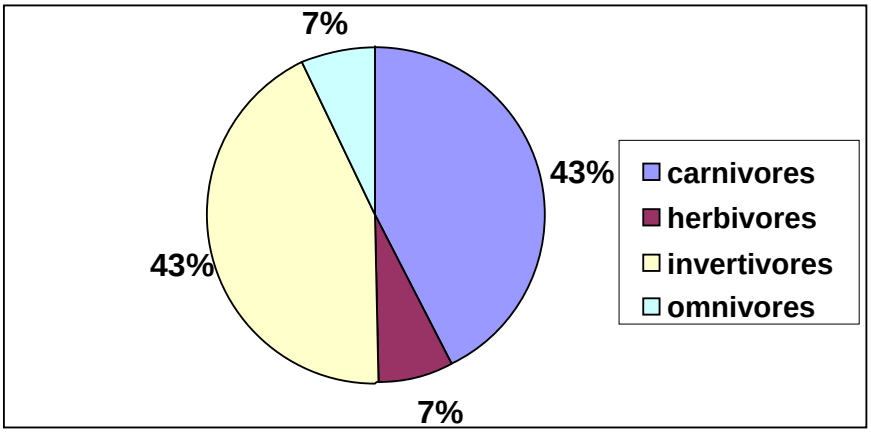

Figure 8 - The relative distribution of vertebrates from Metaliferi area based on their diet.

Taking into account the number of pieces collected, carnivores and invertivores represent the majority groups in the Metaliferi area (Fig.8). Such representation is very relative and inaccurate because the number of crocodile teeth and turtle plates create a huge gap with remaining vertebrate groups. Therefore, this distribution regarding the diet, in each site indicates that the herbivores are dominant, except the Oarda de Jos lens where the the majority consists of invertivores (Fig. 9).

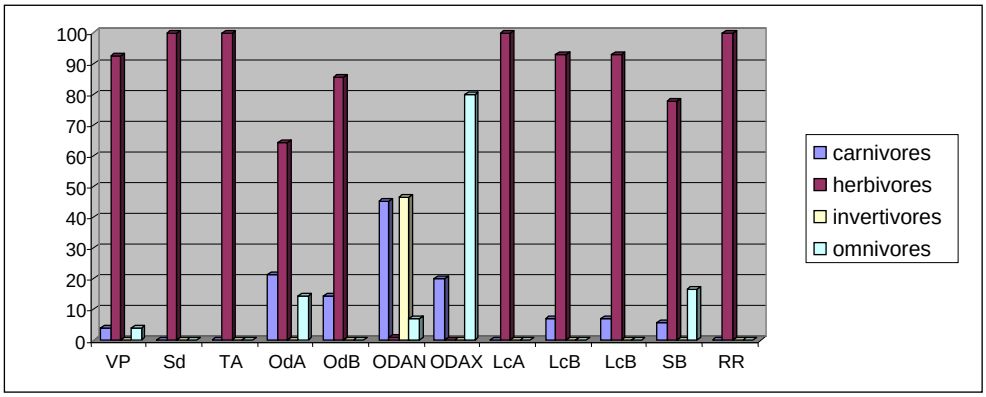

Figure 9 - The relative frequency of vertebrates on each site from Metaliferi area based on their diet.

Evaluation of vertebrates biodiversity from the Metaliferi area involved counting the identified fossil remains (NISP), identification of present species on each site (NSP), identification of the number of each species individuals (NMI) and determination of Shannon and Simpson biodiversity indices.

The first indicator of biodiversity is the number of species but it is relative because it is considered that the number of species is equal to osteological representative element. The errors occur when a taxon, being difficult to estimate the number of species, is represented by a large number of remains of the same element such as vertebrae, isolated teeth or turtles plates.

Tabel 1 - The qualitive analysis of the vertebrates association on each site from Metaliferi area. Abreviations: NISP - the number of identified specimens; NMI - the minimum number of individs; NSP - the number of species.

	VP	Sd	TA	OdA	OdB	ODAX	ODAN	LcA	LcB	SB	RR
NISP	107	1	1	12	7	5	2239	3	14	18	5
NMI	8	1	1	6	4	2	78	2	8	9	2
NSP	5	1	1	6	4	2	36	2	4	5	1
Shannon index	0.984	0	0	1.474	1.154	0.5	1.67	0.637	1.091	1.165	0
Simpson index	0.569	0	0	0.694	0.612	0.32	0.747	0.444	0.612	0.58	0

Taking in consideration the number of remains identified, they allow the establishment of diversity indices such as Simpson and Shannon. The Simpson index keeps track of both number of species and it's proportion in the association, being sensitive to the equitability of taxa distribution. When the diversity values approach to 0 it means it belongs to a heterogeneous ecosystem and when the values are close to 1 it corresponds to a homogeneous ecosystem (Gregorius & Gillet, 2008).

For the Metaliferi area we can observe a balance between faunal associations of various sites and the most diverse and balanced site is represented by the Oarda de Jos lens (Table 1).

Skeleton elements

A total of 276 macroremains were collected from 12 Cretaceous sites from the Metaliferi area except the Oarda de Jos lens which will be analyzed separately. Among these, 59 pieces (21.38%) do not show morphological features that allow systematic identification.

The most abundant skeletal remains are represented by vertebrae (21.38%), ribs (12.68%) and dermal elements (6.52%). The less frequent are isolated teeth (2.90%) and cranial fragments (1.45%).

From Oarda de Jos lens (ODAN) there were over 3,000 pieces recovered of which 2239 parts were identified. The most remains collected are isolated teeth, from which the most numerous being the crocodilian assigned to the three taxa and by fish (Fig.10).

	ODAN
teeth	807
cranial frag.	122
vertebrae	267
chevrons	3
ribs	1
scapulae	14
iliums	122
ischiums	23
pubis	3
femurs	114
tibiae	94
ulnae	112
phalangs	30
osteoderms	252
humerus	117
urostyles	42
coracoids	26
turtle plates	90
total	**2239**

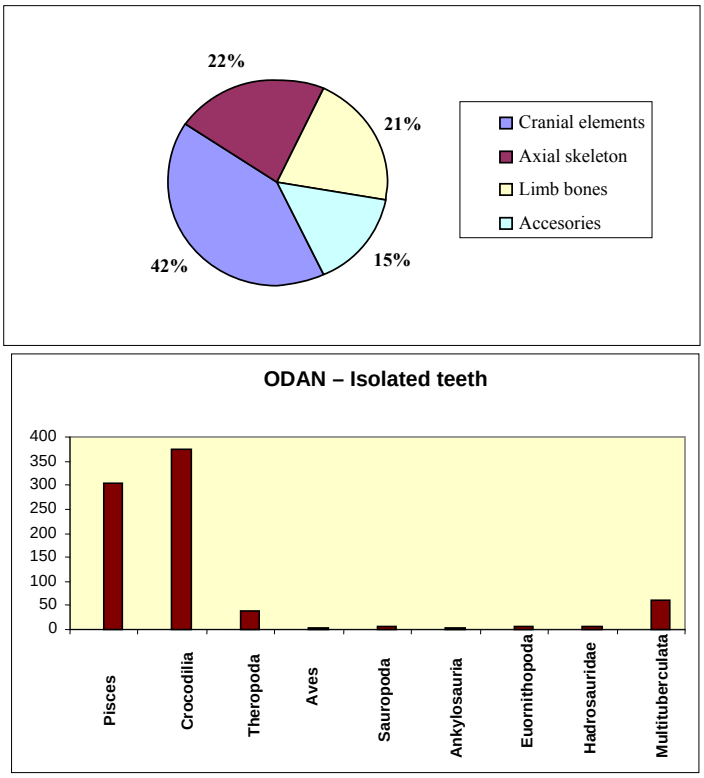

Figure 10 - Collected remains from the Oarda de Jos lens with the graphic representation of the main osteological groups and isolated teeth.

Chapter 7 - Paleobiogeography

Many global paleogeographical reconstructions (e.g. Scotese, 2004) and Europe (e.g. Dercourt et al., 2000) during the Upper Cretaceous allowed a better knowledge of the paleogeography where the "Haţeg Island" fauna has evolved also including the Metaliferi area. Recent studies on biogeographical origins of European vertebrates were made by Pereda-Suberbiola (2009) in which there can be included taxa presents from Haţeg Basin. Thus, with laurasian affinities (sensu Russell, 1993) are albanerpetontids, discoglossids, paramacellodids lizards, crocodilians and basal oviraptosaurs and euramericans for alligatoroids and nodosaurids and some endemic taxa (*Kallokibotion*, dortokids, rhabdodontids, kogaionids).

Taxa with gondwanian affinities are considered the madtsoiids, sebecosuchian crocodilians and titanosaurid sauropods. Based on faunistic and phylogenetic analysis taxa, Weishampel et al. (2010) established paleogeographic connections of present taxa from the Haţeg Basin which are also found in Metaliferi area.

The lepisosteidae are a group of fish showing originar forms in Gondwana, being frequently found in the South America and also in Europe (Cavin & Brito, 2001). Reported from Cretaceous sites from France, Spain and Portugal, the presence of this group in Europe was produced by the phenomenon of dispersion.

Characids with diversification during Cretaceous, are represented by a very poor material. All extinct species of this group include freshwater forms. With gondwanian origins, it's possible that during the Early Cretaceous land bridges might conected Europe and Africa and the representatives taxa of this group had came by dispersion (Otero et al., 2008).

Chelonian taxa presents in the Upper Cretaceous deposits from România are considered endemic. Regarding dortokids turtle, they show accurate distribution after the North Atlantic opening.

During Upper Cretaceous, Europe was dominated by eusuchians, mentioned especialy from the northern part of Spain and southern France, but also from Romania. The presence of *Allodaposuchus genus* in Europe still raises many questions about its origin (Buscalioni et al., 2001). The only non-eusuchian taxa present in Romania is *Doratodon* which show Gondwanan affinities (Pereda-Suberbiola, 2009).

Geographical distribution of *Zalmoxes genus* indicates a spreading by vicariancy, on a route between Western Europe and North America, while the distribution of *Telmatosaurus* endemic genus show laurasian affinities (Weishampel et al., 2010). With an uncertain phylogenetic position, *Struthiosaurus genus* curently is considered to have origins in North America.

The Kogaionidae multituberculates have a restricted distribution to the Maastrichtian Haţeg Basin, Rusca Montană Basin and Metaliferi area (e.g. Rădulescu & Samson, 1996; Csiki & Grigorescu, 2002; Codrea et al., 2002a, 2009, 2010a; Smith et al., 2002; Csiki et al., 2005) and Paleocene widely spread in Spain, Belgium, France and România (Vianey-Liaud, 1979; Gheerbrant et al., 1999). Cladistic analysis realised assigning the kogaionids as the most basal group of cimolodont multituberculates represents an endemic group with euramerican affinities (Csiki & Grigorescu, 2006).

The most of taxa present in România were small-sized due to adaptation to island living environment. Exepting theropods which have gondwanian affinities, the remaining genera present have laurasian origins (Pereda-Suberbiola, 2009; Weishampel et al., 2010).

Paleogeographical reconstructions show that the Late Cretaceous paleoenvironment from România was characterized by a climate where the seasons alternate by dry and rainy ones, as it is in the present in Asia with many flood plains localised around the meandering or braided rivers.

The paleosols encountered at Vurpăr as Nălaț-Vad and Pui from Hațeg Basin are mature showing stable areas with moderate or intense flood plains (Therrien, 2005).

Paleogeographical reconstructions made for Europe in the late Cretaceous include "Hațeg Island" in an archipelago which also include the Metaliferi area (Dercourt et al., 2000). The Baron Nopcsa (1914, 1923) was the first who supported the idea of insular evolution of Cretaceous vertebrates fauna from Hațeg Basin, argued by the low taxonomic diversity, retention of primitive characters and small sized taxa compared with the species and genera discovered on other continents.

Subsequent studies based on morphometric and histologic analysis proves the dwarfism of the dinosaurs in our country (Weishampel et al., 1991, 2003; Jianu & Weishampel, 1999; Stein et al., 2010; Benton et al., 2010). Deciphering this dwarfism insular phenomenon and the possible cases where research of several articles and books, which provided usefull informations through parallelization of the Cretaceous fauna with Pliocene, Pleistocene, Holocene one or current types like elephants, deers, hippopotams and other herbivores from Mediterranian zone (Lomolino, 2005; Benton et al., 2010).

In the Upper Cretaceous, regarding " Hațeg Island " the most likely cause of dinosaurs dwarfism was limited food resources and the presence of three groups of herbivores (titanosaurid sauropods, hadrosaurids and euornithopods) on the island (Benton et al., 2010).

Chapter 8 - Conclusions

The present thesis aimed to study the vertebrate assemblages from Metaliferi area and the taphonomic and paleoecologic interpretation of this fauna. The research was made differently, by distinct methods for macrovertebrates and microvertebrates. Regarding the macrovertebrates, the study included the inventory of existing remains in the Paleotheriology Laboratory from Biology-Geology Faculty of Cluj-Napoca (UBB), while new fosils were

collected during field campaigns at the main sites, and processed in laboratory and taxonomically assigned.

The discovery of microvertebrates accumulation at Oarda de Jos in the summer of 2007, performed by a team of paleontologists from the Faculty of Biology-Geology (UBB, Cluj-Napoca) – as the first reported site with microvertebrates from the Metaliferi area, was completed by collecting and processing a quantity of 2400 kg of sediment using screen-washing technique in the laboratory. Over 3000 remains recovered, thus, being evidentiated a remarkable diversity of terminal Cretaceous vertebrates, enriching the range of taxa present in the Metaliferi area. In addition to vertebrate, there were also invertebrate recoveries which were represented by gastropods, charofite, ostracoda and crab chelipeds.

Systematic analysis of the remains revealed a biodiversity of taxa, similar to the one found in the Haţeg Basin. The studied vertebrate assemblage include both large vertebrates (dinosaurs) and small vertebrates, belonging to 15 groups, some of which were first reported in this section: fishes (Lepisosteidae, Characiforme), "salamanders-like" (Allocaudata), frogs (Anura), lizards (Squamata) and theropods (*Richardoestesia* sp., ?*Paronychodon* sp.).

The only location where fish bones were collected is Oarda de Jos lens, including isolated elements such as: teeth fragments, ganoid scales and several vertebrae more or less fragmented. Remains were assigned to two families: Lepisosteidae and Characidae.

Garfish are represented by different types of teeth belonging to four morphotypes based on morphological and dimensional criteria. The characteristics of teeth argue the presence of ?*Lepidotes*, *Lepisosteus*, *Atractosteus* or Lepisosteide indet. Rhomboidal-shaped scales covered by ganoin and opistocelic vertebrae can be attributed to the same family.

The remains of Characidae are documented by a low number of pieces, represented exclusively by teeth, which however are rare in the Europe during Cretaceous. Teeth were classified according to the number of cusps in two morphotypes with two or three cusps. The new location from Oarda de Jos outstands by the number of fossil fish bones collected, of the Lepisosteidae and Characidae (inventory includes 575 pieces) being the most important and richest localion in the late Cretaceous of România.

Material belonging to albanerpetontids found in Oarda de Jos lens includes 60 pieces: cranial elements, vertebrae and limb bones. The importance of the bone remains are given by novelty and variety, revealing more information on the association of vertebrates that lived in this area in the Upper Cretaceous. The Alba material probably represents two new species of the genus *Albanerpeton* (James Gardner, written communication).

Material belonging to anurans from Oarda de Jos includes 872 bones, being the best represented vertebrates. Morphology of some elements such as jaws, iliums, scapulae or urostyles indicates the presence of Discoglossidae. The most important pieces are the ilium fragments which present distinct morphological differences in the dorsal crest, differences in size of supraacetabular and acetabular fossa which would indicate the presence of different taxa.

Fossil remains belonging to turtles in the Metaliferi sedimentary area can be assigned, according to morphology, in two groups: Cryptodira and Pleurodira. The first group is found at Oarda de Jos, Sebeş, Vurpăr and is a frequent presence in Haţeg Basin sites. The second group includes fossil related to the Dortokidae.

Numerous fragments of maxillae, premaxillae, vertebrae and limb bones belonging to Lacertilia indet. were recovered from the Oarda de Jos lens. Based on tooth morphology, there were several different kinds of lizards attributable to: g.*Becklesius*, g.*Bicuspidon* or Squamata indet. The probable presence in the site from Oarda de Jos two genres - g.*Becklesius* and g.*Bicuspidon* - known so far only from Haţeg Basin, it is not unexpected. In other words, the association of lizards discovered in the lens is comparable to that reported one from the Haţeg Basin, with a similar variety but different taxa.

The material from Alba area belonging to the crocodilians includes isolated teeth, frontals, vertebrae and osteodermes. The teeth, as the most numerous elements, whit a variety of morphologies, can be attributed to species *Allodaposuchus precedens*, g.*Acynodon* and g.*Doratodon*. Two frontals of some juvenile specimens found in the the Oarda de Jos lens can be attributed to the genus ?*Allodaposuchus*, based on morphology and the type of ornamentation. The remains and their morphological diversity raise ome difficulties in assessing faunal diversity of the crocodiles in Alba assemblages. However, it can be concluded that crocodiles faunas occupied an important position in ecological niches, the group being the main predator from this area if we rely on the number of the remains found in comparison with the second group of predators - theropods, very poorly represented.

The probable presence of an azdarchid pterosaur Oarda de Jos lens is documented by two fragments of mandible / maxilla being the first records of this kind in Metaliferi area. The material of small pterosaurs from the Oarda de Jos lens enriches the diversity of vertebrates from the Upper Cretaceous from Transylvania and documents their presence in continental environments.

The material belonging to theropod dinosaurs found in the Metaliferi area is fragmented and isolated. The osteological inventory contains predominantly isolated teeth and an ungual

phalanx recovered from the Oarda de Jos lens which were atributed to g.*Richardoestesia*, g? *Paronychodon*, Dromaeosauridae indet. and Theropoda indet. Two pieces (one humerus and one ?pubis) which belong to these dinosaurs were collected from Vurpăr. Tooth size indicates the existence of small theropods, which were predominant, while the presence of ungual phalanx discovered next to the teeth would indicate the presence of a larger specimen.

Assigning to the Aves based on external morphology of three isolated teeth remains an open discussion. They distinguished two morphotypes. First is gracile and has a very sharp tip and accessory cusp - an argument for assigning the Aves indet. Second doesn't present denticuls on neither of the hulls and is more robust, taxonomic position remains uncertain and being able to be attributed to the theropods too. The Upper Cretaceous birds material discovered in România nowadays include only limb bones remains, the presence of dental remains not being signaled .

The fossil inventory belonging to sauropods contains 47 pieces collected from 8 sites, all being isolated remains with a higher or lower fragmentation degree. Isolated teeth collected from Oarda de Jos lens, assigned to titanosaur sauropods, are the first report of its kind in the Metaliferi area.

The material atributed to the species *Struthiosaurus transylvanicus* was collected from Vurpăr from red beds and includes both elements of the axial and appendicular skeleton. The rather large number of osteoderms discovered (17 pieces) with different shapes and sizes can play an important role in restoring the species that lived in " Haţeg Island ".

An attention must be focused on the humerus (VP-12), as being the first reported piece of its kind in Romania. Identification and comparison of the skeletal element with similar material was difficult, the remains of nodosaurids from Upper Cretaceous of Europe being fragmented, isolated and rare. The Vurpăr fragment shows a morphology close to that *Sauropelta edwardsi* species's humerus, an ankylosaur found in North America. The humerus which was found at Vurpăr can help for defining the species from our country.

The euornithopods material found in the study area comprises predominantly fragmented and isolated bone parts, except for an accumulation of the Vurpăr. The inventory is composed of elements from the axial skeleton (vertebrae, ribs) and limb bones (femur, tibia) some being in connection. From the Oarda de Jos lens, using the screen-washing technique, there have been recovered a total of eight teeth with obvious traces of transport.

The recovered bones belong to some juvenile specimens or subadult and we have given them preliminary to *Zalmoxes*. The inventory comprises of 58 pieces, confirming *Zalmoxes* among the herbivores in this area.

The *Telmatosaurus transsylvanicus* osteological inventory of the studied Upper Cretaceous localities include both cranial and limb bones elements such as tibia, femurs and radius. Cranial remains are represented by a jugal from Sebeş and 5 isolated teeth from the Oarda de Jos lens. Of all Cretaceous herbivores present in this area, hadrosaurs are the least represented if the number of pieces found is taken as a criterion.

The multituberculate material found in the Oarda de Jos lens is represented only by isolated dental elements (62 pieces) which can be preliminary attributed, based on morphology, to Kogaionidae. This finding from the Oarda de Jos lens will certainly contribute to a better understanding of Kogaionidae evolution.

Numerous egg shells fragments, which do not exceed 1 cm in size, were collected by screen-washing technique in Oarda de Jos site. External morphological analysis (observed on binocular) and internal crystalline structure (photographed with the electronic microscope) allowed identification of two morphotypes assigned to dinosaurs (tubospherulitic, prolatospherulitic) and two morphotypes assigned to lizards (type geckonoid).

Based on preliminary analysis of the studied osteological material, we conclude that the association of vertebrates from the Metaliferi presents similarities to the one described from the Haţeg Basin. Amongst microvertebrates, there are some remarkable groups of fishes, albanerpetontids, anurans and lizards which are represented by the most consistent material at Maastrichtian from Romania.

The taphonomic analysis focused on the size, form and degree of preserving fossils. Two classes could be distinguished by predominant sizes: the first in Oarda de Jos lens association, where 90% of specimens collected have a size of 1 cm, while the second class comprises of pieces from different sites with large vertebrates which are between 5-10 cm. In terms of form, remains have been classified into four categories, most of them having an elongated shape (predominantly limb bone) which are preferentially oriented after their long axis.

In the study area we have identified three taphonomic modes in which the fossils are found, each mode having a different value as a source of information for paleoecology interpretation: 1. partial skeletons from Vurpăr site in two accumulations, 2. isolated bones (predominantly) to Vurpăr, Oarda, Lancrăm, Sebeş, Râpa Lancrăm şi Râpa Roşie; 3. lens accumulation with fossil vertebrates from the Oarda de Jos.

The majority remains are assigned to the second class of abrasion which indicate a subaerial exposure on a surface, followed by a transport for a short distance, the most representative being Vurpăr. A feature of fossil remains collected from Metaliferi area is

represented by the development of carbonatic concretions on their surface, as a crust covering totally or partialy the bones.

Traces of predators activity were observed on a femur (ODA-2) from the Oarda de Jos, most likely caused by a crocodile as indicated by numerous remains found in this location and on two vertebrae (VP-121, VP-5) from Vurpăr.

The analysis of studied fossil material from Metaliferi area showed a balance at taxonomic level, between different locality assemblages, whilw the most diverse and balanced fossiliferous point represented by the Oarda de Jos lens. Paleoecological comparative studies realised through different histograms show a dominance of terrestrial vertebrates represented by the herbivores group. An exception to this is the of the Oarda de Jos lens, where the majority are semi-aquatic vertebrates with an omnivorous diet and subsidiary carnivorous.

After the Haţeg Basin, the Metaliferi area is the second area of importance to paleontologicaly document the association of Maastrichtian continental vertebrates in Romania.

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