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Taphonomic analysis of the Middle Triassic marine vertebrate assemblages from Lugașu de Sus and Peștiș (Bihor, North-Western Romania)

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Abstract. Two Middle Triassic marine vertebrate assemblages from Lugașu de Sus and Peștiș, North-Western Romania were analyzed. The marine reptiles have same representatives at Peștiș and Lugașu de Sus. Nothosaurids are more abundant at Peștiș, whereas the prolacertiform *Tanystropheus* is more frequent at Lugașu de Sus. Invertebrate fauna consist of crinoids, echinids, brachiopods and mollusks. Crinoids and terebratulid brachiopods are more common in the Lugașu de Sus fauna, bivalve diversity is higher at Peștiș, where terebratulids are missing and spiriferinid brachiopods occur. Qualitative and quantitative taphonomical analyses indicate different depositional environments for Lugașu de Sus and Peștiș bone-bearing deposits. Whereas the Lugașu de Sus marine assemblage has been deposited in a calm, low energy, lagoonal environment, the Peștiș assemblage has been accumulated in a near-shore, wave dominated, shallow marine environment.

Keywords: Taphonomy, marine vertebrates, Middle Triassic, North-Western Romania

Introduction

The marine Middle Triassic sites Lugașu de Sus and Peștiș are located near Aleșd, north-western Romania (Fig. 1). The Peștiș site was initially discovered in 1964 by geologist Dumitru Istocescu (Diaconu et al., 1965), during geological

mapping works. Istocescu reported the discovery to paleontologist Tiberiu Jurcsak from Țării Crișurilor Museum Oradea, who together with fossil preparator Elisabeta Popa, has performed several fieldtrips to Peștiș in order to collect samples of limestones and marly limestones with invertebrate and vertebrate remains for over a decade. In 1974 they discovered two other Middle Triassic outcrops with similar faunal content at Lugașu de Sus – Gruiu Pietrii and Valea Fruntii, named later as Locus Jurcsak and Locus Popa. A third outcrop at Lugașu de Sus, located opposite to Locus Popa, has been discovered by Radu Huza in 1992 and was named Locus Huza. The researches of these deposits were continued in 1995 due to a joint Romanian-French research project, when an excavation campaign took place. The field researches were led by Dr. Jean-Michel Mazin – University of Poitiers (at that time) and Radu Robert Huza – Țării Crișurilor Museum, with the participation of Elisabeta Popa, E. Posmoşanu – Țării Crișurilor Museum and Franck Métayer – University of Poitiers. These deposits have yielded a rich marine fauna consisting of vertebrates and invertebrates (Jurcsak 1973, 1975, 1976, 1977, 1978, 1982, 1987; Huza et al, 1987; Popa et al 1992; Posmoşanu, 2008). The history of the research is summarized in Popa et al (1996) and Posmoşanu (2008).

Taphonomical processes of these Triassic faunal assemblages have not been studied thoroughly. During initial research of these Middle Triassic fossil sites, little attention has been paid to the record of taphonomical field observations. There are only few notes on vertebrate taphonomy regarding the presence of tooth marks and related scavenging activity (Jurcsak, 1978). The aim of this paper is to provide qualitative and quantitative taphonomy of the Middle Triassic marine assemblage from Lugașu de Sus and Peștiș.

Material and method

The current taphonomical analyses is based on the examination of the Triassic material hosted in the collections of Țării Crișurilor Museum Oradea (MTCO), on field observations noted during the 1995's excavation campaign and on observations made during fossil preparation process.

The Middle Triassic collection of Țării Crișurilor Museum Oradea consists of over 1300 specimens from Lugașu de Sus and Peștiș including limestone samples with vertebrate and invertebrate remains, as well as prepared vertebrate or invertebrate specimens. Almost 57% of the specimens came from the Lugașu de Sus deposits and 43% from Peștiș. The main part of the collection comes from the 1969-1990 field campaigns, consisting of limestone samples that have been

excavated, in most of the cases without the full record of their sedimentological context, therefore the samples are somewhat biased. The samples are partly prepared, resulting over 450 catalogued vertebrate specimens, 49% coming from Peștiș and 51% from Lugașu de Sus. There might be other hundreds of vertebrate specimens in the unprepared samples, especially if we take into account the microvertebrate remains.

Institutional Abbreviation. MTCO – Țării Crișurilor Museum Oradea.

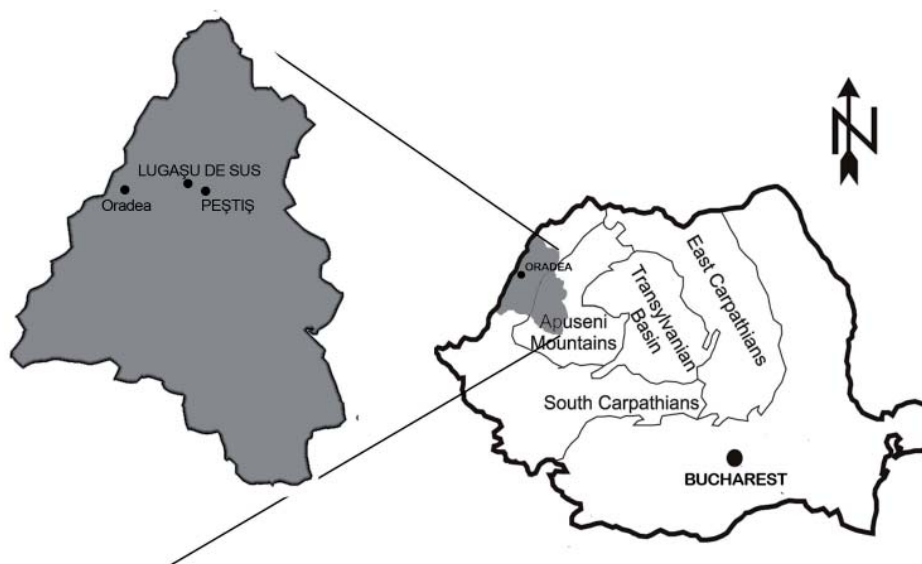


Fig. 1 - Location of Lugașu de Sus and Peștiș Middle Triassic vertebrate bearing site.

Lithological features

Lithological studies of the Triassic deposits in the area comprising Peștiș and Lugașu de Sus have been made by geologists of the Romanian Geological Institute during 1962-1970 (Diaconu et al, 1965; Istocescu et al, 1968). Istocescu et al. (1968) described the fossiliferous horizon in the North-Eastern area from Peștiș, consisting of greenish-grey marly shales, with thin black limestone intercalations. From these horizons they identified the following invertebrates: *Encrinus* sp., *Coenothyris* aff. *vulgaris*, *Aulacothyris incurvata*, *Myophoria elegans*, *Cuspidaria siliqua*, *Cassianella* sp., *Chlamys* cf. *asperulatus*, *Entolium* sp., *Modiola paronai*

and numerous vertebrate bone fragments, considering this horizon of Upper Anisian in age. They noted that this horizon is covered by grey limestones and dolomites of Ladinian age (Istocescu et al., 1968).

Jurcsak (1973) published his first paper on the Middle Triassic vertebrate fauna of Peştiş - Lion Valley, briefly describing the lithological aspects. The fossils were collected from bioclastic limestones and calcareous mudstones, which are covered by thin marly layers. Jurcsak (1976) mentioned further lithological features of the Middle Triassic deposit from Peştiş, respectively that at the base of the deposit there is a thin sandstone layer which contains some coal fragments. He noted that at Peştiş the bioclastic black limestone lumachelle frequently contained invertebrate and vertebrate remains (Jurcsak, 1976). Unfortunately, the Peştiş fossiliferous outcrop was destroyed during the road construction in the late '80s.

The Middle Triassic fossil bearing sediments from Lugaşu de Sus are represented by grey, layered limestones, which contain intercalated thin marly levels. The lithological descriptions of the two fossil deposits from Lugaşu de Sus (Gruia Pietrii and Valea Fruntii) were briefly mentioned by Jurcsak (1976). He noted that the rare vertebrate remains are preserved in grey weathered limestone slabs, covered by greenish marly shales.

Due to the French - Romanian research team, led by Dr. Jean-Michel Mazin and Radu Robert Huza, a summer excavation campaign took place in 1995, which allowed more detailed field observations. The lithology of the three fossil sites, namely: Locus Popa, Locus Jurcsak and Locus Huza, was examined and paleontological/sedimentological material from Locus Huza was collected.

Dr. J. M. Mazin and R. Huza have established 7 different layers for Locus Huza. The main lithological layers were noted consisting of grey micritic limestones, bioclastic limestones and thin marly levels (Fig. 2):

1. Grey micritic limestones with small veins of calcite, with fragments of bivalves and rare brachiopods, rare fragments of bones (0,14 m), displayed over a marly level
2. Grey micritic limestone, with some bioclasts, bivalve external moulds and isolated crinoids, scarce fragments of bones. There is a thin marly level at the base (0,10 m)
3. Oolitic recrystallised limestone, with brachiopod and rare crinoid remains, bioclasts and pyrite (0,28 m)
4. Black-greyish recrystallised limestone (0,17 m)
5. Oolitic and bioclastic limestone, with bone fragments, brachiopods and crinoids (0,18-0,25 m)
6. Grey micritic limestone (0,08 – 0,15 m) – no record of vertebrate remains

7. Oolitic recrystallised limestone, with bioclasts and pyrite (0,10-0,15 m)

8. Calcareous mudstone and fine micritic grey limestone (0,36 m)

The most abundant layer in vertebrate skeletal elements is layer no. 5, but isolated vertebrate skeletal remains were recorded from layer no. 1 and 2 as well.

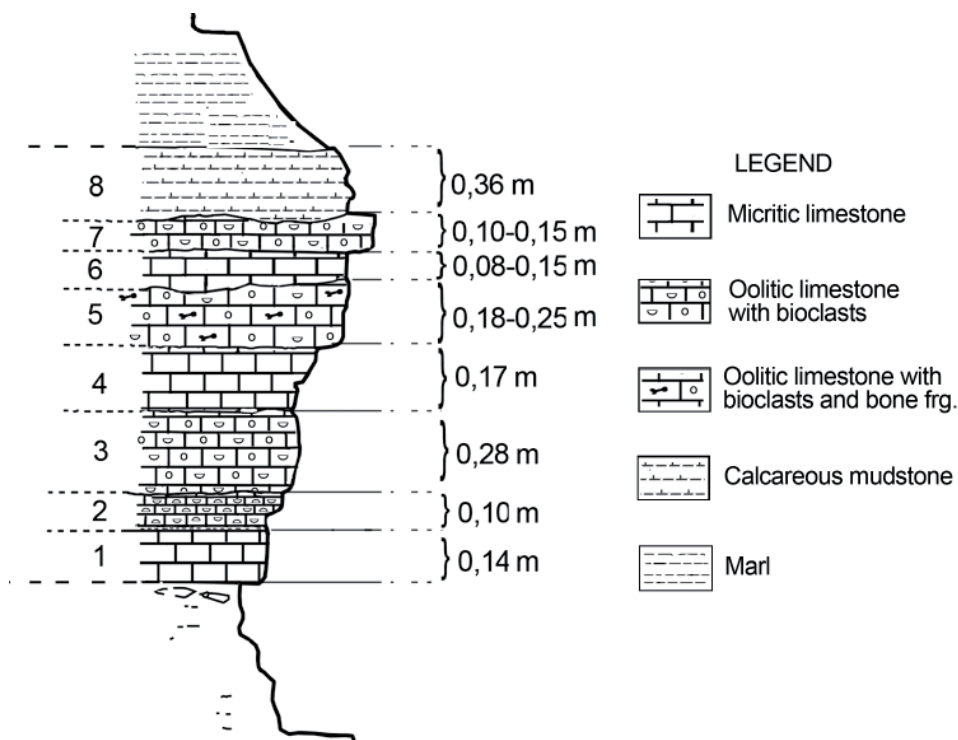


Fig. 2 – Lithology of Locus Huza – Lugașu de Sus (modified after the 1995th fieldnotes of Dr. J.M. Mazin and R. Huza)

The invertebrate faunal assemblage

Invertebrate remains from Lugașu de Sus and Peștiș represent 66% of the collected samples and 34% have a content of vertebrate skeletal remains.

Although the list of invertebrate fauna was published several times (Jurcsak, 1973, 1976, 1978), the crinoid and mollusk fauna needs to be revised. Jurcsak (1973) published the first record of vertebrates at Peștiș – Lion Valley, mentioning the abundance of invertebrate remains in comparison with vertebrate skeletal parts. Later he published the list of invertebrates from Lugașu de Sus

consisting of *Cidaris roemeri*, *Encrinus liliiformis*, *Pentacrinus* sp., *Coenothyris aff. vulgaris*, *Pleurotomaria* sp. (Jurcsak, 1976).

Crinoid columnals and pluricolumnals are over-represented in the collection, being more abundant in the Lugaşu de Sus sediments. Jurcsak (1978) summarized the invertebrate faunal list for both Middle Triassic deposits, which comprises crinoids, brachiopods and mollusks. Among the crinoid taxa Jurcsak (1978) identified *Encrinus liliiformis*, *Entrochus silesiacus*, *Dadocrinus gracilis* and *Pentacrinus dubius* and the echinoids *Cidaris roemeri* and *Miocidaris* sp. were listed. Recent analyses of the collection show that *Encrinus* occurs in both deposits, *Pentacrinus* is frequent at Lugaşu de Sus and rare at Peştiş, and *Dadocrinus* is present only at Lugaşu de Sus. Among echinids *Cidaris roemeri* occurs at Lugaşu de Sus and *Miocidaris* sp. was reported for the Peştiş assemblage.

Brachiopods were also listed by Jurcsak (1978), consisting of *Lingula* sp., *Spiriferina fragilis*, *Coenothyris vulgaris* and *Aulacothyris incurvata*. Whereas *Lingula* is present in both deposits, the terebratulid species *Coenothyris vulgaris* and *Aulacothyris incurvata* occurs only in the Lugaşu de Sus sediments and *Punctospirella (Spiriferina) fragilis* was recorded only from Peştiş.

Mollusks are represented by shells and shell fragments of gastropods and bivalves. According to Jurcsak (1978) the bivalve fauna consists of *Pseudomonotis* sp., *Lima striata*, *Chlamys* cf. *asperulatus*, *Entolium* sp., *Placunopsis* sp., *Enantiostreon difforme*, *Mytilus* sp., *Modiola paronai*, *Nucula goldfussi*, *Myophoria elegans*, *Homomya* cf. *albertii* and the gastropods comprises: *Worthenia* sp., *Loxonema detritum* and *Omphaloptycha* sp.. Bivalve and gastropod diversity is higher at Peştiş in comparison with Lugaşu de Sus. The occurrence of *Placunopsis* sp. and *Myophoria* sp. was recorded in both deposits, *Modiola* sp. was recorded frequently in the Peştiş sediments. Whereas *Chlamys* was identified only in sediments from Lugaşu de Sus, *Plagiostoma striatum (Lima striata)* was recorded only at Peştiş.

Cephalopods, which are frequent in the Muschelkalk of Germany, are very rare in the studied Middle Triassic sediments, being absent at Peştiş, only one specimen of *Ceratites* sp. was identified at Lugaşu de Sus.

The fossil bearing Middle Triassic deposit from Lugaşu de Sus also provided a cephalothorax fragment of a decapod crustacean, listed by Jurcsak (1978) as *Pemphix* sp.

The vertebrate faunal assemblage

The vertebrate fauna is diverse consisting mainly of marine reptiles and fishes. Among vertebrates marine reptiles, sauropterygians and cyamodontoid placodonts are over-represented (Jurcsak 1973, 1975, 1976, 1977, 1978, 1982,

1987; Huza et al., 1987; Popa et al, 1996, Posmoşanu, 2008). Jurcsak (1976) has described at Peştiş a new species of Nothosaurid, namely *Nothosaurus transsylvanicus* JURCSAK 1976, based on a skull fragment (MTCO 7653), formerly mentioned as *Nothosaurus* cf. *procerus* (Jurcsak, 1973). Later Jurcsak described a new species of *Tanystropheus*, *T. biharicus* JURCSAK 1975, based on a cervical vertebra (MTCO 8988), from Gruiu Pietrii deposit – Lugaşu de Susu de Sus.

Jurcsak (1976, 1977, 1978, 1982, 1987) has identified non-armored placodonts (Placodontoidea), namely the genera *Placodus* and *Paraplagodus*, as well as armored placodonts (Cyamodontoidea), mentioning *Psephoderma*, *Placochelys* and *Psephosaurus*. These placodonts were described based on fragmentary, isolated osteoderms or bone fragments and their identification on species level is almost impossible. Re-examination of some specimens has revealed the fact that all the remains of placodontian reptiles from Lugaşu de Sus and Peştiş represent the armored placodonts, Cyamodontoidea (Rieppel, 1995; Posmoşanu, 2008).

A caudal vertebra from Peştiş was identified as belonging to the ichthyosaurid *Mixosaurus* cf. *helveticus*. (Jurcsak, 1976), which is absent in the Lugaşu de Sus fauna.

The fish fauna is less well studied, up to now 3 selachian and 5 osteichthyes species have been identified based on isolated teeth and scales. The first report of a selachian and an osteichthyes genera from Lugaşu de Susu de Sus was made by Jurcsak (1976), based on a tooth of *Hybodus reticulatus* and scales of *Colobodus* sp. Later, Jurcsak (1977) determined from Peştiş the selachians *Hybodus* sp. and *Acrodus* sp. and a chondrosteian fish cf. *Birgeria* sp. Jurcsak (1978) also listed *Hybodus* cf. *multiconus*, *Palaeobates angustissimus*, *Birgeria* sp., *Gyrolepis quenstedti*, *Saurichtys* sp, *Colobodus* sp. and some Ganoidea indet from Peştiş and *Colobodus* sp. from Lugaşu de Sus.

The taxonomic composition of the skeletal remains from Lugaşu de Sus and Peştiş shows many similarities to the equivalent faunas from other regions of Europe. Fish diversity is higher at Peştiş, sauropterygians, prolacertiformes and cyamodontid placodonts have same representatives at Peştiş and Lugaşu de Sus. Nothosaurids are more abundant at Peştiş, whereas the prolacertiform *Tanystropheus* is more frequent at Lugaşu de Sus.

Taphonomical analyses of the fossil assemblage

Shape and size

The isolated vertebrate remains in the fossiliferous deposits from Lugaşu de Sus and Peştiş are scattered irregularly on the surface of the limestones.

Most of the bone fragments recovered from these sediments are black or dark brown in color. The vertebrate material ranges in size from microscopic remains to specimens with a maximum length of approximately 120 mm. The largest specimens are the vertebral arches of *Nothosaurus* cf. *mirabilis* and the cervical vertebra of *Tanystropheus biharicus*. The majority of the remaining bones are considerably smaller ranging between 10 and 30 mm in length.

The smallest size range is represented by microvertebrate remains. They consist especially of fish teeth, scales and dermal denticles ranging in size between 0,5-2 mm coming from Lugaşu de Sus - Locus Huza site. Samples from the first 4 level were subjected to acid preparation. Their study is undergoing and the results will be published in a separate paper.

All of the main categories of bone fragment shapes are present within the collection. In samples from Lugaşu de Sus and Peştiş the occurring shapes are discs, cuboids, rods, blades and “miscellaneous” with an irregular shape which does not fit into other categories. The most commonly occurring vertebrate shapes are discs and cuboid shapes, representing osteoderms and vertebral centra (Fig. 3).

Orientation

The long bones do not have any use for current interpretations and are scattered completely irregularly across the limestone (Fig. 4). A slightly sorting can be observed, robust elements like vertebral centra and osteoderms are over-represented and long bones are rare.

Fractures

All of the bones from the Lugaşu de Sus and Peştiş sediments are isolated and disarticulated elements. Long bone specimens are frequently broken and incomplete. The most commonly occurring breaks are transverse or straight – irregularly perpendicular through the shaft of the bone. The majority of the fragmented skeletal elements have been broken at some point in their *post mortem* history.

There are some specimens from Lugaşu de Sus which show the evidence of bite marks (Fig. 4), already noted by Jurcsak (1978), confirming the presence of scavengers.

Abrasion

Generally the bones from Lugaşu de Sus sediments are not well-rounded and do not present signs of intense abrasion, only few specimens show low grade abrasion. Bone fragments preserved in the bioclastic black limestone level at

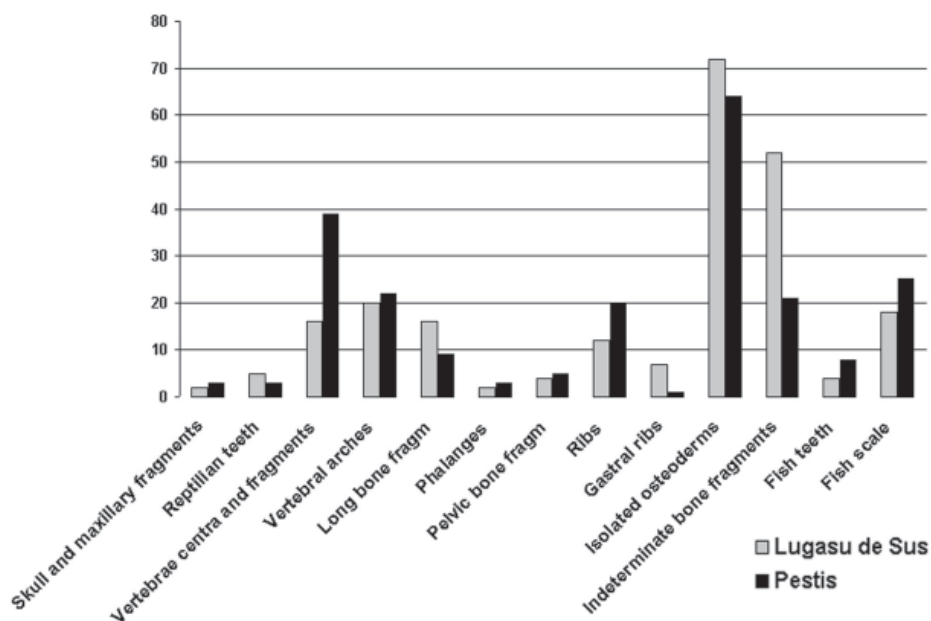


Fig. 3 – Skeletal abundance of Lugașu de Sus and Pestis marine vertebrate assemblages.



Fig. 4 – Bones with bite marks in a limestone sample from Lugaș (MTCO 9870)

Peştiş are extremely fragmented and show a higher grade of abrasion, but the bones preserved in the interbedded mudstone levels are unabraded.

Weathering

Some of the samples which were recovered from the surface of the limestone, show some degree of recent weathering. Examination of *in situ* specimens at Locus Huza confirms that the incomplete nature of the vertebrates was present before recent weathering.

Taphonomical interpretations

Experimental studies regarding taphonomic processes of terrestrial vertebrate assemblages were frequently used, but same experiments for marine vertebrate analyses are less common and have been used recently (Brandt et al., 2003a, b; Liebig et al., 2003; Irimis & Elliot, 2006). Recent studies of marine vertebrate taphonomy include geochemical analyses of the shallow marine assemblages in order to test reworking of vertebrate bones, relative abundance of trace metal elements can reflect the microenvironment of burial (Trueman et al., 2003)

Brandt et al. (2003a, b) have performed experimental studies regarding the decay processes and disarticulation in terrestrial as well as freshwater and seawater environments. They observed that decay and disarticulation time was shortest in water environment and was affected by differences in properties of the skin between species and the reaction of each type of skin to water saturation. According to Brandt et al (2003a) lizard remains floated a longer period of time (21 weeks), bacterial activity degraded the flesh, and insect larvae infected the carcasses and caused some damage but had limited actions. Other experimental studies have been performed in order to analyze how abrasion and weathering affect modern faunal assemblages in marine or freshwater environments (Irimis & Elliott, 2006; Brandt et al., 2003a,b; Liebig et al., 2003).

Near-shore wave-dominated marine environments can progressively abrade vertebrate teeth and bones (Irimis & Elliott, 2006). Bone fragments preserved in the bioclastic black limestone level at Peştiş are extremely fragmented and show a higher grade of abrasion, indicating a wave-dominated, near shore environment.

The absence or very low grade of abrasion and weathering on the Middle Triassic vertebrate specimens at Lugaşu de Sus indicate that the specimens haven't been transported too far or for a long period of time. Probably the bones have been deposited in a low energy, marine environment.

Studies regarding the taphonomy of marine invertebrates are common in the last decades (Feldman, 2005; Kidwell, 1991, 2008; Tomšových, 2006; Zuschin et al., 2003) and were very useful in the interpretations of the physical taphonomy of the Lugașu de Sus and Peștiș marine assemblage.

All crinoid remains are completely disarticulated at both Lugașu de Sus and Peștiș sediments and are represented by separate columnals, ossicles, or stem parts. Individual pluricolumnals and columnals are unabraded and usually preserved on the weathered surface of the bioclastic limestone slabs at Peștiș. At Lugașu de Sus crinoids occur rarely in the first layers of the lithological sequence in micritic limestones, as well as in the oolitic, recrystallized limestones with bioclasts and disseminated pyrite, but become more abundant in the 5th layer of bioclastic limestone, co-occurring with sauropterygian and fish bone fragments.

Coenothyris is the most common taxon for the Triassic shallow marine environments, it is present in both Germanic Epicontinental Sea Realm and Northwestern Tethys (Feldman, 2005; Bonuso & Bottjer, 2008). Brachiopods having punctae, such as *Coenothyris vulgaris*, due to their low metabolic rates, the possibility to close their valves for longer periods of times and decrease the metabolic rates and respiration by the punctae, are well adapted to poor oxygen environments than any other marine organisms (Kaim, 1997). Terebratulid brachiopods, including *Coenothyris* were collected at Lugașu de Sus – Locus Huza, from the 3rd oolitic recrystallized limestone, which contains bioclasts and pyrite, indicating that the pore water in the bottom of the sediment was anoxic, at least for short periods of time. Oxygen depleting of marine environments might be caused by transgression periods resulting in biogenic influx, which increase biogenic productivity. Although *Coenothyris* is much rarer at Lugașu de Sus in comparison with the Germanic Epicontinental faunas, its depositional environment indicate a calm, shallow lagoon with periodically poor oxygen environment.

At Peștiș the brachiopods, represented by *Punctospirella fragilis*, an open shallow subtidal species, occurs in the bioclastic limestones in association with crinoid columnals and rare disarticulated bivalves, such as *Plagiostoma* and rarely *Enantiostreon difforme*. Bioclastic limestones are poorly sorted and loosely packed with disarticulated shells of the bivalves. The high degree of fragmentation of the bivalve shells indicate an accumulation caused by storm events or one that have been deposited in a near-shore, wave dominated high energy environment.

These bioclastic limestones, according to Jurcsak's observations are alternating with grey mudstone shales. Bivalve species occurring in the grey mudstones of Peștiș are more abundant in comparison with the Lugașu de Sus deposits. In these mudstones some of the shells have been completely dissolved during diagenesis and are preserved as external or internal moulds. These are

represented by semi-infaunal suspension feeders like *Modiola* sp., *Gerwilleia* sp. or *Hoernesia* sp. The isolated, disarticulated bones from these mudstones are fragmented, but generally without any sign of abrasion, therefore haven't been transported too far or for a long period of time.

Conclusions

Taphonomical analyses of the marine faunal assemblages indicates different depositional environments for the Lugaşu de Sus and Peştiş Middle Triassic deposits.

The marine reptiles like sauropterygians, prolacertiformes and cyamodontid placodonts have the same representatives at Peştiş and Lugaşu de Sus. Nothosaurids are more abundant at Peştiş, whereas the prolacertiform *Tanystropheus* is more frequent at Lugaşu de Sus. The isolated, disarticulated skeletal elements are irregularly scattered in the limestones and mudstones. The most commonly occurring vertebrate shapes are discs and cuboid shapes, representing cyamodontid osteoderms and nothosaurid vertebrae. The post mortem processes that affected the death reptile bodies include bacterial attack as the first agent in the initial decay of the carcasses. The vertebrate skeletal parts probably had arrived at the sea floor in various stages of soft tissue decay, dropped from the decomposing carcasses floating in the water.

Vertebrate specimens from Lugaşu de Sus show the evidence of bite marks, indicating that the bones might have been scattered by scavengers. The invertebrate fauna is dominated by crinoids and brachiopods, short periods of anoxic conditions are indicated by disseminated pyrite and the abundance of *Coenothyris*.

The Lugaşu de Sus marine assemblage has been deposited in a low energy, shallow lagoon environment

The lack of any sign of scavenging marks on the bones from Peştiş might indicate that the location of most of the remains was at or slightly above mean high water, which probably limited the effectiveness of scavenging animals, similar to the experiment performed by Liebig et al. (2003) on recent marine mammal carcasses. The more fragmented and abraded nature of the bones, with a mixture of brachiopod (*Punctospirella*) and bivalve shells, shell fragments and crinoid columnals, indicate a shallow marine accumulation deposited in a near-shore, wave dominated environment.

Further studies of the Middle Triassic fauna, as well as geochemical analyses will give new insights on the post-mortem history of these marine assemblages.

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