NKFIH OTKA PD 131557 final report

In the proposal of OTKA PD 131557 grant, I mentioned four main projects that I wanted to complete during the period of the application. By the fourth year of my grant, I managed to complete all four and published the results in seven high ranked scientific journals. Although I received the grant for three years, due to the difficulties caused by the COVID-19 pandemic, I submitted a formal request to the NKFIH office to extend the grant for another year.

Completed projects:

1) *Rare-earth element geochemical and palaeontological research in the Haţeg Basin*:

Beginning of the 20th century, Ottokár Kadić discovered a rich and diverse Late Cretaceous vertebrate material around Valiora in Haţeg Basin. However, this important vertebrate collection was mixed after the 2nd World War and thus this unprovenanced material could not be used for further palaeoecological investigations. During the grant period, we carried out new field work around the village of Valiora, in order to rediscover the former sites, as well as to survey fossil bearing successions in detail and also to look for new potentially bone-bearing horizons. This project was finished in 2020 and the results of our investigations were published in the following paper: **Botfalvai et al. (2021a**). The published research includes a historical overview of Ottokár Kadić's excavations and documentation of the positions of the excavation sites as well as the taphonomical and trace element analyses on the vertebrate material.

Additional outcome of this research was the discovery of two important dinosaur sites (named as K2, NVS see Botfalvai et al. 2021a) in valleys near Valiora. These new sites yielded hundreds of well-preserved vertebrate fossils. Between 2021 – 2023, ten days excavation (per year) were conducted at these sites and more than 800 well-preserved vertebrate remains were collected. An unexpected result was the discovery of a new species of land gastropod among the collected vertebrate material, which was published in as *Ferussina petofiana* sp. n. (**Páll-Gergely et al. 2023**). The vertebrate material that has already been collected suggests that this part of the basin hosts vertebrate fossil localities with previously unacknowledged potential, whose palaeontological and geological investigations would provide new data for dinosaur research in many respects.

During the grant period, we described a new dortokid turtle species (*Dortoka vremiri* sp. n.) from the Upper Cretaceous (Maastrichtian) Sînpetru Formation of the southern Haţeg Basin in Romania and determined its palaeoecological role in comparison with the *Kallokibotion bajazidi* based on taphonomic studies. The detailed taphonomical investigation of the turtle remains from Haţeg Basin pointed out that the dortokid preferred the aquatic or semiaquatic lifestyle, while the *Kallokibotion bajazidi* was a semi-terrestrial species (**Augustin et al. 2022**).

2) *Geochemical investigation of the mixed Máriahalom vertebrate fauna at the Paleogene-Neogene boundary in the Central Paratethys:*

Rich and diverse vertebrate fauna is known from the sandpit of Máriahalom (Mány-Zsámbék Basin) including remains of marine, freshwater, and terrestrial vertebrates. However, it was not clear until this study whether the animal remains from different biotopes represent similar age or they were mixed and reworked from different deposits from different ages. The succession of the Máriahalom site belongs to the Egerian stage (late Chattian – early Aquitanian), thus the Paleogene/Neogene boundary is difficult to detect because the index fossil for the Aquitanian is absent in the Central Paratethys region. The age of the Máriahalom site is of paramount importance to the present study, because the Late Oligocene-Early Miocene was a key period of early diversification of the major extant carnivoran lineages, therefore strontium isotope composition of marine vertebrates (shark teeth) and also well-preserved marine molluscs have been analysed to see whether the site could be more precisely dated with Sr-isotope stratigraphy. The similar distribution patterns of the normalized REE data from the bones and teeth of the marine, terrestrial, and freshwater animals indicate that all the remains investigated in this study were fossilized in similar diagenetic environments and the reworked fossils of significantly different age can be excluded. Since our REE geochemical studies have shown that both terrestrial and marine remains are contemporaneous, if we determine the age of marine remains, we can apply it to terrestrial remains. During this study, $^{87}Sr/^{86}Sr$ ratios of different aragonitic mollusc shells and enamel of shark teeth were measured in order to determine the age of the Máriahalom fossils. Based on our Sr-isotope analyses an Aquitanian age of 21.4 ± 0.4 My was suggested for the sediments of the Máriahalom site, which is in contrast to the suggested Late Oligocene age proposed by the mammalian fauna. The proven Aquitanian age for the Máriahalom assemblage is significant because remains of *Microbunodon minimum* are also present in the

assemblage, which taxa is an important species in the Mammal Zonation (see Microbunodon event=MP28-30). The Aquitanian age for the Máriahalom mammal locality suggests that *Microbunodon minimum* may have survived till the MN 1–2 mammal zone in the Central Paratethys region indicating that the upper age limit of the *Microbunodon* event (MP30) may not be precisely constrained since it is generally problematic to correlate terrestrial faunas with better-dated marine faunas. This project was published in the Swiss Journal of Palaeontology in 2023 (**Kocsis et al. 2023**)

3) *Rare-earth element geochemical investigations of the Neogene vertebrate fossils of Pécs-Danitzpuszta locality:*

The vertebrate remains of the Pécs-Danitzpuszta locality have a reworked status and thus their original fossilizational environment was partly unknown until this study. However, based on REE composition of the vertebrate fossils, the former depositional environment could be determined. The differences in REE composition helped to separate the Badenian and Sarmatian (as well as probably the Pannonian) fossils in the mixed vertebrate assemblage of Pécs-Danitzpuszta, allowing further paleontological and palaeoecological investigations of this important vertebrate material (**Botfalvai et al. 2023**). Furthermore, during this study more than 60 vertebrate samples (bones and teeth) were investigated from 11 Miocene vertebrate localities across the Mecsek Mts. in Hungary, that provided useful insight into the Neogene trace element environment of the Central Paratethys region.

4) *Rare-earth element geochemical investigations and vertebrate taphonomy in other vertebrate localities:*

I was able to join an international research group excavating and investigating Neogene vertebrate fossils from Borneo (Brunei Darussalam). I investigated the rare-earth element (REE) composition of different fossiliferous apatite (from freshwater and marine vertebrates) in order to determine the provenance of the mixed Miocene vertebrate assemblages discovered from Penanjong Beach and Ambug Hill sites of Brunei Darussalam. The REE analyses of fossil bones and teeth indicates that the remains collected from two different sites most probably originated from the same bone-bearing layer as well as these geochemical investigations provided insight into REE fractionations during the fossilization of bone apatite. This project was published in the Historical Biology journal (**Kocsis et al. 2020**).

During the grant period, we discovered and published an early Coniacian new vertebrate locality from the coal-bearing Gosau Group of the Tiefengraben locality near St. Wolfgang, Austria. This diverse assemblage is composed of at least 60 taxa including gastropods, bivalves, ostracods, termites, fishes, crocodiles, and dinosaurs. Detailed taxonomical, taphonomical and sedimentological investigations were conducted on this vertebrate site to determine the former palaeoenvironments of the mixed vertebrate material which were redeposited from different palaeoenvironments (**Ősi et al. 2021**).

Projects beyond the plan:

1) *The social lifestyle of Cretaceous ankylosaurs:*

   Due to the Covid-19 pandemic, the research abroad and the laboratory works have been restricted during 2020. In the "free research time" we wrote a review work about the palaeoecological and social behaviour of the ankylosaurus dinosaurs, which were published in the Cretaceous Research (**Botfalvai et al. 2021b**).

2) *Taxonomical investigation of the Tanystropheus material of Villány*

   We published a detailed anatomical study and taxonomical descriptions of the Middle and Late Triassic *Tanystropheus* and other archosauromorph reptile discovered from Villány Mts. (**Ősi et al. 2020**).

3) *Ichnotaxonomy of the vertebrate footprints of Ipolytarnóc locality*

   In 2021, I had the opportunity to work on a Interreg SKHU Program awarded by the Bükk National Park, the main goal of the project was to carry out a taxonomic revision of the footprints of the Ipolytarnóc site. Detailed ichnotaxonomical analyses were carried out on two large-sized pentadactyl footprint types using high quality 3D models (**Botfalvai et al. 2022**).

(Although it may not fit in this report, I feel I should mention it. My son was born in September 2022, which, by definition, could not yet be "planned" when the application was submitted in 2019. This "new project" also tied up a lot of energy, which I tried to make up for in 2023.)

Postponed research:

A more extensive REE geochemical investigation was planned on the vertebrate bonebeds of the Haţeg Basin in order to understand the sedimentary, and possibly climatic, conditions during fossilisation. However, this project had to be postponed due to the Covid-19 pandemic by two years. In 2023, 35 bone and tooth were sampled from different paleoenvironments of the Haţeg Basin and were measured by LA ICP MS as a pilot study. Unfortunately, initial measurements have not yielded significant scientific results, because most of the measured samples overlapped significantly (probably due to the unknown postdiagenetic modifications). To solve this problem, I plan to carry out further measurements on more bone and tooth samples, which may shed light on why the phenomena suggested in the proposal did not show the expected geochemical distributions.

Publications and conference attendance:

Between 2019 – 2023, I published all together 6 Q1 journal articles, two of which I was the first author, while in two cases I am the last author. Besides these publications, I have three other publications (Botfalvai et al. 2021b, 2022; Ősi et al. 2020) not closely related to this grant. During this time, my independent citations have increased significantly, from 98 to 261.

I participated in several scientific conferences where I presented the results of my investigations:

2020

- 2nd Palaeontological Virtual Congress
- 23. Magyar Őslénytani Vándorgyűlés

2021

- The 13th Romanian Symposium of Palaeontology
- 35th IAS meeting of Sedimentology
- 18th Conference of the European Association of Vertebrate Palaeontologists
- 22. Nemzetközi Bányászati, Kohászati és Földtani Konferencia
- 24. Magyar Őslénytani Vándorgyűlés

2022

- 25. Magyar Őslénytani Vándorgyűlés

2023

- 4th Palaeontological Virtual Congress
- The 14th Romanian Symposium of Palaeontology

- 25. Magyar Őslénytani Vándorgyűlés

Thesis supervision:

- PhD student1: János Magyar (ELTE TTK, Department of Paleontology) working on the taxonomical investigation of the vertebrate remains discovered from the Valiora Valley and he will publish his first results in 2024 about the collected Rhabdodontidae material.
- PhD student2: Zsófia Román (ELTE TTK, Department of Paleontology) working on the material of Equidae discovered from different Cenozoic sites of Hungary.
- I was involved in the thesis supervision of four BSc (Lutz Réka, Mizsei Regina, Béres Eszter, Viktória Káposztás, ELTE TTK) and one MSc (Zsófia Román, ELTE) thesis, all were graded to be excellent.

Science promotion and media coverage:

I presented my research in a total of 21 online or print publications and participated in 5 radio interviews during the duration of the project.

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