

## THE BONE-BEARING UPPER TRIASSIC OF UPPER SILESIA, SOUTHERN POLAND: INTEGRATED STRATIGRAPHY, FACIES AND EVENTS – INTRODUCTORY REMARKS

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Compared to the marine Muschelkalk carbonates, the fossil-impoverished and monotonous continental succession of the Upper Silesian Keuper for a long time did not attract more systematic investigations (see Szulc, 2007). The discovery of a spectacular vertebrate fauna by Jerzy Dzik and his group at Krasiejów, near Opole (Dzik *et al.*, 2000) and later finds in the vicinity of Lubliniec, Woźniki and Zawiercie marked a turning point, since they appeared to have great significance for the study of the rapidly evolving terrestrial Triassic tetrapods, including the early dinosaurs. However, the leading palaeobiological issue on a worldwide scale (Sues and Fraser, 2010) has contrasted strongly with the inadequate regional knowledge of its basic stratigraphic and environmental context. The discrepancy first of all concerns the age inferences, which in turn render ambiguous any conclusions about the evolution and habitat for the vertebrates studied (Racki, 2010; Bodzioch, 2012). Thus, a multidisciplinary, stratigraphic-event study of the Silesian Upper Triassic succession became essential for any challenge to the reliability of the crucial implications in the palaeontological vertebrate record.

This thematic issue, comprising 8 articles by authors from nine Polish institutions, the USA and Germany, presents the results of the project “The evolution of terrestrial environments of the Upper Silesian Keuper as the biotopes of vertebrates” (Grant N N307 11703), awarded to Grzegorz Racki by the Ministry of Science and Higher Education. The project has been realized in the Polish Academy of Science, the Institute of Paleobiology (2010) and the Institute of Geological Sciences (2011–2014) and focused on the comprehensive study of the bone-rich higher slice of the Keuper succession (middle and upper Keuper in a traditional sense; Römer, 1870), in terms of stratigraphy, sedimentology, mineralogy and geochemistry (Racki, 2010). The last two aspects, including a chemostratigraphic perspective, were presented previously by Środoń *et al.* (2014).

The opening article by Szulc *et al.* (1) deals with the regional lithostratigraphic setting of the vertebrate localities as a prerequisite for more advanced studies and provides a general introduction to the accompanying articles. A major lithostratigraphic unit, formally defined in Polish by Szulc and Racki (2015) for the middle Keuper as the Grabowa Variegated Mudstone-Carbonate Formation, is described in detail here with reference to a composite, regional reference section, about 260 m thick and based on two new borehole sections. The essentially Norian Grabowa Fm is subdivided formally into three members (Ozimek Mbr, Patoka Mbr and Woźniki Mbr). Moreover, two informal bone-bearing levels (Krasiejów and Lisowice) have been delineated within the marly mudstone-sandstone strata of the Patoka Mbr.

The crucial problems of timing and genesis of these bone beds are discussed in depth in the critical overview by Szulc *et al.* (2) that follows; indeed, this is the main outcome of the grant from an ecosystem stratigraphy perspective. The stratigraphic arguments, previously proposed by the authors from the Institute of Paleobiology of the Polish Academy of Science and Warsaw University, are discussed comprehensively. The earlier interpretations are shown as leading to inadequately documented and questionable age assignments for the separate bone-bearing fragmentary portions of the Keuper succession. Therefore, in place of (at least) three widely separated bone-bearing intervals, ranging in age from the Carnian to Rhaetian (i.e., in an interval of 25 Ma), two Norian bone-bed levels only are proposed as being not very different in age (less than 10 Ma). In particular, the widespread Lisowice level is thought to be the sedimentary record of a mid-Norian tectonic-pluvial event. As highlighted in this issue, however, this age assignment is still somewhat preliminary in the context of the primary weaknesses in Upper Triassic non-marine stratigraphy, including the lack of global stratotypes for the stage boundaries. The key significance of the chemostratigraphic infer-

ences of Środoń *et al.* (2014) to the regional scale of the stratigraphic framework is strongly stressed. From a taphonomic viewpoint, a common hydraulic-sedimentological, fluvial mode of bone concentration, combined with catastrophic floods during wet episodes, is assumed for the Fossil-Lagerstätten being studied. However, the augmented conservation of the accumulated tetrapod hard parts is doubtless important, too.

As reviewed by Lucas in a worldwide biochronological context in this issue, the revised age assignment of the Silesian tetrapod faunas has a substantial implication. Even if the assemblage of the Krasiejów level is still regarded as referable to a late Carnian land-vertebrate faunachron, Lucas significantly notes that “the possibility that the Krasiejów tetrapods fill a gap in the early Norian record of tetrapods merits consideration”. The Norian age of the Lisowice level is well reasoned in Lucas’s opinion, especially in that the previously presumed paradox of the oddly relict “Rhaetian” fauna is largely lost, because the mid-Norian assemblage in fact fits the data on global distribution much better. This article actually raises the fundamental question of the temporal ranges of tetrapod taxa in phylogenetic paths (still poorly understood) as well as that of stratigraphically complete reference successions.

Fijałkowska-Mader *et al.* present the results of palynological studies for the borehole and outcrop sections, including the tetrapod localities. This well-illustrated documentation of biostratigraphy and palynofacies, regardless of frequently inconclusive (in terms of dating) or barren samples and poor palynomorph preservation, provides critical arguments for the Norian timing of the Grabowa Fm. In particular, the mid-Norian age assignment of the Lisowice level (in the lower part of *Classopolis meyeriana* b Subzone) is confirmed successfully for several sites.

The palaeomagnetic results, presented in this issue by Nawrocki *et al.*, allow the tentative correlation of the Upper Silesian composite reference section with the stratigraphically more extensive core from the Książ Wielkopolski IG-2 well, drilled in the more distal Polish part of the Germanic Basin. In contrast to the lower Keuper segments, the magnetic polarity zonation is far less conclusively recognized in the Grabowa Fm, but an overall agreement with the chemo- and palynostratigraphic premises is nevertheless noteworthy. The correlation potential of this stratigraphic tool still waits to be fully revealed in the Upper Silesian sequences, but especially on a supra-regional scale (Szulc, 2007).

The two next papers refer to more specific Keuper themes addressed under this grant. In the paper by Konieczna *et al.*, Nd and Sr isotope data are used to decipher the provenance of the siliciclastic series. The isotopic signature proves the dominance of old crust in the source areas. The authors concluded that this part of the Germanic Basin was fed with fine-grained clastics from the Bohemian Massif domain, i.e., the Saxothuringian units of the East Sudetes, and most likely it also was supplied with sediment from the area, where the Tepla-Barrandian Unit occurs.

Charcoals from the bone-bearing sites of the Zawiercie area were studied petrographically (SEM, reflected light microscopy) by Kubik *et al.* Different morphotypes of out-

standingly preserved charcoals perhaps represent different plant taxa, only partly recognized in the palaeobotanic record (see Philippe *et al.*, 2015). The highest burning temperatures implied by Kubik *et al.* reached above 600 °C, while largely surface fires affecting dead twigs and stems are deduced from the presence of fungal tubular structures.

Last, but not least, a contribution by Becker supplements this Upper Triassic issue, although it is only indirectly linked with the project. Conchostracan biostratigraphy presently is believed to be often a useful tool for the age determination of the Silesian tetrapod localities, as an alternative method to the frequently ineffective palynostratigraphy. Becker to a large extent disproves this. In a case study of the Permian–Triassic boundary interval, the vague nature of this biochronostratigraphic approach was categorized. From the Keuper perspective, regardless of conchostracan taxonomy and flaws in terrestrial stratigraphy, correlation with the conodont-based stratigraphy in marine stratotype sections will be a fundamental challenge.

In summary, the guest editors hope that, jointly with the earlier contribution of Środoń *et al.* (2014), serious progress in the knowledge of the Upper Silesian Keuper has been fruitfully achieved as a result of this grant. At least in a stratigraphic context, this ASGP thematic issue should be a conclusive, heuristic stimulus for more consistent studies, including those in vertebrate research. Nevertheless, the potential for understanding some mostly unresolved problems also is outlined:

1. An advanced study of facies development in the Keuper climatostratigraphic framework, paired with cyclostratigraphic and sequence analysis, is in preparation by Szulc and Jewuła. In this context, the key question of the diachronous lithostratigraphic boundaries, implied from chemostratigraphic indices by Środoń *et al.* (2014), requires examination on the broader scale of the Polish Basin;

2. The lithostratigraphy of the lower and uppermost parts of the Keuper (i.e. below and above the Grabowa Fm), including the tentatively proposed Miedary bone-bearing level, encompassing several bone beds in a broad Muschelkalk-Keuper transition, awaits formal revision;

3. The complex problem of hiatuses and disconformities in the mudstone-dominated succession is tentatively outlined by Szulc *et al.* (1), but the proposed link with Early Cimmerian block tectonics in the syndepositionally active Kraków–Lubliniec zone requires comprehensive examination;

4. In addition to the well-evidenced Bohemian source area (Konieczna *et al.*), the provenance for the eastern Silesian localities, including the coarse-grained Norian and Rhaetian lithological varieties, remains an attractive research theme with a connection to the Moesian Platform as a probable source terrain (Mariusz Paszkowski, pers. comm., 2014; cf. Środoń *et al.*, 2014);

5. Taphonomic and genetic issues of the Silesian bone beds are briefly reviewed by Szulc *et al.* (2). This important aspect of the vertebrate record, however, also requires far more refined study in terms of diagenesis, mineralogy and geochemistry (exemplified by rare earth elements), as well as reference to the diverse factors controlling the pattern of reworking, paired, for example, with fluvial facies architecture at particular bone-bearing sites. Notably, the real pros-

pect of the discovery of the next tetrapod occurrences in the Zawiercie–Lubliniec zone is anticipated as an inevitable consequence of the precise stratigraphic assignment of the bone-enriched intervals.

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