Palaeoecological implications of the hybodont shark Lissodus of the Rhetaian Central European Basin using oxygen isotopes

JAN FISCHER, SILKE VOIGT, JÖRG W. SCHNEIDER, MATTHIAS FRANZ, MICHAEL M. JOACHIMSKI

1 TU Bergakademie Freiberg, Geologisches Institut, Bereich Paläontologie, Bernhard-von-Cotta-Straße 2, D-09596 Freiberg; j.fischer1@yahoo.de, schneiderj@geo.tu-freiberg.de, franz@mailserver.tu-freiberg.de
2 Goethe Universität Frankfurt am Main, Institut für Geowissenschaften, Altenhöferallee 1, D-60438 Frankfurt, svoigt@ifm-geomar.de
3 Geozentrum Nordbayern, Friedrich-Alexander Universität Erlangen-Nürnberg, Fachgruppe Krustendynamik, Schlossgarten 5, D-91054 Erlangen, joachimski@geol.uni-erlangen.de

The biogenic fluorapatite in shark teeth enameloid is extremely resistant against diagenetic alteration, and reliably reflects the ambient water chemistry at the time of tooth mineralization (VENNEMANN et al. 2001). Thus, the oxygen isotope composition of teeth allows conclusions about the isotopic composition of the ambient aquatic fluid. In this way we will obtain new insights about ancient terrestrial palaeoenvironments, the possible migration behavior of analyzed taxa, as well as the hydrological cycle of the early Mesozoic.

The hybodont taxon Lissodus represents a small shark with a durophagous bottom-dwelling lifestyle. Lissodus occurs in marine and non-marine deposits, and the palaeoecology of this taxon is controversially discussed. Because of the continuous tooth replacement in sharks, the tooth δ18O values of Lissodus can be used to differentiate between marine or freshwater signatures and to decipher whether this shark lived permanently in freshwater or had a diadromous behavior. In the present study, small-sized (2-3 mm) teeth of Lissodus minimus from Late Triassic (Rhetaian) bone beds from 3 different localities in Germany were investigated for the oxygen isotope composition of their enameloid layer. In total, we analysed 22 teeth from Kallenberg (Thuringia), 23 teeth from Mooseberg (Thuringia), and 21 teeth from Stuttgart-Möhringen (Baden-Württemberg) for δ18O values by single tooth measurements. The mean δ18O values are 16.8 ± 0.4 % for Kallenberg, 15.6 ± 0.6 % for Mooseberg, and 15.4 ± 0.6 % for Stuttgart-Möhringen with the standard deviations being comparable to standard deviations calculated for δ18O values in different teeth from individual recent sharks (VENNEMANN et al. 2001). Moreover, the mean δ18O values of the shark teeth from the different locations are in a similar range. Published values for a definite marine setting are available from brachiopods of the Dolomites (KORTE et al. 2005) providing a δ18O signal for the Late Triassic Tethys that is about 4-5 % heavier than those of Lissodus.

The strong difference in δ18O indicates an extensive brackish or even freshwater environment of Lissodus minimus within the Central European Basin, at least in middle and southern Germany. In spite of continuous tooth replacement, no significant heavier δ18O values were observed that could indicate a marine or marginal marine setting and subsequent migration. During the formation of tooth enameloid Lissodus occupied a non-marine environment with the δ18O values of the studied teeth from each locality suggesting no habitat migration. The generally low δ18O values of the shark teeth indicate a strong freshwater supply into the basin by drainage systems from the Vendianian Swell during the latest Triassic. Future analyses of the geographically widely spaced bone beds and associated faunal assemblages possibly will show regional differences and refer to a slow transgression in the Late Triassic of Central Europe.

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Introduction

The precipitation of biogenic fluorapatite in shark teeth enameloïd (Fig. 1) is independent of metabolic processes (vital effect). As the material is extremely resistant against subsequent diagenetic alteration, it reliably reflects the ambient water chemistry at the time of tooth mineralization (VENNEMANN et al. 2001, ZACK et al. 2009). Thus, the oxygen isotope composition of teeth allows conclusions regarding the isotopic composition of the ambient aquatic fluid at the time of tooth mineralization. This gives the opportunity to obtain new insights about ancient palaeoenvironments, the migration behavior of analysed taxa (KOCZIS et al. 2007), as well as the isotopic composition of meteoric waters and the hydrological cycle of the early Mesozoic (Fig. 3).

The hybodont (Lissodus) (Fig. 2), a small durophagous bottom-dwelling shark, occurs in marine and non-marine deposits. Thus, the palaeoecology of this taxon is controversially discussed (FISCHER 2008). Because of the continuous tooth replacement in all sharks, the tooth δ18O values of Lissodus can be used to differentiate between marine or freshwater signatures, and to decipher stationary or diadromous behavior.

Material and Results

Stratigraphy

| Locality               | taxa          | n  | mean δ18O%
|------------------------|---------------|----|-------------
| Lower Rhétaën (Upper Keuper) |               |    |             
| Kaltenberg, Thuringia | Lissodus minor | 22 | 16.5 ± 0.4%
| Moserberg, Thuringia  | Lissodus minor | 22 | 15.3 ± 0.6%
| Moserberg, Thuringia  | Lissodus minor | 23 | 15.3 ± 0.6%
| Stollberg-Degerloch, Bads-Württemberg | Hyodus sp. | 4  | 15.5 ± 0.2%
| Hildesheim-Ottersum, Lower Saxony | Lissodus minor | 21 | 14.6 ± 0.5%
| Letterkuner (Lower Keuper) |               |    | 15.9 ± 0.1%
| Veringen-Steinbach, Bads-Württemberg | Lissodus minor | 2  | 11.7 ± 0.2%
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| Upper Muschelkalk |               |    |             
| Buchholz, Thuringia  | Lissodus minor | 5  | 19.2 ± 0.4%
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| Buchholz, Thuringia  | Hyodus sp.    | 5  | 18.5 ± 0.3%
| Kielheim, Franconia | Lissodus minor | 2  | 16.9 ± 0.4%
| Birkfeld, Franconia | Lissodus minor | 4  | 17.4 ± 0.4%

Tab. 1 Small-sized teeth of Lissodus and additional ichnosynusia of Hyodus (Tab. 1) from Rhétaën bone beds of four different localities in Germany were investigated for the oxygen isotope composition of their enameloïd layer. In total, we analysed 22 teeth from Kaltenberg (Thuringia), 37 teeth from Moserberg (Thuringia), 21 teeth from Stollberg-Degerloch (Bads-Württemberg), and 3 teeth from Hildesheim-Ottersum (Lower Saxony) for δ18O values employing single toothmeasurements.

All measurements were done via high temperature reduction in Erlander using the analytic procedure described by JOACHIMSDICK et al. (2004) and ZACK et al. (2009). Samples were measured in Erlander. The overall reproducibility is better than ± 0.2 ± 0.15. The mean δ18O-values are 16.8 ± 0.4% for Kaltenberg, 15 ± 0.6% for Moserberg, 15.4 ± 0.6% for Stollberg-Degerloch, and 15.9 ± 0.1% for Hildesheim-Ottersum with the standard deviations being comparable to standard deviations of 0.6-1.1% calculated for δ18O-values in different teeth from individuals of the sharks (VENNEMANN et al. 2001). Furthermore, 21 teeth from different sharks (Lissodus, Hyodus, and Hyodus) from Upper Muschelkalk localities in Thuringia and Franconia were measured together with three teeth of Melosirensis from brackish swamps of the Bads-Württemberg, Lower Keuper (Letterkuner) (Tab. 1) in order to get comparable material with marginal marine respectively brackish δ18O values.

Discussion

Tethys Rhétaën

Lower Keuper Upper Muschelkalk

| marine δ18O-values of the different localities | in a similar range | published values for | a definite marine setting are available from brachipods of the Dolomites Alps (KORTE et al. 2003) providing a δ18O signal for the Late Triassic Tethys that is about 4-5% heavier than those of the Rhétaën bone beds. Moreover, it is noticeably lighter than the brackish δ18O signal of the brackish Lemmnoni swamps or most data from the Muschelkalk Sea, besides δ18O values most proximal to the Vendian-Bohemian Massif.

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Conclusion

Future analyses of the geographically widely spaced bone beds and associated faunal assemblages possibly will show regional differences and refer to a slow transgression in the Late Triassic of Central Europe. Demonstrating that a habitat migration is not noticeable does not necessarily indicate no migration behavior. With increasing resolution a verification of migration behavior could be probable, at least for Hyodus.

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2 Goethe Universität Frankfurt am Main, Institut für Geowissenschaften, Max-von-Laue-Allee 1, 60438 Frankfurt, Germany
3 Geowissenschaftliches Institut der RHEA (Rheinische Eifel-Arbeitsgemeinschaft für Naturkunde) des Rheinland-Pfalz, Arnsberg, Germany

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