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Oxygen and strontium isotopes from fossil shark teeth: Environmental and ecological implications for Late Palaeozoic European basins

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ABSTRACT

Fossil shark remains occur in both marine and nonmarine Late Palaeozoic deposits, therefore their palaeoecology is controversial. The oxygen and strontium isotopic composition of biogenic fluorapatite in 179 teeth, scales and spines predominantly of hybodontid (*Lissodus*) and xenacanthiform (*Orthacanthus*, *Xenacanthus*, *Bohemiacanthus*, *Triodus*) sharks from various Late Carboniferous (Moscovian) to Early Permian (Artinskian) basins of Europe are used as ecological tracers to decipher diadromous or obligate freshwater lifestyle of the investigated taxa. The $\delta^{18}O_P$ values of the different shark teeth range from 11.7 to 20.2‰ within the different basins with mean values of 16.9 ± 0.5‰ for the Bohemian Massif, 16.2 ± 0.8‰ for eastern Germany, 18.2 ± 1.0‰ for southwestern Germany, 18.5 ± 0.7‰ for southern-central Spain, 17.6 ± 0.4‰ for Sardinia, and 16.6 ± 0.5‰ VSMOW for the French Massif Central. The tooth $\delta^{18}O_P$ values from the basins are mostly depleted by 1–5‰ relative to those of shark teeth from contemporaneous marine settings. Oxygen isotope signatures of co-occurring taxa do not show systematic differences excluding habitat effects for different shark groups. However, distinctly higher $\delta^{18}O_P$ values from Puertollano and Saar–Nahe can be attributed to significant evaporative enrichment in ^{18}O of the ambient water in the ancient lacustrine environments due to a warm and dry climate and sufficient residence time in the basins. The strontium isotopic composition of the teeth varies between 0.70824 and 0.71216 with a mean value of 0.71031. These $^{87}Sr/^{86}Sr$ ratios are always more radiogenic in comparison to the $^{87}Sr/^{86}Sr$ record of seawater of their stratigraphic age. Overall, the investigated tooth samples yield low $\delta^{18}O_P$ and high $^{87}Sr/^{86}Sr$ values deviating from bioapatite values expected for contemporaneous marine vertebrates and typical for freshwater settings. This indicates a fully freshwater adapted lifestyle for a variety of fossil shark taxa in Late Palaeozoic European basins.

1. Introduction

Fossil shark remains are abundant in Late Carboniferous and Early Permian deposits of continental basins of Europe being mostly represented by isolated teeth (e.g., Schneider, 1985; Hampe, 1994; Soler-Gijón, 1997; Štamberg and Zajíc, 2008; Fischer et al., 2010). Analyses of the spatial taxa distribution revealed a highly diverse, widespread, and uniform shark-association within the European basins during the latest Carboniferous (Gzhelian) (Schneider and Zajíc, 1994; Schneider et al., 2000) that became increasing patchy during the Early Permian (Fischer et al., 2010; Fig. 1). According to this observation, nearly all Carboniferous basins were connected by a complex drainage system that gave aquatic vertebrates the possibility for exchange. However, the presence of shark remains in continental basins together with contradicting facies interpretations of sedimentary deposits led to different interpretations concerning a marine influence during the late Palaeozoic in Europe. Two contrary assumptions exist about the palaeoecology of these ancient shark communities. On one hand, they are considered to have been euryhaline fishes in marginal marine coastal, lagoonal to estuarine influenced environments (Soler-Gijón, 1999; Schultze and Soler-Gijón, 2004; Schultze, 2009; Carpenter et al., 2011). This view is based on the record of several members of specific fossil shark families from marine strata, their global occurrence, and the marine restriction of extant shark egg capsules as well as analogies with modern diadromous sharks (see also Soler-Gijón, 1993, 1997). The similarity of aquatic shark faunas in different European basins is explained by those authors assuming

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