As part of recent research to try to constrain the palaeoceanographic and paleoclimatic conditions during the Miocene marine sedimentation in the circum-Alpine region, a number of geochemical approaches have been applied to well-preserved fossils as well as their embedding sediments (e.g., REE composition, $^{87}\text{Sr}/^{86}\text{Sr}$, $^{143}\text{Nd}/^{144}\text{Nd}$, $\delta^{18}\text{O}$ values).

While studying samples from the Swiss Upper Marine Molasse some “exotic” results have been obtained. Two shark teeth from the La Molière area have very low $\delta^{18}\text{O}$ values (11.3±0.1 ‰) compared to teeth sampled from the same species in the same locality (20.7 to 21.8‰) as well as other localities in Switzerland, Germany, Austria, Hungary and Slovakia (range between 19.5 and 23.5‰; n=155). Unlike the two exceptions, all other teeth can be interpreted as having formed under open-ocean conditions, with O-isotope compositions reflecting prevailing climatic conditions (Vennemann & Hegner, 1998; Vennemann et al., 2001; Janz & Vennemann, 2005; Kocsis & Vennemann, 2005).

Different compositions have also been measured for the $^{87}\text{Sr}/^{86}\text{Sr}$ of the two teeth from La Molière (0.707840 and 0.707812) and the other teeth of the Swiss Molasse (range between: 0.70842 to 0.70902). With regard to the Sr isotope measurements, most samples have $^{87}\text{Sr}/^{86}\text{Sr}$ compatible with Lower Miocene open ocean seawater. Some exceptions exist though having $^{87}\text{Sr}/^{86}\text{Sr}$ somewhat higher than expected for open ocean conditions that might reflect a local influence through erosion of high $^{87}\text{Sr}/^{86}\text{Sr}$ crystalline rocks, however their O-isotope compositions are still typical of those for teeth formed in an open marine environment.

In case of the two teeth of La Molière, the low values for $^{87}\text{Sr}/^{86}\text{Sr}$ correspond well to compositions expected for freshwater whose isotopic composition is controlled by Mesozoic calcareous rocks of the Alps and the Jura mountains, known to have been exposed in the area surrounding the locality of La Molière during the Miocene (e.g., Schlunegger et al., 2001; Kuhlemann and Kempf, 2002).

As both O and Sr are known to be incorporated into the phosphate structure during growth of the teeth and are commonly robust to post-mortem alteration, we interpret these isotopic compositions as typical for the paleoenvironment in which the sharks lived, that is a freshwater origin of the two teeth from La Molière. All other teeth from this locality as well as the other localities recorded normal marine seawater. Thus according to our interpretation some Miocene sharks often visited rivers just as some living species do today (e.g. *Carcharhinus leucas*), and stayed long enough to form teeth recording the geochemical composition of the river water. This interpretation is supported by rare earth element patterns of the “freshwater” teeth, as they are similar to those of the other teeth from La Molière, all of which reflect diagenesis in a typical marine environment.

Accepting that the teeth have formed while the sharks were in a freshwater environment and given the same approximate temperature conditions as for their marine counterparts, the extremely low $\delta^{18}\text{O}$ values of the teeth suggest meteoric waters with minimum $\delta^{18}\text{O}$ values of about –10‰. As the O isotope composition of meteoric water is directly related to mean ambient temperature and this in turn to the mean altitude in mountainous areas (e.g., Schürch et al., 2003), these low values support a significant altitude of the Alps during the Lower Miocene (roughly similar to that of today). Collectively, the analyses to date indicate a Lower Miocene palaeogeographic situation with a high mountain belt adjacent to a marginal sea, which generally has had good connections to the open oceans for most of the time.
REFERENCES

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