

Clay Minerals of the North Alpine Molasse Sediments' Archives of Alpine Upliftment and Climatic Change?

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It has been known for some time, that the H- and O-isotope composition of clay minerals formed in a weathering environment reflects that of the average ambient precipitation (e.g., Lawrence and Taylor, 1971). As the H- and O-isotopic composition of precipitation is largely controlled by climatic and/or topographic factors, the H- and O-isotope composition of pedogenic clay minerals in sediments may be used as a proxy for climatic and/or topographic changes in the source terrain (e.g., Stern et al., 1997; Chamberlain and Poage, 2000). This possibility of determining changes in the climate and/or topography has been addressed for the Alpine orogeny by examining the clay mineralogy and H- and O-isotope composition of clays, in parallel with the O-isotope composition of carbonates in Late Oligocene to Late Miocene molasse sediments of southern Germany. The molasse sediments form part of a foreland basin sedimentary sequence, characterized by two large transgressive-regressive sedimentary cycles, representing alternating marine and freshwater sedimentation. The sediments have largely been derived from Alpine carbonate, metamorphic, and igneous rocks.

The less than 2 μm size fraction of the molasse sediments examined in 16 samples taken from outcrops and drill cores, consist of a mixture of chlorite, illite, and quartz, in relatively uniform proportions throughout the sequence. The H-isotope composition of this size fraction changes continuously from δD values (relative to VSMOW) of around 62 permil in the Lower Marine Molasse (LMM) to 98 permil in the lower part of the Upper Freshwater Molasse (UFM), with clays in both freshwater cycles always having somewhat lower values compared to those from the preceding marine units. This change in the H-isotope composition would be compatible with decreasing temperatures throughout sedimentation and/or continued upliftment of the source terrain. A cooling trend would be in agreement with the overall global cooling during the Tertiary. However, precipita-

tion estimated to be in equilibrium with the clay minerals would indicate either extremely cool climates or a source terrain changing in average elevation from about 1000 to 3000 m, given typical altitude effects for the precipitation. Both possibilities are not compatible with current estimates of climatic and topographic conditions for the Alpine source terrain (e.g., Vennemann and Hegner, 1998; Frisch et al., 1998). Furthermore, while the $\delta^{18}\text{O}$ values (all relative to VSMOW) for the less than 2 μm size fraction of the chlorite-illite-quartz mixture differ significantly between different sedimentary cycles (values of 19.9 to 21.1 permil for the LMM; 16.0 to 19.3 for the Lower Freshwater Molasse; 16.4 to 17.9 for the Upper Marine Molasse; 19.2 to 19.4 for the UFM), they do not change continuously from higher towards lower values. The O-isotope compositions of this silicate fraction also correlate very well with those of the carbonates (28.0 to 28.4 permil for the LMM; 26.5 to 29.3 for the LFM; 23.2 to 26.8 for the UMM; 24.3 to 26.1 for the UFM) from the same samples. As the carbonates represent mixtures of detrital and authigenic carbonates, it can be concluded that the clay mineral fraction is largely of authigenic origin. Hence, the clays of the north Alpine molasse can not be used to estimate changes in climate during the sedimentation but rather reflect the fluids present during diagenesis of the molasse units.

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