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Low-temperature oxidation of magnetite – a humidity sensitive process?

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Extensive multi-parameter palaeoclimate records were obtained from two long-term lacustrine archives at the Tibetan Plateau: the Qaidam basin (2.69-0.08 Ma) and Heqing basin (0.90-0.03 Ma). At present the region of the Qaidam site has an arid climate (<100 mm mean annual precipitation) while the Heqing site is located in the sub-tropical region with monsoonal rainfall. Magnetic properties play a prominent role for palaeoclimate interpretation in both records. Several parameters show a 100 kyr eccentricity cyclicity; in the Qaidam record also the Mid-Pleistocene Transition is seen. Both magnetic records are controlled by different absolute and relative contributions of magnetite and its altered (maghemitized) phases as well as hematite. Weathering conditions likely cause a systematic variation of magnetic mineralogy due to low-temperature oxidation (LTO). Maghemitization is well recognized as an alteration process in submarine basalts but about its relevance for climate-induced weathering in continental environments little is known. Various factors i.e. humidity, temperature, seasonality, duration of specific weathering conditions, and bacterial activity could be responsible for maghemitization (LTO) and transformation to hematite (or goethite) when a critical degree of LTO is reached. These factors may lead to a complex interplay, but one has to note that water acts as an electrolyte for Fe(II) to Fe(III) oxidation at the crystal surface and due to maghemitization-induced lattice shrinking a larger internal particle surface area becomes exposed to oxidation. We suggest that humidity is the most crucial driver for the two studied archives - for the following reasons: (1) The overall parameter variations and catchment conditions are well in agreement with an LTO scenario. (2) In the Qaidam record we observe a direct relationship of a humidity sensitive pollen Ratio with magnetic susceptibility (reflecting the degree of alteration by LTO). (3) In the Heqing record carbonate erosion that reflects higher precipitation matches with stronger maghemitization. In the arid Qaidam region we interpret the humidity variation by regional water recycling related to glacial-interglacial periods. In the sub-tropical Heqing region humidity fluctuations may be caused by a changing relative influence of the Indian summer monsoon.