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Significance of the giant Lower Cretaceous paleoweathering event

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Weathering profiles typically develop at the interface with the atmosphere, and thus, record the fluctuations in the paleoatmosphere's chemistry and climatic conditions. Consequently they are one of the main archives to upgrade our understanding on paleoclimate and the Earth's environmental history. In this presentation, we will focus on the linking between paleoatmosphere compositions, weathering rates, and their impact on the subsequent sedimentary records.

Distribution of the Lower Cretaceous lateritic weathering facies.
During the Early Cretaceous, sea level drops and wide exondations lead to development of deep "lateritic" weathering profiles. Thick kaolinitic weathering profiles occured on the Hercynian basements and diverse kaolinitic and ferruginous weathering products covered the Jurassic limestone platforms. This major lateritic event is not restricted to Europe but also well know in North-America (up to Canada), South-America (down to Argentina), and in Australia.
Moreover, recent paleomagnetic and radiometric datations revealed that numerous kaolinitic and ferruginous formations, which classically were ascribed to Tertiary ages, date back to the Lower Cretaceous period (Thiry et al., 2006). Additionally, the Bonherz iron ore deposits in the paleokarsts of the Jurassic limestone plateform of the Paris Basin also have to be reconsidered as of Cretaceous age, probably as well as the Tertiary age of the Swiss and Bavarian Jura Bonherz.

Paleoclimatic interpretation.
During a long time, the interpretation of these paleoweathering features has been a major palaeoclimatic argument. The spreading out of deep kaolinitic weathering profiles (from the Scandinavian and Canadian shields to southern Argentina and Australia, which was still situated close to Antarctica at that time) has lead to considerations, that during this period a warm and wet climate prevailed globally, with very little latitudinal differentiation. These paleoclimatic interpretations stand in contradiction to the paleobotanical data and the interpretation of the glacial origin of some sedimentary figures, such as dropstones. Additionally, some isotopic data are contradictory to the hypothesis of a warm climate around the whole world; in fact the data indicate cold water masses or even glaciation at high latitudes (Bornemann, 2008). On the other hand, numerous paleontological as well as some isotopic data support the theory of a greenhouse Earth during Cretaceous times (Sellwood & Valdes, 2006.

Cretaceous paleoatmosphere.
Taking in account the composition of the paleoatmosphere during the Cretaceous has considerably enriched the paleoclimatic debate. It is know that the CO2 concentrations of the Cretaceous atmosphere may have been 5 to 10 times higher than present day values (Berner & Kothavala, 2001). These high CO2 concentrations have often been used to explain higher rates of silicate mineral alteration. Nevertheless, although it is well understood that the CO2 content of the atmosphere controls the climate and therefore weathering, the specific mechanisms that intervene have rarely been studied. Here we will examine some aspects of the influence of CO2 upon weathering in order to reconsider the nature and the distribution of the Lower Cretaceous paleoweathering features.

Simulation of granite weathering in high CO2 atmosphere.
Two models, one of rainwater in equilibrium with the present day atmosphere and another with a CO2 atmospheric

level 10 times higher than present day values (similar to the Lower Cretaceous atmosphere) have been developed and applied to a granite weathering simulation (Schmitt, 1999).
The modelling shows that the successive minerals are the same for both simulations. But, under high atmospheric CO_2 content, kaolinite appears with three times less rainwater flushed through the profile. This means that under similar rainfall and temperature conditions profiles would deepen three times faster than under present atmospheric conditions. Increased pCO_2 has no direct effect on the appearance of gibbsite and hence on bauxite formation. Simulation of granite weathering at higher temperature (35 instead of 25°C) shows that gibbsite appears earlier, with about 20% less rainwater flushed through the profile, as a result of the increase in silica solubility between 25 and 35°C.
The modelling also shows that elevated atmospheric CO_2 values strongly accelerate the formation of deep kaolinitic profiles. This explains why deep kaolinized profiles, and kaolinite deposits have been widespread during the Cretaceous, even at extratropical latitudes, and under cool, moderately humide climate conditions. There is no direct effect of the simulated increased CO_2 atmosphere on the rapidity of bauxitisation, but we know that the induced greenhouse effect and the particular Cretaceous paleogeography have both resulted in an increase in rainfall and in an important warming at intermediate latitudes. The simulation shows that the conjunction of these two factors is likely responsible for the expansion of the bauxites during the Cretaceous.

Imprint in the sedimentary record
The massive kaolinite formation during the Lower Cretaceous had a major impact on the clay mineral series of the sedimentary basins. The Upper Cretaceous sea level rise lead to the reworking of the kaolinitic weathering cover. Nevertheless the kaolinitic weathering paleoprofiles remained in place on wide continental areas until the Tertiary. A major reworking of these paleoprofiles occurred in Europe during the early Tertiary, when the climate became seasonally drier and vegetation cover more sparse, combined with the first Alpine tectonic movements. The kaolinite deposits of the Lower Eocene are mostly inherited from the Lower Cretaceous giant paleoweathering event.

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