The uranium mineralization of Pen Ar Ran (Armorican Massif), France: An atypical "vein type" deposit

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Twenty percent of the uranium produced in France was extracted in the Armorican Massif, in three different locations (Pontivy, Guérande et Mortagne) which belong to the "High Heat Production Belt", a 100 km wide NW-SE zone characterized by elevated contents in radioactive elements present in most of the geological formations [1], including 320 to 315 Ma old peraluminous granites [2].

In the Guérande uranium district, the Pen Ar Ran deposit is located in a deformed zone, at the contact between porphyroids and quartzitic black schists. This deformed zone corresponds to an E-W shear zone that affected both the metamorphic formations (porphyroids and black schists) and the intrusive Guérande leucogranite, during its emplacement. Mineralization is under the form of massive veins carrying pechblende and sulphide that are spatially associated with the leucogranite. However, this uranium deposit is different from the other "vein type" known in France because of the unusual nature of its uranium oxides (between pechblende and uraninite). Furthermore, the fluids responsible for this mineralization are hotter (350-400°C) than elsewhere.

The question of the source of the uranium is also complex. The uranium content of the metamorphic formations is rather low (around 3 ppm) but it is also low in the leucogranite (max. 9 ppm). It is however possible that the uranium was leached out of the granite by surface derived oxidizing fluids while the granite was still at depth [3]. Therefore, the leucogranite could represent the source of the uranium. In order to test this hypothetis, we performed a comprehensive petrological, geochemical, and geochronological study of the Guérande granite and compared these data to the available data from the porphyroid and the uranium mineralization.

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Controls on redox-nutrient cycling in the Cretaceous greenhouse ocean: Insights from S isotope systematics

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Oceanic anoxic events (OAEs) were a frequent occurrence in the Cretaceous greenhouse ocean. Based on a variety of paleoredox indicators, euxinic water column conditions are commonly invoked for these OAEs. However, in a high resolution study of OAE3 deep sea sediments [1], revised paleoredox indicators suggest that euxinic conditions fluctuated with anoxic ferruginous conditions on orbital timescales. Building upon this, we here present new data for a continental shelf setting at Tarfaya, Morocco, that spans a period prior to, and during, the onset of OAE2. We again find strong evidence for orbital transitions from euxinic to ferruginous conditions. The presence of this distinct cyclicity during OAE2 and OAE3 in shallow and deep water settings, coupled with its occurrence on the anoxic shelf prior to the global onset of anoxia, suggests that these fluctuations were a fundamental feature of anoxia in the Cretaceous ocean.

The observed redox cyclicity has major implications for the cycling of phosphorus, and hence the maintenance and longevity of OAEs. However, despite this significance, controls on the observed redox cyclicity are essentially unknown. Here, we utilize S isotope measurements (pyrite S and carbonate-associated S) from the deep sea and shelf settings to model oceanic sulphate concentrations across the redox transitions. Perhaps surprisingly, we find no evidence to suggest that ferruginous conditions arose due to extensive drawdown of seawater sulphate (as pyrite-S and organic-S) under euxinic conditions. Instead, S isotope systematics in the deep sea imply increased sulphate concentrations during ferruginous intervals. Based on these observations and other major element data, we infer that the redox cyclicity instead relates to orbitally-paced fluctuations in continental hydrology and weathering, linking the redox state of the global ocean to climate-driven processes on land.

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