Glendonite formation in Early Jurassic dark shales – Evidence for methane seepage in northern Germany

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Glendonites ($CaCO_3$) were found in two horizons of Early Jurassic (Upper Pliensbachian, spinatum zone) dark shales near Cremlingen, northern Germany. These distinctly shaped calcite crystals are pseudomorphs after the mineral ikaite, a calciumcarbonate hexahydrate, that is usually linked to formation in waters with near-freezing temperatures, organic-rich sediments, high alkalinity and high phosphate concentrations. Few of the marine findings of ikaite have been directly linked to the seepage of methane. Glendonites are common carbonate minerals that are known throughout the geologic history but their occurrence has been used up to now as indicators of cold climates or cold water temperatures. The glendonites of the Cremlingen section have been identified as carbonate precipitates induced by anaerobe oxidation of methane by their distinct light $\delta^{13}C$ values of up to -42 ‰PDB. Individual calcitic carbonate concretions show even lighter values of up to -48 ‰PDB. The sparse benthic biota and lacking evidence of a chemosynthetic community indicates that the methane seep was probably located in a largely oxygen-deficient system. The microfauna in the adjacent strata is composed of species-rich and thermophile calcifying organisms. This points towards a temperate or sub-tropic climate zone. Since paleo-reconstructions from that area suggest a shallow epicontinental ocean during this time interval, we assume that bottom water temperatures were clearly above ikaite-favoring temperatures. These findings suggest that ikaite and, in the fossil record, glendonites can be methane-induced carbonate formations at methane seeps. Maybe in a larger dimension then yet recognized, especially since ikaites have only a limited physico-chemical stability.

Petrogenesis of S-type syntectonic granites from Carrazeda de Ansiães, Northern Portugal

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A suite of syntectonic granites (G1 to G10) occurs in the Carrazeda de Ansiães area. They were emplaced during the post-collisional stage of the Variscan orogeny and intruded Cambrian and Ordovician metasediments producing micaschist and hornfels contact metamorphism aureoles.

Structural and petrographic data of granites G1 to G6 yield evidence for ductile and brittle deformation, characteristic of late magmatic and solid states, and ID-TIMS U-Pb ages for zircon and monazite show that they are the oldest granites of the Carrazeda de Ansiães area (329.9 ± 0.8 Ma – 318.9 ± 1.9 Ma). These six granites contain quartz, microcline, plagioclase, biotite, muscovite, tourmaline, zircon, sillimanite, apatite, monazite, ilmenite and rutile. Generally, they have more muscovite than biotite and contain surmicaceous enclaves.

Granites G1 to G6 are alkali-calcic and peraluminous, with ASI ranging between 1.21 and 1.45 and normative corundum of 2.63 – 4.77 %. Variation diagrams for these granites and their minerals, their REE patterns, $\delta^{18}O$ of 10.55 – 11.80 ‰, different mean values of $^{87}Sr/^{86}Sr_i$ and εNd_t for G1 (0.7097 ± 0.0000; -6.3), G2 (0.7149 ± 0.0008; -8.2), G4 (0.7112 ± 0.0006; -8.0) and G5 (0.7124 ± 0.0007; -7.5) show that they correspond to distinct pulses of S-type granite magmas, resulting from partial melting of heterogeneous metasedimentary material. Two series can be distinguished: a) G2 and G3 and b) G5 and G6. Modelling of major and trace elements show that the most silicic samples of granite G2 and granite G3 are derived from granite magma G2 by fractional crystallization of quartz, K-feldspar, plagioclase and biotite and that G6 is derived from G5 by fractional crystallization of K-feldspar, plagioclase and biotite. The $^{87}Sr/^{86}Sr_i$ values do not show variation from G2 to G3, indicating that fractional crystallization was the main mechanism; this is supported by the Rb-Sr isochron and relatively uniform εNd_t and $\delta^{18}O$ data. However, in the G5 and G6 series, there was also a contemporaneous assimilation of metasedimentary material, as shown by $^{87}Sr/^{86}Sr_i$, εNd_t data and a Rb-Sr errorchron.