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GLENDONITE OCCURRENCES IN THE TREMADOCIAN OF BALTICA: FIRST EARLY PALAEOZOIC EVIDENCE OF MASSIVE IKAITE PRECIPITATION IN TEMPERATE LATITUDES

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The Tremadocian (Early Ordovician) is currently considered a time span of greenhouse conditions with tropical water surface temperature estimates, interpolated from oxygen isotopes, approaching 40°C (Bassett et al., 2007; Trotter et al., 2008). In the high-latitude Baltoscandian Basin, these data are in contrast with the discovery of glendonite, a pseudomorph of ikaite ($CaCO_3 \cdot 6H_2O$) and valuable indicator of near-freezing bottom-water conditions. Previous records of glendonites display an apparent gap from Neoproterozoic to Permian times (James et al., 2005; Selleck et al., 2007). However, similar calcareous nodular aggregates embedded in Tremadocian black shales of the East Baltica (so-called "antraconites") have been known for more than 150 years. These aggregates are documented from numerous localities in the Türisalu and Koporiye formations (*Cordylodus angulatus – Paltodus deltifer pristinus* zones) exposed along 600 km of the Baltic-Ladoga Glint and sporadically in the Orasoja Member (Kallavere Formation). All these units accumulated in the Baltoscandian Basin, an epeiric sea with a central flat-floored depocentre rimmed to the south (recent coordinates) by a chain of low islands and associated shoal complexes (Popov et al., 1989; Heinsalu and Bednarczyk, 1997). During Tremadocian times, the basinal depocentre recorded black shale deposition episodically punctuated by wave and storm-induced processes, pointing to a sediment-starved, distal offshore-dominant clayey substrate, in which organic matter and trace metals became highly concentrated due to extremely low deposition rates and an exceptionally low influx of siliciclastic material. In contrast, nearshore environments comprised uncemented, well-washed, cross-laminated quartzose sands, which included high concentrations of allochthonous obolid coquinas that were continuously reworked along the shorelines (Popov et al., 1989). Perhaps the most surprising aspect of this new record is that the precipitation of glendonite is contemporaneous with the record of conodonts displaying low $\delta^{18}O$ values, which would suggest high temperatures (>40°C) in the water column. Therefore, the early Tremadocian sediments of Baltoscandia contain both "greenhouse" pelagic signals and near-freezing substrate indicators. This apparent paradox suggests both the influence of isotopically depleted freshwater yielded by fluvial systems, and the onset of sharp thermal stratification patterns in a semi-closed basin, which should have played an important role in moderating subpolar climates and reducing latitudinal gradients.

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