Iron from Land:
The Origin of Middle Permian (Trold Fiord) Glauconite in the Sverdrup Basin, Arctic Canada

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Summary

We present evidence that the relative abundance of glauconite in the Sverdrup Basin during the Middle Permian was due to the progressive encroachment of the sea and associated shoreface erosion of older iron-rich red beds and paleosols at a time of passive subsidence. In this context, dissolved iron was supply from land and not through upwelling as glauconite-rich deposits are generally interpreted in the literature.

Introduction

Glauconite is a group of green marine clays rich in Fe^{+2} and Fe^{+3} common in sedimentary rocks. Three factors are necessary for glauconite formation: (1) low sedimentation rates, (2) availability of dissolved iron, and (3) physical and/or biological reworking of the host sediment in and out of the oxic and anoxic zones beneath the sediment-water interface. In the modern oceans, these conditions are met in areas of upwelling on the outer shelf or in a slope environment where glauconite often occurs in condensed horizons. Glauconite-rich strata in the rock record are generally interpreted in a similar fashion. In both modern and ancient occurrences, iron is generally believed to be derived from the sea, often associated with other upwelled nutrients such as phosphorus and nitrogen.

Here we present evidence from the Trold Fiord Formation of the Sverdrup Basin that a significant Permian increase in glauconite abundance is unrelated to upwelling in a deep offshore setting (Reid et al., 2007, 2008). Instead, glauconite accumulated in a proximal setting, ranging from lower shoreface to offshore transition zone. Iron was supplied from land as a result of coastal onlap and shoreface erosion of iron-rich red beds and paleosols of the Upper Carboniferous to Lower Permian Canyon Fiord Formation.

Method

Glauconite is common in the Middle Permian (Wordian-Capitanian) Trold Fiord Formation, a green basin-fringing unit of the Sverdrup Basin, Arctic Canada (Thorsteinsson, 1974). We measured three unweathered sections of the Trold Fiord Formation in an area immediately west of McKinley Bay, on NW Ellesmere

Island, Nunavut (Fig. 1). In that area, the Trold Fiord Formation passes westward into biogenic carbonates and spiculitic cherts of the Degerböls Formation that represent more distal shelf sedimentation. In addition to detailed lithological and sedimentological descriptions in the field, we conducted a series of petrographic and geochemical tests to characterize the mineralogy of the glauconite. We identified four lithofacies representing proximal storm-dominated sedimentation ranging from lower shoreface to offshore transition zone to proximal offshore (Fig. 2). Based on the interpreted environments and observations of key stratigraphic surfaces, we grouped the studied succession into two long-term stratigraphic sequences, interpreted as representing Wordian and Capitanian sedimentation respectively (Fig. 3). Glauconite abundance was then plotted against the sequence stratigraphic framework (Fig. 3).

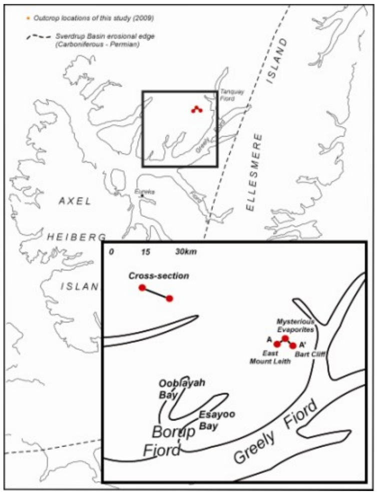

Figure 1: Location map

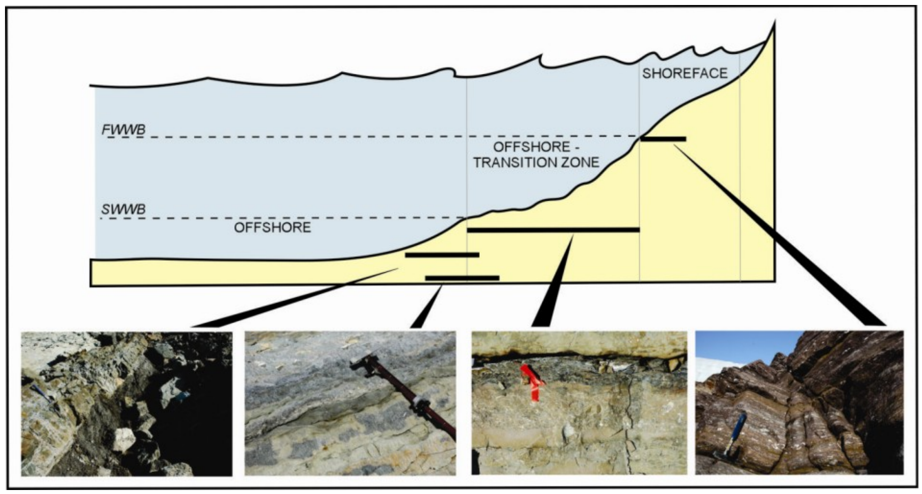

Figure 2: Range of lithofacies and environments, Trold Fiord and Degerböls Fms.

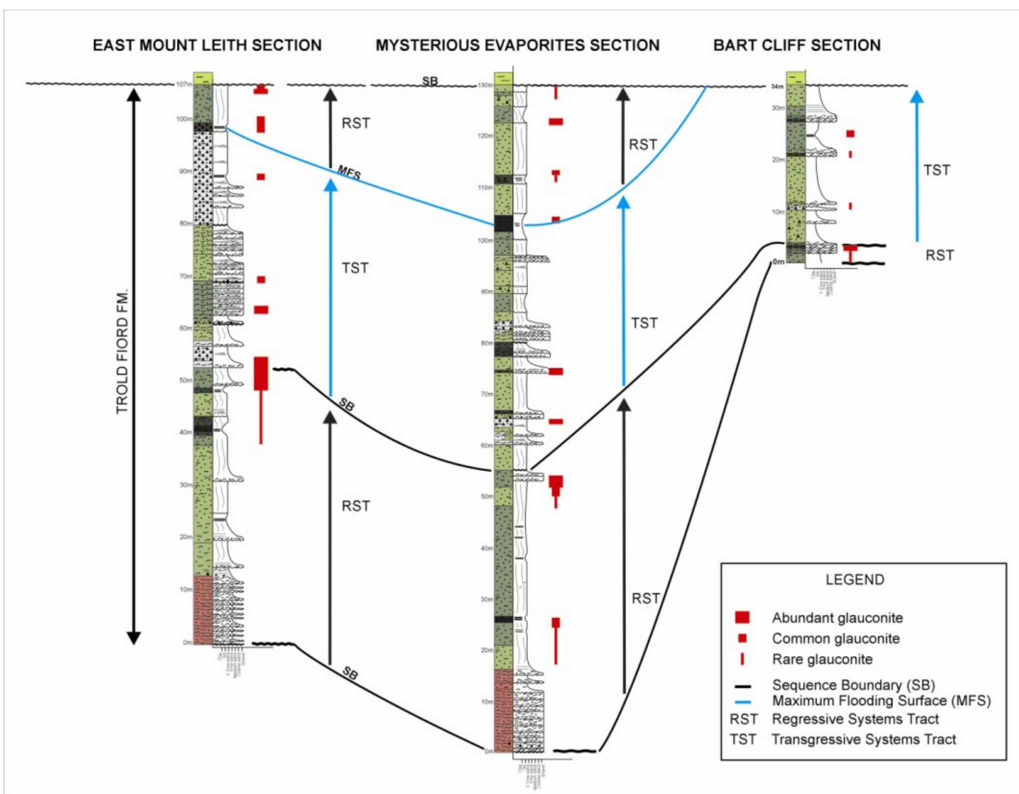

Figure 3: Sequence stratigraphic cross-section

Results

The Wordian and Capitanian Trold Fiord Formation (glauconitic sandstone) and correlative Degerböls (spiculitic chert) formations form a relatively thin and uniform stratigraphic blanket that ranges from 120 m to the west to 34 m to the east, suggestive of low sedimentation rates at a time of passive subsidence. Lithofacies analysis of the Trold Fiord Formation in the study area indicate sedimentation on a storm dominated shelf with lithofacies ranging from middle to lower shoreface in the proximal areas, to shallow and deep offshore transition zone in the intermediate area, and to deeper water upper offshore in the distal area (Fig. 2). A rich suite of ichnofossils in all three studied formations suggest open marine, well oxygenated conditions across the shelf. Two long-term transgressive-regressive (T-R) sequences are recognized based on the distribution of the various lithofacies and their environmental interpretations (Fig. 3).

The so-called mineral glauconite, which is locally abundant in the Trold Fiord Formation, is shown, through our geochemical analysis, to be represented by a variety of minerals that range from variably altered glauconite to iron-rich illite and chlorite. Petrographically, there is evidence of both autochthonous glauconite and parautochthonous glauconite. Autochthonous glauconite formed in an environment that ranged from proximal offshore to the mid offshore-transition zone. Parautochthonous glauconite were remobilized by storms and transported landward into the more proximal offshore transition zone and lower shoreface environment. Glauconite is not everywhere abundant in the Trold Fiord Formation. It does occur in significant abundance at certain stratigraphic horizons only, irrespective of the systems tract (TST or RST) (Fig. 3).

Discussion

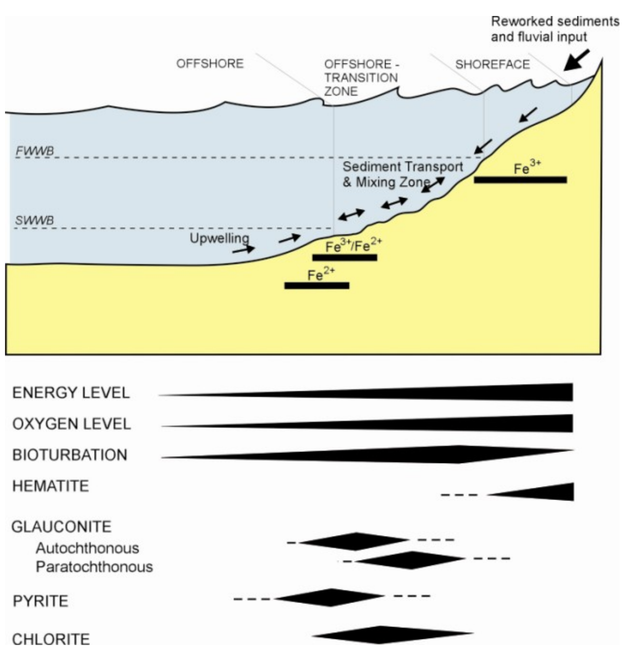

Figure 4: Distribution of hematite, glauconite and pyrite across depositional spectrum of the Trold Fiord Formation

As in the modern environment, low sedimentation rates played a major role in glauconite formation. Yet similar conditions, before and after Trold Fiord deposition did not lead to significant glauconite deposition. The glauconite accumulated in a proximal setting, ranging from deep shoreface to offshore transition zone and little or no glauconite occurs in the more distal shelf setting, suggesting that upwelling did not play a major role (Fig. 4**).** We observed a continuum from red haematitic middle shoreface deposit, where iron is an oxidized state (Fig. 2), green glauconitic where iron is in both an oxic and reduced state, and distal areas where iron, if present, is in a reduced state in the form or pyrite (Fig. 5). This continuum reflects processes immediately beneath the sediment-water interface and suggests that dissolved iron was supplied from land.

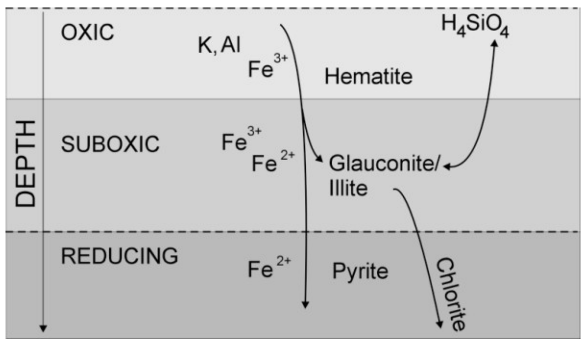

Figure 5: Formation of hematite, glauconite and pyrite in different depth-related diagenetic zones

The emergence of glauconite following the Roadian-Wordian boundary, and its common occurrence up until the Latest Permian is contemporaneous with a progressive landward impingement of Middle and Upper Permian sequences following the end of fault-controlled subsidence at the Roadian-Wordian boundary. A new regime of passive subsidence enabled progressively younger sequences to impinge upon increasingly landward areas. Shoreface erosion and ravinement associated with the coastal onlap of each sequences, both during the RST and TST led to the erosion of significantly older strata belonging to the Canyon Fiord Formation. As these strata were rich in red iron-rich material, they became the source of iron in the basin. Accordingly, Trold Fiord strata rest unconformably upon Canyon Fiord strata near the erosional edge of the Late Paleozoic Sverdrup Basin. The glauconite system stopped abruptly during the Latest Permian, as further landward incursion led to the overstepping the Canyon Ford zero-edge by the Blind Fiord and Bjorne formations, thus shutting down an important source of iron. Furthermore, the rates of clastic sedimentation increased several folds, smothering the glauconite forming process.

Conclusions

Glauconite in the Trold Fiord Formation resulted from low sedimentation rates, pervasive bioturbation and dissolved iron supplied from land.

References

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