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Geochemical Conditions Related to Glendonite Formation: a Case Study from Ellef Ringnes Island, Nunavut

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Summary

Glendonites, calcite pseudomorphs after the metastable mineral ikaite ($CaCO_3 \cdot 6H_20$), have been described within early Cretaceous strata of the Sverdrup Basin. Based on observations of modern ikaite occurrences, consensus within the scientific literature suggests that the presence of glendonite indicates host sediment accumulation under near freezing, highly alkaline, orthophosphate-rich bottom water conditions. Laterally extensive glendonite horizons occur in the Valanginian of the Deer Bay Formation and the Aptian-Albian of the Christopher Formation, though detailed chemo-stratigraphic studies of these glendonite bearing shales have been limited. This study evaluates environmental conditions leading to ikaite formation primarily using chemo-stratigraphic profiles created for measured sections within both the Deer Bay and Christopher formations exposed on Ellef Ringnes Island. Preliminary results imply oxic bottom-water conditions at the time of deposition. In the modern environment, it is known that the oxidation of ascending, methane-rich fluids produces alkaline conditions highly saturated with respect to carbonate. Though their morphology is highly variable, a large proportion of glendonites examined (particularly in the Christopher) exhibit restricted crystal growth in one direction, suggestive of ikaite development at the sediment-water interface rather than within the zone of sub-oxic diagenesis beneath the sediment-water interface. Results of stable isotope analyses are pending, however, carbon isotope values are expected to reflect methane-related organic carbon sources given previous, unpublished results. The findings of this study may have implications regarding broad-scale gas migration within the Sverdrup Basin during the early Cretaceous. Additionally, if the above mentioned environmental parameters, as observed at modern ikaite localities, are assessable in ancient sediments, then glendonites can be utilized more accurately in paleoenvironmental interpretations.

Introduction

Glendonites were first described within Permian siltstones of the Sydney Basin (David et al., 1905). They have since been recognized within strata ranging in age from Precambrian (Johnston, 1995; James *et al.,* 2005) to Recent (Selleck *et al.,* 2007). Glendonites from Cretaceous strata have been described from high latitude localities in Australia, Spitzbergen, and the Canadian Arctic Archipelago, leading to the interpretation of possible glacial environments during an otherwise warm period in earth's history (De Lurio et al., 1999; Price, 1999). Though the identity of the parent mineral was initially uncertain, ikaite is now widely accepted as the precursor to glendonite (Suess et al., 1982; Swainson and Hammond, 2001).

Ikaite forms at temperatures between -1.9 ^{o}C and 7^{o}C, but readily decomposes to calcite and water at higher temperatures (Suess et al., 1982; Shearman and Smith, 1985; Rickaby et al., 2005). The limited thermal stability range of ikaite has been used to uphold glendonites as indicators of cold water, and by extension, cold climates (Price, 1999, 2010; Selleck *et al.* 2007). This association was made even before the suggestion of an ikaite precursor (Suess *et al*., 1982), based on paleogeographic distributions of glendonites and their association with cold water faunal assemblages, fossil wood, and dropstones (Kemper and Schmitz, 1975; Kaplan, 1979). However, cold temperatures alone will not result in ikaite precipitation and growth. It has been suggested that this also requires alkaline environments supersaturated with respect to calcite and containing high concentrations of a chemical inhibitor, such as dissolved phosphate, to suppress anhydrous calcite nucleation (Shearman and Smith 1985; Swainson and Hammond, 2001; Rickaby *et al.*, 2006). These conditions are commonly encountered on high latitude shelves in association with organic-rich marine sediments (Selleck *et al.* 2007) or in the proximity of methane seeps (Greinert and Derkachev, 2004).

Methodology and Points of Discussion

The material used in this study was collected from exposures at six localities situated on north-central and south-eastern Ellef Ringnes Island, Canadian Arctic Archipelago, during the summer of 2010 (Fig. 1 and Fig. 2). Sample sites were chosen by reviewing previously produced maps and reports (Stott, 1969), or by additional field investigation. In conjunction with the collection of glendonite specimens, three sections were measured and systematically sampled – one within the upper Deer Bay Formation and two within the lower Christopher Formation.

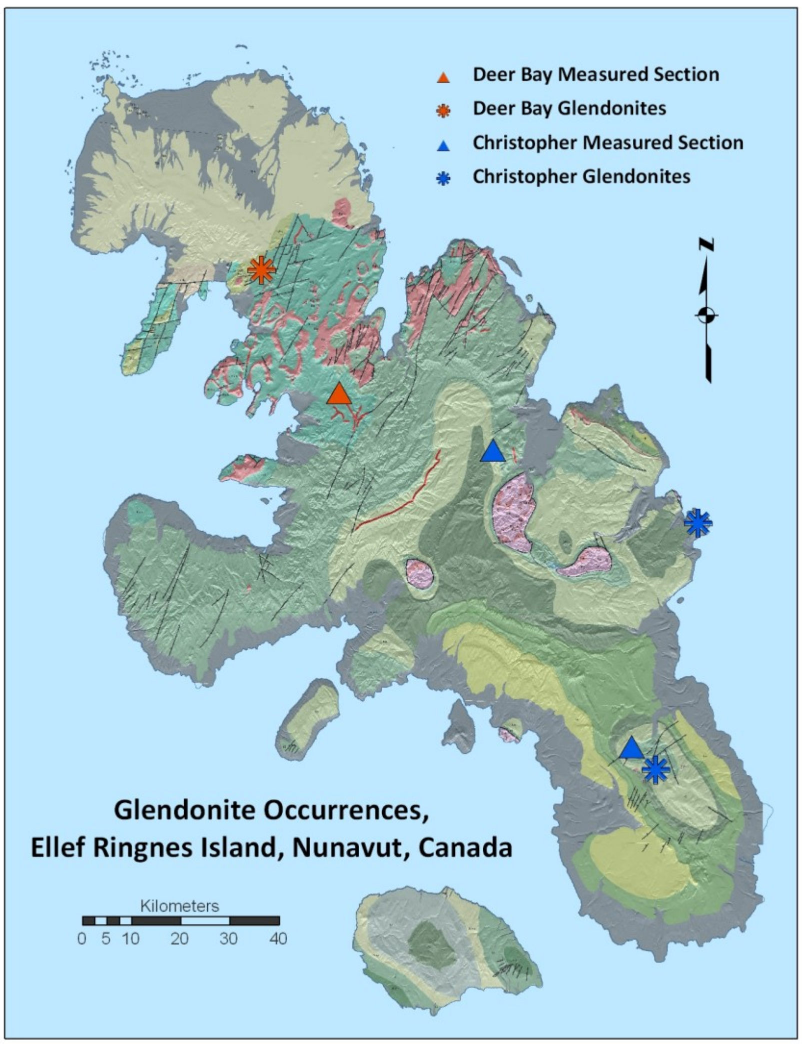

Figure 1: Observed glendonite occurrences and measured section localities, 2010 field season, Ellef Ringnes Island.

Chemostratigraphic profiles of the three measured sections will be presented, which synthesize results from geochemical, isotopic, and rock eval analyses derived from both the glendonites themselves and the shales in which they are found. Interpretation of environmental conditions represented in the Deer Bay will be compared with those from the Christopher. Implications for glendonites as indicators of hydrocarbon migration and paleoclimate will be discussed.

Figure 2: A) exposure of the Deer Bay Formation and location of the Deer Bay measured section near Louise Bay, Ellef Ringnes Island. B) a glendonite from the Christopher Formation near Dumbbells dome, exhibiting preferential crystal growth in one direction. C) an abundant glendonite winnowing horizon in the Deer Bay Formation.

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