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Tracking lateral $\delta^{13}C_{carb}$ variation in the Paleoproterozoic Pechenga Greenstone Belt, the north eastern Fennoscandian Shield

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ABSTRACT

The Kuetsjärvi Sedimentary Formation (KSF) records the global Paleoproterozoic (ca. 2200–2100 Ma) positive $\delta^{13}C$ excursion of sedimentary carbonates. This event is here called as the Lomagundi-Jatuli isotopic excursion. In this study, lateral $\delta^{13}C_{carb}$ variation in the KSF and local basinal factors amplifying global $\delta^{13}C_{carb}$ value were investigated and a secular $\delta^{13}C$ curve for the KSF was constructed. Sedimentary carbonate samples from a new drillcore (Drillcore 5A) from the KSF were analysed for $\delta^{13}C$, $\delta^{18}O$ and selected major and trace elements. The $\delta^{13}C$ values of the samples vary from 5 to 8‰ (VPDB) and the $\delta^{18}O$ values from −18 to −10‰ (VPDB). Most of the samples have retained their primary C isotopic composition, as they do not show correlation between the Mn/Sr ratios and the $\delta^{13}C$ and $\delta^{18}O$ values. The new results were compared to those previously obtained from another drillcore (Drillcore X) from the KSF (ca. 25 km along strike from Drillcore 5A). Both cores show a similar kind of generally upward decreasing trend in $\delta^{13}C$, excluding some negative and positive spikes in Drillcore X and samples close to a contact with a Fe-picrite dyke in Drillcore 5A. A secular $\delta^{13}C$ curve of the KSF was constructed based on the least altered $\delta^{13}C$ data from the cores 5A and X. The secular $\delta^{13}C$ curve of the KSF may represent the latest part of the Lomagundi-Jatuli isotopic excursion.

1. Introduction

The Paleoproterozoic positive $\delta^{13}C$ excursion of sedimentary carbonates provides evidence for a major perturbation in the global carbon cycle (e.g. Baker and Fallick, 1989a,b). Based on well-dated successions, this event has been constrained to between ca. 2200 and 2100 Ma (Karhu and Holland, 1996). The extreme enrichment in ^{13}C was first reported from Jatulian sedimentary carbonate units in Russian Karelia (Galimov et al., 1968), in the Peräpohja Belt of Finland (Schidlowski et al., 1975) and most thoroughly in the Lomagundi Basin, Zimbabwe (Schidlowski et al., 1975, 1976). Accordingly, the excursion is here referred as the Lomagundi-Jatuli isotopic excursion (LJIE). Since the first reports, the LJIE has been documented in many other localities worldwide, including Scotland (Baker and Fallick, 1989a), Ukraine (Zagnitko and Lugovaya, 1989), North America (e.g. Bekker et al., 2003a; Melezhik et al., 1997), South-America (e.g. Bekker et al., 2003b), Africa (e.g. Bekker et al., 2001; Buick et al., 1998), Australia (Lindsay and Brasier, 2002), India (e.g. Maheshwari et al., 1999; Sreenivas et al., 2001) and China (Tang et al., 2011). On the Fennoscandian Shield, sedimentary carbonate successions with highly positive $\delta^{13}C$ values are known in Norway (Baker and Fallick, 1989b; Melezhik and Fallick, 1996), Finland (e.g. Karhu, 1993), Sweden (Karhu, 1993; Melezhik and Fallick, 2010) as well as in Karelia and Kola Peninsula in NW Russia (e.g. Karhu, 1993; Karhu and Melezhik, 1992; Melezhik et al., 1999; Melezhik and Fallick, 1996; Yudovich et al., 1991).

The shape of the Paleoproterozoic secular $\delta^{13}C_{carb}$ trend is not known in detail. The compilation of Karhu and Holland (1996) defined a single carbon isotope excursion lasting 100–200 Ma, but the details of the curve are poorly known. Defining the shape of the Paleoproterozoic secular $\delta^{13}C_{carb}$ trend is important for chemostratigraphic purposes because chemostratigraphy can be used as a tool in correlating distant sections and global events in the Proterozoic, where biostratigraphic correlation methods cannot be applied (e.g. Sial et al., 2010). The $\delta^{13}C$ values of marine sedimentary carbonate units reflect the δ^{13} composition of dissolved inorganic carbon (DIC) in seawater at the time of deposition (e.g. Holser et al., 1988). As the residence time of DIC in the oceans is longer than the mixing time of the oceans, the ocean basins are relatively homogeneous relative to the isotopic composition of carbon and major $\delta^{13}C$ variations in marine carbonates can be correlated over a wide area (e.g. Scholle and Arthur, 1980).

The Paleoproterozoic Kuetsjärvi Sedimentary Formation (KSF) of the Pechenga Greenstone Belt in the north eastern

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Fennoscandian Shield is one of the sedimentary successions that records the LJIE. Previous investigations have reported high $\delta^{13}C$ values in sedimentary carbonates, ranging from 2 to 10‰ (e.g. Karhu, 1993; Karhu and Melezhik, 1992; Melezhik et al., 2003, 2004; Melezhik and Fallick, 1996, 2001, 2003). Drillcore-based data suggest that the least-altered $\delta^{13}C$ values exhibit a smooth decreasing stratigraphic trend from 8.9 to 5.8‰ with several short-term positive and negative spikes with an amplitude up to 1.7‰ (Melezhik et al., 2005). Such spikes could be explained either by unusually rapid restructuring of the global carbon reservoir or due to amplification by local factors in ^{13}C-enrichement in seawater.

Consequently the objectives of this paper are (i) the investigation of lateral, basinal variations of $\delta^{13}C_{carb}$ values by studying and comparison/contrasting two distant, densely sampled, cored sections, (ii) the deciphering of local basinal factors possibly amplifying the global $\delta^{13}C_{carb}$ value, and (iii) the construction of a detailed secular $\delta^{13}C_{carb}$ curve by combining two datasets.

The objectives are achieved by investigation and detailed sampling of a core from a newly made drillhole that intersected the entire thickness of the Kuetsjärvi Sedimentary Formation. The obtained analyses of carbon isotopic composition will be compared with data reported from another cored section located at a distance of ca. 25 km along strike (Melezhik et al., 2005).

2. Geological setting and lithostratigraphy

The KSF is a part of the Pechenga Greenstone Belt, which belongs to a larger, approximately 1000 km long, discontinuous volcano-sedimentary belt in the north-eastern part of the Fennoscandian Shield (e.g. Melezhik and Sturt, 1994) (Fig. 1). This larger belt has been interpreted as an intracontinental rift developing into an intercontinental rift with a subsequent aborted oceanic phase and arc–continent collision (e.g. Melezhik and Sturt, 1994), but more extensive ocean opening followed by oceanic floor subduction and arc–continent collision has also been suggested (Berthelsen and Marker, 1986).

The Pechenga Greenstone Belt comprises the North and South Pechenga groups (e.g. Melezhik and Sturt, 1994). The KSF belongs to the North Pechenga Group, which consists of four paired sedimentary–volcanic cycles (Fig. 1), separated by either non-depositional unconformities or faults (Melezhik and Sturt, 1994). Berthelsen and Marker (1986) suggested that the ca. 2400–2000 Ma sediments of the North Pechenga Group have been accumulated in environments ranging from terrestrial through shallow- to deep-water marine. Melezhik and Fallick (2005) and Melezhik et al. (2005) interpreted the depositional environment of the KSF as evolving from deltaic through shallow lacustrine to a sea-influenced rift-bound lake.

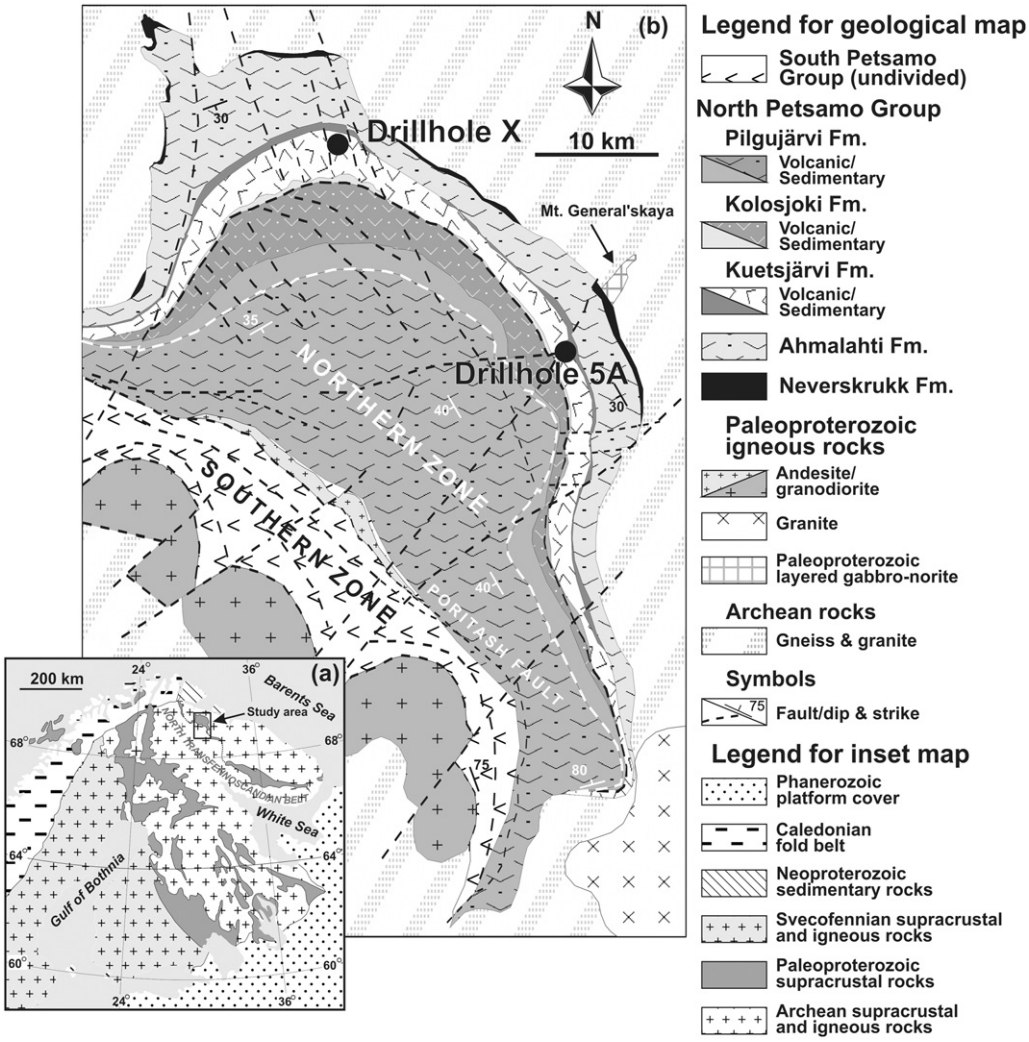

Fig. 1. Location of (a) the Kuetsjärvi Sedimentary Formation and (b) Drillholes 5A and X. Modified from Melezhik and Fallick (2005).