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Sedimentary and volcanic facies recording the Neoarchaean continent breakup and decline of the positive $\delta^{13}C_{carb}$ excursion

A. Wanke[a], V. Melezhik[b,*]

[a] *Department of Geology, University of Oulu, Pl 3000, 90014 Finland*
[b] *Geological Survey of Norway, N-7491 Trondheim, Norway*

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Abstract

The Palaeoproterozoic Kalix Greenstone Belt, at the northern end of the Bothnian Bay in Sweden, comprises three groups. The *Lower group*, a ca. 3000 m thick unit of subaerially erupted, tholeiitic, intraplate, basalts interbedded with fluviatile conglomerates, represents the volcano-sedimentary succession deposited in a rift setting. These units are truncated by a break-up unconformity above which is the *Middle group*, an 800 m thick succession of dolograinstones, stromatolitic dolostones, arenites, volcanoclastic and mafic volcanic rocks. Stromatolite morphologies and the occurrence of distinctive sedimentary structures, including planar and herringbone cross-bedding, hummocky cross-stratification, symmetrical and asymmetrical ripples, desiccation cracks and tepees, indicate markedly variable depositional environments associated with transition from a marine-influenced, rifted margin to a rimmed carbonate shelf. Sedimentation was accompanied by subaerial mafic volcanism and syndepositional tectonics. The *Upper group*, a more than 2000 m thick unit of deep-water shales, was deposited on the drowned carbonate platform of the *Middle group* in response to tectonically enhanced subsidence. This study provides a detailed Palaeoproterozoic depositional history of the Fennoscandian Shield from rifting to passive margin development associated with both dispersal of the Neoarchaean supercontinent and decline of the Proterozoic positive isotopic excursion of $^{13}C/^{12}C$ in sedimentary carbonates. In contrast to many previously reported ^{13}C-rich Palaeoproterozoic carbonates, which were deposited in non-marine to restricted or partly restricted settings, the carbonate facies reported herein were well connected to the oceanic realm and thereby represent a good opportunity to test ‘restricted-marine’ versus ‘open-marine’ models for how the carbon cycle functioned in Deep Time.

Keywords: Fennoscandian Shield; Palaeoproterozoic; Rift; Passive margin; Rimmed shelf; Dolostone; Stromatolites

1. Introduction

Aspler and Chiarenzelli (1998) suggested that at the end of the Archaean, continental plates had assembled into two supercontinents. The first included the Zim-

* Corresponding author. Tel.: +47 73 90 40 00; fax: +47 73 92 16 20.
E-mail address: victor.melezhik@ngu.no (V. Melezhik).

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babwe, Kaapvaal, Pilbara and São Francisco cratons, and cratonic blocks in India. The second, called Kenorland (Williams et al., 1991), included the Archaean cratons in North America as well as the Fennoscandian and Siberian shields. Both supercontinents subsequently experienced a protracted break-up, caused by the rise of a mantle plume and associated intraplate rifting followed by final dispersal.

With respect to the Fennoscandian Shield, incipient break-up and rifting started at ca. 2500 Ma. At around 2400 Ma, a phase of basin inversion was initiated but subsequently aborted and was followed by reactivation and formation of a series of intercontinental rift zones (Melezhik and Sturt, 1994; Melezhik et al., 1997). The culmination of the repeated rifting finally resulted in the opening of the ca. 2100–2000 Ma Kola Ocean (Marker, 1985; Balagansky et al., 2001; Daly et al., 2001). The separation of the Neoarchaean supercontinent resulted in invasion of seawater (Gaál and Gorbatchev, 1987; Strand and Laajoki, 1999) into rift-bound lacustrine and lagoonal depositional systems and demise of stromatolite abundance and diversity (Melezhik et al., 1997).

The break-up of the Neoarchaean supercontinent coincides in time with a sharp decline of the Palaeoproterozoic positive isotopic excursion (Karhu, 1993), one of the greatest in Earth's history (Melezhik et al., 1999). To date, the causal mechanisms of this largest and earliest perturbation of Earth's global carbon cycle remain enigmatic and debatable and the relationship between rapid isotopic decline, depositional environments and tectonic settings remains poorly documented and not fully understood (Melezhik and Fallick, 1996; Shields, 1997; Melezhik et al., 1999, 2005). In part, this is a consequence of the fact that very few places house a record of this particular period of time. A study conducted in one of such place, the Wyoming craton, has shown that the decline of the isotopic excursion was associated with the break-up of Kenorland (Bekker and Eriksson, 2003; Bekker et al., 2003). The Fennoscandian Shield is another place where sedimentary successions record both the final break-up of the Archaean craton and the decline of the Palaeoproterozoic isotope excursion, and here there are only two sites, the Peräpohja Schist Belt (Perttunen, 1985) in Finland and the Kalix Greenstone Belt (Lager and Loberg, 1990; Öhlander et al., 1992) in Sweden. Both areas contain a sedimentary-volcanic succession spanning the transition from intracontinental rifting to drifting and a rapid decline of the Palaeoproterozoic positive isotopic excursions of $^{13}C/^{12}C$ in sedimentary carbonates (Karhu, 1993). Thus, these sites offer a rare opportunity for investigating the evolution of depositional environments which were associated with the Palaeoproterozoic isotope excursion. In this paper we report on the sedimentary succession of the Kalix Greenstone Belt, with the major objectives to determine: (i) the interplay between deposition and tectonic processes during the transition from an intracontinental rift setting to a marine environment; (ii) the influence of clastic and volcanic input on biological activity; (iii) stromatolite morphologies and depositional environments; and (iv) palaeoenvironmental and tectonic constraints for forthcoming isotopic work on the decline of the positive excursion of $^{13}C/^{12}C$ in sedimentary carbonates.

2. Geological setting and lithostratigraphy

The Kalix Greenstone Belt is located within the Swedish portion of the Fennoscandian Shield at the northern end of Bothnian Bay (Fig. 1a). The belt exhibits a volcano-sedimentary sequence of Palaeoproterozoic age (Öhlander et al., 1992) with a varied suite of carbonate, siliciclastic, volcanoclastic and volcanic rocks (Lager and Loberg, 1990). Although the rocks have been metamorphosed to greenschist facies, their primary sedimentary and volcanic structures are well preserved. The belt is physically isolated from other areas of Palaeoproterozoic rocks and, although it is separated from the neighbouring Peräpohja Belt in Finland by only a 40 km wide, synorogenic, granitoid intrusion (Fig. 1a), stratigraphic correlation between these two areas represents a challenge (Karhu, 1993).

In the Kalix area, the depositional basement is unknown and the supracrustal sequence has been informally subdivided into three groups (Lager and Loberg, 1990). The *Lower group* (*LG*) is a ca. 2500 m thick unit (Fig. 2) composed of mafic lavas and tuffs interbedded with minor fluviatile, polymict conglomerates and arenites. The lavas are represented by massive, subophytic, porphyritic and amygdaloidal varieties showing evidence for subaerial eruption (Lager and Loberg, 1990).

The *Middle group* (*MG*), which is a main focus of this study, is separated from the underlying mafic lavas