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Dating Palaeoproterozoic glacial deposits of the Fennoscandian Shield using detrital zircons from the Kola Peninsula, Russia

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ABSTRACT

New age constraints from detrital zircon U-Pb geochronology from clastic sediments and diamict deposits obtained maximum depositional ages for the Seidorechka and Polisarka Sedimentary formations of the Imandra-Varzuga Greenstone Belt of the Kola Province, NW-Russia. These delimit the deposition of Palaeoproterozoic Huronian-age glacial deposits of the Fennoscandian Shield from c. 2430 Ma to <2411 Ma. The time constraint allows comparison to the first two of three possible glacial intervals recognised in the Huronian Supergroup, Canada, and South African diamict deposits. Intercontinental comparisons support these constraints, the assumption of a glacial origin of the diamictites and, further, the eventually global extent of the event. Similar age distributions and depositional ages of c. 2400 Ma within the Neverskrukk Formation of the Pechenga Greenstone Belt support a correlation with the Imandra-Varzuga Greenstone Belt succession, which was traditionally based on lithostratigraphic observations.

The detrital zircon age spectra of eight analysed samples show an Archaean dominance and reoccurring peaks around 2800–2750 Ma,which indicate similar origins for the zircons. Such peaks are corroborating with a major global crustal generation event being recorded in detrital zircon spectra worldwide. Additionally, certain age populations around 2440 Ma and 2500 Ma are present and indicate a correlation with intrusive magmatism that affected the region at that time and support a correlation based on overlapping age distributions.

1. Introduction

The Fennoscandian Shield is one of the best known Precambrian regions and comprehends an almost complete archive of the Archaean to Palaeoproterozoic. The Archaean–Palaeoproterozoic transition between 2500 and 2000 Ma marks a time of incisive upheavals in Earth's climate, atmosphere chemistry and palaeogeography, including the Great Oxidation Event, the global Huronian glacial events, the Lomagundi Jatuli carbon isotope excursion and significant changes in the P and S cycles (e.g. Martin et al., 2012; Bekker et al., 2006, reviewed in Melezhik et al., 2005, 2012a and references therein). Deposits related to such changing events are preserved in the Fennoscandian rock successions, especially Palaeoproterozoic greenstone belts of the Kola and Karelia provinces. Formations of the studied Pechenga and Imandra-Varzuga greenstone belts (Fig. 1) contain e.g. isotopically heavy carbonates of the Lomagundi-Jatuli Event, organic carbon-rich sedimentary rocks indicating the onset of the deposition of the first petroleum reservoirs (shungites) and most important for this study glacial diamictites of assumed Huronian age. These were observed in the Polisarka and Neverskrukk formations of both considered greenstone belts (Fig. 2).

The Palaeoproterozoic Huronian glaciation is one of the major events of global significance during this period of Earth's history. It occurred presumably worldwide as up to three glacial sub-events while reaching up to low latitudes. Its diamictite deposits have been observed in North America, South Africa, Australia, Fennoscandia and others (Young, 1970; Evans et al., 1997; Hannah et al., 2004; Melezhik, 2006), which led Kirschvink (1992) to propose it as the first global low latitude glacial event, a "Snowball Earth" stage. It is supported by the assumed existence of the supercontinent Kenorland, named after the Kenoran orogeny by Williams and Schmidt (1997) and as one of two assumed supercontinents of the Neoarchean (Aspler and Chiarenzelli, 1998) made up mainly of the Superior, Slave, Siberiaand Fennoscandia cratons (Melezhik, 2006; Williams et al., 1991). During this supercontinental stage most of

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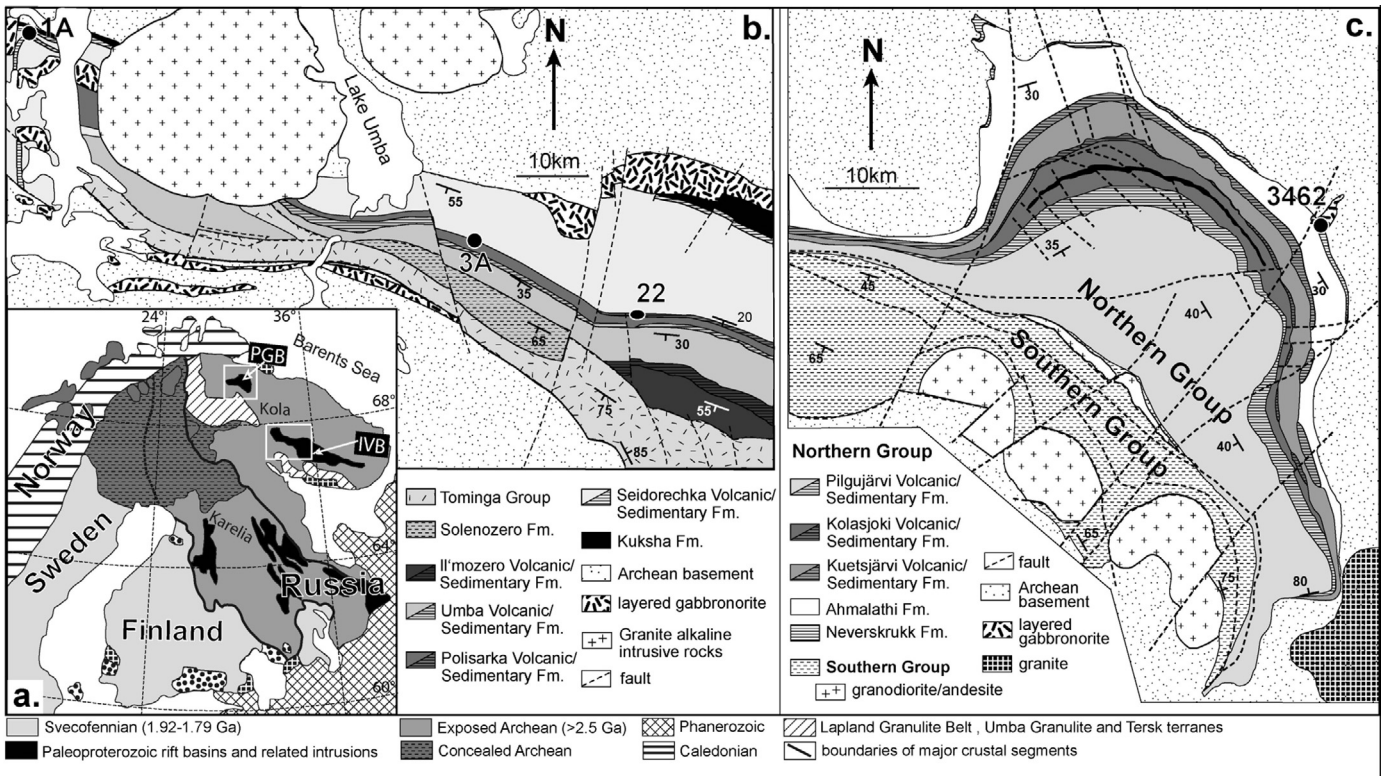

Fig. 1. Simplified geological map of the Fennoscandian Shield with study areas and sample locations. (a) Overview of the Fennoscandian Shield with different aged domains. White boxes show studied greenstone belts (after Daly et al., 2001); (b) Eastern Imandra-Varzuga Greenstone Belt (IVB, after Zagorodny et al., 1982), (c) Pechenga Greenstone Belt (PGB, modified after Predovsky et al., 1974). Black circles illustrate the sample sites or drill locations. A coloured version of the figure is available in the online supplementary material.

the cratons were positioned near the equator in tropical latitudes (Williams and Schmidt, 1997).

The onset of glacial conditions was preceded by the beginning break-up of Kenorland around 2450 Ma, accompanied by increased magmatic activity and the deposition of banded iron formations (Strand and Laajoki, 1993). Factors contributing to the onset of glacial conditions include the drawdown of atmospheric CO_2, due to tectonic re-organisation related to the supercontinental stage (Young et al., 2001; Evans, 2003) and the rise of oxygen at around 2320 Ma (Kopp et al., 2005; Bekker et al., 2004). Furthermore, Melezhik (2006) proposed multiple causes including silicate weathering of fresh basaltic surfaces in newly-formed large igneous provinces, which consumed atmospheric CO_2.

Typical glaciogenic deposits in Palaeoproterozoic sections, related to the Huronian, show lithological similarities as they contain diamictites, polymict conglomerates and varve-like laminated sedimentary rocks containing dropstones (Young, 1970; Young et al., 2001; Marmo and Ojakangas, 1984; Ojakangas, 1985; Long, 2004; Melezhik et al., 2013a). The type locality for the Huronian-age glaciogenic rocks in the Fennoscandian region is the Urkaavaara Formation in Finland (Marmo and Ojakangas, 1984), where thick glacigenic deposits in its lower part and a thinner unit in the upper part point to one or two closely spaced glacial cycles. On a global scale, in the eponymous Canadian Palaeoproterozoic Huronian Supergroup, three diamictite bearing formations crop out in the Gowganda, Bruce and Ramsay Lake formations (Young et al., 2001, Fig. 2). This suggests at least three glacial events (Young et al., 2001; Hannah et al., 2004). Geochronological data from volcanic rocks below the base of the earliest diamictites in the Ramsay Lake Formation (Copper Cliff Rhyolite, 2450 +25/-10 Ma, Long, 2004) and

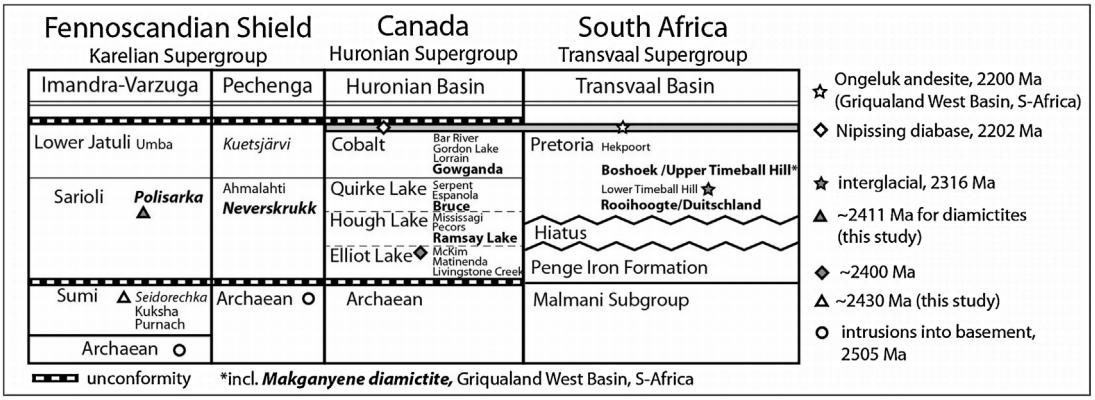

Fig. 2. Glacial deposits and their stratigraphic and chronostratigraphic correlation for Fennoscandia, Canada and South Africa. Formations containing diamictites are bold. Age data are from Amelin et al. (1995), Evans (1997), Hannah et al. (2004) and Young et al. (2001).