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Tracing Archaean terranes under Greenland's Icecap: U–Th–Pb–Hf isotopic study of zircons from melt-water rivers in the Isua area

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ABSTRACT

The Archaean gneisses of the Nuuk area (southern West Greenland) are partitioned into tectonostratigraphic terranes – blocks of arc-like crust that evolved independently until they coalesced by collisional orogeny. To 'map' terranes to the east under the Inland Ice, sand samples were taken from rivers issuing from the edge of the Icecap; three from the Isua area and one from ~20 km to the south. Bedrock along this part of the ice front consists of ~3820–3600 Ma amphibolite facies rocks. 40 km south of Isua (Kapisilik terrane in the Ivisaartoq area) and also from ~10 km to the north there are Mesoarchaean amphibolite facies gneisses (3070–2950 Ma) exposed at the ice front. In the moraine fields in the Isua area there are erratic blocks of granulite facies gneisses. These were sourced from a hidden terrane to the east under the ice because no such rocks are exposed in the Isua area.

The majority of the zircons from the sand samples yielded close to concordant U–Pb ages. Apart from one 2414 Ma grain, all are Archaean. The Isua sands show ~2695, 2710 and 2730 Ma; then 2790, 2805 and 2840 Ma clusters with a few grains back to 2950 Ma and then a complex 3440–3960 Ma spectrum. Less than 1% of the grains have ages between 3000 and 3400 Ma. In the Isua sands, Neoarchaean and late Mesoarchaean zircons form >50% of the population. The sand 20 km to the south shows a similar span of zircon ages, but there is a 2960 Ma peak not seen in the Isua sands.

As the Eoarchaean and late Mesoarchaean–Neoarchaean cycles progress, the spread of Th/U and ε_{Hf} values seen in each zircon age population increases. This is interpreted as repeated addition of juvenile material to the crust, but also with increasing amounts of high temperature tectonothermal recycling of older materials within a package. However, there is no isotopic evidence for any contribution of Eoarchaean crust to the later ≥2750 Ma Archaean cycle(s), showing evolution in disparate terranes. Furthermore, no evidence for Hadean material beneath the ice is seen in either the U–Pb ages or Hf isotopic compositions of the detrital zircons. On the other hand, 2750–2500 Ma metamorphic zircons show a spread of initial ε_{Hf} values of zero to −25, with the most negative indicating zircon growth in Eoarchaean rocks. Overall these results closely mirror those obtained from direct sampling of rocks of the Archaean terranes exposed beyond the Icecap.

The zircon data indicate that Mesoarchaean rocks equivalent to the Kapisilik terrane are absent under the ice. Instead, zircons were sourced from a late Mesoarchaean to Neoarchaean terrane affected by high grade metamorphism, whose age spectra perfectly matches the Tasiusarsuaq terrane to the southeast of Nuuk. Guided by the zircon results and aeromagnetic signatures, a terrane map is presented that extrapolates the Tasiusarsuaq terrane northwards under the Inland Ice towards the Tuno terrane in the north of the craton. Implications for different syntheses on the evolution of Archaean crust in southern West Greenland are discussed.

1. Introduction

Much of Greenland's geology is blanketed by the Inland Ice – causing difficulties in linking the geology on the east and west coasts and also more locally along the ice margins. The distribution of Precambrian terranes of different ages has been assessed

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by aeromagnetic signatures (e.g., Rasmussen and Thorning, 1999; Rasmussen and van Gool, 2000), plus a limited geochronological programme from the GISP2 borehole (72°35′ N 38°27′ W) revealed direct age constraints (Nutman and Kalsbeek, unpublished U–Pb zircon analyses; Weis et al., 1997, whole rock Rb–Sr, Sm–Nd and Pb–Pb analyses). This provides the broadest-scale information, such as the disposition of major Palaeoproterozoic belts versus blocks of cratonic Archaean crust. Further information can be obtained from material that has been derived from under the ice cap. For example in West Greenland near the ice margin in the study area there are rare erratic blocks of low pressure granulite facies rocks (C.R.L. Friend and A.P. Nutman, unpublished field observations), where no such rocks are exposed. In this paper we present U–Th–Pb–Hf isotopic data for zircons from rivers issuing from the ice-front, to assess the geology hidden under the ice east of the Isua supracrustal belt and the adjacent metagranitoid and gneiss complex (Fig. 1). This area is important because it forms the world's best-preserved sample of early terrestrial crust (e.g., Nutman et al., 2013a,b and references therein). Specific objectives were to determine (i) the distribution of Eoarchaean (~3800 and ~3700 Ma)

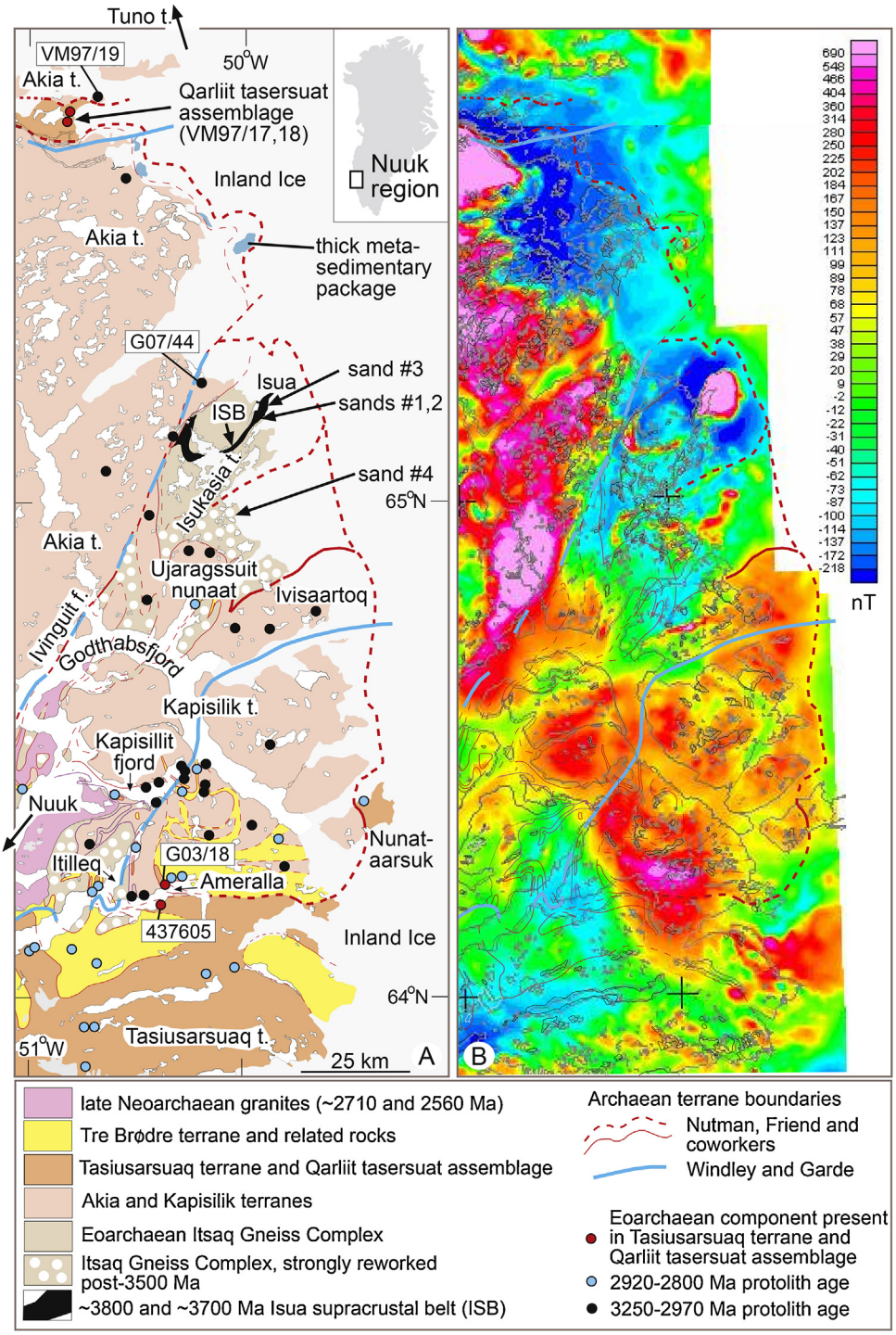

Fig. 1. (A) Archaean terrane map of the ice margin from East of Nuuk to Qarliit tasersuat, west Greenland. (B) Geological units and aeromagnetic signatures covering the same area. Inset in (A) shows the location in Greenland.

Aeromagnetic map reproduced with the permission of the Geological Survey of Denmark and Greenland.