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The origin and compositions of Mesoarchean oceanic crust: Evidence from the 3075 Ma Ivisaartoq greenstone belt, SW Greenland

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Abstract

The Mesoarchean (ca. 3075 Ma) Ivisaartoq greenstone belt contains well-preserved primary magmatic structures, such as pillow lavas, volcanic breccias, and clinopyroxene cumulate layers (picrites), despite the isoclinal folding and amphibolite facies metamorphism. The belt also includes variably deformed gabbroic to dioritic dykes and sills, actinolite schists, and serpentinites. The Ivisaartoq rocks underwent at least two stages of post-magmatic metamorphic alteration, including seafloor hydrothermal alteration and syn- to post-tectonic calc-silicate metasomatism, between 3075 and 2961 Ma. These alteration processes resulted in the mobilization of many major and trace elements. The trace element characteristics of the least altered rocks are consistent with a supra-subduction zone geodynamic setting and shallow mantle sources. On the basis of geological similarities between the Ivisaartoq greenstone belt and Phanerozoic forearc ophiolites, and intra-oceanic island arcs, we suggest that the Ivisaartoq greenstone belt represents a relic of dismembered Mesoarchean supra-subduction zone oceanic crust. This crust might originally have been composed of a lower layer of leucogabbros and anorthosites, and an upper layer of pillow lavas, picritic flows, gabbroic to dioritic dykes and sills, and dunitic to wehrlitic sills.

The Sm–Nd and U–Pb isotope systems have been disturbed in strongly altered actinolite schists. In addition, the U–Pb isotope system in pillow basalts appears to have been partially open during seafloor hydrothermal alteration. Gabbros and diorites have the least disturbed Pb isotopic compositions. In contrast, the Sm–Nd isotope system appears to have remained relatively undisturbed in picrites, pillow lavas, gabbros, and diorites. As a group, picrites have more depleted initial Nd isotopic signatures (ε_{Nd}=+4.23 to +4.97) than pillow lavas, gabbros, and diorites (ε_{Nd}=+0.30 to +3.04), consistent with a variably depleted, heterogeneous mantle source.

In some areas gabbros include up to 15 cm long white inclusions (xenoliths). These inclusions are composed primarily (>90%) of Ca-rich plagioclase and are interpreted as anorthositic cumulates brought to the surface by upwelling gabbroic magmas. The anorthositic cumulates have significantly higher initial ε_{Nd} (+4.8 to +6.0) values than the surrounding gabbroic matrix (+2.3 to +2.8), consistent with different mantle sources for the two rock types.

Keywords: Archean; Greenstone belt; Oceanic crust; Pillow basalt; Anorthosite; Ocelli; Isotope

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1. Introduction

Archean greenstone belts are composed predominantly of variably metamorphosed and deformed mafic to felsic volcanic and siliciclastic sedimentary rocks (Condie, 1981; Goodwin, 1991; Eriksson et al., 1994; Condie, 2005). There are also volumetrically minor banded iron formations (BIF), komatiites, gabbros, anorthosites, serpentinites, cherts, and carbonates (locally stromatolitic) in some Archean greenstone belts (Condie, 1981; Goodwin, 1991; Condie, 2005). Geochemical data derived from the study of Archean greenstone belts over the last three decades show the occurrence of diverse volcanic rock types, suggesting diverse magmatic processes, such as plume and arc magmatism, in oceanic or continental settings for their origin (Dostal and Mueller, 1997; Polat et al., 1998; Kusky and Polat, 1999; Polat and Hofmann, 2003; Dostal et al., 2004; Smithies et al., 2005a, b; Kerrich and Polat, 2006). In addition, greenstone belts from 3.8 to 2.5 Ga include volcanic rock types reported from Phanerozoic convergent margins, such as boninites, picrites, adakites, Mg-andesites, and Nb-enriched basalts (Polat and Kerrich, 2006; and references therein). The distribution of rock types and the internal structure of many Archean greenstone belts suggest that they are the products of multiple geological processes, such as tectonism, magmatism, sedimentation, and metamorphism, operating over different spatial and temporal scales (Corcoran and Dostal, 2000; Sandeman et al., 2004; Kerrich and Polat, 2006). Collectively, the geological characteristics of many Archean greenstone belts are comparable to those of lithotectonic assemblages occurring in Phanerozoic convergent plate boundaries (Kusky and Polat, 1999; Şengör and Natal'in, 2004; Kerrich and Polat, 2006; and references therein).

Thermal and geodynamic models and geochemical and isotopic constraints derived from Archaean mafic–ultramafic rocks suggest that oceanic crust formation must also have occurred in the Archean. From thermal modeling, Abbott et al. (1994) inferred that Neoarchean mid-ocean ridge crust was ~11 km-thick, in contrast to ~7 km-thick in-situ oceanic crust developed at modern mid-ocean ridges. Numerical and modeling studies infer

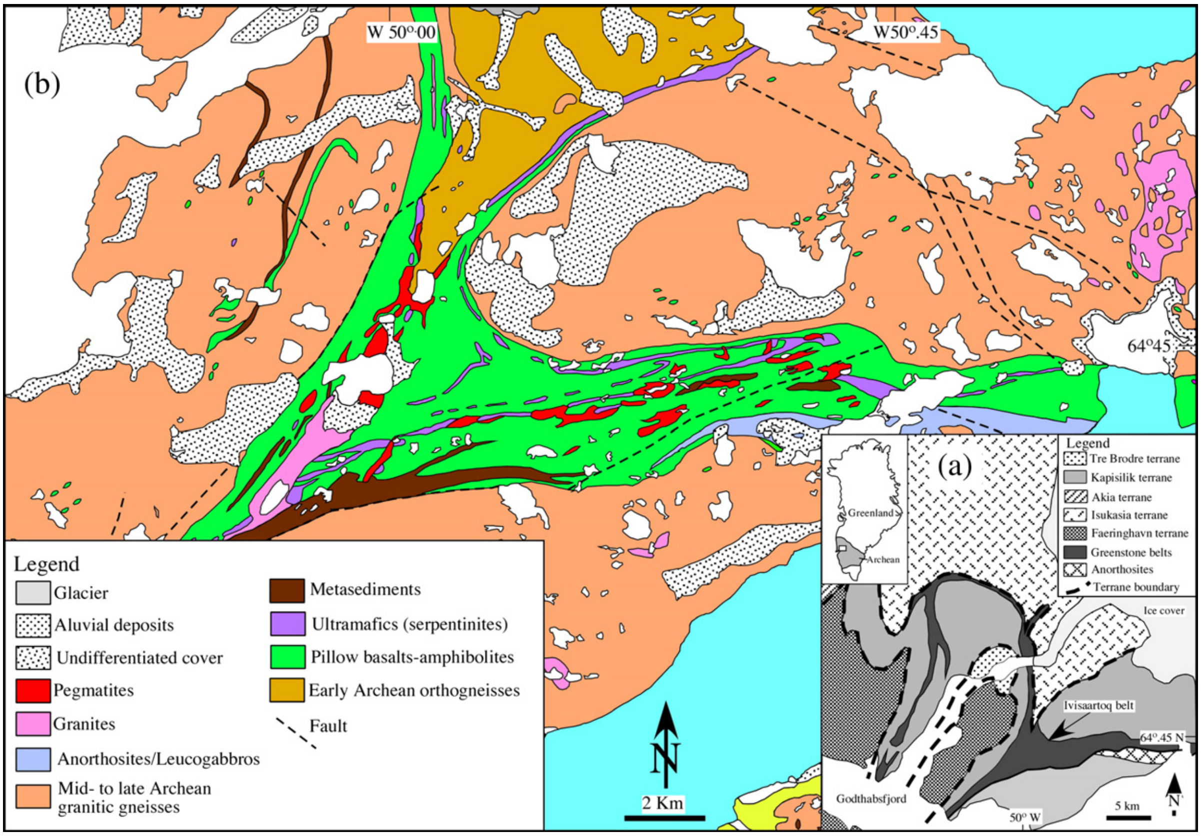

Fig. 1. (a) A simplified geological map of the northeastern Nuuk region, showing the Eoarchean to Neoarchean tectonic terranes and location of the Ivisaartoq belt. Modified from Friend and Nutman (2005). (b) Geological map of the Ivisaartoq and surrounding area. Modified from Chadwick and Coe (1988).