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Provenance and characteristics of rocks from the Yermak Plateau, Arctic Ocean: Petrographic, geochemical and geochronological constraints

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ABSTRACT

The Yermak Plateau is a prominent bathymetric feature of the Arctic Ocean. To the west it is bordered by the Fram Strait, which forms the only deep-water connection between the Arctic and the other global oceans. Origin, crustal nature and age of the Yermak Plateau are largely unknown. For this study, we investigated dredged rocks of two sites from the Yermak Plateau. Based on petrography, geochemistry, and geochronology, we distinguished between ice-transported and in-situ rocks. Ice-transported material was most likely derived from outcrops of the High Arctic Large Igneous Province (HALIP) on Franz Josef Land, the Siberian trap province, and presumably from northern Svalbard. Our data from the in-situ rocks, in conjunction with previously published geophysical data, show that the investigated parts of the Yermak Plateau are composed of stretched continental crust strongly affected by alkaline magmatism. The continental rocks represent a direct continuation of the exposures on northern Svalbard. Alkaline magmatism took place at ~51 Ma and was related to continental rifting in an extensional setting. The melts were formed by low degrees of partial melting of the sub-continental lithospheric mantle and are probably associated with the high-amplitude magnetic anomalies described for the northeastern Yermak Plateau. Extension of the Yermak Plateau was contemporaneous with spreading of the adjacent young Eurasian Basin, and occurred during the peak of compressional deformation affecting North Greenland, Svalbard, and Ellesmere Island. These contrasting regimes were probably compensated by transpression and strike-slip movements along the DeGeer and Wegener Faults. The date of ~51 Ma for extension-related magmatism also provides age constraints for the extension-related formation of the Sophia Basin (and thus for water exchange between the Eurasian Basin, the area of the DeGeer Fault and the young Norwegian-Greenland Sea), and for the sediments covering the horst-and-graben structures of the Yermak Plateau.

1. Introduction

The conjugated aseismic rises Yermak Plateau and Morris Jesup Rise are the dominant bathymetric features of the Eurasian part of the Arctic Ocean. They border the entrance of the Fram Strait (Fig. 1), which forms the only deep-water connection to the global oceans. Their formation may thus have influenced early oceanic circulation patterns and therefore, the climatic evolution of the Arctic realm. Geodynamic evolution, composition, and age of the Yermak Plateau, however, are still poorly constrained. Since the harsh climatic conditions of the Arctic impede geologic investigations, existing models are mostly not derived from direct sampling of the plateau basement, but almost entirely based on seismic, gravity, heat flow, and magnetic data (e.g. Feden et al., 1979; Jackson et al., 1984; Jokat et al., 1995; Brozena et al., 2003; Ritzmann and Jokat, 2003; Jokat et al., 2008; Geissler et al., 2011).

Based on spreading anomalies in the Eurasian Basin, it is assumed that the Yermak Plateau/Morris Jesup Rise evolved between 55 and 35 Ma (Vogt et al., 1979). High amplitude magnetic anomalies (>1000 nT) located on the northern part of the Yermak Plateau let Feden et al. (1979) to suggest that its origin is related to hotspot activity with the main formation period around 35 Ma. Aeromagnetic investigations from this northern part of the Yermak Plateau indicate highly intruded and stretched continental or even oceanic crust (Jokat et al., 2008). However, seismic velocities of the acoustic basement obtained by Jackson et al. (1984) indicate that the Yermak Plateau has a bimodal composition, with thick oceanic crust (6.7–7.2 km/s) north of ~82° N and thinned continental crust (5 km/s) further south. Low seismic velocities up to 5.8 km/s south of 81° N also give no evidence for plume related activity, but rather indicate a crust with continental affinities (Ritzmann and Jokat, 2003).

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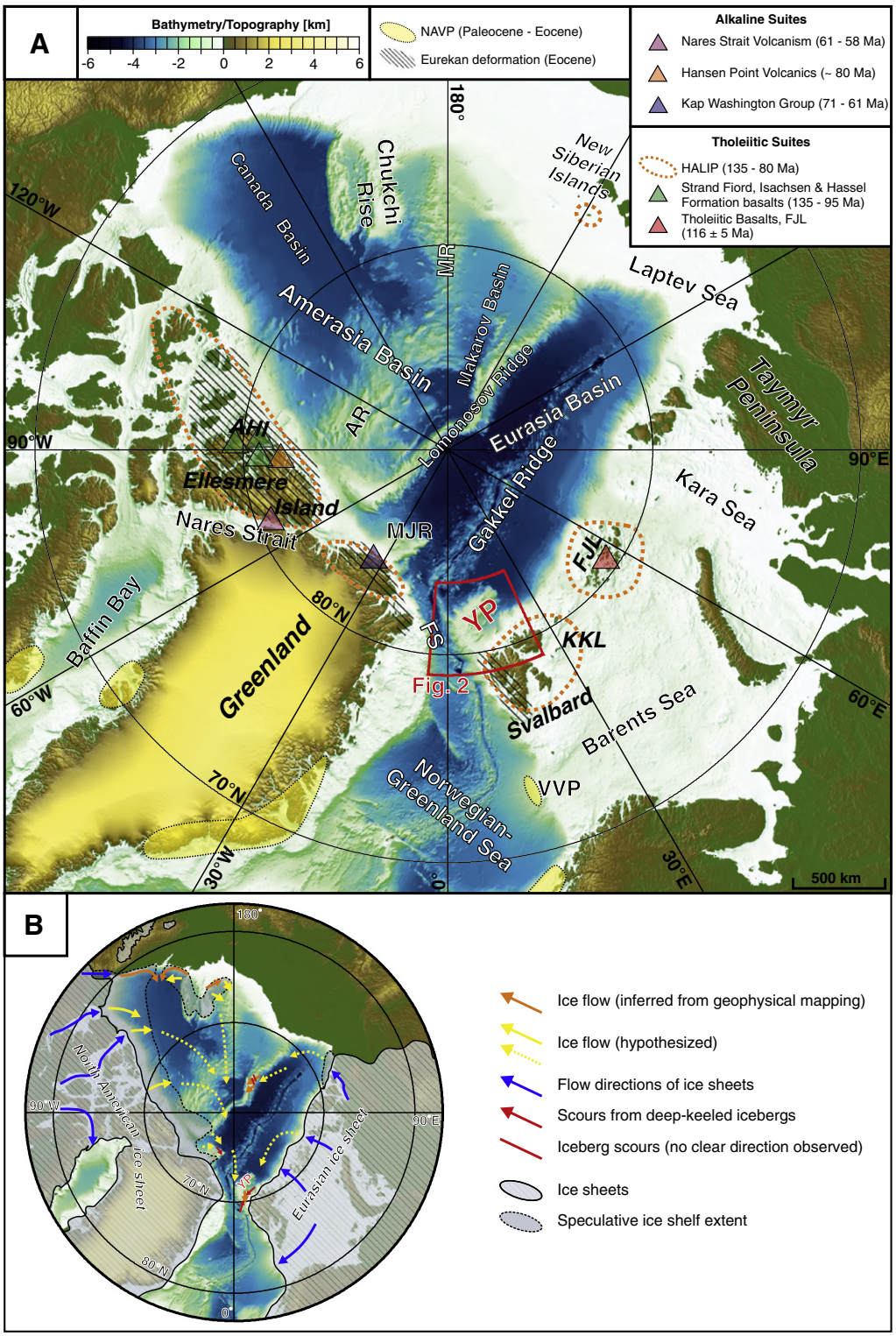

Fig. 1. (A) Overview map of the Arctic Ocean and surrounding areas with occurrences of tholeiitic and alkaline magmatic suites. Ages of the magmatic suites are compiled from the literature (Storey et al., 1998; Grachev et al., 2001; Maher, 2001; Estrada and Henjes-Kunst, 2004; Buchan and Ernst, 2006; Storey et al., 2007; Tegner et al., 2008; Estrada et al., 2010; Tegner et al., 2011; Thorarinsson et al., 2011). The Map is created with Generic Mapping Tools (GMT) using the International Bathymetric Chart of the Arctic Ocean (IBCAO) from Jakobsson et al. (2008). AHI = Axel Heiberg Island, AR = Alpha Ridge, FJL = Franz Josef Land, FS = Fram Strait, HALIP = High Arctic Large Igneous Province, KKL = Kong Karls Land, MJR = Morris Jesup Rise, MR = Mendeleev Ridge, NAVP = North Atlantic Volcanic Province, VVP = Vestbakken Volcanic Province, YP = Yermak Plateau. (B) Tentative reconstruction of MIS 6 ice shelves modified after Jakobsson et al. (2010). From the present sea-level, 92 m (Rabineau et al., 2006) are subtracted from IBCAO grid (Jakobsson et al., 2008). North American (Late Wisconsian) Ice Sheet (Dyke et al., 2002) and Eurasian (Late Saalian) Ice Sheet (Svendsen et al., 2004) with speculative extent at MIS 6 are shown (England et al., 2009).

Here we present the first detailed petrographic, geochemical and geochronological study of rocks directly derived from basement outcrops of the Yermak Plateau. Our samples are taken from two dredges, one located in the northern part of the plateau along the margin of the magnetic anomalies, and one from further southwest (Fig. 2). However, conclusions on the basement geology are difficult