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Correlations between the Lomonosov Ridge, Marvin Spur and adjacent basins of the Arctic Ocean based on seismic data

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ABSTRACT

Seismic profiles across the Lomonosov Ridge, Marvin Spur and adjacent basins, acquired near the North Pole by the drifting ice-station NP-28, provide a reflection image of the upper parts of the Ridge that is readily correlatable with those acquired by the Alfred Wegner Institute closer to the Siberian margin. A prominent flat-lying composite reflection package is seen in most parts of the Ridge at a few hundred meters below the sea bottom. Underlying reflections are variable in intensity and also in dip. The base of this reflection package is often accompanied by a sharp increase in P-velocity and defines a major angular discontinuity, referred to here as the Lomonosov Unconformity.

The Arctic Coring Expedition (ACEX) cored the first c. 430 m section on the Lomonosov Ridge near the North Pole, in 2004 defining the deeper water character of the Neogene and the shallower water Paleogene sediments. These boreholes penetrated the composite reflection package towards the base of the hole and identified sediments (our Unit III) of late Paleocene and early Eocene age. Campanian beds at the very base of the hole were thought to be representative of the units below the Lomonosov Unconformity, but the P-velocity data suggest that this is unlikely.

Correlation of the lithologies along the top of the Lomonosov Ridge and to the Marvin Spur indicates that the Marvin Spur is a sliver of continental crust closely related to, and rifted off the Ridge. This narrow (50 km wide) linear basement high can be followed into, beneath and across the Makarov Basin, supporting the interpretation that this Basin is partly resting on thinned continental crust. In the Makarov Basin, the Paleogene succession is much thicker than on the Ridge. Thus, the condensed, shallow water succession (with hiati) was deposited on the Ridge during rapid Eocene to Miocene subsidence of the Basin.

In the Amundsen Basin, adjacent to the Lomonosov Ridge, the sedimentary successions thicken towards the Canadian margin and the reflections on the Ridge are not readily identifiable. The approximate ages of the sedimentary units are inferred from their relationships to the linear magnetic anomalies in the Basin. Lomonosov acoustic basement dips gently into the Basin over a distance of about 100 km and the linear negative anomaly, previously thought to be chron 25, is probably related to a rift-related mafic intrusive complex.

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1. Introduction

The Lomonosov Ridge (Fig. 1), a narrow (c. 50–150 km), c. 1700 km long sliver of continental crust, reaches across the Arctic Basin from the Canadian to Siberian margins. It is separated from Barents-Kara continental margin by the Eurasian Basin composed of the Amundsen and Nansen basins, and the ultra-slow spreading Gakkel Ridge. The bathymetry and linear magnetic anomalies provide evidence of rifting and migration away from Eurasia in the early Cenozoic (Taylor et al., 1981; Brozena et al., 2003; Glebovsky et al., 2006). The geology of the northern part of the Eurasian margin is dominated by the N-striking Caledonide Orogen (Gee, 2005) and much of the crust beneath Lomonosova (the terrane that was a part of Eurasia prior to the Cenozoic) was probably dominated by bedrock related to this orogen, overlain by younger Paleozoic and Mesozoic successions (Dibner, 1998; Grantz et al., 2001), as exposed on the northern islands of the Barents-Kara shelves (Gee et al., 2006).

The Marvin Spur is a remarkably linear, 25–50 km wide ridge that is separated from the Lomonosov Ridge on its Amerasian side by a trough of similar width. The latter narrows towards the Canadian margin and the Spur converges and appears to merge with the Lomonosov Ridge at c. 87°N. Towards the Siberian Margin, this trough

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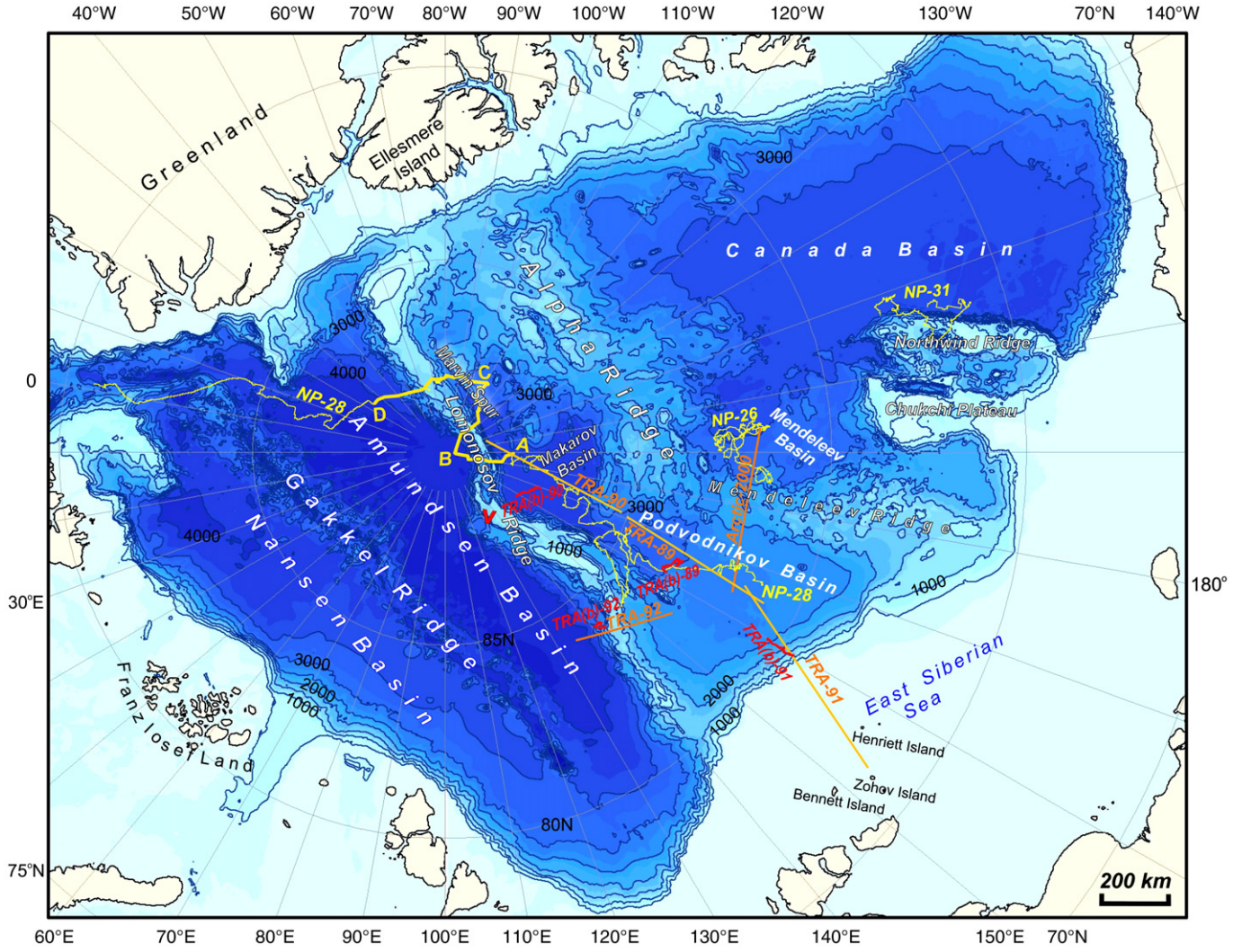

Fig. 1. Location map of the NP-28 track and the other relevant Russian profiles in the Arctic Ocean. The yellow line is the NP-28 track; the part of this profile treated in this paper is marked as a thick yellow line. TRA-89–TRA-92 and "Arctic-2000" are integrated research profiles including wide angle seismic, reflection seismic and potential field data acquisitions. TRA(b)-89–TRA(b)-92 are reflection seismic profiles for determination of the velocity structure of the sedimentary cover (Langinen et al., 2006). **V** is the location of the ACEX drillholes.

separating the Spur from the Lomonosov Ridge widens into the Makarov Basin. The crest of the Marvin Spur plunges gently towards and into the Makarov Basin, and has been shown by Cochran et al. (2006), on bathymetric and gravity data, to continue across most, if not all of this deep (c. 4000 m bsl) basin.

Seismic reflection profiles across the Lomonosov Ridge (Jokat et al., 1992; Kim et al., 1998; Kristoffersen, 2001; Jokat, 2005; Coakley et al., 2005; Langinen et al., 2006) and adjacent parts of the Eurasian and Amerasian basins have provided evidence concerning the shallow structure of this key feature of the high Arctic Basin. Wide-angle refraction seismics, together with potential field data constrain the deeper structure, with a crustal thickness of c. 27 km and a velocity structure characteristic of continental margins (Mair and Forsyth, 1982; Ivanova et al., 2002). The reflection profiling has shown the presence of a young sedimentary succession, a few hundred meters to a kilometer thick and probably of Cenozoic age uncomfortably overlying older successions (Jokat et al., 1992). Several other seismic profiles across the Ridge have identified similar unconformable relationships (eg. Langinen et al., 2006). We refer to this regional angular discordance as the Lomonosov Unconformity.

Recent drilling on the Lomonosov Ridge near the North Pole on the Arctic Coring Expedition (ACEX) by the Integrated Ocean Drilling Program (IODP) in 2004 (Backman et al., 2005, 2006; Moran et al., 2006; Jakobsson et al., 2007) has confirmed the Cenozoic age of the sedimentary units on the top of the Ridge. It now appears possible to interpret much of the younger tectonic history, based on correlation from the ACEX drillhole along the Ridge, both towards the Siberian and Canadian margins.

This paper examines in some detail the seismic evidence obtained in 1987–1989 by the Soviet ice-station North Pole-28 (NP-28) (Langinen et al., 2004, Lebedeva-Ivanova et al., 2006). This ice-station started its crossing of the Arctic Ocean above the Podvodnikov Basin at c. 81°N. It passed near the North Pole, and was finally abandoned above the Yermak Plateau (c. 81°N) north of Svalbard. NP-28 crossed the Lomonosov Ridge three times (Fig. 2), on the second and third times also traversing across the Marvin Spur.

In addition to the three NP-28 profiles treated here, the Alfred Wegner Institute (AWI) lines at the ACEX drillhole and two other seismic lines are important for interpreting the Marvin Spur–Makarov Basin relationships. One is a reflection profile (TRA(b)-90, Fig. 2) presented and discussed by Langinen et al. (2006) which crossed the central part of the Makarov Basin in 1990; the other is the northern end of the TransArctic (TRA-90, Figs. 1 and 2).

2. Experimental method

Seismic reflection data acquisition on the NP-28 was carried out by the Polar Marine Geological Research Expedition (PMGRE) and one of

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