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Crustal structure and tectonic evolution of Enderby Land, East Antarctica, as revealed by deep seismic surveys

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A B S T R A C T

Subsurface crustal structures of the metamorphic terrains in Enderby Land, East Antarctica, were obtained on the basis of data from deep seismic surveys along with connecting reliable tectonic models. The lithospheric structure of the early-Paleozoic Lützow-Holm Complex (LHC) at the western side of Enderby Land was delineated by inland dipping velocity models and lower crustal reflectivity by the Japanese Antarctic Research Expedition. The seismic profiles across the Prince Charles Mountains (PCM) and Princess Elizabeth Land (PEL) by the Soviet Antarctic Expedition demonstrated the graben structure beneath the Amery Ice Shelf. The Lambert graben and the underlying rift structure in the central part of the profile appeared to be associated with the Cretaceous breakup. Tectonic evolution of the wider area in Enderby Land is discussed by combining the coastal structure with that toward the inland plateau of the Gambursev Subglacial Mountains (GSM), with geological aspects concerning the amalgamation and separation of the Gondwana supercontinent.

1. Introduction

Deep seismic surveys of continental crust have been conducted in many geological terrains of the Earth in these last few decades. From the 1990's particularly, several refraction and reflection deep seismic surveys (DSS) in Precambrian terrains have demonstrated the details of continental growth processes (Brown et al., 1996; Clowes et al., 1999; Goleby et al., 1998). In contrast, neither of the polar regions have yet been extensively investigated by modern high-resolution imaging. In recent years, however, several interesting features, such as the delaminated lower crust and its subduction regimes into the upper mantle lithosphere, have been found in the Archean and Proterozoic terrains of the Canadian Shield (Cook et al., 1999; Gabriela et al., 2005; Lynn et al., 2005). Although there have been several crustal studies using broadband seismographs at permanent coastal stations in the Antarctic (Kanao, 1997; Reading, 2004), deep seismic surveys on the thick ice sheet over the Antarctic continent have scarcely been conducted and the structure of the interior continent remains a significant frontier.

The crustal structure of the whole Antarctic continent has been investigated by deep surveys conducted in the 1970's (Bentley, 1983; Kadmina et al., 1983). After the 1990's, many near-vertical reflection surveys conducted to detect shallow crustal structures have been undertaken in West Antarctica and the Antarctic Peninsula (Jokat et al., 1997; King and Bell, 1997; Sroda et al., 1997; Vedova et al., 1997). Therefore except for the seismic surveys by Russian and Japanese Antarctic programs as demonstrated in this paper, onshore seismic surveys over the East Antarctic continent (inside the Pre-Cambrian terrains) have been lacking in the last two decades. Accumulating knowledge of the crustal architecture with relevant tectonics in Antarctica could give us a firm insight into the amalgamation and separation history of the Rodinia and Gondwana supercontinents.

During the International Polar Year in 2007–2008 (IPY2007–2008), the Gamburtsev Mountain SEISmic experiment (GAMSEIS) deployed many broadband seismic stations over the large highland on the ice sheet from the crest of the Gamburtsev Subglacial Mountains (GSM) to the vicinity of Dome-F, the Japanese inland station. S-wave receiver functions and Rayleigh phase velocities determined by using the data indicate that the cratonic crust surrounding the GSM is 40–47 km in thickness. This thickness agrees with that beneath Dome-F derived from gravity surveys held by the Japanese Antarctic Research Expedition, and is also consistent with average Pre-Cambrian terrains (Kanao et al., 2012). Beneath the GSM, the crustal thickness increases up to 55–58 km and has been interpreted as providing isostatic compensation for the high mountain elevations.

In this paper, we review the crustal structure of the wider area of Enderby Land, East Antarctica, by comparing the results of Russian and

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Japanese seismic surveys, as well as the more recently deployed broadband networks in the inland plateau of East Antarctica. The tectonic evolution of Enderby Land is interpreted by combining the structure from the coasts to the inland plateau by taking into account the geological aspects for amalgamation and separation of the supercontinents.

2. Geological background

The geological features of Enderby Land have been attributed to several crustal terrains associated with the evolution of Gondwana (Fig. 1). As viewed from Western Enderby Land and the adjacent Eastern Dronning Maud Land, there are several distinct geological units; these are, from the east to the west, the Napier Complex (Archaean), the Rayner Complex (late-Proterozoic), the Lützow-Holm Complex (LHC) (early-Paleozoic) and the Yamato–Belgica Complex (early-Paleozoic). The late Proterozoic structures are interpreted as resulting from the initial uplift and exhumation of the Archaean Napier Complex, where the oldest metamorphic rocks (of original ages of 4000 Ma) were found in the broadening Archaean blocks (Black et al., 1987; Ellis, 1987). Additionally, Enderby Land is known to have higher seismic velocities than other adjacent regions, with its center around the Napier Complex, as determined by surface wave tomographic studies (Ritzwoller et al., 2001; Roult et al., 1994). Moreover, the depth of the lithospheric root beneath the Napier complex obtained from seismic body wave tomography is found to be about 250 km (Polet and Anderson, 1995).

The LHC experienced a regional metamorphism in the early Paleozoic (Shiraishi et al., 1992, 1994). Metamorphic grade increases progressively from the Prince Olav Coast (amphibolite facies; eastern part of the LHC) to the Soya Coast (granulite facies; western part of the LHC) and the maximum thermal axis lies at southern Lützow-Holm Bay in a NNW-SSE

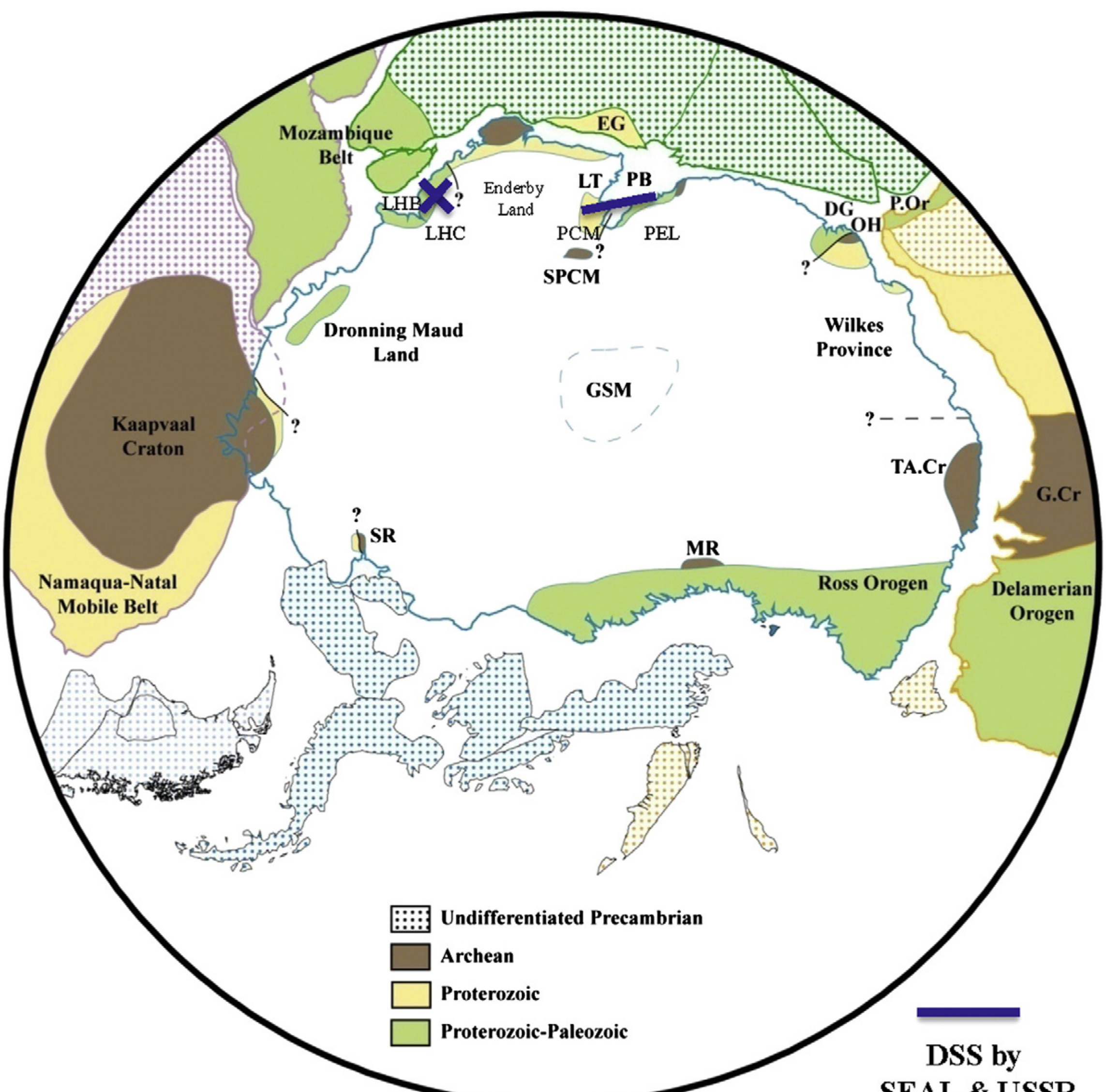

Fig. 1. Gondwana reconstruction at 480 Ma, centered on East Antarctica (modified after Lawver et al., in press), showing the geologic ages of major exposed coastal outcrops (Fitzsimons, 2003). The areas corresponding "Undifferentiated Precambrian" terrains belonging to each continental blocks of Gondwanaland (Australia, Africa, South America and Antarctica) are distinguished by different colors (yellow dot, green dot, brown dot, and light blue dot), respectively. Abbreviations are as follows: SR – Shackleton Range; SPCM – Southern Prince Charles Mountains; LT – Lambert Terrane; EG – Eastern Ghats; PB – Prydz Bay; DG – Denman Glacier; OH – Obruchev Hills; P.Or – Pinjarra Orogeny; TA.Cr – Terre Adélie Craton; G.Cr – Gawler Craton; MR – Miller Range; GSM – Gamburtsev Subglacial Mountains; Lützow-Holm Bay (LHB). The Russian seismic survey in 1973 was conducted from the Prince Charles Mountains (PCM) to the western edge of the Princess Elizabeth Land (PEL), in order to cross over the Amery Ice shelves in PB (blue solid line). Whereas the Japanese seismic profiles in 2000 and 2002 (two blue solid lines) were situated on the Lützow-Holm Complex (LHC), in the western part of the Enderby Land.