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Late Mesozoic–early Cenozoic intermediate–acid intrusive rocks from the Gerlache Strait area, Antarctic Peninsula: Zircon U–Pb geochronology, petrogenesis and tectonic implications

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ABSTRACT

This paper reports zircon U–Pb geochronology, whole-rock chemistry and Sr–Nd–Hf isotopic data of intermediate-acid intrusive rocks from the Gerlache Strait area, Antarctic Peninsula. These intrusive rocks can be divided into three groups. Group #1 has an emplacement age of ca. 117 Ma, and is further subdivided according to K_2O contents into High-K (HKS) and Low-K (LKS) Subgroups. The HKS monzogranites are weakly peraluminous, and yield $\varepsilon_{Hf}(t)$ and $\varepsilon_{Nd}(t)$ values of +0.9 to +2.3 and +0.1 to +2.3, respectively, with corresponding model Nd ages (T_{DM}^{Nd}) of 766–471 Ma, indicating that they were derived from the partial melting of dominantly early Neoproterozoic to early Paleozoic juvenile basaltic materials with minor involvement of sediments. In contrast, the LKS granodioritic magma was derived from partial melting of early Paleozoic juvenile basaltic materials with $\varepsilon_{Hf}(t)$ and $\varepsilon_{Nd}(t)$ values of +10.3 to +12.5 and +5.4 to +5.5, respectively, and corresponding T_{DM}^{Nd} ages of 548–500 Ma. Group #2 consists of granite porphyry that formed at ca. 82 Ma and is characterized by positive values of $\varepsilon_{Hf}(t)$ (+5.1 to +8.1) and $\varepsilon_{Nd}(t)$ (+1.9 to +3.1) with weakly peraluminous chemistry and corresponding T_{DM}^{Nd} ages of 712–548 Ma, suggesting that it was generated from partial melting of dominantly Neoproterozoic juvenile basaltic materials with minor involvement of sediments. Group #3 comprises dioritic–granodioritic rocks that were emplaced at ca. 62–54 Ma. These rocks have Mg# values of 39–46, and $\varepsilon_{Hf}(t)$ and $\varepsilon_{Nd}(t)$ values of +6.7 to +12.2 and +3.6 to +7.2, respectively, with corresponding T_{DM}^{Nd} ages of 529–307 Ma, indicating that they were derived from partial melting of Paleozoic juvenile basaltic materials with minor injection of mantle materials. Spatially, the lithology of these plutons roughly changes from acid to intermediate from east to west, concomitant with increasing $\varepsilon_{Hf}(t)$ and $\varepsilon_{Nd}(t)$ values and decreasing initial $^{87}Sr/^{86}Sr$ ratios and T_{DM}^{Nd} ages. This trend reflects changes in source characteristics from a Gondwana affinity to a juvenile crust affinity. Overall, the southeast-to-northwest migration of magmatism in the northern Antarctic Peninsula since the Mesozoic may have been related to retreating subduction of the paleo-Pacific plate.

1. Introduction

The Antarctic Peninsula is a curvilinear tectonic–magmatic belt, bordered by oceanic floor of the South Pacific to the west, and the Weddell Sea to the east (Fig. 1A; Barker, 1982; Tangeman et al., 1996). The geological and tectonic evolution of the Antarctic Peninsula is complex due to the tectonic activity of the Southern Pacific tectonic domain since the Mesozoic. The structural deformation and magmatism that occurred during the Cretaceous along its western margin is particularly complicated (Larson, 2005; Seton et al., 2009; Vaughan and Livemore, 2005). These phenomena were caused by subduction of the paleo-Pacific plate beneath the western Antarctic Peninsula, which triggered significant tectonic movements and large-scale magmatism. The Mesozoic to Cenozoic volcanic rocks are known as the Antarctic Peninsula Volcanic Group (Johnson, 1996; Storey and Garrett, 1985; Thomson and Pankhurst, 1983), and are concomitant with intermediate–acid intrusive rocks with similar ages and genetic mechanisms (Leat et al., 1995). As the product of subduction of the paleo-Pacific plate, these magmatic rocks (especially those of Cretaceous–early Paleogene age) must have recorded information about crust–mantle interaction. Previous studies suggested that the Mesozoic I- and S-type granitoids of the Antarctic Peninsula were derived from melting of a lithospheric source with minor crustal contamination and partial melting of the sedimentary crust, respectively (Scarrow et al., 1996; Wever et al., 1994). In contrast, mid-Cretaceous mafic dykes from the Black Coast and the Oscar II Coast represent partial

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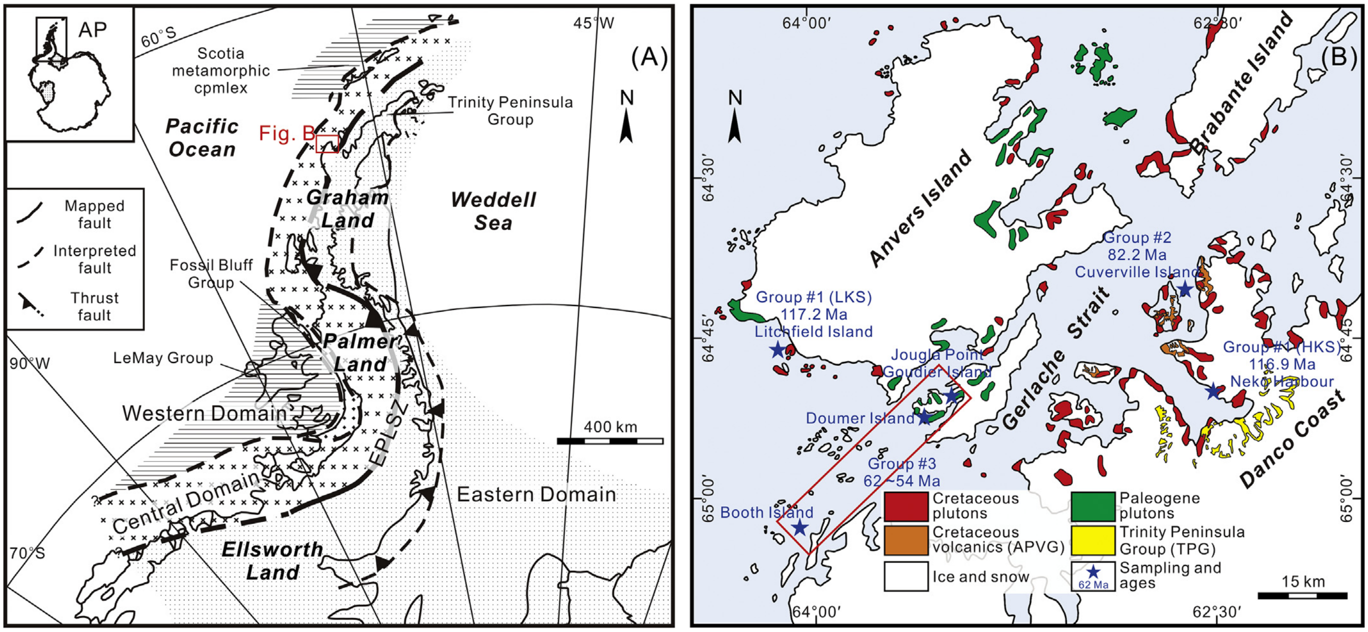

Fig. 1. (A) Map showing the tectonic division of the Antarctic Peninsula (modified after Vaughan and Storey, 2000). (B) Geological map of the Gerlache Strait area (modified after Birkenmajer, 1995; Parada et al., 1990). The red box is the sampling domain of Group #3 dioritic–granodioritic rocks. Abbreviations: AP, Antarctic Peninsula; APVG, Antarctic Peninsula Volcanic Group; EPLSZ, eastern Palmer Land shear zone; TPG, Trinity Peninsula Group. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

melts of sub-arc lithosphere and subduction-modified sub-arc asthenosphere, respectively (Leat et al., 2002).

Arc magmatic rocks are important for understanding subduction and crust growth processes. However, previous studies of arc magmatic rocks have mainly focused on pre-mid-Cretaceous rocks in the eastern Antarctic Peninsula. Few studies have been carried out in the western Antarctic Peninsula, and existing studies have not effectively combined Sr–Nd–Hf isotopic data, which have important implications for understanding source characteristics and the geodynamic evolution of the region. The Gerlache Strait area, located in the western Graham Land of the northern Antarctic Peninsula, is an important locality for studying subduction and accretion processes since the Mesozoic, given its position near the subduction zone and extensive exposure of arc magmatic rocks. Geological surveys of these areas were carried out during the 2012–2013 and 2014–2015 austral field season. This paper presents new zircon U–Pb geochronology, whole-rock geochemistry and Sr–Nd–Hf isotopic data for the intermediate–acid intrusive rocks from both sides of the Gerlache Strait, in order to constrain the age and petrogenesis of these rocks. The tectonic setting of the magmatic pulses along the western margin of the Antarctic Peninsula is also investigated.

2. Geological setting

The Antarctic Peninsula, which is one of the four crustal blocks in West Antarctica, is the most significant tectonic unit along the paleo-Pacific margin of Gondwanaland (Dalziel and Elliot, 1982; Millar et al., 2002; Storey et al., 1988; Tangeman et al., 1996). It can be divided into the Eastern, Central and Western Domains on the basis of tectonic features (Fig. 1A; Vaughan and Storey, 2000). The Eastern Domain is characterized by para-autochthonous rocks of Gondwana (Wendt et al., 2008) and consists mainly of Paleozoic cover rocks and Mesozoic volcanic and sedimentary rocks in the south, while sedimentary successions (the Trinity Peninsula and Botany Bay groups) in the north record a long history of magmatic activity since the Paleozoic (Smellie and Millar, 1995; Tangeman et al., 1996; Vaughan and Storey, 2000). The late Carboniferous to late Triassic turbidites of the Trinity Peninsula Group experienced deformation during the late Triassic to early Jurassic (Smellie and Millar, 1995; Storey and Garrett, 1985), and the middle Jurassic granitic plutons intrude into the Botany Bay Group rocks (Pankhurst et al., 2000). The Central Domain, which remains poorly understood, comprises Mesozoic–Cenozoic or possibly older metamorphic, igneous and sedimentary rocks, including pre-late Triassic marble tectonic breccias (Vaughan et al., 1999), late Triassic granitoids (Scarrow et al., 1996; Wever et al., 1994), an earliest middle Jurassic gabbro–granitoid suite with associated bimodal metavolcanic rocks (Vaughan and Storey, 2000), and post-late Jurassic conglomerates (Davies, 1984). There may exist a Triassic intra-oceanic arc named the Dyer Arc in the eastern Central Domain of the southern Antarctic Peninsula, which is represented by an oceanic island tholeiite and associated plutonic complex preserved beneath the Dyer Plateau ice cap (Vaughan et al., 2012). The Western Domain, which is also poorly constrained, includes Alexander Island in the south, and Elephant and Smith Islands in the north. Alexander Island consists of four main geological units: the LeMay Group basement accretionary complex, middle Jurassic to early Cretaceous fore-arc basin sedimentary rocks, late Cretaceous to Paleogene volcanic and intrusive rocks, and several small outcrops of Neogene alkaline volcanic rocks (McCarron and Millar, 1997). The Scotia Metamorphic Complex on Elephant and Smith Islands represents a subduction complex with metamorphism up to the blueschist to amphibolite facies (Wendt et al., 2008).

The Gerlache Strait area, which narrows southwestward, separates the Palmer Archipelago from the northwest of the Antarctic Peninsula (Fig. 1B; Scott, 1965). Outcrops on both sides of the strait are limited to steep cliff faces, offshore rocks and some areas where bedrock is exposed during summer ablation (Scott, 1965). The following rock units have been distinguished: the Trinity Peninsula Group metasediments, the Antarctic Peninsula Volcanic Group, and the Andean Intrusive Suite (Birkenmajer, 1995). The metasediments of the Trinity Peninsula Group are fine-grained sandstones that are often strongly thermally altered and cut by dykes at Henrky Cove. These metasediments become hornfelsic in contact with a granodiorite intrusion at Forbes Point of Andvord Bay (Birkenmajer, 1995). The rocks of the Antarctic Peninsula Volcanic Group are mainly basalts, andesites and green rhyolites, which are probably Cretaceous in age (Birkenmajer, 1995; Scott, 1965; Zheng