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# Analysis of James Ross Island volcanic complex and sedimentary basin based on high-resolution aeromagnetic data

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ABSTRACT

High-resolution aeromagnetic surveys provide a geophysical tool to help image the subsurface structure of volcanoes and their tectonic framework. Here we interpret high-resolution aeromagnetic data and models for James Ross archipelago and surrounding regions to provide a new perspective on Neogene magmatism emplaced along the eastern margin of the Antarctic Peninsula. Based on the analysis and modelling of magnetic anomalies we were able to image the subglacial extent of Miocene to Recent alkaline rocks of the James Ross Island Volcanic Group and map tectonic structures that appear to have exerted important controls on Neogene magmatism. High-amplitude linear anomalies detected over Mount Haddington stratovolcano were modelled as caused by subvertical feeder bodies extending to a depth of at least 3 km. These feeder bodies may have been emplaced along a N–S oriented volcano-tectonic rift zone.

We also identified several effusive subglacial centres and imaged two concentric magnetic arcs, which we related to Neogene volcanic and subvolcanic lineaments, likely controlled by Mid-Cretaceous strike-slip fault belts and associated deformation zones. The regional magnetic quiet zone that encompasses James Ross Island is caused by the thick sedimentary infill of the Larsen Basin, and a low-amplitude magnetic high within the basin is inferred to reflect a basement push-up structure associated with strike-slip faulting along the eastern edge of the Antarctic Peninsula.

In the offshore regions magnetic anomalies southwest of Tabarin Peninsula and west of Vega Island may reflect recent volcanic structures that have yet to emerge from the sea-floor.



## 1. Introduction

The James Ross archipelago, located between 63°30′ and 64°35′ S, 56°30′ and 58°30′ W, exhibits the most important record of Neogene volcanic activity of all the eastern margin of the Antarctic Peninsula (Adie, 1953; Andersson, 1906; Nelson, 1966). The islands are emplaced on a thick sedimentary wedge of Mesozoic–Cenozoic age that constitutes the western border of James Ross Basin, a section of the marine Larsen Basin (Fig. 1), which developed in a back-arc position with respect to the Mesozoic magmatic arc of the Antarctic Peninsula (del Valle and Scasso, 2004). James Ross and Vega Islands stand out by their greater dimensions, being surrounded by a number of other smaller islands. The James Ross Island Volcanic Group (JRIVG) (Adie, 1953; Andersson, 1906; Nelson, 1966; Smellie, 1999; Smellie et al., 2008) is composed mainly by alkaline basalts and to a lesser extent by tholeiitic basalts of Miocene to Recent age (Nelson, 1966). Iron oxide minerals as magnetite and titanomagnetite appear in association with Cr spinels in the olivinic basalts, dolerites and palagonite-tuffs (Nelson, 1966), making these rocks highly magnetic and potential carriers of significant remanent magnetization (Kristjánsson et al., 2005). On James Ross Island (JRI) at least 50 volcanic effusive eruptions have been identified that were preserved mainly as lava-fed deltas and in smaller proportion as tuff cones (Smellie et al., 2008). The Haddington stratovolcano on James Ross Island (Figs. 2a and 7a) is composed by multiple superimposed deltas of hyaloclastite. It constitutes the greatest effusive centre of the JRIVG with a basal diameter between 35 and 60 km, a height of 1600 m, and includes some minor tuff cones (Smellie, 1999). Secondary centres surround Mount Haddington and are distributed along Ulu Peninsula and Vega Island (with Dobson and Terrapin Hill being the largest) (Figs. 2a and 7a). The majority of the small islands on Prince Gustav Channel comprise small effusive monogenetic centres built mainly by hydrovolcanic deposits (Smellie, 1999).

At about 100 km SW of the JRIVG area, outcrops belonging to the Seal Nunatak Volcanic Group (SNVG) emerge from the Larsen Ice Shelf (del Valle et al., 1983; González-Ferrán, 1983a) (Fig. 1a). These Plio-Pleistocene age rocks (Rex, 1972), comprise monogenetic centres built by pillow lavas and dykes, and in a smaller proportion by hydrovolcanic tephra and subaerial lavas (Smellie, 1999). In the same way as the JRIVG, the SNVG rocks are composed by alkaline basalts (Hole, 1988, 1990; Saunders, 1982), but with a smaller volumetric expression and, up to where the ice shelf allows visual detection, the

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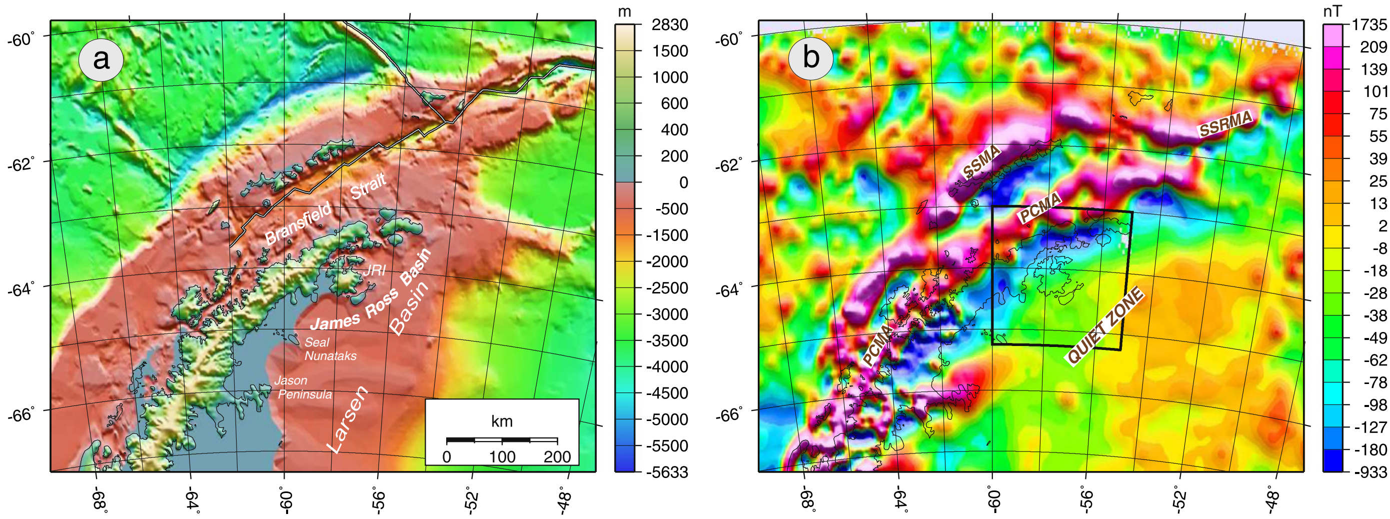


**Fig. 1.** Regional framework. a) Regional topographic image from the GEBCO 1 minute grid (IOC, IHO, and BODC, 2003). Here we indicate the location of outcrops from the JRIVG (James Ross Island Volcanic Group) and related SNVG (Seal Nunataks Volcanic Group). b) Magnetic anomaly image from the ADMAP grid (Golynsky et al., 2001). PCMA: Pacific Coast Magnetic Anomaly; SSMA: South Shetlands Magnetic Anomaly; SSRMA: South Scotia Ridge Magnetic Anomaly. Note the smooth regional magnetic anomaly field over James Ross Island.

group reappears with outcrops at Argo Point, Jason Peninsula (Fig. 1a), some 150 km SW of the Seal Nunataks (González-Ferrán, 1983b; Smellie, 1999). González-Ferrán (1983a,b, 1985) proposed a genetic link between the SNVG and JRIVG basalts, suggesting the existence of an elongated rift zone parallel to the Antarctic Peninsula margin that he termed *Larsen Rift*.

The JRIVG basalts closely resemble ocean island basalts (Hole et al., 1992; Smellie, 1987) and the formation of the volcanic field has been explained as a consequence of mantle upwarp and an asthenospheric flow induced by slab rollback into a region of moderate crustal thinning associated with late Cretaceous–early Tertiary extension (Hole et al., 1991, 1992). Such an origin contrasts with the origin of compositionally similar alkaline basalts in other late Miocene and younger outcrops in the Antarctic Peninsula, which formed following the cessation of subduction and development of slab windows (Hole et al., 1991, 1992, 1995). Alternatively, Mio-Pleistocene dykes from Vega Island that have been geochemically characterized as displaying light relative to heavy rare earth element enrichment (LRRE in relation to HREE) and Nb positive anomalies may have been emplaced in a similar extensional environment to the JRIVG (Salani, 2005).

Newly obtained geochemical data by Košler et al. (2009) point to the importance of tectonic control during the formation of alkaline volcanic rocks in the JRIVG, showing that the presence of enriched mantle component in the back-arc lavas from James Ross Island and its lack in the magmatic rocks found west of the Antarctic Peninsula are consistent with the model of regional extension of Hole et al. (1995). Eagles et al. (2009) suggested that the JRIVG could be related to the slab window that formed below Powell Basin after ridge–crest–trench collisions in the northern Weddell Sea. According to Eagles et al. (2009) the existence of a Maastrichtian–Paleogene calc-alkaline

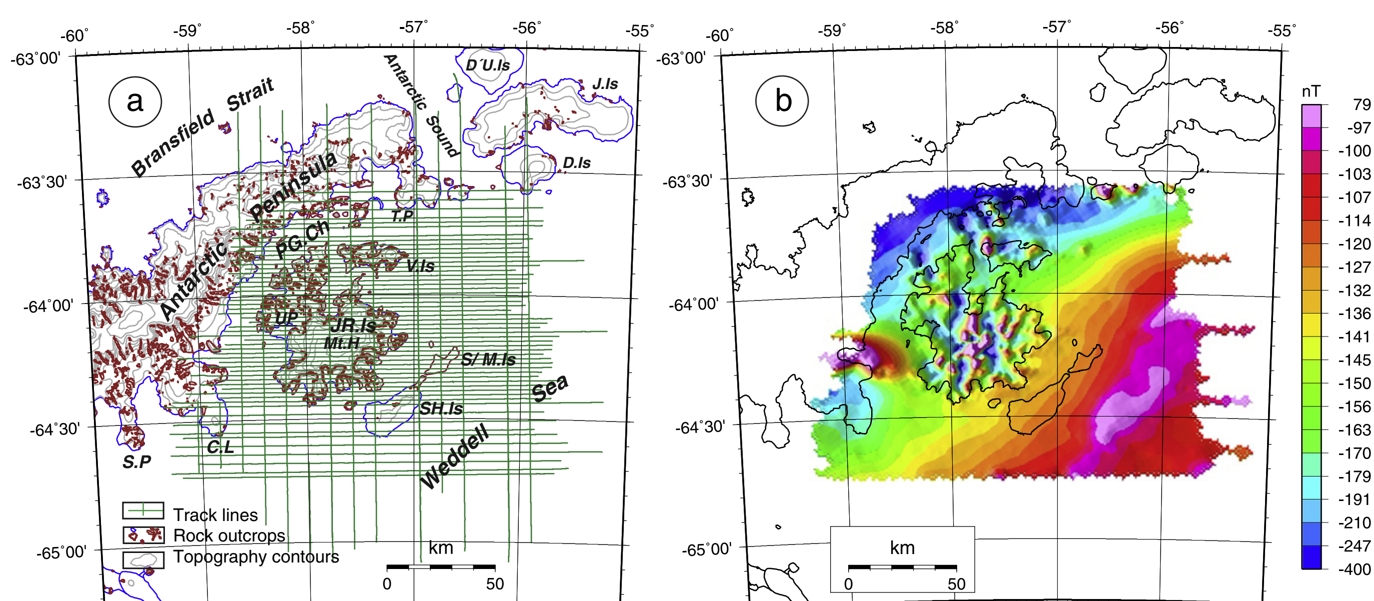


**Fig. 2.** Survey location and magnetic anomaly map. a) Location map of the James Ross group of islands and flight track lines of the aerogeophysical survey BAS-IAA 1998/99. Rock outcrops and topography contours are from the Antarctic Digital Data Base (ADD, http://www.add.scar.org:8080/add/). JR.Is: James Ross Island; Mt.H: Mount Haddington; V.Is: Vega Island; PG.Ch: Prince Gustav Channel; SH.Is: Snow Hill Island; S/M.Is: Seymour/Marambio Island; D.Is: Dundee Island; J.Is: Joinville Island; D'U.Is: D'Urville Island; C.L: Cape Longing; S.P: Sobral Peninsula. b) Magnetic anomaly map resulting from the survey. Colour image is in shaded relief, illuminated from the SW. Colour scale is histogram equalized. Units are nanotesla (nT). Note that the magnetic anomaly values are mostly negative. This is due to the regional field displayed in Figs. 1 and 3.