MAGNETIC ANOMALY DATA FROM A REGIONAL SURVEY: FROM TIERRA DEL FUEGO TO NORTHERN PALMER LAND, ANTARCTIC PENINSULA

Ghidella, M.E.[1*], Forsberg, R. [2], Greenbaum, J.S.[3], Olesen, A.V.[2], Zakrajsek, A.F.[1], and Blankenship, D.D.[3]

[1] Instituto Antártico Argentino - Argentina

[2] Technical University of Denmark (DTU-Space)

[3] Institute for Geophysics, University of Texas at Austin - U.S.A.

Abstract

The IceGrav project is an international aerogeophysical effort jointly carried out by several institutions. Its primary objective is to accelerate the mapping of the gravity field of Antarctica in support of global Geodesy. The secondary purpose is to collect magnetic and ice-penetrating radar data for general Geophysics and Glaciology. In this paper we report on the magnetic data set for the Antarctic Peninsula sector of the aerosurvey, carried out in two deployments during year 2010. The acquired magnetic data sum up nearly 40000 line-km covering the region between Southernmost South America and Palmer Land in the Antarctic Peninsula. Very good quality data tracks cross the Drake Passage, between Tierra del Fuego and the South Shetland Islands. Magnetic lineations are clearly traced on the three segments of the extinct Phoenix plate. An elongated linear anomaly borders the Shackleton fracture zone centered at the adjacent extinct spreading ridge.

Resumen

El proyecto IceGrav es un emprendimiento aerogeofísico internacional llevado a cabo en conjunto por varias instituciones. Su objetivo primario es acelerar el mapeo del campo de anomalías gravimétricas de Antártida en apoyo a la Geodesia global. El propósito secundario es recolectar datos magnéticos y de radar penetrante en el hielo, para Geofísica general y Glaciología. En este trabajo informamos sobre los datos magnéticos del relevamiento en la región de la Península Antártica, que fue llevado a cabo en dos campañas durante el año 2010. Los datos adquiridos suman alrededor de 40000 km lineales cubriendo la región entre el extremo sur de Sudamérica y la Tierra de Palmer en la Península Antártica. Líneas de vuelo con datos de muy buena calidad cruzan el pasaje de Drake, entre Tierra del Fuego y las islas Shetland del Sur. Las alineaciones magnéticas pueden trazarse con mucha claridad en los tres segmentos de la extinta placa Phoenix. Una anomalía alargada linealmente bordea la zona de fractura de Shackleton, centrada en la dorsal del sistema de expansión extinto adyacente.

Introduction

The Danish IceGrav project has made good progress in Antarctica, collecting basic gravity, magnetic and ice radar data from a DC3 platform in the Antarctic Peninsula and East Antarctica regions. The IceGrav project is a close scientific collaboration between DTU, NGA (National Geospatial-Intelligence Agency, USA), the University of Texas (USA), the University of Bergen (Norway), the Argentine Antarctic Institute (Argentina) and the British Antarctic Survey (UK). The primary goal is to measure airborne gravity in hitherto unmapped areas, and eventually contribute to a coordinated Antarctic gravity grid compilation, for basic use in Geodesy, Geophysics, and satellite orbit determination, such as the current global gravity field model EGM08. The secondary goal is to provide basic radar, laser and magnetic data, as made possible by the rather large long-range DC3 aircraft. The primary funding is provided by NGA,

with supplemental funding from ESA (P-band radar) and NASA-IceBridge (University of Texas participation).

In this paper we concentrate on the magnetic data of Antarctic Peninsula sector of the aerosurvey, with particular attention given to the data acquired during the first deployment, in January-February 2010, as more recent data are still being processed. Figure 1, however,

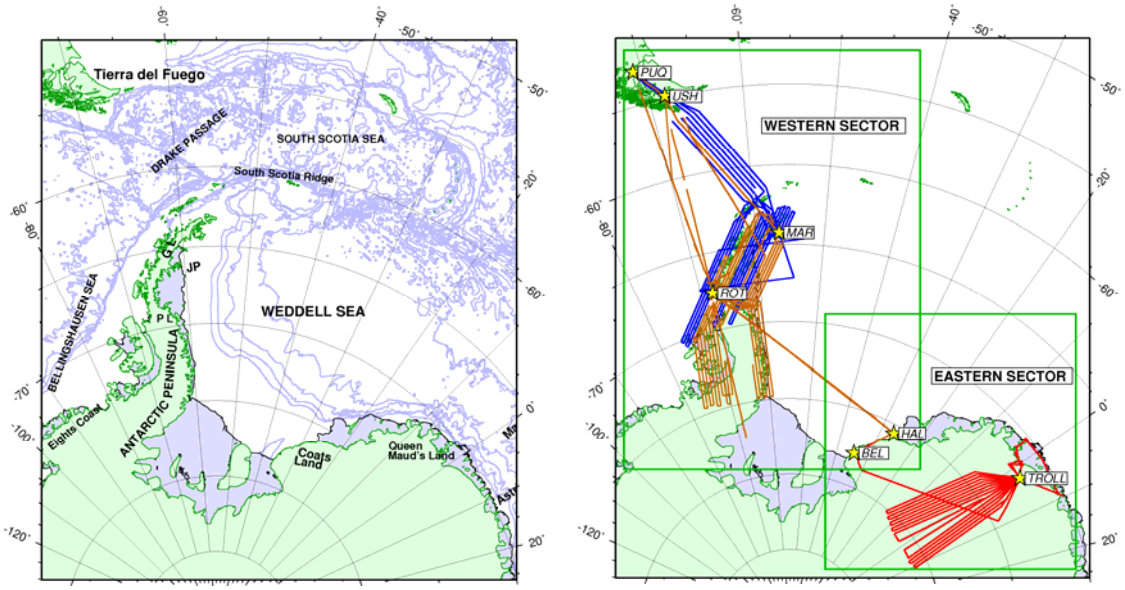

Figure 1: *Left*: Geographic region of the IceGrav aerosurvey. Bathymetry contours from the GEBCO 1^{o}x1^{o} grid are plotted in blue every 1000 m. *Right*: Location of all IceGrav magnetic tracks. Blue: Jan 2010; brown: Oct 2010; red: Feb 2011. Yellow stars are plotted on the airports. PUQ: Punta Arenas; USHU: Ushuaia; MAR: Marambio; ROT: Rothera; BEL: Belgrano; HAL: Halley; TROLL: Troll.

displays the entire geographic area and the total track line coverage until after the last field season, which was mainly in East Antarctica.

Magnetic anomalies of the western sector

The magnetic data of the first season comprise several Drake Passage crossings and a fairly good coverage of the Antarctic Peninsula, 25250 km in all. The data have been edited and carefully corrected for noise and spikes.

A ground scalar magnetometer installed near Marambio Station recorded the total magnetic field for external variation corrections, taking samples every 0.1 sec. Total field despiked data were DGRF corrected to obtain magnetic anomalies. Figure 2 displays the magnetic anomaly map thus achieved (left) and also a map from the ADMAP compilation (Golynsky et al., 2001). For a general description of the intermediate wavelength magnetic anomalies see Maslanyj et al. (1991), LaBrecque and Ghidella (1997), Ghidella and LaBrecque (1997).The new data are of higher resolution than most of those forming part of the ADMAP (see Golynsky et al., 2001, and references therein), allowing for new insights into the Drake Passage tectonic history and the Antarctic Peninsula terrains.

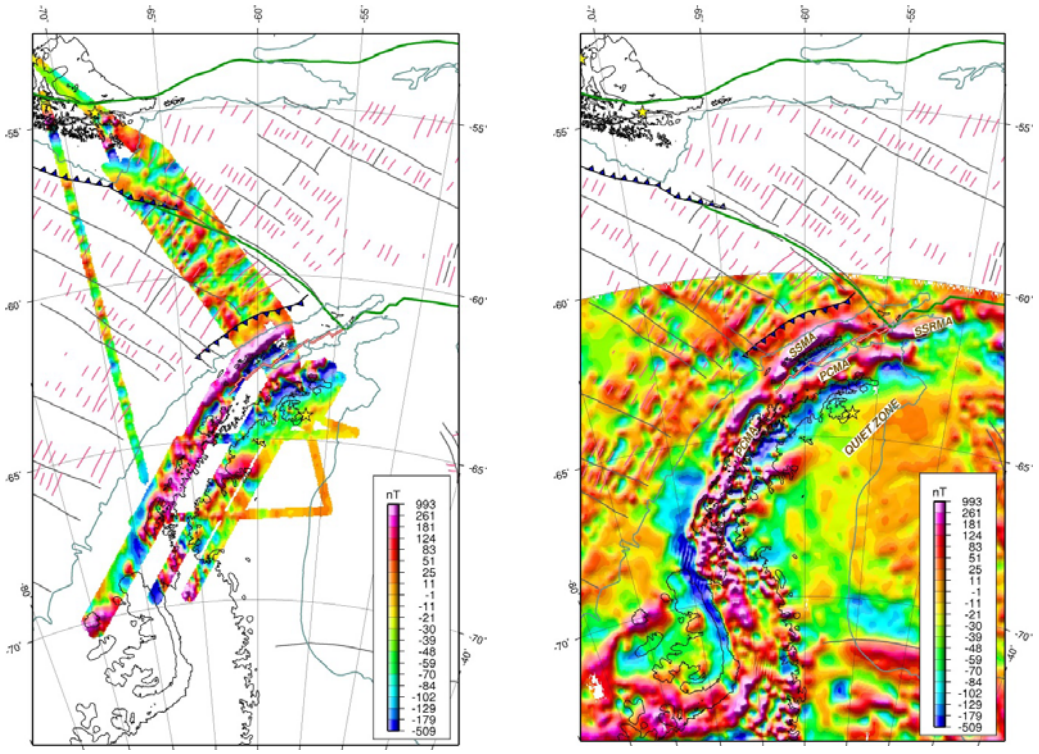

Figure 2. *Left:* Magnetic anomaly image and seafloor magnetic lineations and fracture zones from the Cande et al. (1989) compilation map. Also displayed are tectonic plate boundaries and the 1000 m bathymetry contour of the GEBCO 1^{o}x1^{o} grid. *Right:* Magnetic anomaly map from the ADMAP compilation (Golynsky et al., 2001; http://www.dna.gov.ar/mararg/admap/). MA: magnetic anomalu; SSMA: South Shetland MA; PCMA: Pacific Coast MA; SSRMA: South Scotis Ridge MA.

Comparison with the ADMAP compilation

The map on the left of Figure 3 shows a shaded image of the difference between the ADMAP and IceGrav magnetic anomaly grids. The discrepancies can be better understood if compared to the map on the right, which displays the track lines of the intervening surveys. Differences are bigger in the north, where the ADMAP compilation doesn't yet have high resolution data. In other areas they are around 10 nT, a positive bias that will possibly be better defined by an adjustment of the regional field, after considering both data sets and the newer IceGrav data as well. Therefore, in general, differences are acceptable and close inspection favors the quality and high resolution along track of the IceGrav data.

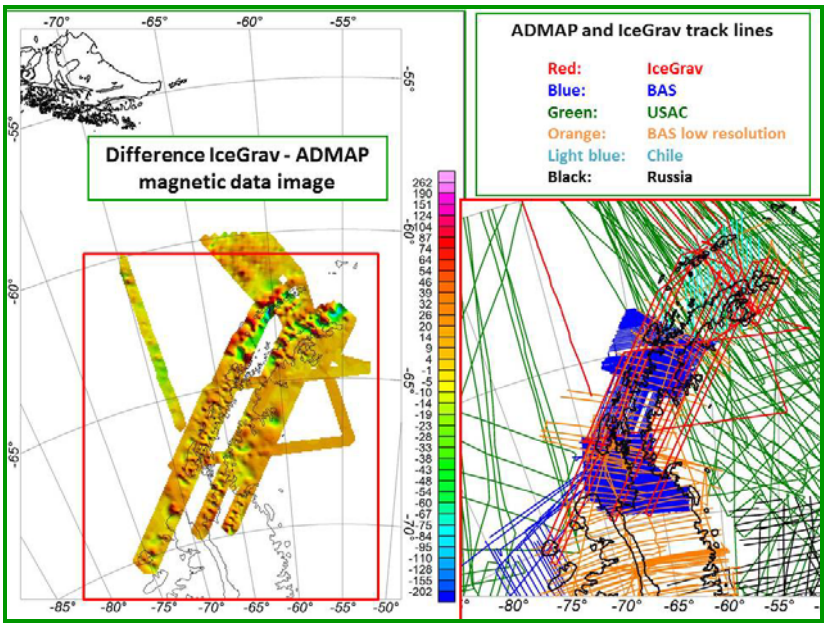

Figure 3. Comparison between ADMAP and IceGrav data and grids. Notice that differences are bigger in the north, where the ADMAP compilation doesn't have high resolution data.

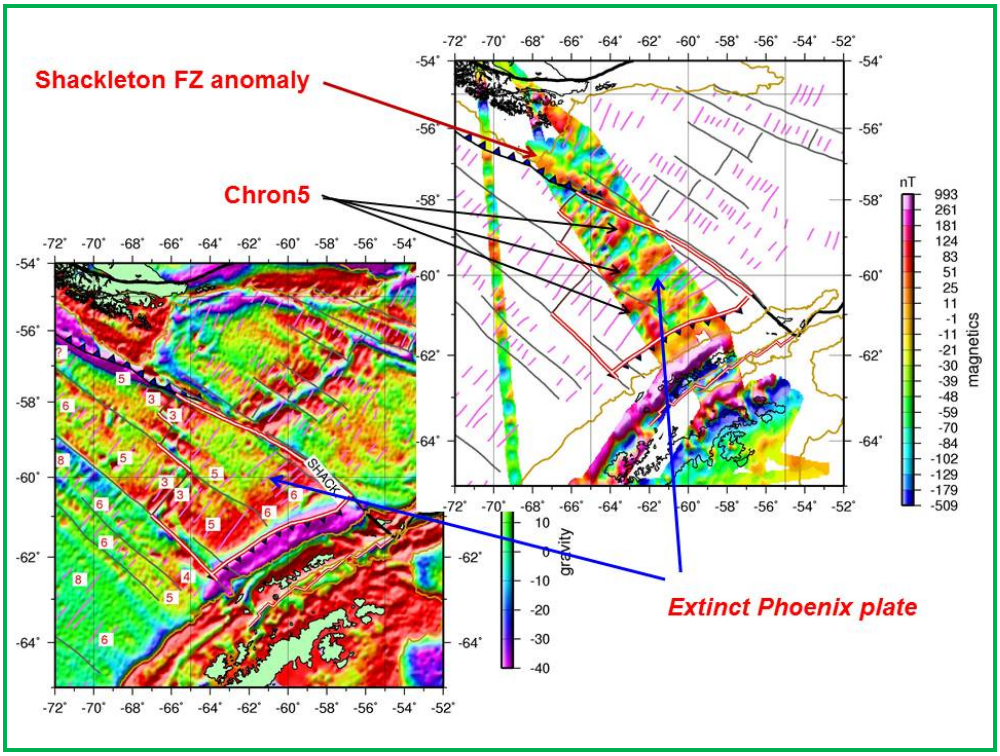

Figure 4. IceGrav first season magnetic anomaly map (right) and free air gravity map from satellite altimetry. Both maps display the magnetic lineations and fracture zones from Cande et al (1989). SHACK: Shackleton Fracture Zone. Notice that the young lineations and their offsets in the extinct Phoenix plate are very well defined by the new data set. Notice also that there is an elongated positive magnetic anomaly centred on the extinct spreading ridge.

Antarctic Peninsula terrains

The Antarctic Peninsula, in the Pacific margin of Gondwana, has a long history of accretion processes that in the Mesozoic resulted in the formation of terrains that can be distinguished according to their lithology and structure (Vaughan and Storey, 2000). These authors identified the East Palmer Land Shear Zone (EPLSZ), which separates recognized geological domains.
Accretionary complex rocks of the Western Domain (WD) and magmatic arc rocks of the Central Domain (CD) may have docked against an already existing Eastern Domain (ED), causing the Palmer Land orogenic event (Vaughan et al., 2002; Ferraccioli et al., 2006). But Ferraccioli et al. (2006) suggest that the CD is not a single microcontinental arc. Instead, they redefine the CD as a composite magmatic arc terrain, comprising two distinct geophysical zones; the western zone (CDWZ) and the eastern zone (CDEZ) (Figure 5, left). The CDWZ features a long-wavelength positive magnetic anomaly, with super-imposed mostly short-wavelength positive magnetic anomalies. The long-wavelength positive magnetic anomaly is part of the Pacific Margin Anomaly (PMA) (Figs. 2 and 5). The sources of this anomaly have been modeled as a ~20 km thick magnetite-rich magmatic arc batholith (Garrett, 1990; Ghidella et. al., 1991).The CDEZ is a broad magnetic low punctuated with similar, but lower amplitude, short-wavelength anomalies.
The middle image in Fig. 5 displays the ADMAP magnetic image with the IceGrav on top. Careful inspection of this figure allows appreciating the clearer definition of the anomalies in the new data and a better definition of the intrusive features. Particularly striking are sharp high amplitude anomalies caused by intrusions related to the magmatic arc and the Pacific Margin Anomaly. Those anomalies spread out from the arc into the Eastern Domain in the Antarctic Peninsula and the eastern margin magnetically quiet zone, in the Weddell Sea.

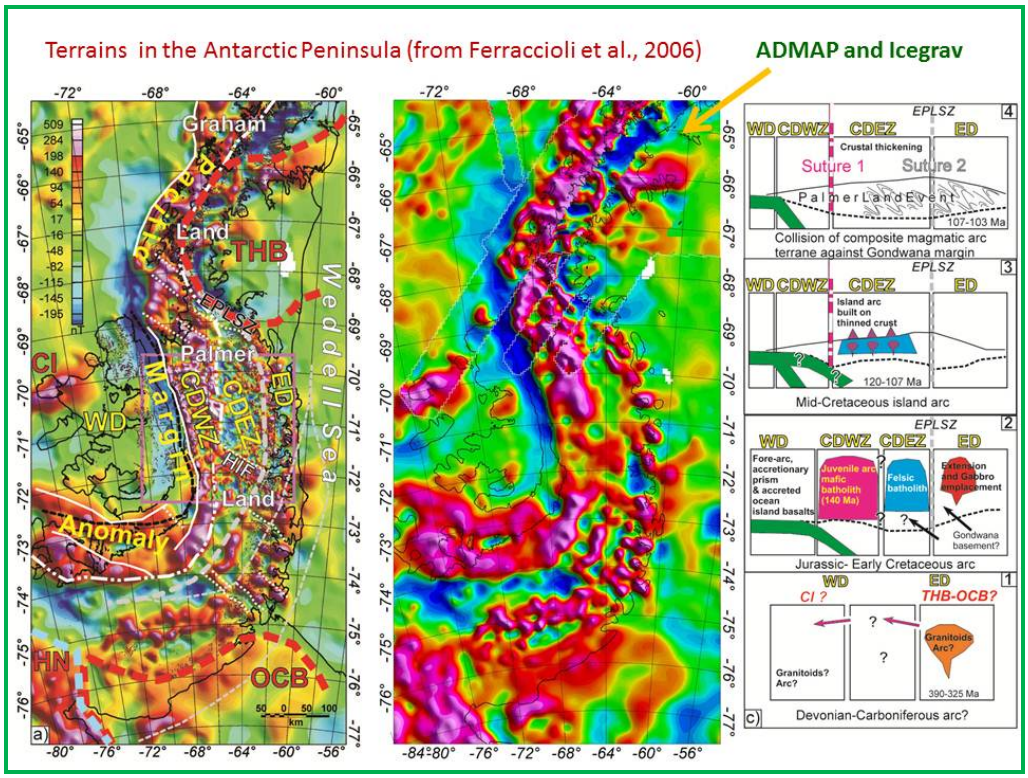

Figure 5. *Left:* Aeromagnetic anomaly map for the Antarctic Peninsula obtained by combining data prior to the IceGrav by Ferraccioli et al (2006). The boundary between the CDWZ and the CDEZ (dash-dotted line) appears to merge with the EPLSZ along the eastern edge of the Target Hill block (THB) and to form part of a >1500 km long zone. Other basement blocks: CI, Charcot Island; OCB, Orville Coast block; HN, Haag Nunataks. *Middle*: IceGrav magnetic anomalies imaged on top of the ADMAP compilation. Color scale is not the same as that on the left. Particularly striking are sharp high amplitude anomalies caused by intrusions that penetrate the Eastern domain. *Right:* Crustal accretion stages of the Antarctic Peninsula from Ferraccioli et al (2006) that may account for the airborne geophysical signatures and available geological constraints.

Work underway

Data processing and integration of the more recent data on the western sector is underway. Interpretation in conjunction with gravity and ice bedrock topography from ice penetrating radar data is quite promising. Integration of the new magnetics with the ADMAP will be done in accordance with the established protocols.

Conclusions

The main differences between the present data and the ADMAP compilation are in the northern Antarctic Peninsula area where there are strong gradients and no previous high resolution magnetic surveys.
Oceanic magnetic lineations are clearly traced on the three segments of the extinct Phoenix plate, and contribute to a better definition of the tectonic history.
An elongated linear anomaly borders the Shackleton fracture zone centered at the adjacent extinct spreading ridge.

Particularly striking are sharp high amplitude anomalies caused by intrusions related to the magmatic arc that stretch seaward from the Pacific Margin Anomaly into the Eastern Domain and the margin magnetically quiet zone.

References

Cande, S.C., J.L. LaBrecque, R.L. Larson, W.C. Pitman, X. Golovchenko, and W.F. Haxby, 1989: Magnetic lineations of the world's ocean basins, AAPG, Tulsa, OK, USA.

Ferraccioli, F. P.C. Jones, A.P.M. Vaughan, P.T. Leat, 2006, New aerogeophysical view of the Antarctic Peninsula: More pieces, less puzzle, Goph. Res. Letters, vol. 33, L05310, doi:10.1029/2005GL024636.

Garrett, S. W., 1990, Interpretation of reconnaissance gravity and aeromagnetic surveys of the Antarctic Peninsula, J. Geophys. Res., 95, 6759-6777.

Ghidella, M.E., LaBrecque, J.L., 1997, The Jurasic conjugate margins of the Weddell Sea: Considerations based on magnetic, gravity and paleobathymetry data. The Antarctic Region: Geological Evolution and Processes, 441-451.

Ghidella, M.E., C.A. Raymond, J.L. LaBrecque, 1991, Verification of crustal sources for satellite elevation magnetic anomalies and their regional tectonic implications. In: Geological Evolution of Antarctica. Editor: M.R.A. Thomson; Cambridge, U.K., pp. 243-250.

Golynsky, A., M. Chiappini, D. Damaske, F. Ferraccioli, J. Ferris, C. Finn, M. Ghidella, T. Isihara, A. Johnson, H.R. Kim, L. Kovacs, J. LaBrecque, V. Masolov, Y. Nogi, M. Purucker, P. Taylor, Torta, M., 2001, ADMAP - Magnetic Anomaly Map of the Antarctic, 1:10 000 000 scale map, in Morris, P., and R. von Frese, eds., BAS (Misc.) 10, Cambridge, British Antarctic Survey.

LaBrecque, J.L., Ghidella, M.E., 1997. Bathymetry, depth to magnetic basement, and sediment thickness estimates from aerogeophysical data over the western Weddell. Basin. J. Geophys. Res. 102, 7929–7946.

R. Livermore, G. Eagles, P. Morris, A. Maldonado, 2004, Shackleton Fracture Zone: no barrier to early circumpolar ocean circulation, Geology 32 (2004) 797–800.

Maslanyj, M.P., Garrett, S.W., Johnson, A.C., Renner, R.G.B., Smith, A.M., 1991. Aeromagnetic anomaly map of West Antarctica (Weddell Sea sector), British Antacrtic Survey, Natural Environment Research Council, Cambridge.

Vaughan, A. P. M., and B. C. Storey (2000), The eastern Palmer Land shear zone: A new terrane accretion model for the Mesozoic development of the Antarctic Peninsula, J. Geol. Soc. London, 157, 1243– 1256.

Vaughan, A. P. M., S. P. Kelley, and B. C. Storey (2002), Mid-Cretaceous ductile deformation on the eastern Palmer Land shear zone, Antarctica, and implications for timing of Mesozoic terrane collision, Geol. Mag., 139, 465– 471.