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A new topographic map for Keller Peninsula, King George Island, Antarctica

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ABSTRACT

The Keller Peninsula (KP), on the King George Island, shelters the Brazilian Comandante Ferraz Station (EACF) and it has been the site from several international research projects. However, this area has not yet been mapped in detail, except for the area around the EACF, which is mapped at 1:500. Aiming to overcome the lack of a detailed and accurate map for the entire KP, this work proposes the use of photogrammetric and GIS techniques for the compilation of a new topographic map at a scale of 1:5,000. The elaboration of this map was based on interior and exterior orientation of aerial photographs, generation and edition of a Digital Terrain Model (DTM), derivation of contour lines from the created DTM and accuracy assessment of the results. Verification of horizontal position and elevation data of the resulting map showed a good correlation with data from other maps, mainly in the area around the EACF and at Flagstaff Hill.

Key words: Keller Peninsula, King George Island, Topographic Map.

INTRODUCTION

The Keller Peninsula (KP), located at Admiralty Bay (AB), King George Island (KGI) (Fig. 1), is an area of special interest for the Brazilian Antarctic Program (PROANTAR). The Brazilian Comandante Ferraz Station (EACF) and great part of the scientific investigations carried out by PROANTAR are located in this area. However, topographic maps in a scale compatible with the logistical management, environmental and scientific activities were not available for the KP.

The KP was firstly mapped in 1951, at a scale of 1:15,000, by the Directorate of Overseas Surveys (DOS) from the British Government's Ministry of Overseas Development (DOS 1951). In 1968, DOS published the first reliable map for KGI, at a scale of 1:200,000, elaborated using metric aerial photographs taken in the summer 1956-1957 (DOS 1968; Bremer et al. 2004). In 1980, the Polish Academy of Sciences (PAN) used metric aerial photographs taken in 1978 and 1979, bathymetric and topographic surveys and AB maps compilations to produce a topographic map of this area at scale of 1:25,000 (PAN 1980). In 1990, PAN published a

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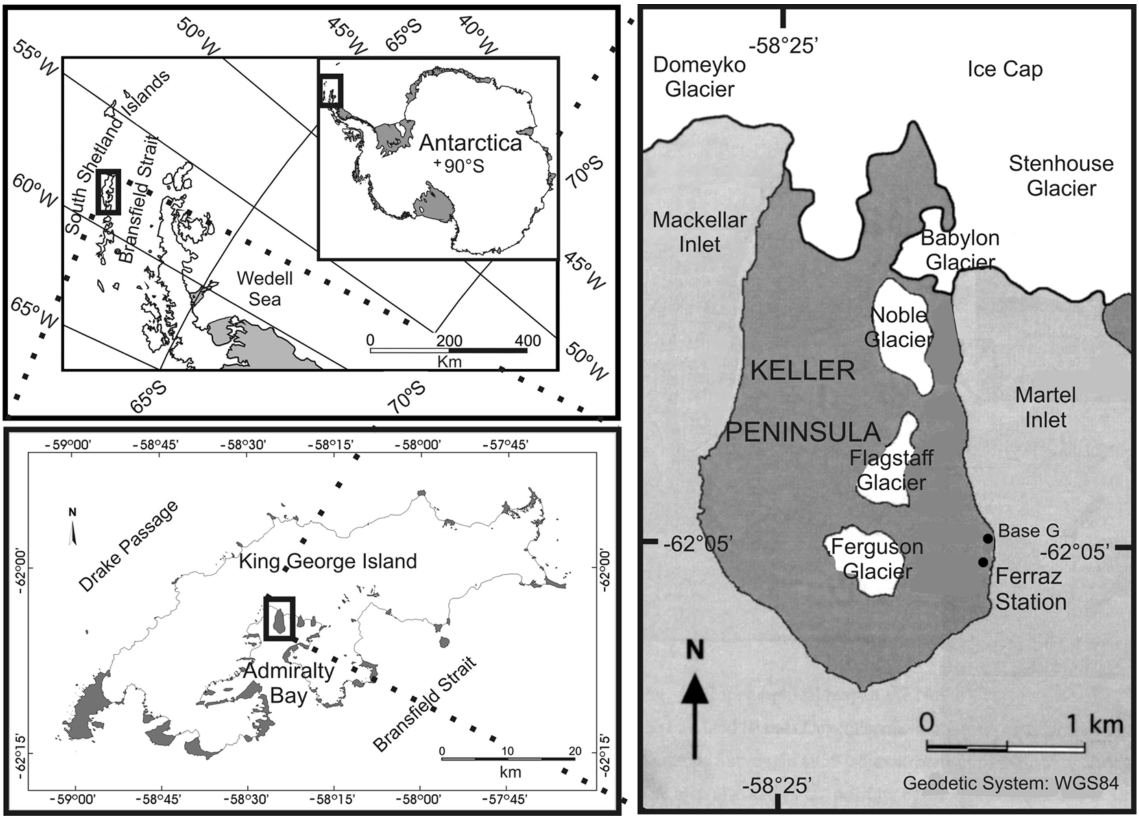

Fig. 1 – Location of the Keller Peninsula, Comandante Ferraz station and the site of the former British Base G (removed in 1987).

new edition of this map, at a scale of 1:50,000, with 25 m contour intervals (Battke 1990). The Hydrographic Service (DHN) of the Brazilian Navy carried out geodesic, topographic and bathymetric surveys of the AB during the 1983-1984 summer, and produced a nautical chart for this region at 1:40,000 (Erwes 1984). A second edition of this chart was published in 1992, updated by surveys carried out during the 1984-1985 summer (DHN 1992; Souza 2008).

The most updated KP base map consisted of a topographic map at a scale of 1:100,000, produced in 2001 by the Institute of Physical Geography (IPG) of the University of Freiburg, Germany, and by Centro Polar e Climático – CPC (formerly called Laboratório de Pesquisas Antárticas e Glaciológicas – LAPAG) at the Federal University of Rio Grande do Sul (UFRGS). This map has 50 m contour intervals, derived from a Digital Terrain Model (DTM) compiled with data from several sources (Braun et al. 2001). However, data source corresponding to the AB area was extracted from the PAN topographic map (IPG and LAPAG 2001). More recently, Francelino et al. (2004) used contour lines from the topographic map elaborated by Braun et al. (2001) and 90 altimetric points surveyed by Differential Global Positioning System (DGPS) for generating a new DTM for the KP. Furthermore, a team from the Laboratório de Topografia e Geodésia da Escola Politécnica, University of São Paulo (USP), Brazil, in collaboration with the project Geoespaço (http://www.inpe.br/antartica/geoespacial.html), carried out in January–February 2006 a topographic survey in the area surrounding the EACF. As a result of this survey, a topographic plan at 1:500 was produced with 1 m contour intervals (Fonseca Jr. et al. 2006). To overcome the lack of a detailed and accurate map for the entire KP area, we compiled new data from photogrammetric and plani-altimetric data to produce a new topographic map for this area at a scale of 1:5,000.

METHODOLOGY

We used a stereopair of panchromatic vertical aerial photographs in 23 × 23 cm format, at 1:50,000 scale, taken by "Servicio Aerofotogramétrico de la Fuerza Aerea de Chile" (SAF) using a photogrammetric camera Wild RC10, with focal length of 88.10 mm. These photographs were taken on January 22, 2003, as part of a flight mission requested by the "Servicio Hidrográfico y Oceanográfico de la Armada del Chile" (SHOA), covering the Antarctic Peninsula and adjacent islands. For the data processing in a Digital Photogrammetric Station (DPS), the aerial photographs were digitized (12.5μm resolution) using a photogrammetric scanner. We used the following methodology: aerial photographs processing in the DPS (i.e., interior and exterior orientation, generation and edition of a DTM); contour lines derivation from the DTM; elaboration of the topographic map; and accuracy assessment of the results.

Interior Orientation

Aerial photographs were processed in a DPS model LPS^{TM} (Leica Photogrammetry Suite – Leica Geosystems GIS and Mapping, LLC), available at CPC. Firstly, a project was created in the LPS^{TM} with the Universal Transverse of Mercator (UTM) projection, zone 21 south (21S), and data referenced to the World Geodetic System 1984 (WGS84) ellipsoid, which is recommended by the Scientific Committee on Antarctic Research (SCAR) for maps at scales larger than 1:1,000,000 (Simões et al. 2004; SCAGI 2009). Photographs were then stored in this project, as well as camera calibration parameters (SAF 1996). For this orientation, a 0.4 pixels Root Mean Square Error (RMSE) was obtained for both photographs.

Exterior Orientation

As a second step, the exterior orientation of the photographs was done. The control points used for this step were acquired from the EACF topographic plan (Fonseca Jr. et al. 2006) and from a DGPS survey carried out in the KP with single-frequency GPS receivers, executed by Bremer and Debiasi (2006). GPS data pos-processing were carried out using reference data from the EACF GPS antenna (Fig. 3), which is a station integrated into the so-called Brazilian Network for Continuous GPS Monitoring (RBMC), managed by the Brazilian Institute for Geography and Statistics – IBGE (Bremer and Debiasi 2006). Due to the lack of a precise local geoid undulation model, for calculation of orthometric heights from the GPS measurements, we used only the horizontal position of these points acquired by DGPS. To overcome the lack of altimetric control points, we used aerial photographs to get points along the AB coastline and considered them as an arbitrary zero level.

A total of 72 altimetric control points were identified in the stereopair along the AB coastline, as well as 21 planimetric control points and 198 tie points on the KP area. For the planimetric data accuracy assessment, 6 check points were selected on the stereopair. A RMSE of 1.2 pixels (approximately 0.76 m of ground resolution) was obtained in the Bundle Block Adjustment (Leica Geosystems 2003). The statistics of the planimetric and altimetric control point's residuals, and check points, are described in Table I.

DTM Generation and Edition

Altimetry points, derived from the stereomodel, were edited in the LPS^{TM}. These points and the data from the EACF topographic plan (Fonseca Jr. et al. 2006) totalized 70,787 points, which were stored in the program ArcGIS^{TM} (ESRI Inc.). In this Geographical Information System (GIS), a DTM was created with the interpolation method so-called Triangular Irregular Network (TIN). A TIN is a vector-based representation of the relief, made up of irregularly distributed nodes and lines

TABLE I
Statistics of planimetric and altimetric control points residuals and of the check points.

Point	Residuals (m)				
	Total	Mean	Standard deviation	Minimum	Maximum
Planimetric	21	1,507	0,643	0,082	2,600
Altimetric	72	0,040	0,448	–0,970	0,893
Check	6	1,572	0,951	0,149	2,549

with three-dimensional coordinates (x, y and z) arranged in a network of non-overlapping triangles (Burrough and McDonnell 1998). This method was selected among others available in ArcGIS™ to derive a more accurate DTM from the huge amount of well-placed original planialtimetric data. The resulting DTM has a 0.63 m ground resolution that is compatible with the density of points stored in the GIS and with the aerial photographs spatial resolution used to derive the altimetric information.

The Topographic Map

Using the ArcGIS™, contour lines with 5 m intervals were extracted from the DTM described in the section above. In Figure 2, the terrain relief is represented at a scale of 1:20,000, with 25 m contour lines intervals. The final product of this work consisted of a topographic map at a scale of 1:5,000, with 5 m contour lines, which is attached to this volume of "Pesquisa Antártica Brasileira", and the digital version is available at http://www.ufrgs.br/antartica.

The projection used in the topographic map was the UTM and data were referenced to the WGS84 ellipsoid, as recommended by SCAR Standing Committee on Antarctic Geographic Information (SC-AGI 2009). In the EACF topographic plan, the point of origin was the so-called Brazilian Horizontal Datum 2006 (Erwes et al. 2012, this volume) located in a geodetic mark northeast of the station (Fig. 3). The altimetric data of this plan have a reference level located on the same geodetic mark, the so-called Provisional Vertical Datum 1984 (Erwes et al. 2012, this volume). In the attached topographic map produced by this work, the altimetric reference consisted of a zero level given by the AB coastline at the date (January 22, 2003) and time (between 6:47 pm to 7:08 pm UTC) of the photographic exposure (Figs. 2 and 3). Buildings mapped on the EACF topographic plan were also represented on the new KP topographic map. Toponyms were based on Birkenmajer (1980), the PAN maps (PAN 1980 and Battke 1990) and on the Composite Gazetteer of Antarctica – CGA (GSSG 2003). Only one place name per feature was chosen, giving priority to the first recorded name, according to the rules proposed by Sievers and Thomson (1995).

Accuracy of the Topographic Map

To assess the accuracy of the altimetric data generated by this study, some features elevations in the new map were compared with the same ones as reported in previous maps, CGA data or in other publications. We used for this assessment the geodetic mark of the EACF (Fig. 3), and Flagstaff Hill, Mount Birkenmajer and Mount Tokarski summits (Fig. 2). Results of these comparations are shown in the Table II.

The EACF geodetic mark elevation is the same in the topographic map and plan (Table II and Fig. 3). As expected, in the area around the EACF all other topographic map altimetric points show high compatibility with data from the topographic plan (Fig. 3) because in this area the EACF plan altimetric data were used for the DTM compilation. For the Flagstaff Hill summit there is a 0.3 m elevation difference between the topographic map and the DOS and PAN maps. The Mount Birkenmajer and Mount Tokarski summits (i.e., the highest

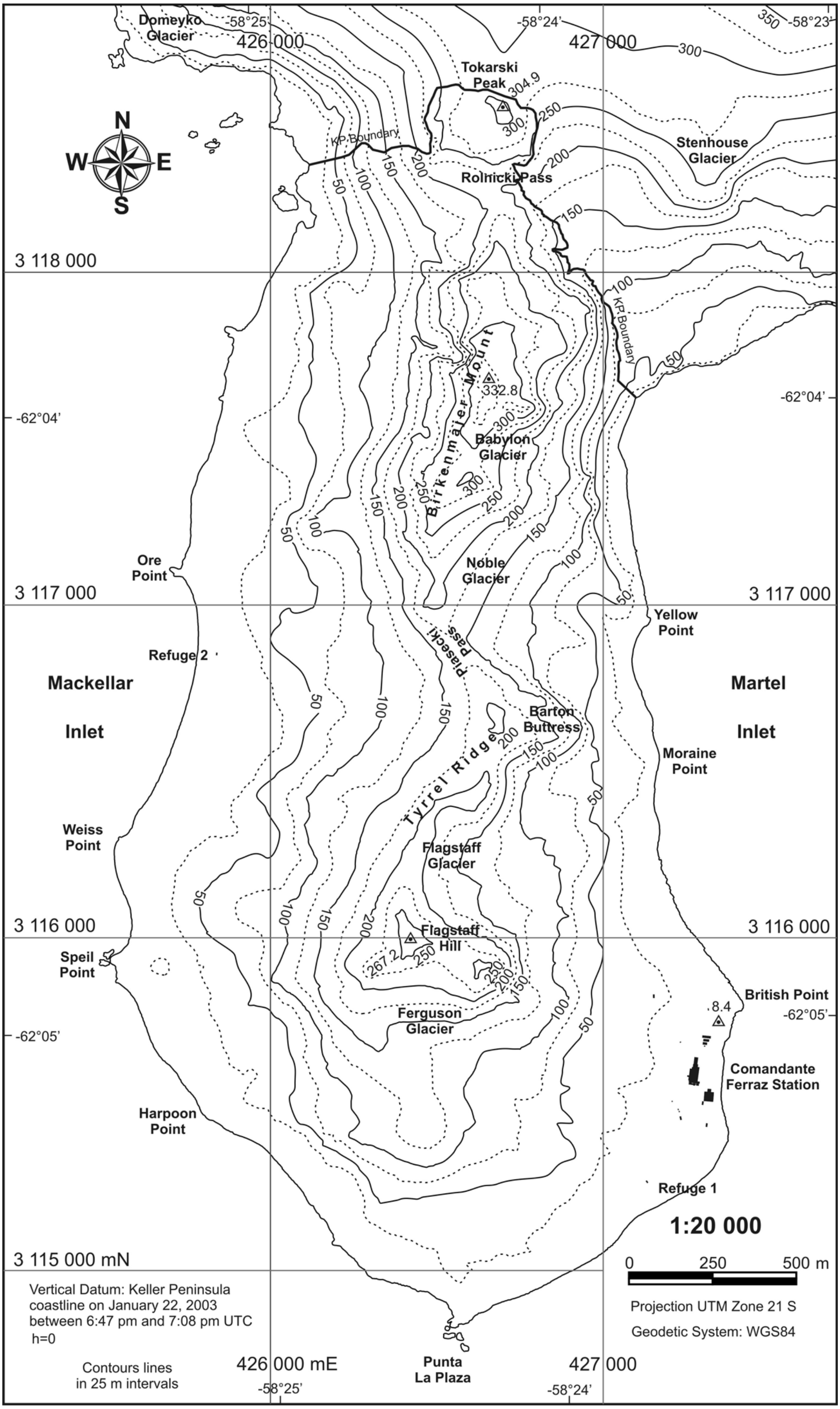

Fig. 2 – Keller Peninsula topographic map produced by this work.

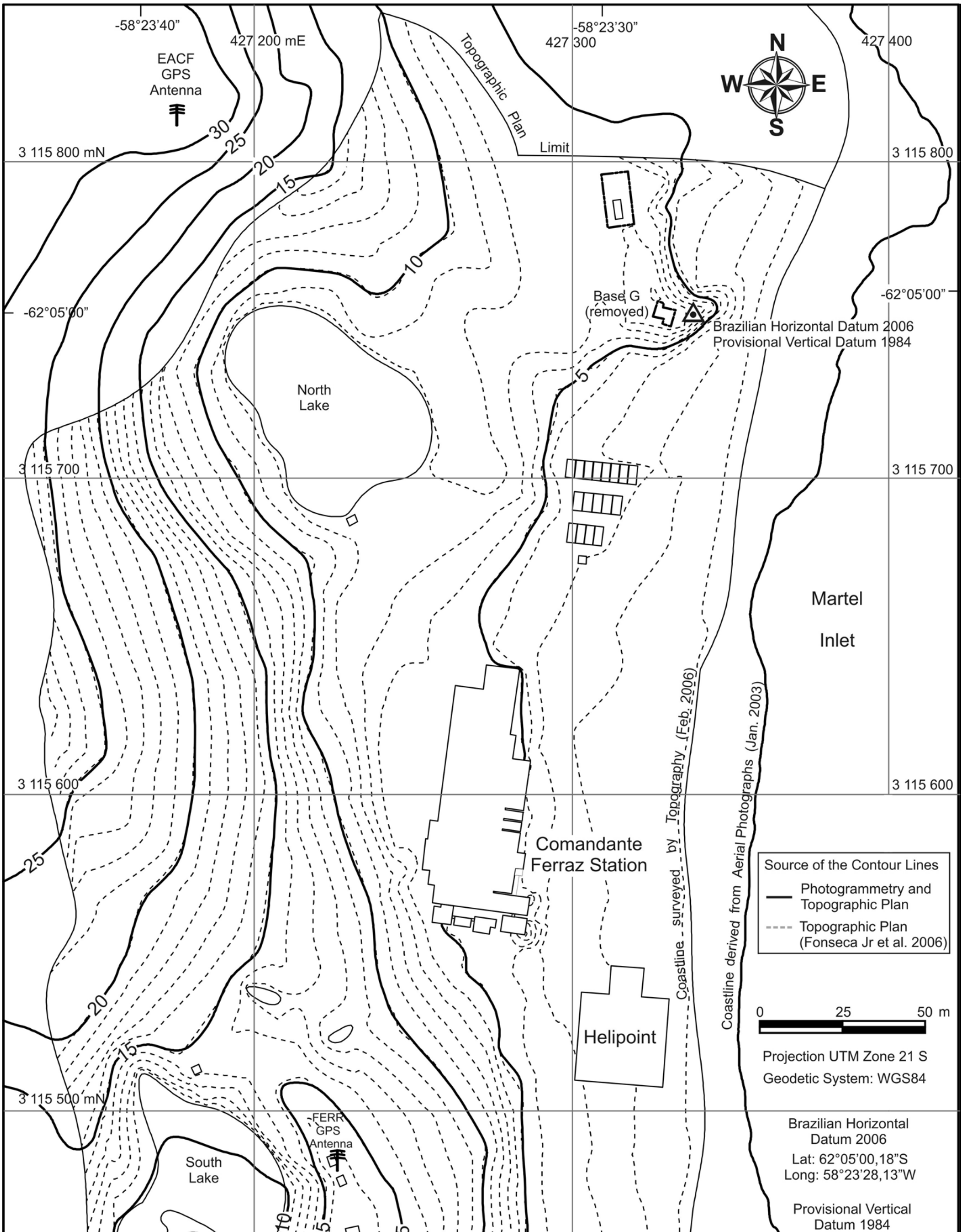

Fig. 3 – Map of the area around the Comandante Ferraz station. It is possible to see the high compatibility of the contour lines from the new topographic map produced in this work with the EACF topographic plan.

TABLE II

Geodetic mark elevations at the EACF and Flagstaff Hill, Mount Birkenmajer and Mount Tokarski summits, as shown in the topographic map produced in this study and in other databases (see text for details).

EACF Geodetic mark	$-62°05'00, 18''$	$-58°23'28, 13''$	8,378	8,378	Fonseca Jr et al. 2006	0,000
Flagstaff Hill	$-62°04'51, 80''$	$-58°24'30, 71''$	267,200	265,000 267,000 267,500	GSSG 2003 DOS 1968 Battke 1990	2,200 0,200 –0,300
Mount Birkenmajer	$-62°05'57, 66''$	$-58°24'12, 72''$	332,805	340,000 360,000	Francelino et al. 2004 GSSG 2003	–7,195 –27,195
Tokarski Peak	$-62°03'30, 98''$	$-58°24'08, 18''$	304,871	320,000	GSSG 2003	–15,129

KP features) showed a significant elevation difference between the topographic map and the CGA data, 27.195 m and 15.129 m, respectively. For the Mount Birkenmajer summit, the highest KP point, the difference between our topographic map and the study by Francelino et al. (2004) was smaller (i.e., 7.195 m). Regarding these highest points, the great elevation difference between the topographic map and CGA data could not be explained, as there are no references in the CGA about the data source or the methodology used for the acquisition of the coordinates and altimetric information. On the other hand, the elevation difference of the Mount Birkenmajer summit between our topographic map and in the work by Francelino et al. (2004) could have resulted from different methods used in the DTM generation.

CONCLUSIONS AND OUTLOOK

Our work resulted in a new KP topographic map at 1:5,000 scale. The acquisition of accurate data compatible with the scale of the produced map is one of the advantages of using a DPS. There is a high compatibility between altimetric data from the topographic map with other maps elaborated by topographic or photogrammetric surveys, in spite of using an arbitrary zero level along the AB coastline for the altimetric data. More precise altimetric results can be achieved with the use of altimetric control points surveyed by geometric leveling. Furthermore, topographic surveys can be carried out to check out the topographic map accuracy. For altimetric studies that demand high precision, it is not recommended the use of information derived from GPS receivers' measurements, as no local geodetic undulation model has been developed for the AB region. For the definition of a unique altimetric datum for this region, a maregraph should be installed in the KP coast.

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RESUMO

A Península Keller (PK), na ilha Rei George, além de abrigar a Estação Antártica Comandante Ferraz (EACF), é o cenário de diversas pesquisas internacionais. Todavia, essa península não possuía uma base cartográfica em escala de detalhe, com exceção da área de entorno da EACF,

que está mapeada em uma planta topográfica na escala 1:500. Para suprir a falta de uma base cartográfica precisa e detalhada para toda a área da PK, este estudo elaborou um mapa topográfico dessa península na escala 1:5.000, a partir de um estereopar de fotografias aéreas métricas em uma estação fotogramétrica digital e usando dados da planta da EACF, armazenados em um Sistema de Informações Geográficas (SIG). A metodologia utilizada na elaboração deste mapa consistiu na orientação interna e externa das fotografias, geração e edição de um Modelo Digital do Terreno (MDT), extração das curvas de nível do MDT e avaliação da precisão dos dados produzidos. Os dados planialtimétricos do mapa topográfico apresentaram boa compatibilidade com outros mapas-base, principalmente na área de entorno da EACF e do morro Flagstaff.

Palavras-chave: Península Keller, ilha Rei George, mapa topográfico.

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