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Terrain analysis of the Keller Peninsula (King George Island, Antarctica) by gis techniques

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ABSTRACT

This study uses a Geographical Information System (GIS) for terrain analysis of the Keller Peninsula (KP), King George Island (KGI), Antarctica, to describe its morphological characteristics. We processed a vertical metric aerial photography and a Digital Terrain Model (DTM) in a Digital Photogrammetric Station to generate an orthophoto and then to create a KP orthophotomap. A more detailed DTM for the area surrounding the Brazilian Comandante Ferraz Station (EACF) was generated adding local points with known elevation. From these DTMs, we derived hypsometric, slope and aspect maps, hillshade models, perspective view scenes and topographic profiles, as well as measurements of distances, perimeters, areas and volumes for the KP and the EACF areas. At KP predominate steep terrain slopes (35.6%), followed by very steep (22.3%), moderate (20%) and abrupt areas (12.8%). Its hillsides are mainly westward (21.3%) and eastward (15.3%) oriented.

Key words: Keller Peninsula, King George Island, terrain analysis, Geographical Information System.

INTRODUCTION

The Keller Peninsula (KP) is at the Admiralty Bay (AB), King George Island (KGI), South Shetlands (Figure 1, Mendes Jr. et al. 2012, this volume), and is composed by a sequence of volcanic-sedimentary rocks, from late Cretaceous to early Tertiary. This peninsula is debris covered by different glacial sedimentary features, such as terraces and moraines, talus cones and ridges (Francelino et al. 2004, Schaefer et al. 2004). The KP western part is glacier free, while there are four small cirque glaciers on the eastern and southeastern tips: Ferguson, Flagstaff, Noble and Babylon (Fig. 1).

Francelino et al. (2004) analyzed the KP landforms by interpreting Small Format Aerial Photographs (SFAF) at a scale of 1:5,000, and analysis of a Digital Terrain Model (DTM) generated by them. Topographic plan data of the Brazilian Comandante Ferraz Station – EACF (Fonseca Jr. et al. 2006) and topographic map data of the KP at scales of 1:20,000 (Figure 2, Mendes Jr. et al. 2012, this volume) and 1:5,000 (attached to this publication) can also be used to assist logistic, scientific and touristic local activities planning. This study derives

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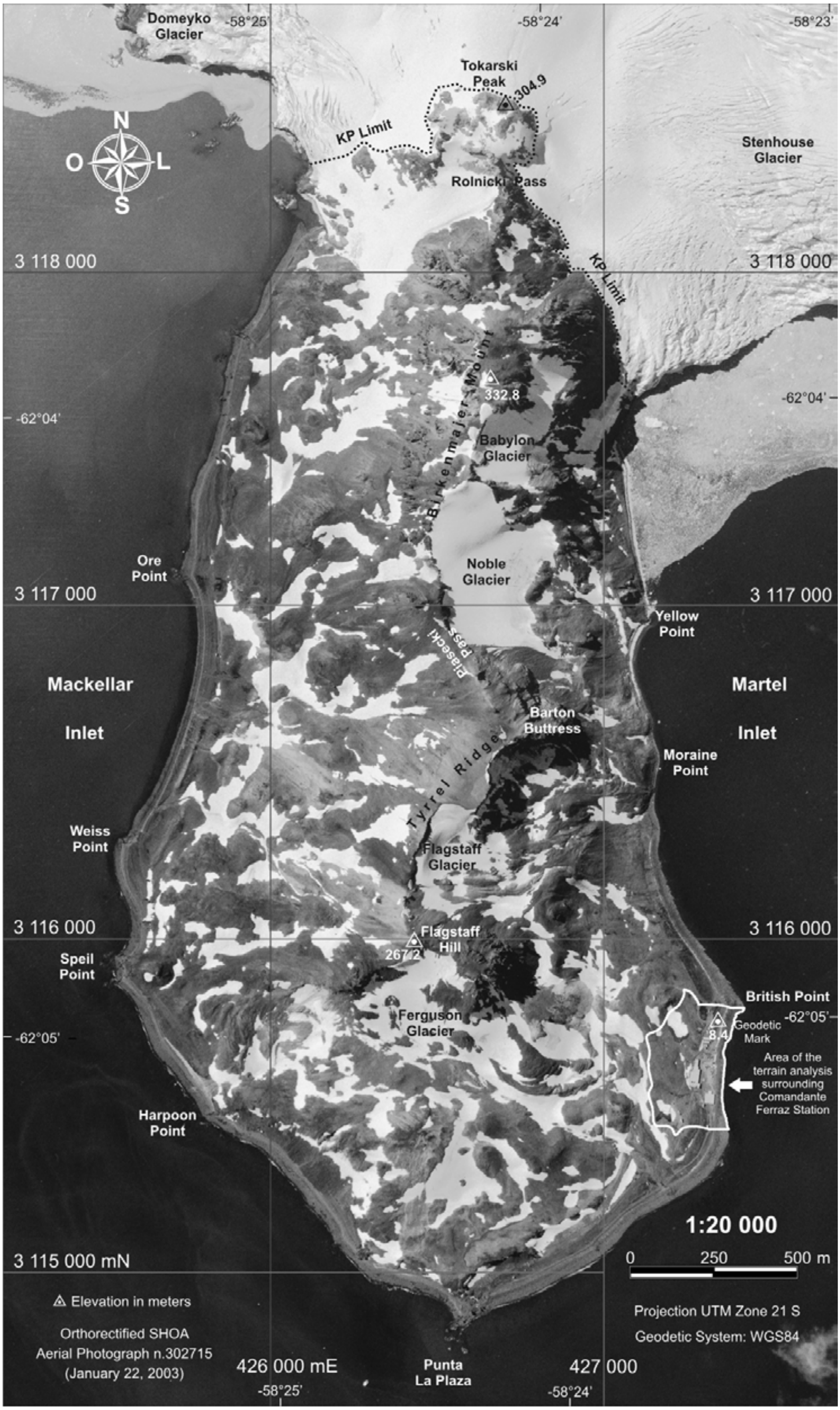

Fig. 1 – The Keller Peninsula orthophotomap.

thematic maps and quantitative data from KP topographic map by using a Geographical Information System (GIS) for terrain analysis.

METHODOLOGY

Altimetric points, the DTM and contour lines used in the production of a KP topographic map (Mendes Jr. et al. 2012, this volume) were stored in the ArcGIS^{TM} software (ESRI Inc.). For the area surrounding the EACF (Fig. 1) was generated a 0.2 m ground resolution DTM, by data interpolation using the so-called Triangular Irregular Network – TIN method (Burrough and McDonnell 1998), which is the same one used for producing the KP DTM (Mendes Jr. et al. 2012, this volume). An orthophotomap was produced and the DTMs stored in the GIS were used for generating thematic maps (i.e., hypsometric, slope and aspect), hillshade models, perspective views and topographic profiles, as well as measurements of distances, perimeters, areas and volumes. We used the Universal Transverse of Mercator (UTM), zone 21 south (21S) to chart all data, referring them to the World Geodetic System 1984 (WGS84) ellipsoid as recommended by the SCAR Standing Committee on Antarctic Geographic Information (SC-AGI 2009).

AREAS DELIMITED FOR TERRAIN ANALYSIS

The coastline of the new topographic map gave the KP area, while the area surrounding the EACF was delimited using the topographic plan, but the coastline is the one from the topographic map (Figure 3, Mendes Jr. et al. 2012, this volume; Figure 1, this paper). The KP and EACF polygons were used to extract data from their respective DTMs, to derive maps, and to quantify absolute and relative mapped areas classes.

ORTHOPHOTOMAP

The orthophotomap (Fig. 1) resulted from the orthorectification of an aerial photograph used to create the DTM from the topographic map. This photography was orthorectified in a Digital Photogrammetric Station (DPS) model LPS^{TM} (Leica Photogrammetry Suite – Leica Geosystems GIS and Mapping, LLC), resulting in a 0.63 m ground resolution image. Some altimetric points and toponyms of the KP topographic map are represented in the orthophotomap.

HYPSOMETRIC MAPS

By the reclassification of the DTM in 15 classes, at 25 m intervals, we produce a KP hypsometric map (Fig. 2). For the elaboration of the EACF hypsometric map (Fig. 5b), the DTM was reclassified in 12 classes, at 2.5 m intervals, a multiple value to the contour lines interval used in the KP topographic map at a scale of 1:5,000.

SLOPE AND ASPECT MAPS

The KP and EACF slope maps (Figs. 3 and 5c, respectively) were elaborated with 6 thematic classes, defined with the same percentage used in the study of Francelino et al. (2004), allowing comparisons with these studies. In the KP and EACF aspect maps (Figs. 4 and 5d, respectively), classes were defined by azimuthal angles values calculated in the ArcGIS^{TM}.

HILLSHADE MODELS, PERSPECTIVE VIEW SCENES AND TOPOGRAPHIC PROFILES

The KP and EACF DTMs were used to generate hillshade models, like those represented in Figures 6a and 7a, illuminated with solar azimuthal angle of 315° and zenithal angle of 45°. The KP DTM and the orthophoto resulting from this study were also used to generate a southward perspective view scene (Fig. 6b). Other perspective model, from the same viewpoint was elaborated for the EACF area (Fig. 7b), by using the EACF DTM and an orthorectified SFAF from a previous study by Mendes Jr. et al. (2007). Buildings mapped on the topographic plan, with its respective elevations, were superposed to the EACF DTM to produce a Digital Elevation Model (DEM), to elaborate the perspective EACF view scene. In respect to the topographic profiles

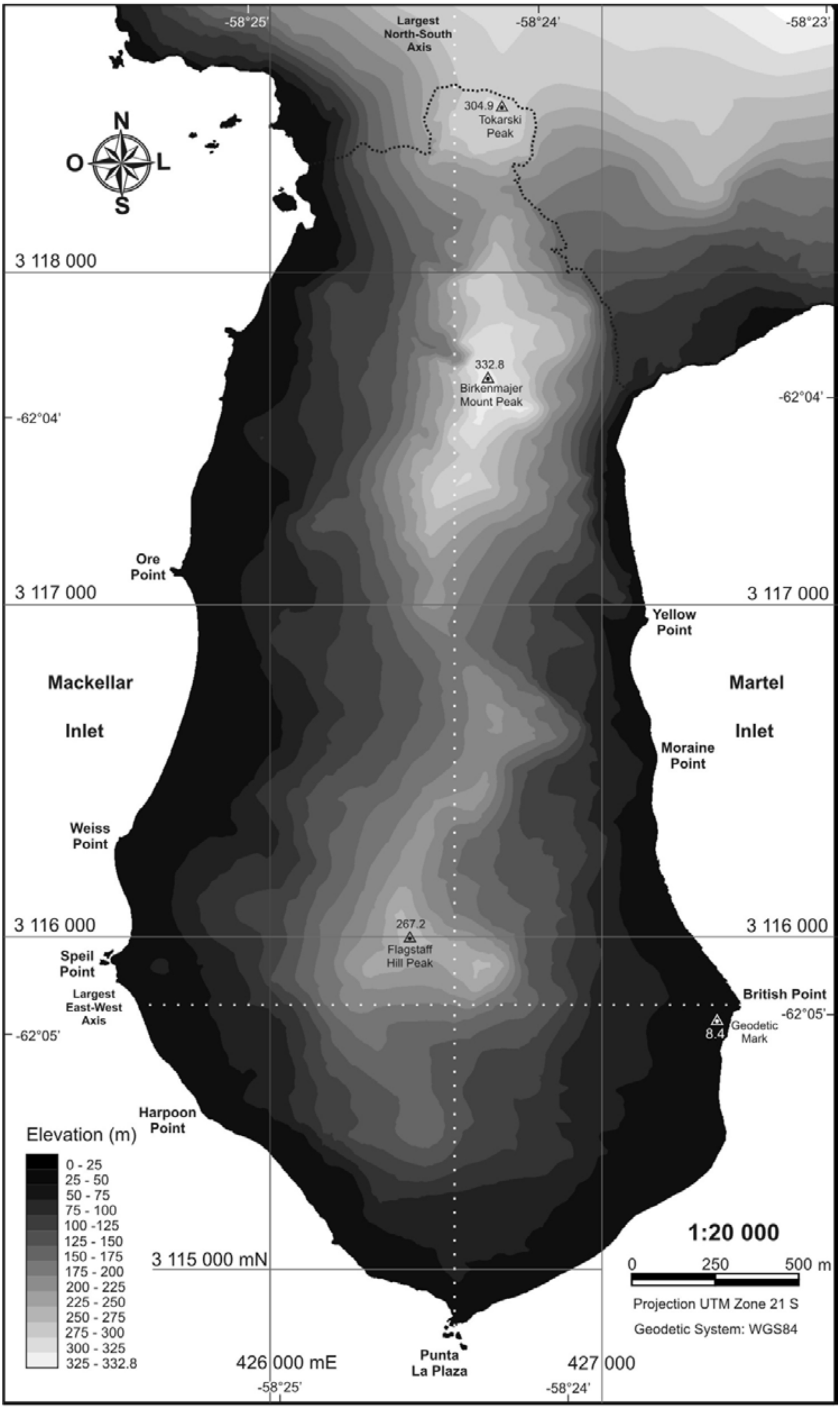

Fig. 2 – Hypsometric map derived from the Keller Peninsula DTM.

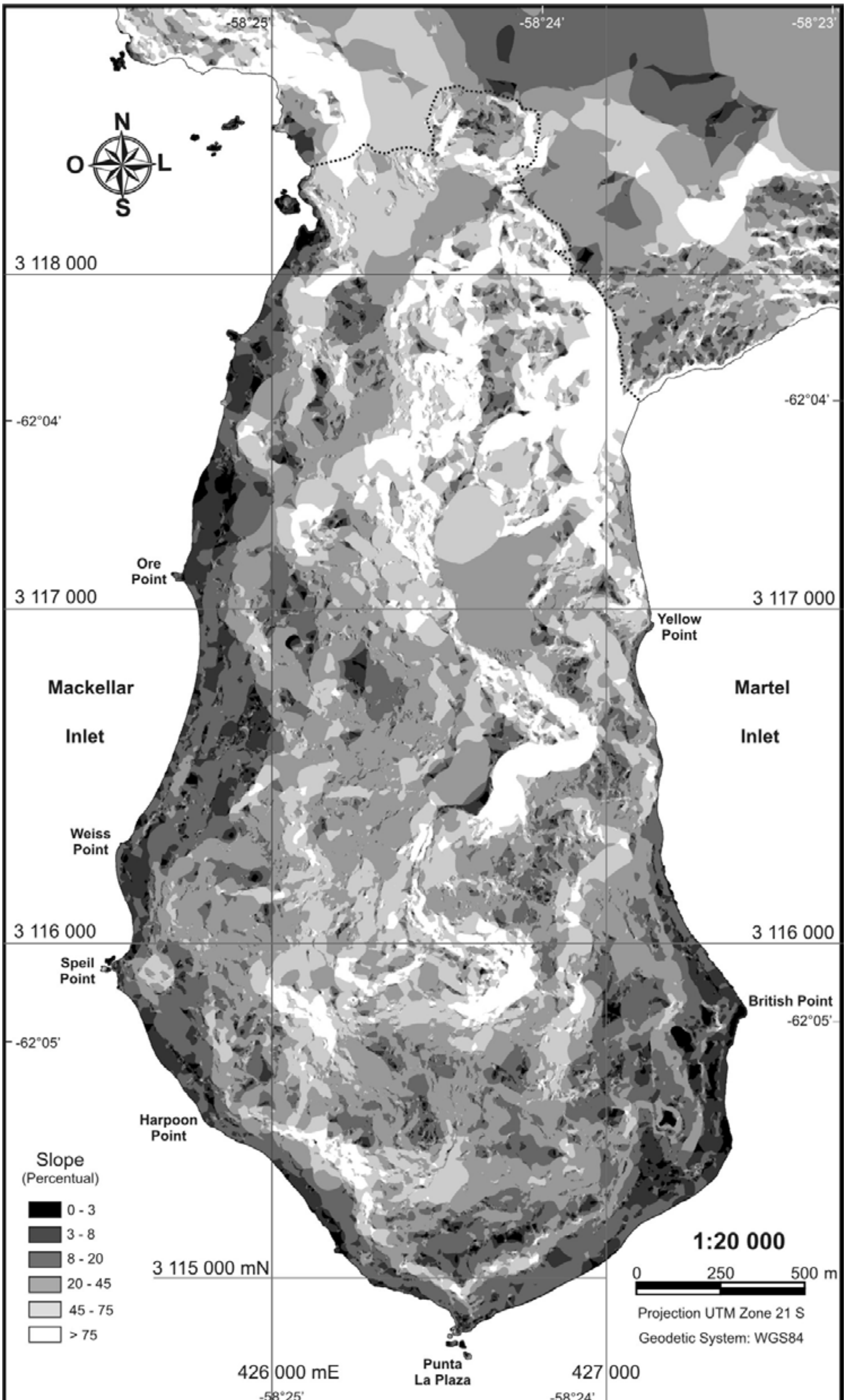

Fig. 3 – Slope map derived from the Keller Peninsula DTM.

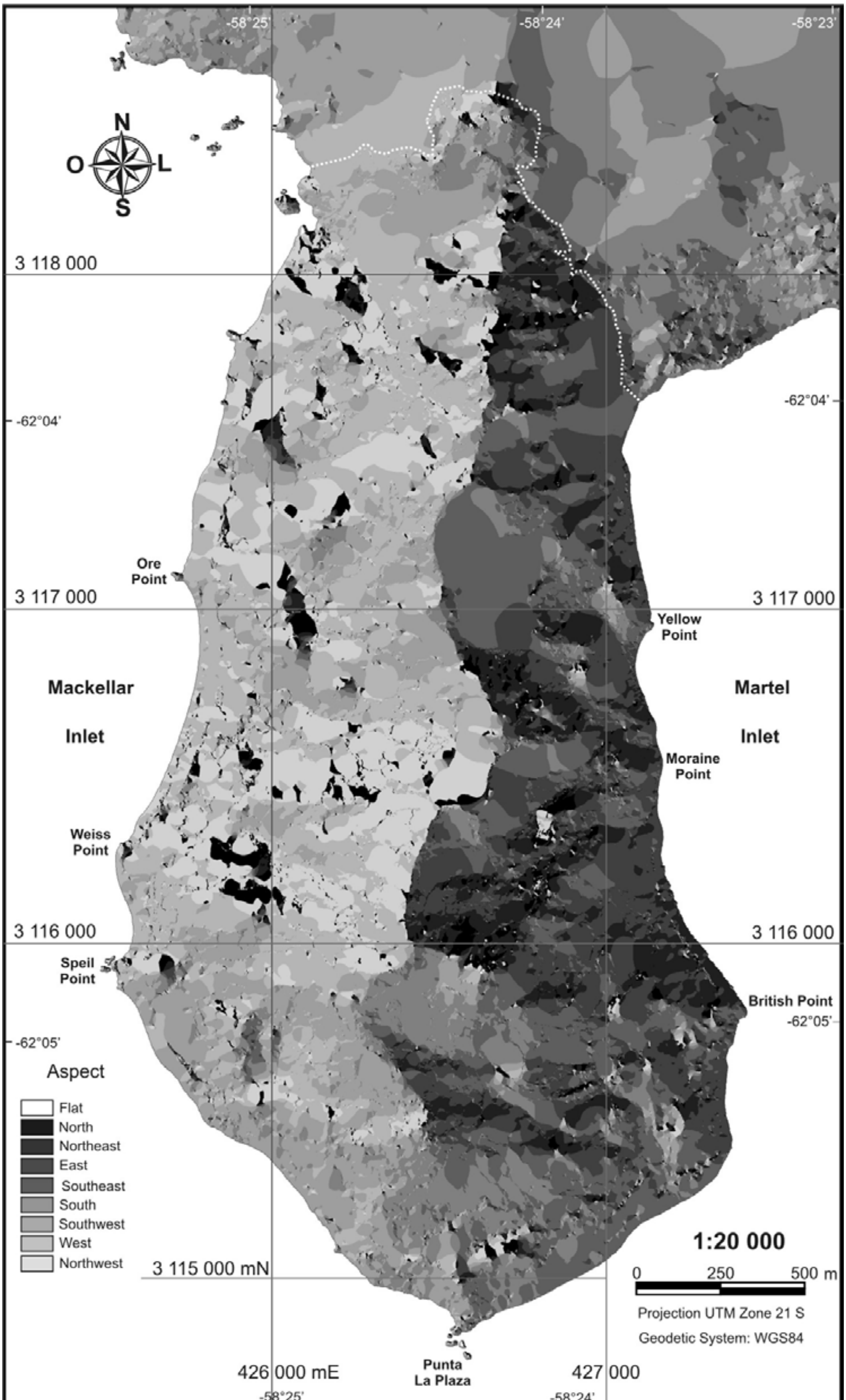

Fig. 4 – Aspect map derived from the Keller Peninsula DTM.

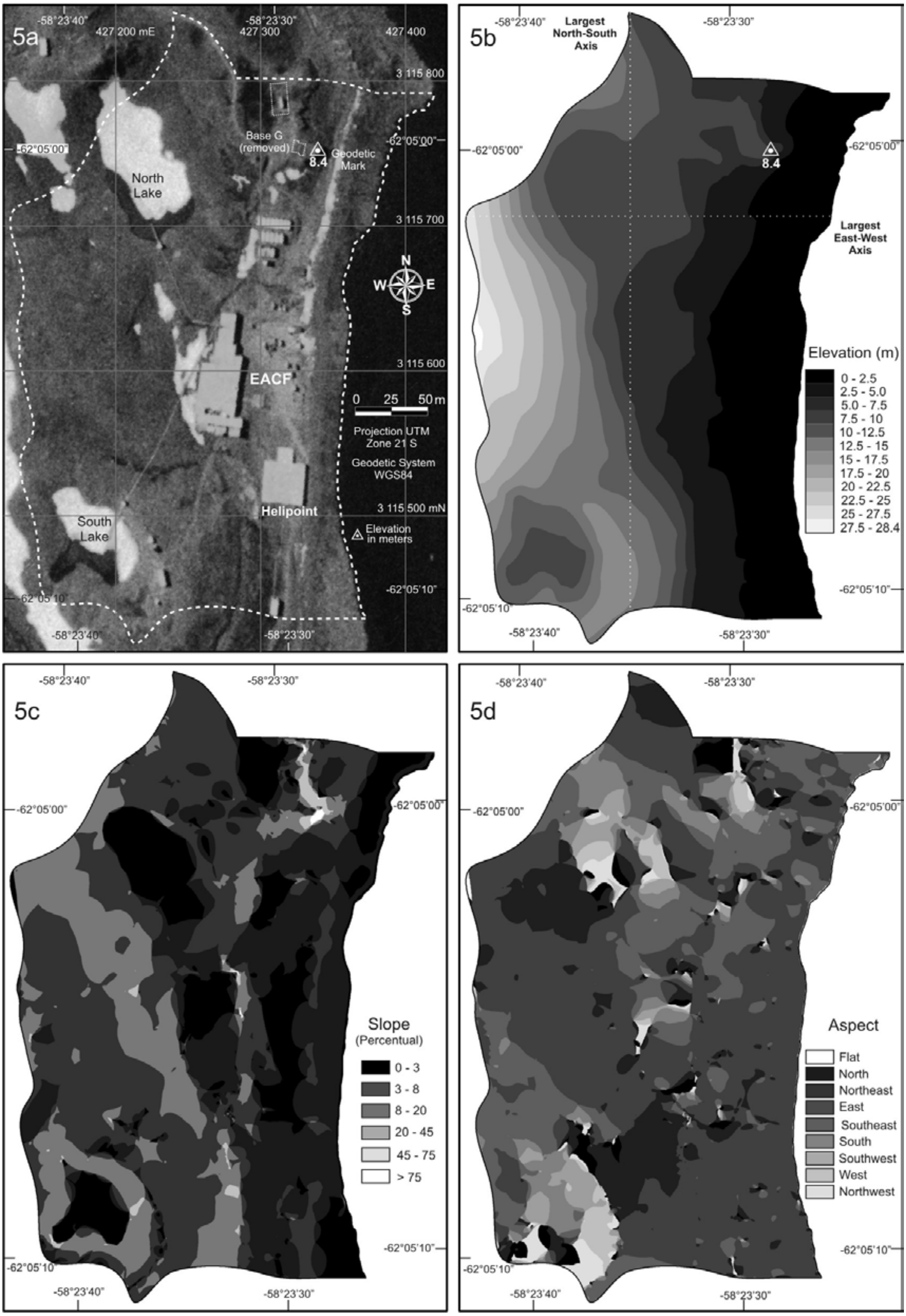

Fig. 5 – The EACF orthophotomap and hypsometric, slope and aspect maps derived from an EACF DTM.

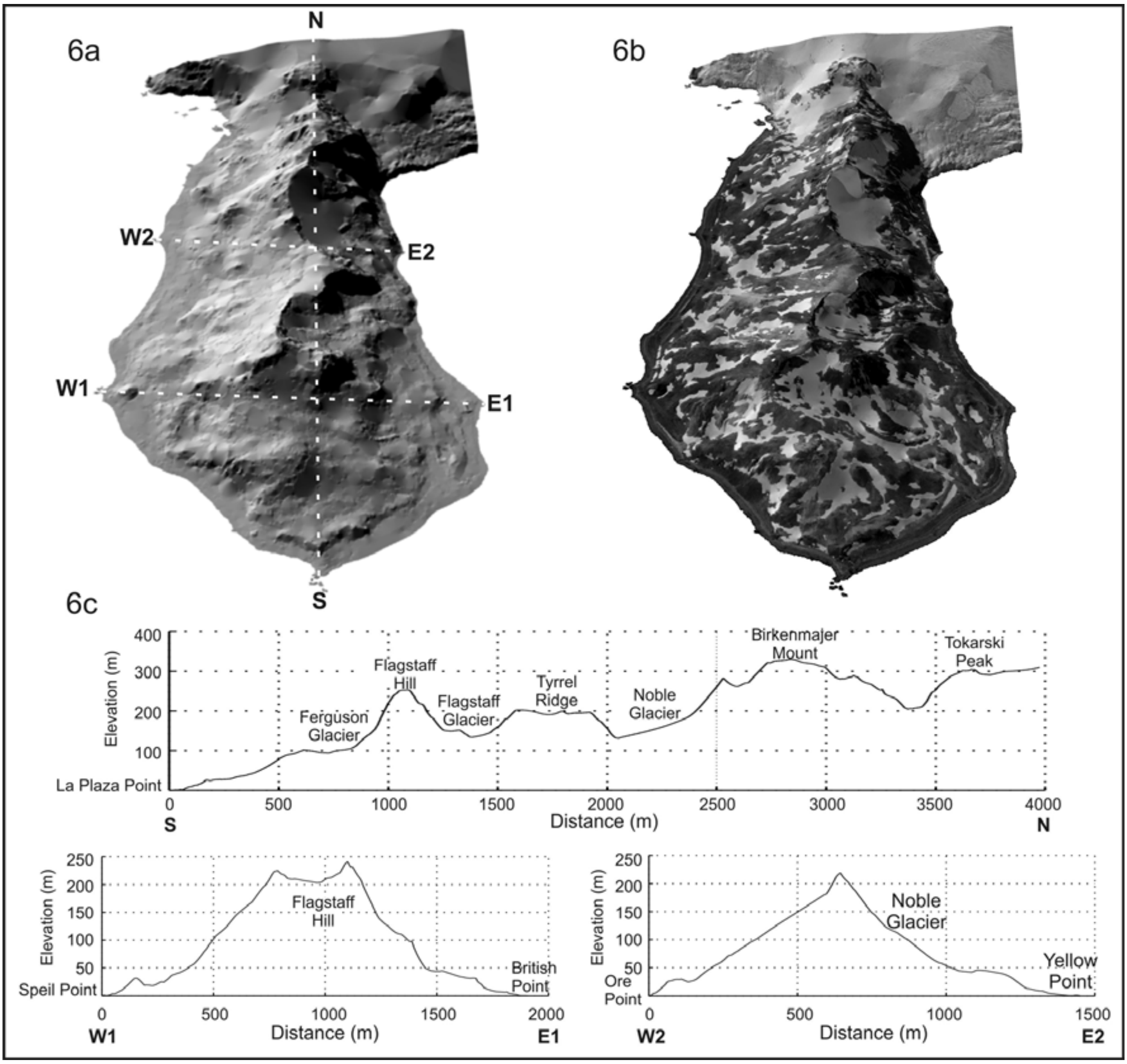

Fig. 6 – Hillshade model and topographic profiles derived from the KP DTM and a perspective view generated with the DTM and the KP orthophoto.

produced in this study (Figs. 6c and 7c), these are cross-sections traced in north-south and east-west direction on the KP and EACF DTMs.

QUANTIFICATION AND DATA INTERPRETATION

Distances, perimeters, areas and volumes for the KP and EACF (Table I) were derived from DTMs. Absolute and relative areas of each class of the hypsometric (Table II), slope (Tables III and IV) and aspect maps (Table V) produced in this study were quantified in the ArcGIS^{TM} software. Results from Table IV were compared with data from Francelino et al. (2004).

The KP has approximately 451.5 ha, the largest north-south axis distance is 3,728 m and the largest east-west one is 1,818 m (Table I). If the Domeyko and Stenhouse glaciers area in the orthophoto (Fig. 1) are also considered in the data quantification, KP has about 578 ha (Table IV), and the largest north-south axis distance is 3,972 m (Table I), agreeing with information from the study by Francelino et al. (2004), who calculated an area of 580 ha for KP and north-south and east-west axis of 3,900 m and 1,840 m, respectively.

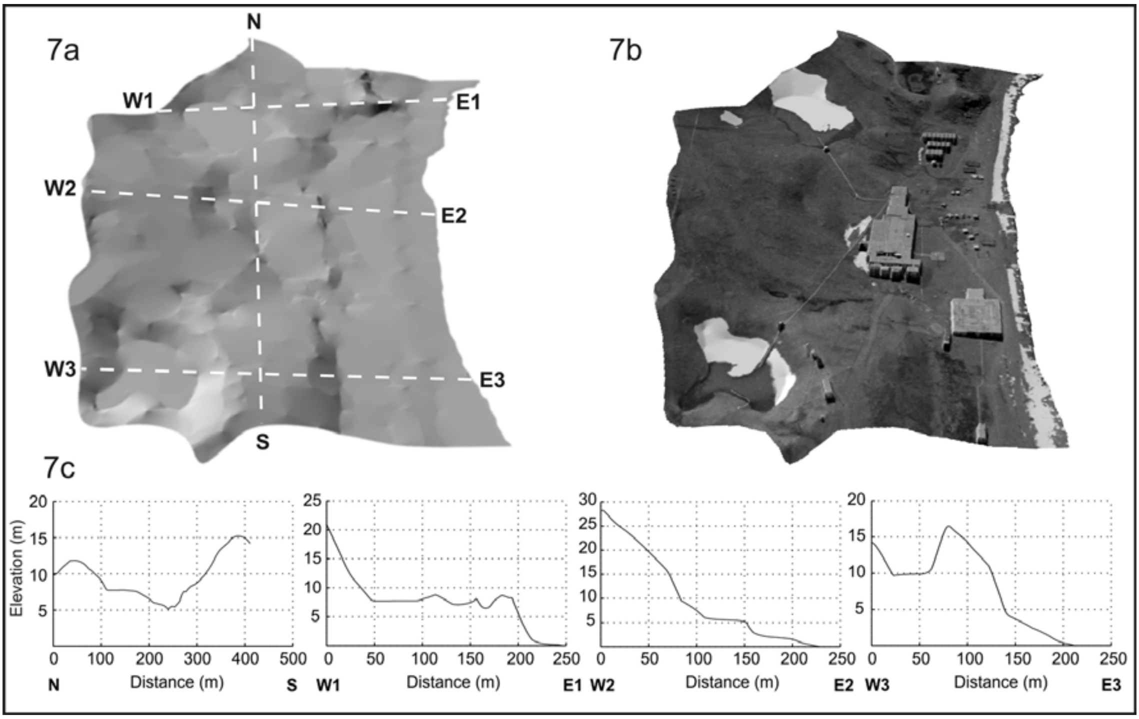

Fig. 7 – Hillshade model and topographic profiles derived from the EACF DTM and a perspective view generated with the DTM and the SFAF from the study of Mendes Jr. et al. (2007).

TABLE I

Distances, perimeters, areas and volumes derived from the DTM for the KP and EACF.

Keller Peninsula		
Perimeter = 10,971.836 m	Area = 451.487 ha	Volume = 433,834,975.840 m^3
Distances (m)		
Description	Horizontal	Surface
Largest KP north-south axis (Fig. 2)	3,972.016	4,295.908
KP limits north-south axis (Fig. 2)	3,728.254	4,049.578
Largest KP east-west axis (Fig. 2)	1,818.050	1,902.022
From Speil Point to British Point	1,905.526	2,034.204
From Weiss Point to British Point	1,942.851	2,060.956
From Ore point to Yellow Point	1,450.457	1,545.152
From Ore point to Moraine Point	1,573.291	1,664.210
EACF		
Perimeter = 1,304.595 m	Area = 8.225 ha	Volume = 705,783.630 m^3
Distances (m)		
Description	Horizontal	Surface
Largest north-south axis (Fig. 5b)	413.523	414.319
Largest east-west axis (Fig. 5b)	251.517	254.925

TABLE II

Statistics, absolute and relative areas of the hypsometric classes for the KP and EACF.

Keller Peninsula			EACF		
Elevation (m)	Area (ha)	Area (%)	Elevation (m)	Area (ha)	Area (%)
0–25	108.286	23.985	0–2.5	1.881	22.869
25–50	64.474	14.280	2.5–5.0	1.011	12.292
50–75	44.233	9.797	5.0–7.5	0.865	10.517
75–100	44.495	9.855	7.5–10	1.513	18.395
100–125	41.296	9.147	10–12.5	0.851	10.347
125–150	35.403	7.841	12.5–15	0.705	8.571
150–175	29.974	6.639	15–17.5	0.485	5.897
175–200	26.282	5.821	17.5–20	0.279	3.392
200–225	19.502	4.320	20–22.5	0.303	3.684
225–250	13.852	3.068	22.5–25	0.215	2.614
250–275	9.737	2.157	25–27.5	0.103	1.252
275–300	8.865	1.963	27.5–30	0.014	0.170
300–325	4.175	0.925			
325–350	0.913	0.202			
Statistics (m)			Statistics (m)		
Min. and Max.	Mean	Std Deviation	Min. and Max.	Mean	Std Deviation
0–332.786	96.456	80.349	0–28.376	8.598	6.544

TABLE III

Statistics, absolute and relative areas of the slope map classes for the KP and EACF.

Slope		Keller Peninsula		EACF	
Type	%	Area (ha)	Area (%)	Area (ha)	Area (%)
Flat	0–3	7.693	1.704	1.372	16.681
Gentle	3–8	33.954	7.520	2.124	25.824
Moderate	8–20	90.531	20.052	3.085	37.508
Steep	20–45	160.860	35.630	1.571	19.100
Very Steep	45–75	100.471	22.253	0.066	0.802
Abrupt	> 75	57.978	12.841	0.007	0.085
Statistics (%)					
Keller Peninsula			EACF		
Min. and Max.	Mean	Std Deviation	Min. and Max.	Mean	Std Deviation
0–1,038.297	40.668	34.313	0–327.490	12.845	10.659

Based on the DTM of this study, the mean KP elevation is 96.5 m and the maximum one is 332.8 m (Table II). The highest mounts are at the northern part of the peninsula: Birkenmajer, 332.8 m, and Tokarski, 304.9 m (Figs. 1, 2 and 6c). About 38.3% of the KP is below 50 m, while the EACF area has a mean elevation of 8.6 m and maximum one of 28.4 m, predominating areas below 10 m of elevation (Figure 5b e Table II).

In the KP slope map the terrain is classified

TABLE IV

Absolute and relative areas of the slope map classes for the KP and Domeyko and Stenhouse glaciers calculated in this study and presented in the study by Francelino et al. (2004).

Slope		Keller Peninsula and Domeyko and Stenhouse glaciers		
Type	%	Area (ha)	Area (%)	
			This work	Francelino et al. 2004
Flat	0–3	8.511	1.472	6.8
Gentle	3–8	37.884	6.554	15.0
Moderate	8 - 20	120.180	20.790	50.1
Steep	20–45	211.392	36.569	23.4
Very Steep	45–75	126.675	21.913	4.6
Abrupt	> 75	73.429	12.702	
Total		578.071	100	100

TABLE V

Statistics, absolute and relative areas of the aspect map classes for the KP and EACF.

Aspect		Keller Peninsula		EACF	
Type	Azimutal angle	Area (ha)	Area (%)	Area (ha)	Area (%)
Flat	—	0.053	0.012	0.025	0.304
North	337.5–22.5	17.790	3.940	0.216	2.626
Northeast	22.5–67.5	38.078	8.434	1.057	12.851
East	67.5–112.5	69.073	15.299	4.126	50.165
Southeast	112.5–157.5	64.250	14.231	1.673	20.340
South	157.5–202.5	39.518	8.753	0.481	5.848
Southwest	202.5–247.5	64.893	14.373	0.278	3.380
West	247.5–292.5	96.369	21.345	0.202	2.456
Northwest	292.5–337.5	61.463	13.613	0.167	2.030

predominantly as steep (35.6% of the total area), followed by very steep (22.3%), moderate (20%) and abrupt areas (12.8%). The mean KP slope is 40.7%, with a standard deviation of 34.3% (Table III). Unlike the study of Francelino et al. (2004), where the KP terrain slope was classified predominantly as moderate, with very steep and abrupt classes representing less than 5% of the total area, in our KP slope map (including Domeyko and Stenhouse glaciers area) the terrain is classified predominantly as steep (36.6% of the total area), followed by very steep (21.9%), moderate (20.8%) and abrupt areas (12.7%) (Table IV). The KP areas of greatest slope (very steep and abrupt areas) are on the Flagstaff Hill, mounts Birkenmajer and Tokarski, on the Tyrrel Ridge hillsides and at the top of cirque glaciers (Figs. 1 and 3). In the EACF surrounding area, the terrain slope is predominantly moderate (37.5%) and gentle (25.8%), steep (19.1%) and flat (16.7%) areas. Near to the coastline, around the EACF, there are gentle, moderate and flat areas. Very steep and abrupt areas are less than 1% of the total EACF area (Table III), occurring only on the hillside near to the British Base G ruins and on slopes adjacent to the EACF building (Figs. 5a and 5c).

KP hillsides are predominantly westward (21.3%) and eastward (15.3%) oriented; few hillsides are northward (3.9%) and northeastward (8.4%) oriented. In the EACF area predominates eastward (50.2%) and southeastward (20.3%) hillsides, according to the aspect maps (Figs. 4 and 5d, Table V).

OUTLOOK

The topographic map, thematic maps and quantitative data from the terrain analysis carried out in this study can be useful for multidisciplinary research projects. All these data can be integrated to the Antarctic Digital Database (ADD – SCAR 2000), the King George Island GIS Project – KGIS (Vogt et al. 2004) and to the Admiralty Bay GIS (Arigony-Neto et al. 2004). Furthermore, the resulting datasets can be used with other georeferenced data for the generation of new thematic maps and in morphometric analyses.

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RESUMO

Este estudo consiste na análise morfométrica da Península Keller (PK), ilha Rei George, Antártica, através de um Sistema de Informação Geográfica (SIG). Uma fotografia aérea métrica vertical e um Modelo Digital do Terreno (MDT) foram processados em uma estação fotogramétrica digital para gerar uma ortofoto, utilizada na elaboração de uma ortofotocarta para a PK. Os pontos cotados na área de entorno da Estação Comandante Ferraz (EACF) foram utilizados para a geração de um MDT local mais detalhado. A partir desses MDTs, geramos mapas hipsométricos, de declividade e aspecto, modelos de sombreamento analítico, vistas perspectivas e perfis topográficos, além de medidas de distâncias, perímetros, áreas e volumes da PK e EACF. Na PK predomina um terreno com declividade forte ondulada (35,6%), seguida pelas classes montanhosa (22,3%), ondulada (20%) e escarpada (12,8%). As vertentes da PK são principalmente orientadas para oeste (21,3%) e leste (15,3%).

Palavras-chave: Península Keller, ilha Rei George, análise morfométrica, Sistema de Informação Geográfica.

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