PKS PUBLIC KNOWLEDGE PROJECT

REVISTA DE GEOGRAFIA (UFPE)
www.ufpe.br/revistageografia

OJS OPEN JOURNAL SYSTEMS

THE LANDFORMS AND PATTERN OF DEGLACIATION OF THE DRAGON GLACIER, KING GEORGE ISLAND, SOUTH SHETLANDS, ANTARCTICA

Kátia Kellem da Rosa[1], Enoil de Souza Junior[1], Rosemary Vieira[1,2] & Jefferson Cardia Simões[1]

1 - Centro Polar e Climático – INCT da Criosfera. Universidade Federal do Rio Grande do Sul, Avenida Bento Gonçalves, 9500, 90450-090 - Porto Alegre - RS, Brasil. Email: katiakellem@gmail.com

2 - Laboratório de Processos Sedimentares e Ambientais (LAPSA) - Universidade Federal Fluminense

Artigo recebido em 28/02/2012 e aceito em 21/01/2013

ABSTRACT
This paper presents results of the application of techniques of landforms mapping for the reconstruction of the evolution of the environments of deglaciation on the Dragon glacier, Martel Inlet, King George Island, South Shetlands. The reconstruction of the changes on the glacier extension was created through moraine positions mapping and historical satellital images. The geomorphological mapping generated contributes to identify processes that influence the formation of glacial geomorphology in relation to glacial dynamics and paraglacial modifications as aeolian action and debris flow. Furthermore the geomorphological mapping serves as a support to monitor environmental changes against the retreat processes as effects of climate variability verified in the area of study. This study presents geomorphological application of the glacier reconstruction modeling method. This approach can be used to validate geomorphological interpretations of marginal deglaciation.
Keywords: glacier reconstruction, geomorphic mapping, remote sensing.

GEOFORMAS E PADRÃO DE DEGLACIAÇÃO DA GELEIRA DRAGON, ILHA REI GEORGE, SHETLANDS DO SUL, ANTARTICA

RESUMO
Este trabalho apresenta resultados da aplicação de técnicas de mapeamento de geoformas para a reconstrução da evolução dos ambientes de deglaciação da geleira Dragão, enseada Martel, ilha Rei George, Shetlands do Sul. A reconstrução das mudanças na cobertura glacial da geleira Dragão foi realizada por meio do reconhecimento das posições morainicas e utilização de imagens de satélites de diferentes anos. O mapeamento geomorfológico possibilitou análises dos processos atuantes na área de estudo, tais como processos erosivos e fluxo de encosta causando retrabalhamento dos depósitos. Diante dos processos de retração glacial constatados na área de estudo, como efeito da variabilidade climática destes ambientes, o mapeamento geomorfológico serve como subsídio para monitoramento de mudanças ambientais. Este estudo demonstra a aplicação da geomorfologia glacial na geração de um modelo de reconstrução glacial. O mapeamento elaborado pode ser usado para validar interpretações geomorfológicas relacionadas a deglaciação.
Palavras-chaves: reconstrução glacial, mapeamento geomorfológico, sensoriamento remote.

INTRODUCTION

Analyzing the spatial distribution of glacial landforms, as moraines, constitute the main record for glacial reconstruction of the extension, thickness, thermal basal conditions, ice direction and velocity flow and revealing pattern of glacier retreat process (BENN & BALLANTYNE, 1994; BENNETT & GLASSER, 1996; CLARK, 1997; BOULTON ET AL., 2001; GLASSER & HAMBREY, 2001; EVANS & TWIGG, 2002; ADAM & KNIGHT, 2003; ETIENNE ET AL., 2003; KLEMAN ET AL., 2006; BENN & EVANS, 2010).

This paper proposes the geomorphological mapping of glacial ice-free areas of the glacier Dragon, located on King George Island, South Shetlands, and aims to infer the extent and position reached by the glacier in its various stages of retreat, and thus contribute to understand the evolution of its deglaciation.

Several studies have provided evidence of glacial retreats in the Martel inlet since 1956 (SIMÕES & BREMER, 1995; BREMER, 1998; PARK ET AL., 1998; SIMÕES ET AL., 1999; BRAUN & GOSSMANN, 2002). The role of glacier reconstruction as a source of palaeoclimatic information has long been recognized through the analysis of empirical relationships between glaciers and climate (SISSONS & SUTHERLAND, 1976; SUTHERLAND, 1984; OHMURA ET AL., 1992; PATERSON, 1994). The retreat processes of those glaciers are related to the present atmospheric warming recorded over the most recent years (Blindow et al., 2010). According to Blindow et al. (2010) the annual mean temperature on the island rising by 1°C during the past three decades. Over the past 30 years, the number of days with liquid precipitation has increased in the summer. These processes accelerated the snowmelt and increased the negative mass balance of local glaciers (BRAUN ET AL., 2001; FERRANDO ET AL., 2009). Thus, this analyze is interest for monitoring glaciers and their adjacent proglacial areas because these regions are sensitive to climatic conditions and may be greatly impacted by recent patterns of accelerated climate change.

STUDY AREA

The Dragon glacier, located in King George Island, South Shetlands archipelago between 61 54’- 62 16’S and 57 35’- 59 02’W, off the Antarctic Peninsula northwestern sector (Figure 1 and 2), is characterized by its proglacial front.

Several studies have provided evidence for a general glacial retreat in the Martel Inlet since 1950 (SIMÕES & BREMER 1995, PARK et al. 1998, BREMER 1998, SIMÕES et al.

1999, AQUINO 1999, BRAUN & GOSSMANN 2002, VIEIRA et al. 2005, ROSA et al. 2009). The retreat processes of those glaciers can be related to the present regional atmospheric warming recorded (Blindow et al. 2010). For the past 30 years, the number of days with liquid precipitation has increased in the summer.

There is exposure of several landforms and proglacial deposits as a consequence of the glacier retreat. These processes were evidenced by Arigony Neto (2001), who signaled a substantial glacier area loss between 1988 and 2000. The substrate of the South Shetlands islands' are largely volcanic in origin (CURL, 1980).

Studies on these environments are widely recognized for their importance in monitoring environmental changes related to the climate variability registered in the area of study.

METHODS

The analysis of the geomorphological transformations and the geographical distribution of moraines was carried out through an interpretation of the QUICKBIRD image obtained in 2006. This imagery has a spatial resolution of 0.61 meters in panchromatic mode which allows both moraines ridges to be mapped accurately. Enhanced techniques were applied to improve the visual interpretation. In this study, we have used Quickibird and SPOT satellite images obtained in 1988, 1995 and 2000 with a spatial resolution of 10 meters in panchromatic mode and 20 meters in multispectral mode. This data was accompanied by fieldwork in the Dragon glacier proglacial area during the summers of 2007 and 2011.

The geomorphological mapping allowed the reconstruction of historical information on the dynamics and evolution of the Dragon glacier. To reconstruct the pattern and style of deglaciation, we have focused specifically on mapping the distribution of the moraines.

RESULTS

The mapping is an effective form of geomorphological analysis generated by the recent glacial activity phase. The features mapped include glacial moraines, meltwater channels and paraglacial landforms as debris flow (Figure 3). This glacier transports sediments towards Admiralty bay through channels.

Moraine systems identified in the mapping have their origin associated with retreat pauses of the Dragon glacier and thus reflect the shape of the side and front margins of the glacier.

With the generated mapping and the recognition of the positions of lateral and frontal moraines of recession, we inferred the extent and position reached by the glacier in its various stages of retreat, contributing to understand the evolution of the deglaciation of the glacier (Figure 3). Results show the degree of shrinkage of the glacier over the last decades (Table 1).

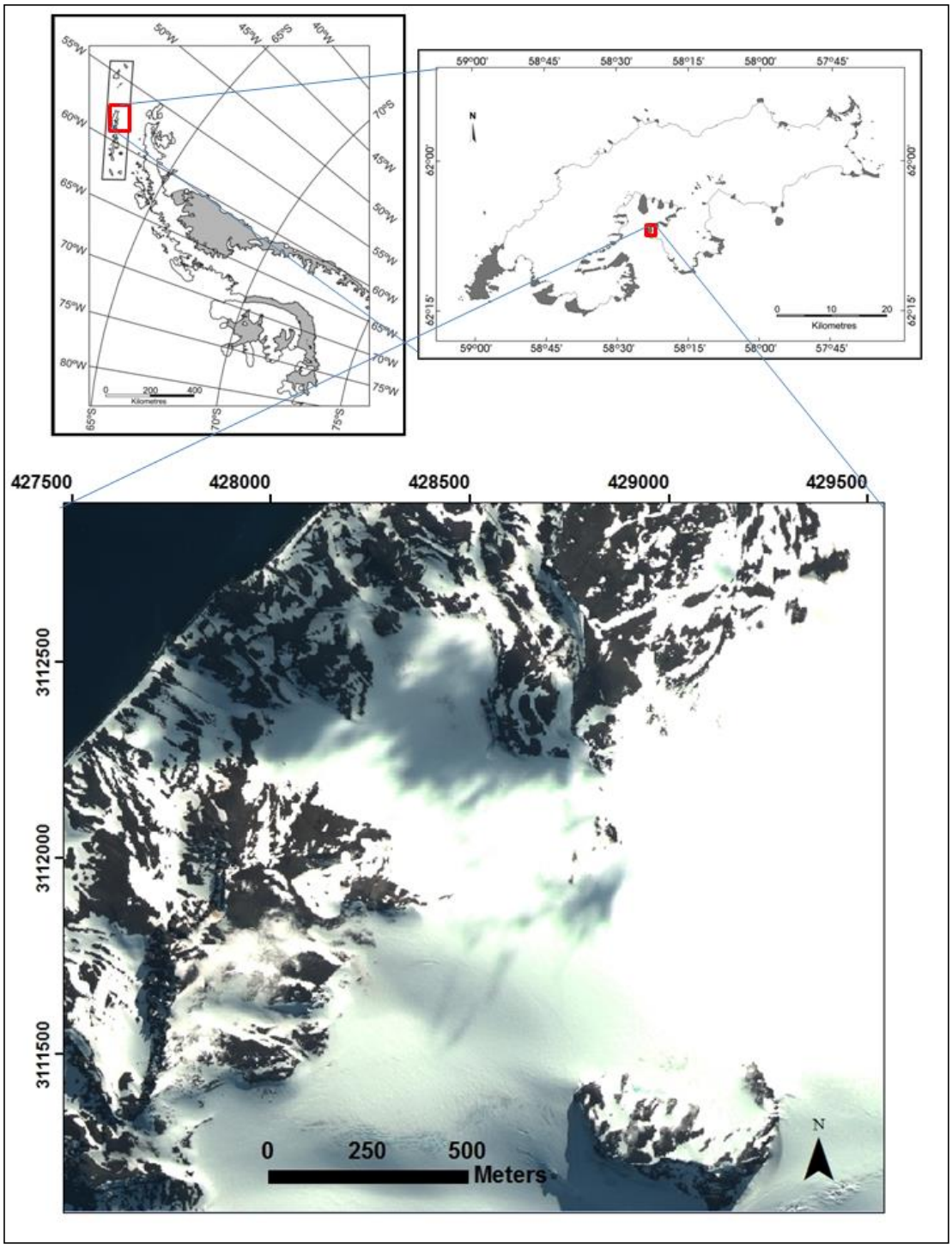

Figure 1 – Satellite image of the Dragon glacier and located map of the glacier in King George Island, South Shetlands, Antarctica.

Figure 2 – Dragon glacier.

Table 1 – Glacier Dragon total area and retreat rate since 1979 obtained for historical satellite images.

Area in 2006 (km²)	**Lost ice area (km²)**			
	2006 - 2000	2000 - 1995	1995 - 1988	1988 - 1979
0.43	0.06	0.06	0.08	0.28

DISCUSSION

The mapping allowed investigations on the deglaciation processes and landscape evolution of ice-free areas as a result of the shrinkage processes of the glacier.

The data indicate that Dragon glacier comprising 0.43 km² (based in a Quickbird image obtained in 2006) has a thin glacier front. The Dragon glacier has presented a significant loss of ice area (0.48 km²), without advances in recent decades. The largest loss ice area recorded was between 1979 and 1988.

Moraines of exposed proglacial area of Dragon glacier are linked to events of stabilization of retreats. By reconstructing the evolution of the glacier, the Dragon glacier became proglacial terminus at the end of the '70s. Landform records indicate probable low tide phases before the '80s. The pattern of ice flow appears to be influenced by local topography. The steep topographic gradient may have influenced the accelerated ice flow towards the inlet Martel during its tide phase. Thus, with the likely negative balance, the glacier retreat has accelerated together with loss of ice thickness at the front of the glacier. Currently, the glacier

is suspended in a circus-shaped valley with accelerated supraglacial ablation processes. The lack of recent deposition of till on the front shows that the ice flow is now apparently stagnated.

The glacier retreat processes have exposed a landscape susceptible to rapid post-depositional change. Free-ice areas recently exposed, mainly moraine deposits, are reworked by aeolian processes and flows of meltwater from seasonal snow. Ridges in shoreline which indicate the presence of moraines of recession on the front of the glacier are often discontinuous due to paraglacial reworking. River erosion and wave action characterize the area of study. Debris flow in accumulation of moraine deposition in steep slopes was observed in proglacial area (Figure 4 and 5) and these reworking processes difficulties of reconstruction due to the lack of correlation between moraine features.

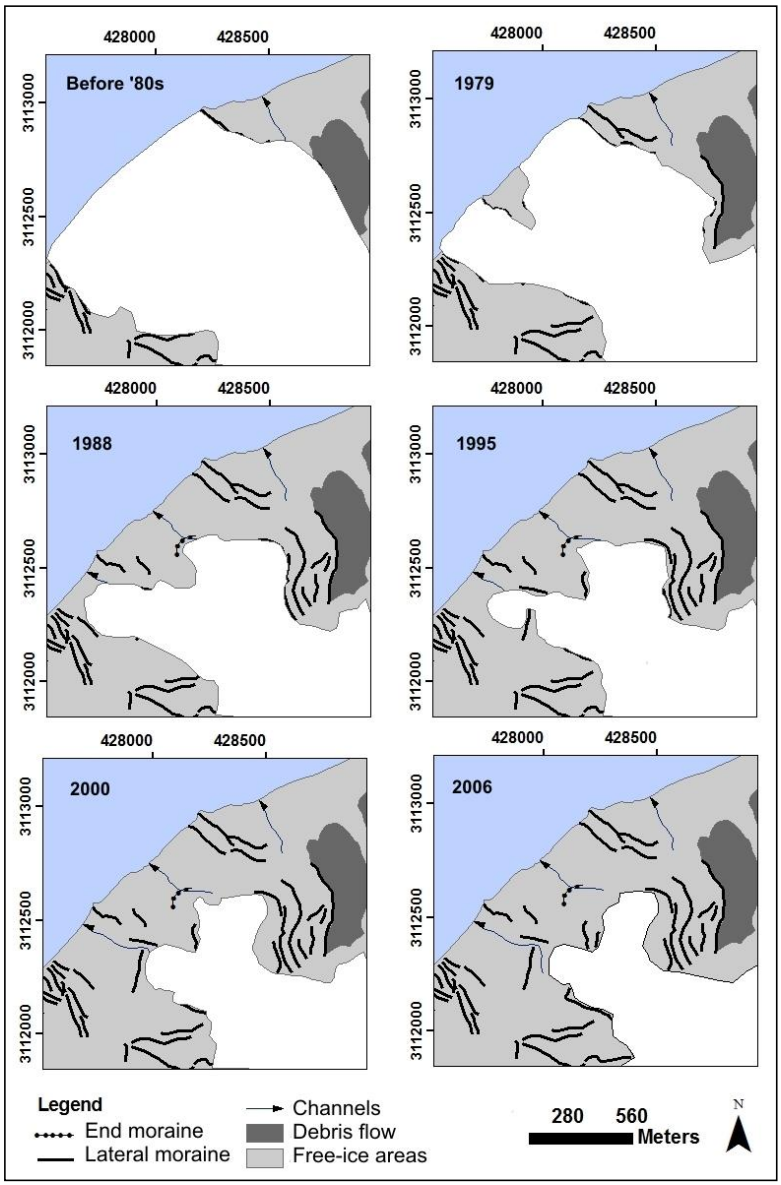

Figure 3 – Geomorphic mapping and reconstruction of the former the Dragon glacier during a pauses in the retreat of the Dragon glacier.

Figure 4 – Debris flow in steep slopes is observed in proglacial area.

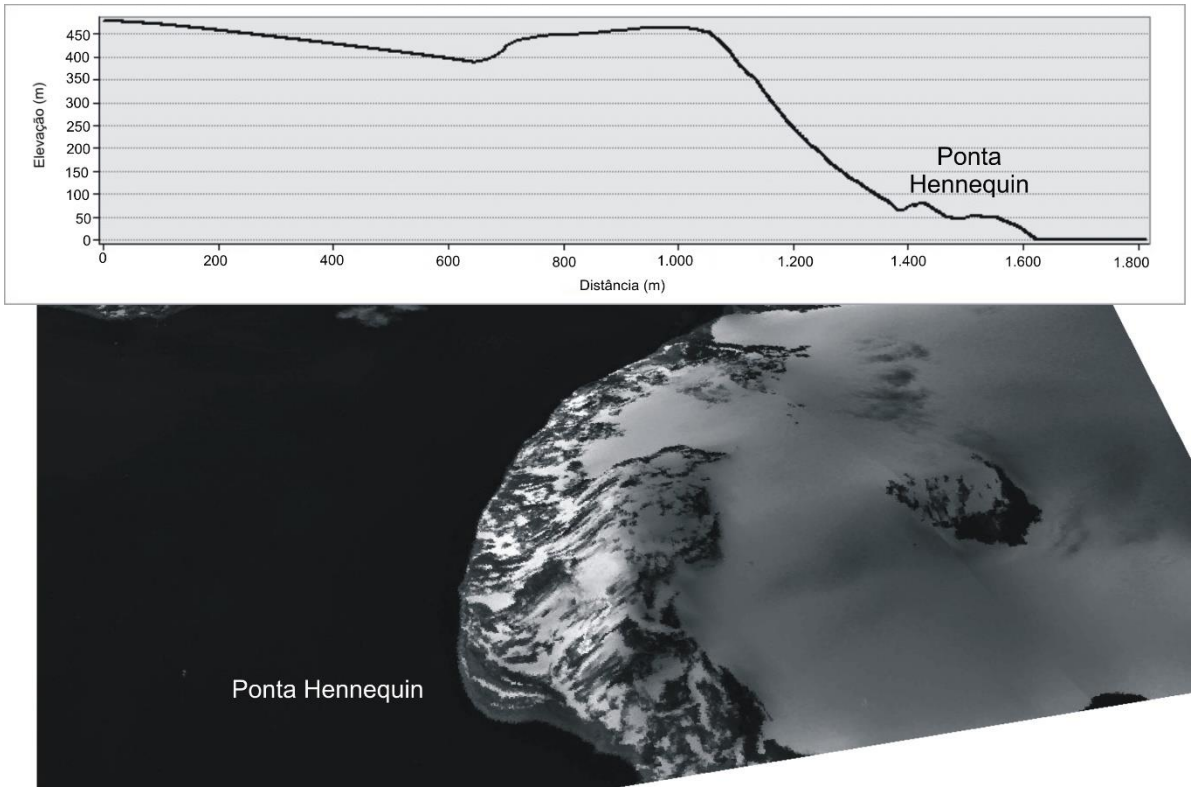

Figure 5 – Slopes is observed in proglacial area.

The previous work discussed above has shown the potential use of high spatial resolution satellite image for geomorphological mapping. The geomorphological mapping made possible for the reconstruction of the past of the area of study.

Techniques of visual interpretation of satellite imagery and geomorphological and field knowledge were critical to the development of the mapping.

CONCLUSION

This study presents a geomorphological application of glacier reconstruction modeling. This approach can be used to validate geomorphological interpretations of marginal glaciation, this provides key glacier dynamic information to examine different geomorphological signatures of former glaciation.

The spatial distribution of the landforms, such as side and front moraines, has contributed for ice-marginal glacial reconstruction. The geomorphological mapping provided an important approach to better understand landform genesis and to reveal patterns and relationships of glacial landforms at various scales and glaciological processes.

Furthermore the geomorphical mapping may be used as support to monitor environmental changes related to the climate variability registered in the area of study.

ACKNOWLEDGMENT

The Brazilian National Council for Scientific and Technological Development (CNPq) and Brazilian Antarctic Program (PROANTAR) provided the support for this research.

REFERENCES

ADAM, W.G. & KNIGHT, P.G. Identification of basal layer debris in ice-marginal moraines, Russell Glacier, West Greenland. Quaternary Science Reviews, v. 14, n. 22, p. 1407-1414, 2003.

AQUINO F.E. Sedimentação moderna associada à geleira de maré Lange, ilha Rei George, Antártica. Porto Alegre: Universidade Federal do Rio Grande do Sul, Msc dissertation. 106 p. [Modern sedimentation associated to the Lange tidewater glacier]. (In. Portuguese). 1999.

ARIGONY-NETO, J. Determinação e interpretação de características glaciológicas e geográficas com sistema de informações geográficas na Área Antártica Especialmente Gerenciada baía do Almirantado, ilha Rei George, Antártica. Porto Alegre: Universidade Federal do Rio Grande do Sul, Dissertação de mestrado. [Determination and

interpretation of glaciological characteristics using a geographic information system for the Admiralty Bay Antarctic Special Managed Area, King George Island, Antarctica]. (In Portuguese), 2001. 84 p.

BENN, D.I. & BALLANTYNE, C.K. Reconstructing the transport history of glaciogenic sediments - a new approach based on the covariance of clast form indices. Sedimentary Geology, v. 1-4, n. 91, p. 215-227, 1994.

BENN, D.I.; EVANS, D.J.A. Glaciers & Glaciation. London: Arnold, 2010. 802 p.

BENNETT M.R. & GLASSER, N.F. Glacial Geology - Ice Sheets and Landforms. Inglaterra: John Wiley & Sons Ltd, 1996. 364 p.

BLINDOW N., SUCKRO S.K., RÜCKAMP M., BRAUN M., SCHINDLER M., BREUER B., SAURER H., SIMÕES J.C. & LANGE M. A. Geometry and thermal regime of the King George Island ice cap, Antarctica, from GPR and GPS. Annals of Glaciology, 51(55): 103-109. 2010.

BLINDOW, N.; SUCKRO, S.K.; RÜCKAMP, M.; BRAUN, M.; SCHINDLER, M.; BREUER, B.; SAURER, H.; SIMÕES, J.C. & LANGE, M. A. Geometry and thermal regime of the King George Island ice cap, Antarctica, from GPR and GPS. Annals of Glaciology, v. 51, n. 55, June 2010, p. 103-109, 2010.

BOULTON, G.S.; DONGELMANS, P.; PUNKARI, M.; BROADGATE, M. Paleoglaciology of an ice sheet through a glacial cycle: the European ice sheet through the Weichselian. Quaternary Science Reviews, v. 20, p. 591-625, 2001.

BRAUN, M. & GOßMANN, H. Glacial changes in the area of Admiralty Bay and Potter Cove, King George Island, Antarctica. In: Beyer, M. & Boelter M. (ed.): GeoEcology of Terrestrial Antarctic Oases, Springer Verlag, p. 75-89, 2002.

BRAUN, M.; SAURER, H.; SIMÕES, J.C.; VOGT, S. & GOßMANN, H. The influence of largescale atmospheric circulation on surface energy balance and ablation on King George Island, Antarctica. International Journal of Climatology, p. 21-36, 2001.

BREMER, U.F. Morfologia e Bacias de Drenagem da Cobertura de Gelo da ilha Rei George, Antártica. Dissertação (Sensoriamento Remoto) - Universidade Federal do Rio Grande do Sul. [Morphology and drainage basins of the King George Island ice cover, Antarctica]. (In Portuguese), 1998.

CLARK, C.D. Reconstructing the evolutionary dynamics of former ice sheets using multi-temporal evidence, remote sensing and GIS. Quaternary Science Reviews, v.9, n.16 p. 1067-1092, 1997.

CURL, J.E. A glacial history of the South Shetland Islands, Antarctica. Ohio State University, Institute of Polar Studies Report, n. 63, 1980. 129 p

ETIENNE, J.L.; GLASSER. N.F.; HAMBREY, M.J. Proglacial Sediment-Landform Associations of a Polythermal Glacier: Storglaciären, Northern Sweden. Geografiska Annaler, Series A: Physical Geography, v. 2, n. 85, p. 149-164, 2003.

EVANS, D.J.A.; TWIGG, D.R. The active temperate glacial landsystem: a model based on Breiðamerkurjökull and Fjallsjökull, Iceland. Quaternary Science Reviews, v. 20-22, n.21, p. 2143-2177, 2002.

FERRANDO, F.A.; VIEIRA, R. & ROSA, K.K. Sobre el calentamiento global en la Isla Rey Jorge: procesos y evidencias en el glaciar Wanda y su entorno. Revista Informaciones Geográficas, v.41, p.25-40, 2009.

GLASSER, N.F. & HAMBREY, M.J. Styles of sedimentation beneath Svalbard valley glaciers under changing dynamic and thermal regimes. Journal of the Geological Society, London, v. 4, n. 158, p. 697-707, 2001.

KLEMAN, J; HÄTTESTRAND, C; STROEVEN, A.P.; JANSSON, K.J.; DE ANGELIS, H.; BORGSTROM, I. Reconstruction of paleo-ice sheets-inversion of their glacial geomorphological record. In: Knight, P.G. (Ed). Glacier Science and Environmental Change. Oxford: Blackwell Publishing Ltd., 2006.

OHMURA, A; KASSER P; FUNK M. Climate at the equilibrium line of glaciers. Journal of Glaciology, n. 38, p. 397–411, 1992.

PARK, B.K.; CHANG, S. K.; YOON, H.I.;CHUNG, H. Recent retreat of ice cliffs, King George Island, South Shetland Islands, Antarctic Peninsula. Annals of Glaciology, n. 27, p. 633-635, 1998.

PATERSON, W.S.B. The Physics of Glaciers (3rd edition). Pergamon: Oxford. 1994.

ROSA K.K.;VIEIRA R., FERRANDO F.A.; SIMÕES J.C. 2009. Feições sedimentológicas e geomorfológicas do ambiente de deglaciação das geleiras Wanda e Ecology, ilha Rei George, Antártica. Pesquisas em Geociências (UFRGS), 36:315-326. [Sedimentological and geomorphological features of the deglaciation environment of Wanda and Ecology glaciers, King George Island, Antarctica]. (In Portuguese).

SIMÕES, J.C. e BREMER, U.F. Investigations of King George Island ice cover using ERS-1/SAR and SPOT imagery. Revista SELPER, v. 1-2, n. 11, p. 56-60, 1995.

SIMÕES, J.C.; BREMER, U.F.; AQUINO, F.E.; FERRON, F.A. Morphology and variations of glacial drainage basins in King George Island icefield, Antarctica. Annals of Glaciology, n.29, p. 220-224, 1999.

SISSONS JB, SUTHERLAND, D.W. Climatic inferences from former glaciers in the south-east Grampians, Scotland. Journal of Glaciology, n. 17, p. 325–346, 1976.

SUTHERLAND, D.W. Modern glacier characteristics as a basis for inferring former climates with particular reference to the Loch Lomond Stadial. Quaternary Science Reviews 3: p. 291–309, 1984. BREMER U.F. 1998. Morfologia e Bacias de Drenagem da Cobertura de Gelo da ilha Rei George, Antártica. Msc dissertation. Universidade Federal do Rio Grande do Sul. [Morphology and drainage basins of the King George Island ice cover, Antarctica]. (In Portuguese).

PARK B.-K.; CHANG S.-K.; YOON H. I.; CHUNG H. Recent retreat of ice cliffs, King George Island, South Shetland Islands, Antarctic Peninsula. Annals Glaciology, 27: 633-635. 1998.

VIEIRA R.; ROSSATO M.S.; AQUINO F.E.; SIMÕES J.C. Feições morfológicas associadas ao ambiente de deglaciação da geleira Ecology, ilha Rei George, Antártica. Revista Brasileira de Geomorfologia, 6(2): 51-60. [Landforms associated to the

proglacial environment of Ecology Glacier, King George Island, Antarctica] (In Portuguese). 2005.