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A GEOLOGIAL MAP OF THE ANTARCTIC PENINSULA – EXTRACTING GEOLOGICAL INFORMATION BY REMOTE SENSING

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INTRODUCTION

The Antarctic continent comprises an area of 12,093 million km² of which over 99 % are covered by a thick layer of ice. Only the remaining >1 % are ice-free and therefore can be used for the research on geological aspects. The ice-free regions are restricted to the coastal areas and the tops of the mountain ridges, so called Nunataks. Because of climatic changes – a constant warming especially on the Antarctic Peninsula – the ice-free surface in coastal regions is constantly increasing. Therefore this PhD project concentrates on the Antarctic Peninsula and the South Shetland Islands. Since the 1960s the British Antarctic Survey (BAS) collected geological information for six maps at a scale of 1: 500 000 covering the total area of the Antarctic Peninsula. Selected areas also were mapped in detail either by BAS or other investigators, but up to now no detailed geological map could be achieved covering the whole area of the Ant-arctic Peninsula and the South Shetland Islands - mostly because of the thick ice cap and climatic conditions. This project takes advantage of remote sensing methods as analysing satellite images – including active and passive systems – and aerial photographs to achieve geological information. The extracted information shall lead to a detailed map that can provide a foundation for further investigations on the Antarctic Peninsula.

AVAILABLE DATASETS AND THEIR FUNCTIONALITY FOR THE PROJECT

So far four types of remote sensing data (Landsat TM 5, ASTER, ERS 1/2 and aerial photographs) are available but the database will be extended by TerraSAR data after Dec 2006. There also exists a vague plan to fly an airborne mission with the HyMAP sensor (hyperspectral data) depending on a suitable financing. Landsat TM data has a spatial resolution of 30 m per pixel

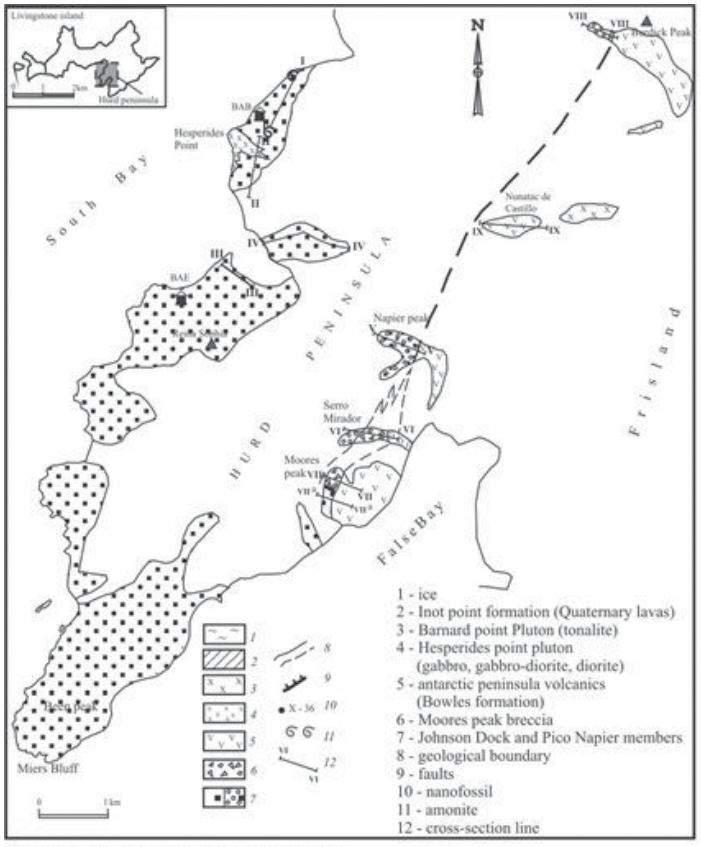
and covers the electromagnetic wavelength range of 0.4-2.5µm in 6 spectral bands [http://eros.usgs.gov/products/satellite/band.html]. Therefore images of this sensor type are predominantly used for an overview and the distinction of structural features shown in a lager scale. ASTER has three advantages to Landsat TM data: the spatial resolution goes down to 15 m per pixel, the wavelength range between 0.4-2.5µm is covered by 9 spectral bands and the ASTER instrument has a backward looking ability which allows the building of digital elevation models (DEM) [http://asterweb.jpl.nasa.gov/characteristics.asp]. The ASTER dataset therefore offers a comprehensive opportunity to extract more details than Landsat TM data. Within the wavelength range of 0.4-2.5µm chemical features e.g. of rocks show specific spectral signatures and on the strength of this connection it is possible to distinguish different rock types by their chemical composition. Both ERS 1/2 and the TerraSAR system offer radar data which can be used for detecting structural data.

TEST-SITE HURD PENINSULA

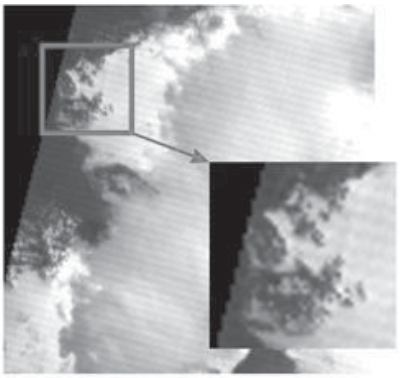
The basic approach of this project is to receive as much various information from different datasets as possible to obtain and based on it to build a detailed geological map. This work concentrates on the first test-site Hurd Peninsula on Livingston Island, South Shetland Islands, Antarctic Peninsula because:

1. The Hurd Peninsula (62° 40’ S / 60° 22’ W), that comprises of 27 km², consists of an ice-free area of about 10 km² [Kraus, S. 2005] and therefore represents one of the larger ice-free areas either on the South Shetland Islands and the Antarctic Peninsula.
2. There already exist detailed geological maps of the test-site which can be used as reference information to verify the results of the remote sensing processing.
3. The geological lithology of the Hurd Peninsula is well known even so discussions on specific areas still continue. The lowermost rocks are represented by the Miers Bluff Formation (MBF) which is considered a multiply deformed and metamorphosed turbidite sequence [Willan, R. C. R. et al. 1994; Zheng, X. et al. 2003]. The formation is unconformably overlain by the Moores Peak Breccia which referring to [Willan, R. C. R. 1996] consists of brecciated material of the Antarctic Peninsula Volcanic Group (marine-sedimentary and volcanic rocks). The uppermost formation comprises volcanic rocks of the magmatic arc of the Mount Bowles Formation [Smellie, J. L. et al. 1995]. All

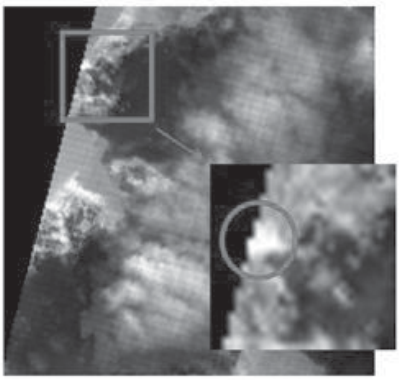
three formations were intruded by gabbros to quartzdiorites [Kamenov, B. K. 1997] and are often cut by dykes varying from rhyoliths to basalts [Kraus, S. 2005].Data processing, results and discussion In a first attempt of data processing an ASTER-scene of the Hurd Peninsula was picked and geo-referenced to UTM Zone 21 S, WGS 84. Following other data corrections band ratios were processed from this scene to clarify geological features in the area. ASTER-band ratios combinations of 4/1, 4/9, and 4/3 x 2/3 were made which correspond to band ratios of 5/1, 5/7 and 5/4 x 3/4 of Landsat TM data. According to [Kusky, T. M. et al. 2002] this ratios can be used to distinguish felsic and mafic rocks. The Landsat TM combination 5/1 and for ASTER data consequently 4/1 (SWIR/ VIR) helps especially to extract clay minerals. The ASTER ratio 4/1 offered the possibility to distinguish



Schematic geological map of Hurd Peninsula.
Slightly modified after D. Dimov (Univ. of Sofia, Bulgaria, kind p.c.).



ASTER image showing part of the Hurd Peninsula
Band 1 (556 nm) of ASTER dataset
close up: Hesperides Point and surroundings



Band ratio 4/1 (band 4: 1656 nm) of ASTER dataset shown above. Marked area in close up displays Hesperides Point

Figure 1: l: geolocial map of Hurd Peninsula; r: two ASTER images displaying part of Hurd Peninsula.
Hesperides Point shows a significant spectral signature of clay minerals and therefore the exposed parts of the pluton must be highly alterated. The surrounding MBF mainly consists of sandstones and minor parts of mudstones. Mudstones do not seem to play a major part in the surroundings of Hesperides Point because they cannot be traced in the ratio images and sandstones show such a low content of clay minerals that they can be neglected.

the geology in the NW of the Hurd Pensinsula around Hesperides Point. Hesperides Point itself is a pluton of gabbro, gabbro-diorite to diorite composition which is surrounded by rocks of the MBF. As can be seen in figure1 Hesperides Point can be clearly distinguished from the surrounding MBF in the ratio 4/1. This extraction can be done by the obviously different exposed amount of clay minerals of the two rock-types.

CONCLUSION AND OUTLOOK

The processed example shows that distinction of geological features already is possible by ASTER data. Therefore it can be assumed that the combination of additional data- sets of different sensor types will help to improve the results and hence to create a detailed geological map. The presented work verifies the possibility of extracting geological features on the Antarctic Peninsula by using remote sensing methods. On the strength of these results this project will continue gathering datasets of as much sensor types as possible to extract even more detailed information as are shown in this work.

REFERENCES:

Kamenov, B. K. (1997): *Geochemistry and petrology of the Hesperides Point Intrusion, Hurd Peninsula, Livingston Island*. International Symposium on Antarctic Earth Sciences, 7th, Siena, Italy, Sep. 10-15, 1995. Proceedings. Antarctic region: geological evolution and processes, edited by C.A. Ricci, Publisher: Siena, Italy, Terra Antartica Publication. Italy 341-352.

Kraus, S. (2005): *Magmatic dyke systems of the South Shetland Islands volcanic arc (West Antarctica): reflections of the geodynamic history*. (PhD thesis published online http://edoc.ub.uni-muenchen.de/archive/00003827/): 160pp.

Kusky, T. M. and Ramadan, T. M. (2002): *Structural controls on Neoproterozoic mineralization in the South Eastern Desert, Egypt: an integrated field, Landsat TM, and SIR-C/X SAR approach*. Journal of African Earth Sciences 35 107-121.

Smellie, J. L., Liesa, M., Muñoz, J. A., Sàbat, F., Pallàs, R. and Willan, R. C. R. (1995): *Lithostratigraphy of volcanic and sedimentary sequences in central Livingston Island, South Shetland Islands*. Antarctic science 7 (1): 99-113.

Willan, R. C. R. (1996): *The Moores Peak Formation, a Cretaceous debris-avalanche deposit in the Antarctic Peninsula Volcanic Group, Livingstone Island, South Shetland Islands*. Journal of South American Earth Sciences 9 (3/4): 251-264.

Willan, R. C. R., Pankhurst, R. J. and Herve, F. (1994): *A probable Early Triassic age for the Miers Bluff Formation, Livingston Island, South Shetland Islands*. Antarctic Science 6 401-408.

Zheng, X., Kamenov, B., Sang, H. and Monchev, P. (2003): *New radiometric dating of the dykes from the Hurd Peninsula, Livingston Island, South Shetland Islands*. Journal of South American Earth Sciences 15 (8): 925-934.