DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2015/78

Image-data from Storeelv, Motzfeldt Sø, South Greenland

Erik Vest Sørensen

GEOLOGICAL SURVEY OF DENMARK AND GREENLAND
DANISH MINISTRY OF CLIMATE, ENERGY AND BUILDING

GEUS

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G E U S

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1. Introduction

The Motzfeldt Centre (1273 +- 6 Ma, figure 1) is one of the major central complexes in the Gardar Province of alkaline igneous activity (Tukianinen, 1988; McCreath et al. 2012; Tukiainen 2014). The Motzfeldt Sø REE deposit, part of the Motzfeldt centre, shows significant Ta-Nb enriched zones in altered syenite and minor pegmatite and diorite dykes, and high grade REE intersections that are related to pegmatite intrusives at depth (Sørensen & Kalvig 2011; EURARE 2015).

Joint research between the Geological Survey of Denmark and Greenland (GEUS) and the Korean Institutes of Geoscience and Mineral Resources (KIGAM) has been conducted in the Motzfeldt Sø area with the objectives of evaluating the geology in the Storeelv area.

In preparation to the joint 2015 field season in the area, a small project was established focusing on utilizing available image-data for 3d-map products (terrain model, orthophotos and 3d-mapping) in a small area in the Storeelv area (Figure 1). The map products were meant as an aid to the field geologist as well as a founding stone for future work in the area.

The purpose of this report is to describe available archive image-data and the newly collected image-data, the processing of this data and the thereof derived data products.

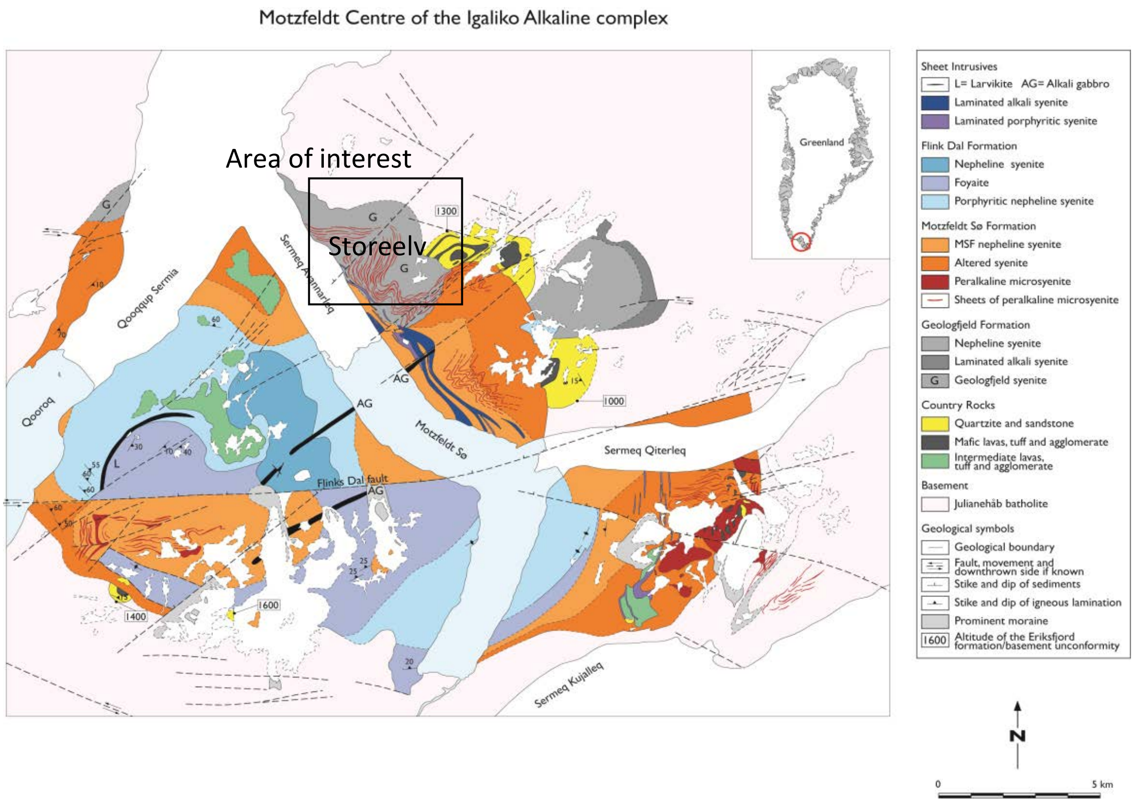

Figure 1. *Geological map of the Motzfeldt Center showing the location of the Storeelv study area (inset box).*

2. Existing data

Image-data used in this project comes from 5 different sources as summarized in table 1 and described below.

Dataset	Year	Processing step	Included in appendix
Analogue aerial photographs	1981	Scanning and georeferencing in ArcGIS	Georeference othophoto sample map with contours
Coloured aerial photographs	2006	DTM and orthophoto production in SocetSet	DTM, shaded relief, othophoto and 20 m contours
Analogue oblique photographs	1987-1988	Scanning and georeferencing in Photoscan	Google-KMZ file, orthophoto
Digital oblique stereo-images	2008	Setup for 3d mapping in Stereo Blend and SocetSet	Google-KMZ file, orthophoto
New oblique stereo-images	2015	New data acquisition - no post processing	

Table 1. *Overview table summarising the image data used in this project.*

2.1 Image data

2.1.1 Analogue aerial photographs

The GEUS archive contains a printed version of a monochrome orthophoto produced in 1982.The orthophoto (1:10.000) was produced from a set of monochrome aerial photographs (1:36.000) from the Geodetic Institute flight GI-1981. A series of different versions of the orthophoto with or without sample locations and contours exists. A version of the orthophoto containing sample locations was made available during the course of this project.

2.1.2 Coloured aerial photographs

The GEUS archive contains a set of coloured aerial photographs collected over the Gardar province in 2006. The images were collected in an analogue format at a scale of around 1:36.000 using a RMK Top 15 aerial camera. The images have subsequently been scanned at 14 µm and oriented based on triangulation of inertial GPS-data delivered with the flight. The accuracy of the orientation, expressed by the average root mean square error of the triangulation is around 1.5 m xyz.

2.1.3 Analogue oblique photographs

GEUS The GEUS archive contains a set of analogue oblique images taken with a handheld camera through an open window in a helicopter in 1987 and 1988. The images were taken with a small frame camera and are highly unstructured in terms of stereo-photography basics (overlap and viewing direction). It was not possible to retrieve the calibration report for the camera during this project and the camera model is unknown.

2.1.4 Digital oblique stereo-images

GEUS The GEUS archive contains a set of Oblique digital images taken from a helicopter in 2008. The images were taken with a 21 mega pixels Canon EOS-1Ds Mark III digital single lens reflex camera. The camera was calibrated before field work using a test field at the Technical University of Denmark. The result of the calibration is given as distortion pairs and calibrated focal length and principal point displacement is given in table 2 and is believed to be accurate to within 1/3 of a pixel.

		Radius in mm																		
		0	1.3	2.6	3.9	5.2	6.5	7.8	9.1	10.4	11.7	13	14.3	15.6	16.9	18.2	19.5	20.8	22.1	23.4
Lens distortion in microns	Canon EOS 1D MarkIII	0	0	-1	-5	-11	-22	-37	-57	-82	-113	-150	-190	-234	-281	-327	-371	-411	-441	-459
	Canon EOS 5D MarkII	0	0	-2	-5	-12	-23	-39	-60	-87	-119	-157	-199	-244	-291	-338	-382	-419	-446	-459

	Focal length (mm)	Principle point displacement (mm)	
		x	y
Canon EOS 1D MarkIII	34.326	-0.053	0.294
Canon EOS 5D MarkII	34.333	-0.010	0.038

Table 2. *The camera systems were calibrated before being deployed in the field using a steel grid with around 100 marked points (located at the Technical University of Denmark (Dueholm, 1992)). The result of the calibration is approximately 1/3 pixel.*

2.1.5 Digital oblique stereo-images collected in 2015

New oblique stereo-images were collected during field work in 2015. The images were collected with a Canon EOS 5D Mark II camera equipped with a fixed 35 mm lens. The lens, which was focused and locked at infinity using duck-tape, was calibrated before field work using a test field at the Technical University of Denmark. The result of the calibration is given in table 2 as distortion pairs and calibrated focal length and principle point displacement. The calibration is believed to be accurate to within 1/3 of a pixel.

The approximate camera position of the images is shown in figure 2. Further processing of the images for 3d-mapping purposes would be as described in paragraph 3.4. However, no processing of the new data has been undertaken during this project.

3. Processing of data

3.1 Georeferencing of the 1981 orthophoto sample map

The 1981 orthophoto sample map was scanned using a non-photogrammetric scanner and made available as a GIS-layer (Figure 2 and appendix A) by georeferencing the orthophoto using control points in the coloured aerial photographs (paragraph 2.1.2). In order to minimize time spent during georeferencing, only the area of interest was properly georeferenced. Areas outside the study area do therefore appear deformed in the digital version included in appendix A.

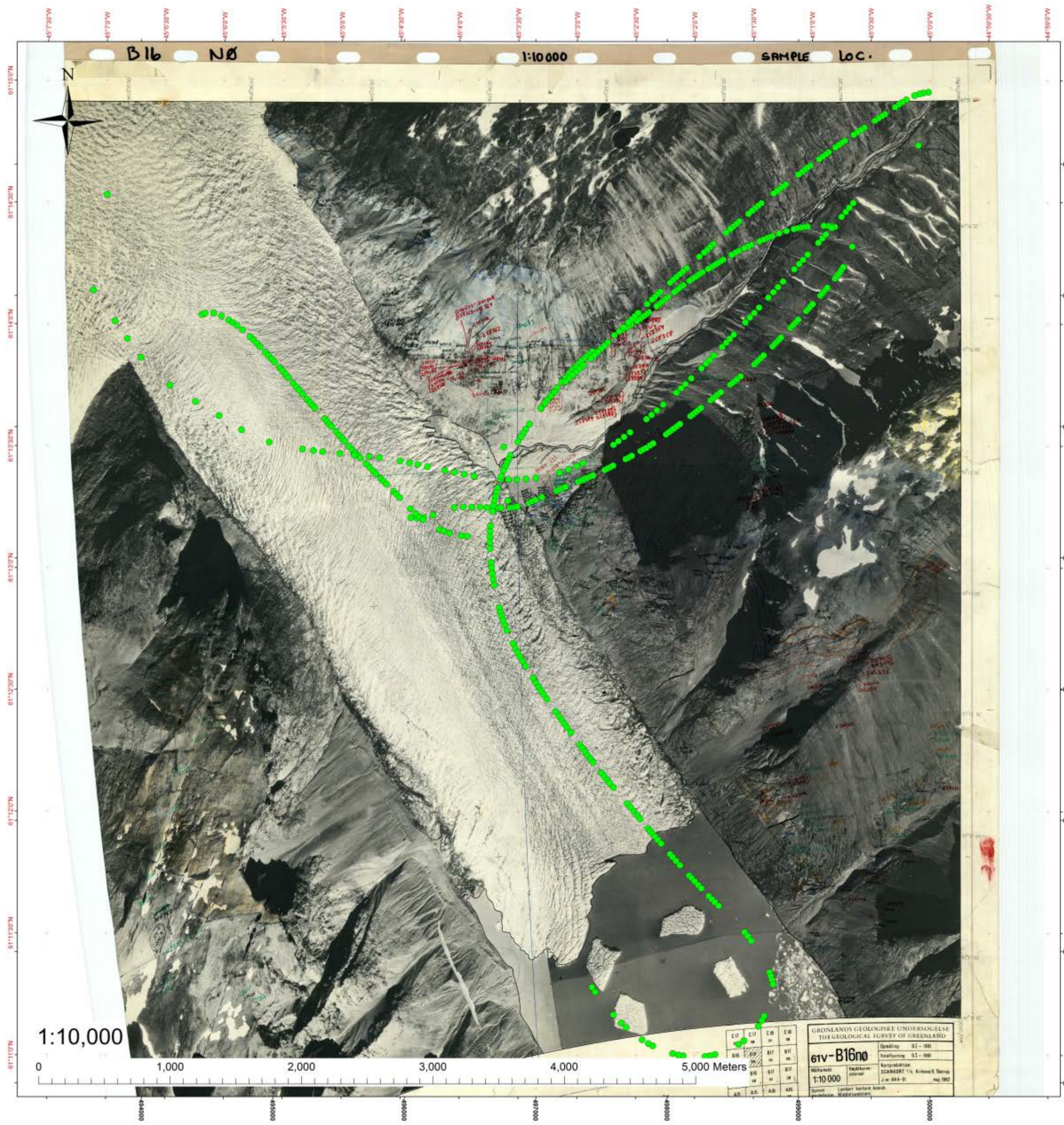

Figure 2. Georeferenced orthophoto sample map from 1982. Green dots are the approximate position of oblique stereo-imagery taken in 2015.

3.2 Terrain model and orthophoto production from coloured aerial photographs

A terrain model was produced from the coloured aerial photographs using a photogrammetric workstation running the commercial photogrammetric mapping and geospatial analysis software package SocetSet v5.6 from BAE Systems. The NGATE terrain extraction model residing within SocetSet (BAE systems, 2007) was used for the terrain extraction. NGATE performs an image and edge correlation routine on every pixel. The extracted terrain model has grid spacing of 0.5 m and the most obvious inaccuracies have been manually removed during post-editing. The extracted terrain model is shown in figure 3 and is included in appendix A. The extracted model for most areas is of good quality. However, areas covered in shadows generally are of poorer quality. These areas generally coincide with extremely steep topography.

The extracted terrain model was subsequently used to generate an orthophoto (0.5 GSD) from the area using the mosaic module residing within SocetSet. The orthophoto is shown in figure 4 and included in appendix A.

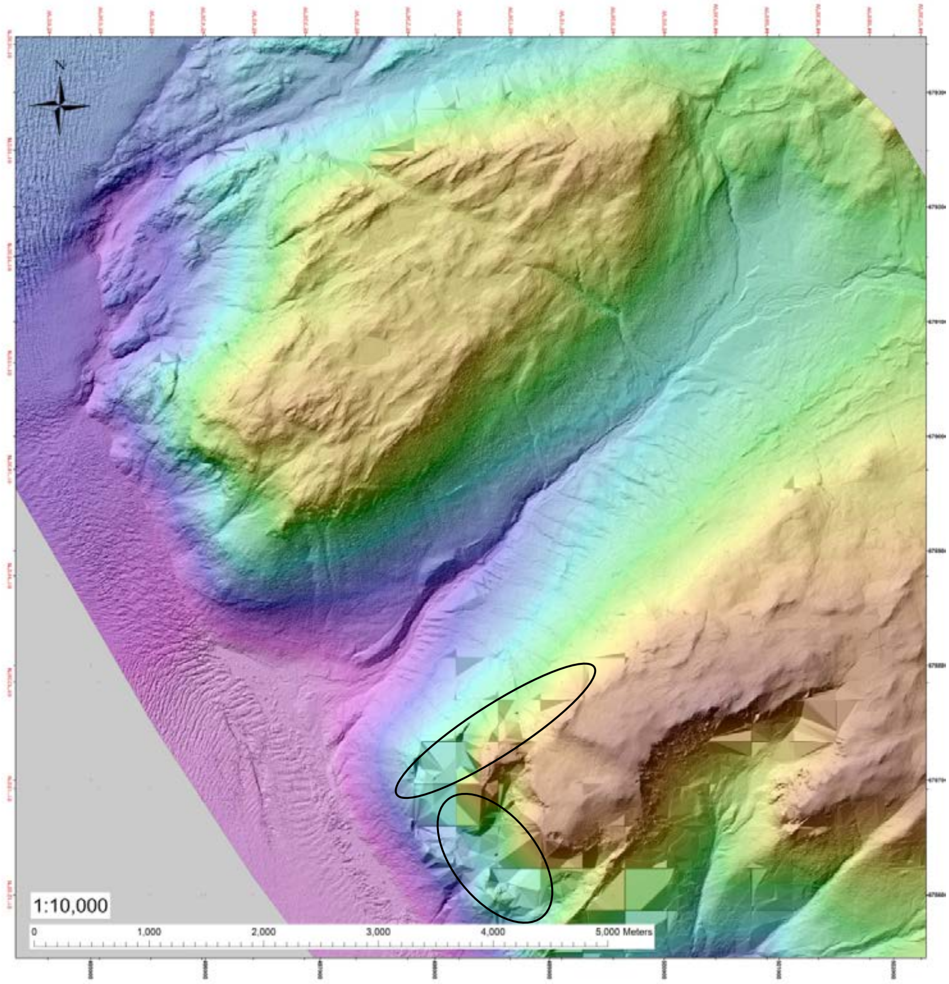

Figure 3. Generated terrain model overlain on a shaded relief model. Encircled areas correspond to area with poorer data quality. These areas are typical areas in shadow or areas with extremely steep topography.

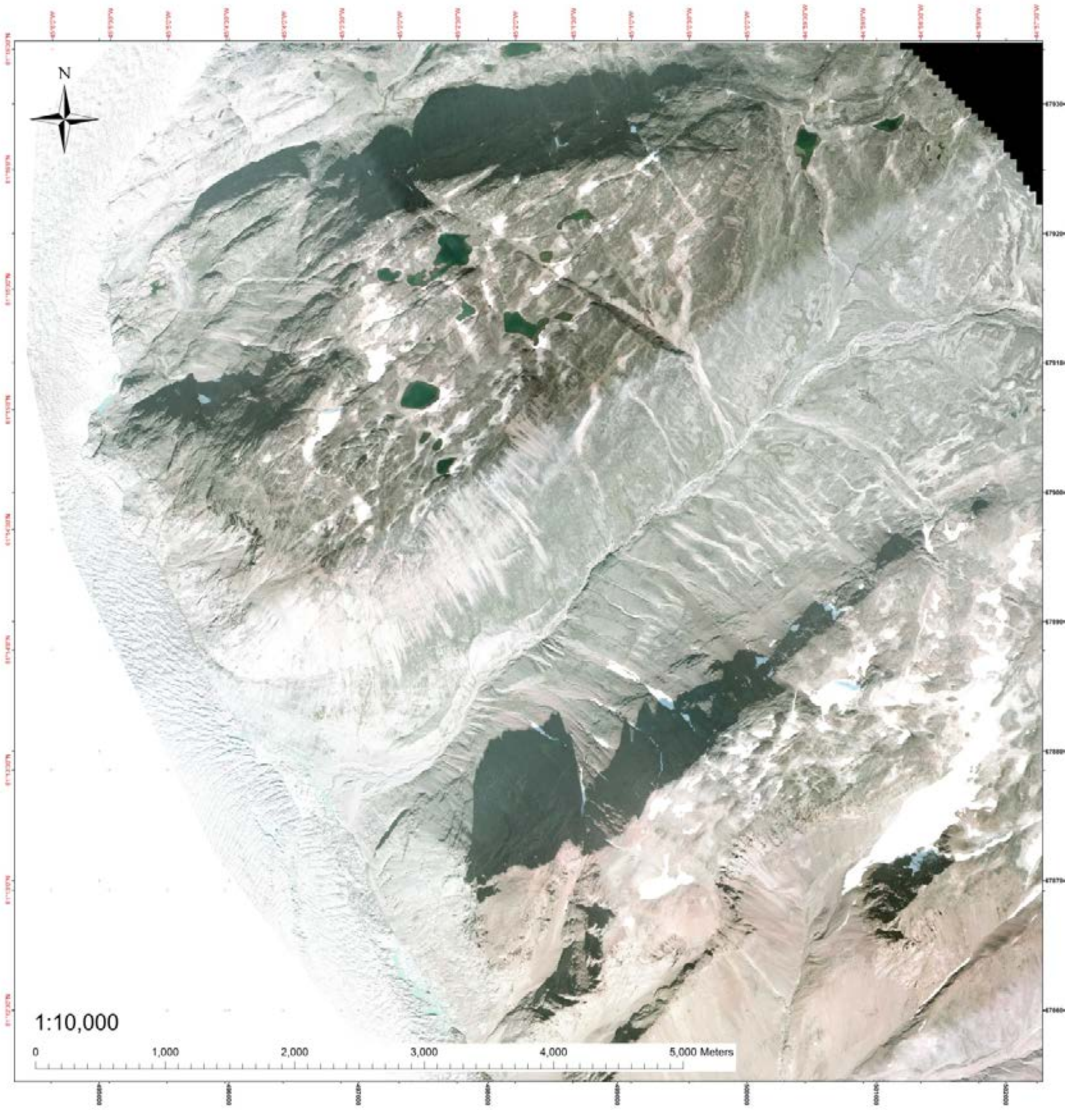

Figure 4. *Orthophoto (0.5 m GSD) of the study area in the northern area of Motzfeldt Sø. Areas in shadows generally* correspond *to areas in the terrain model that are of poorer quality.*

3.3 Scanned analogue oblique photographs

The analogue oblique photographs were invoked in this project as an additional data product to the coloured high resolution aerial photographs. Whereas aerial photographs generally are very useful for interpreting regional structures, highly oblique images provide better views of the geology at closer range. This is both because of the viewing angle, which resembles the way the geologist sees the geology in the field, as illustrated in figure 5, but also in many cases because of higher resolution. This is very useful for geological mapping in steep terrain, such as the cliffs facing towards Motzfeldt Sø.

The images were scanned at the Geological Museum, Copenhagen University at 2450 dpi resolution using an Ultrascan 5000 scanner. The scanner uses a glass plate to minimize distortion in the photographic film (positives). The scanner is calibrated at a routinely basis, and the distortion was negligible for the purpose of this project. Because of lacking camera calibration and the unstructured way the images have been acquired (stereo-overlap, viewing angle and scale) the images were setup using a combined structure from motion (Lowe, 2004; Snavely et al, 2008; Fonstad et al., 2013) and Multi View Stereo (Hirschmüller, 2005; James and Robson, 2012; Favalli et al., 2012) approach. We used the professional version of Photoscan from Agisoft to orient the scanned photographs and subsequently extract a terrain model and an orthophoto based on the scanned photographs. Ground control for absolute orientation was taken from the coloured aerial photographs by manual point picking. The extracted terrain is shown in figure 6 and is included in appendix A as a Google KMZ file for viewing in Google Earth.

Figure 5. *Example of a scanned oblique photograph from the southern flank of Geologfjeld at the entrance to Storeelv valley. The different perspective compared to a traditional vertical aerial photograph helps the geologist in interpreting the geology and is helpful in the planning phase for field work.*

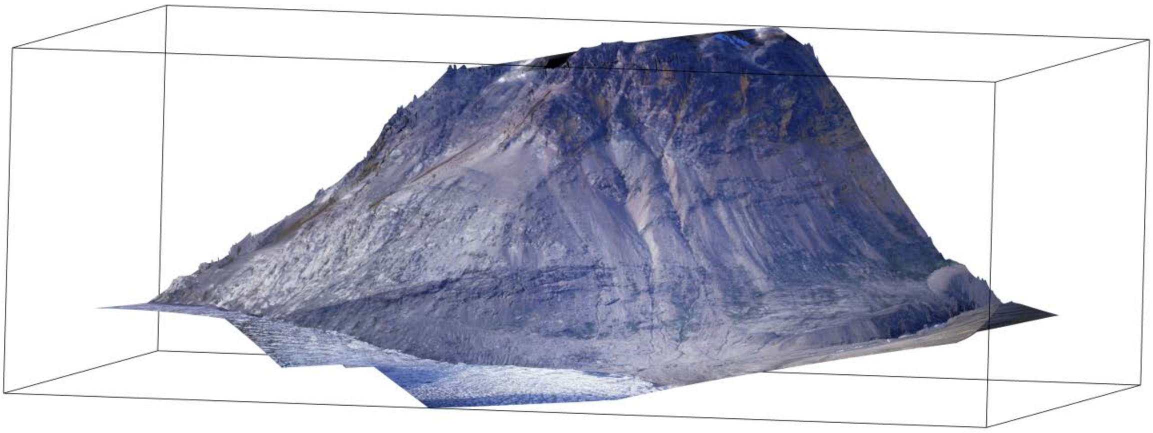

Figure 6. *Illustration of the model generated from the scanned oblique images. Size of the bounding box is approximately 3200 m x 2900 m x 1100 m. The model shows the southern flank of Geologfjeld at the entrance to the Storeelv valley.*

3.4 Preparation of the 2008 oblique stereo images

The 2008 digital oblique stereo images were invoked into this project using similar reasoning as for the scanned analogue images (paragraph 3.3). The 2008 images are part of a flight covering most of the steep cliffs around Motzfeldt Sø, but unfortunately not the 2015 field area. In contrast to the analogue images, the 2008 images were taken with continuous stereo-overlap. This makes it possible to use the images for detailed 3d-mapping purposes. An example of the images is given in figure 7.

A small subset of the dataset from the cliff section just east of the Storeelv valley were made available for 3d-mapping purposes during the course of this project using the photogrammetric software package Socet Set from BAE Systems. The orientation process of the images essentially consists of two steps. First step is the relative alignment of images through tie-point connection. Tie points were extracted semi-automatically using SocetSet. Whereas the second step connects the images to ”real world” coordinates by control point picking in the coloured aerial photographs. The images were triangulated together using Bingo-F bundle adjustment software. The accuracy of the bundle adjustment amounts to around 3 m xyz. That is how well the image-block is place in absolute space. However the geometric error within the block is around 1/3 of a pixel. This is much less than the pixel size, which for the images is around 0.7m. So, essentially the pixel size determines the geometric accuracy of the images.

With the images oriented it is possible to use the photogrammetric workstation in the photogrammetry laboratory at GEUS for detailed 3d-mapping of the steep cliffs at the entrance to the Storeelv valley. A small 3d-surface model of the images has for the purpose of illustration (Figure 8) been produced following similar methodology as for the scanned oblique images (paragraph 3.3).

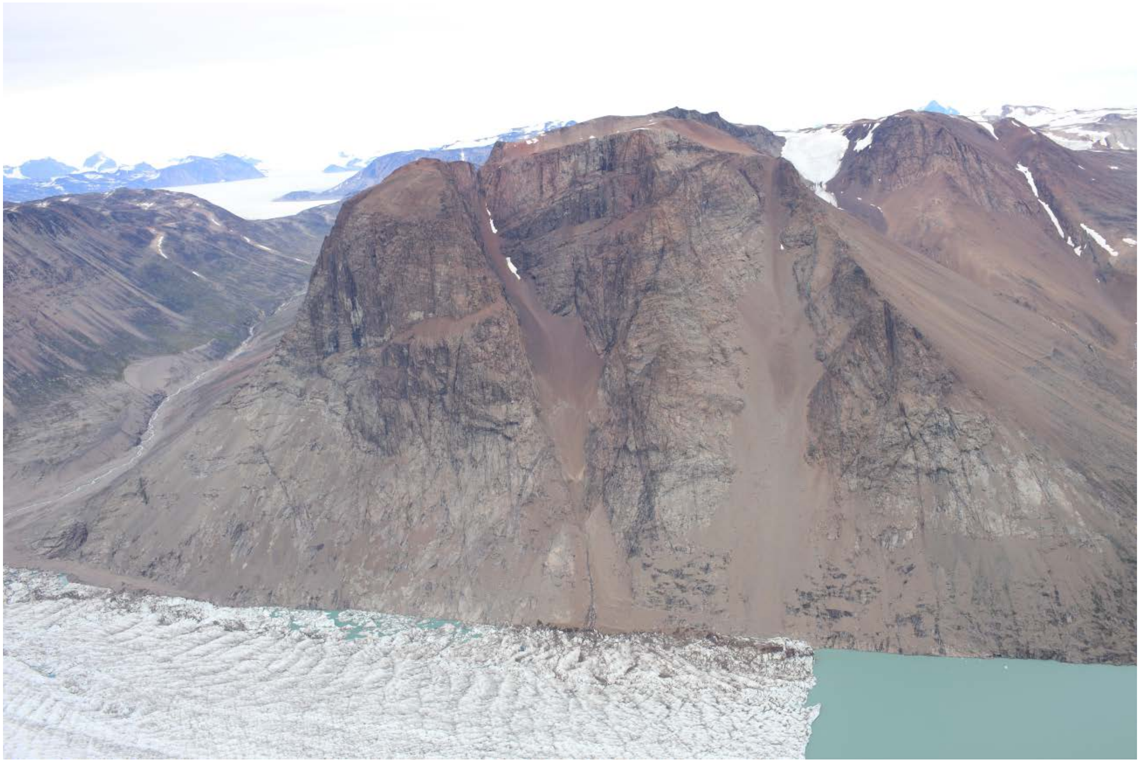

Figure 7. *Example of an oblique image from the 2008 flight. Oblique stereo-images are particular helpful in steep terrain such as the near vertical cliffs at the entrance to Storeelv valley.*

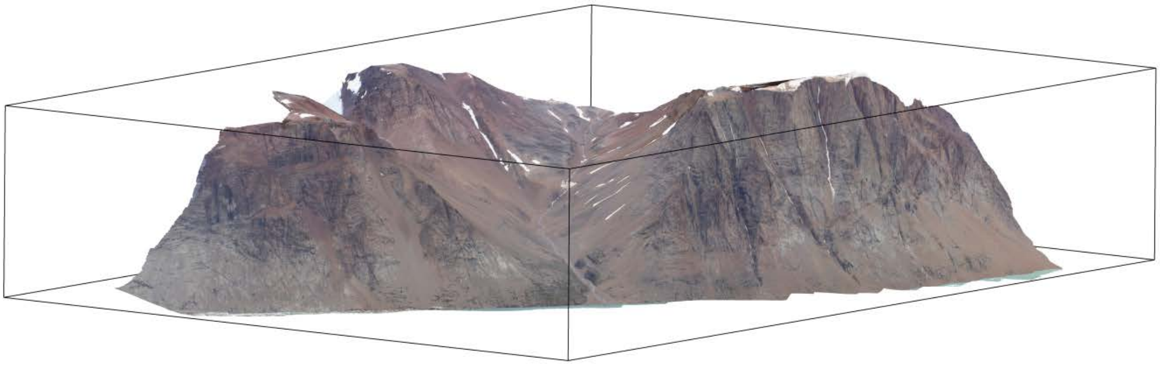

Figure 8. *Illustration of the model generated from images from the 2008 flight. The model shows the steep south facing cliffs east of Storeelv. The size of the bounding box is approximately 7100 m x 5100 m x 1400 m.*

4. Recommendations

It is suggested that the oblique stereo-images collected in 2015 are prepared for 3d-mapping purposes. This will give a coherent coverage of the Storeelv area with high resolution images, both oblique and traditional aerial photographs. Future work should focus on exploiting the image data in greater detail. That is a dedicated 3d-mapping effort where geological features are systematically mapped and linked to geochemistry and structural observations in three-dimensions.

5. Acknowledgements

The Geological Museum at Copenhagen is thanked for providing access to their professional photogrammetric scanner and Niels Jákob Korsgaard is especially thanked for his technical assistance during the scanning process.

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