DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2011/41

Faults and fracture systems in the Nuuk area

Structural analysis and photo-interpretation of faults and fracture systems along the coast of Nuuk prepared for TELE-Greenland

Pierpaolo Guarnieri & Peter Roll Jakobsen

GEOLOGICAL SURVEY OF DENMARK AND GREENLAND
MINISTRY OF CLIMATE AND ENERGY

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1. Introduction

1.1 Background

The background for this project are problems with an existing cable line on the seafloor southwest of Nuuk, which is damaged by ice bergs on water depths of 5 to 15 m. Tele-Greenland has suggested a plan for a drilling (HDD) to direct the cables from the shore and to a water depth of at least 200 m. There is however some uncertainties if the character of the rocks might cause problems during drilling. Especially the presence of faults and fracture systems might cause problems. The character of the rocks might also have an influence of the choice of drilling technique. TELE-Greenland has therefore requested GEUS to make a geological characterisation of the area.

1.2 Objective

The objective is to give a geological description and interpretation of the area, with special attention to structures that might be relevant for geotechnical investigation.

2. Geological setting

The rocks in the Nuuk area are about 3000 million years old. They consist mainly of Nuuk Gneiss, tonalitic/granodioritic gneisses, amphibolites and dioritic gneiss/metagabbro (McGregor, 1993,) (Figure 1). The Nuuk gneiss is differentiated into a light grey gneiss and a dark gneiss (Henriksen et al., 2000; Bridgewater et al., 1976). The light grey gneiss and the dark grey gneiss were the grey and banded gneiss in the previous fracture investigations (Jakobsen & Karlsen, 2001; Jakobsen & Larsen, 2004a & 2004b).

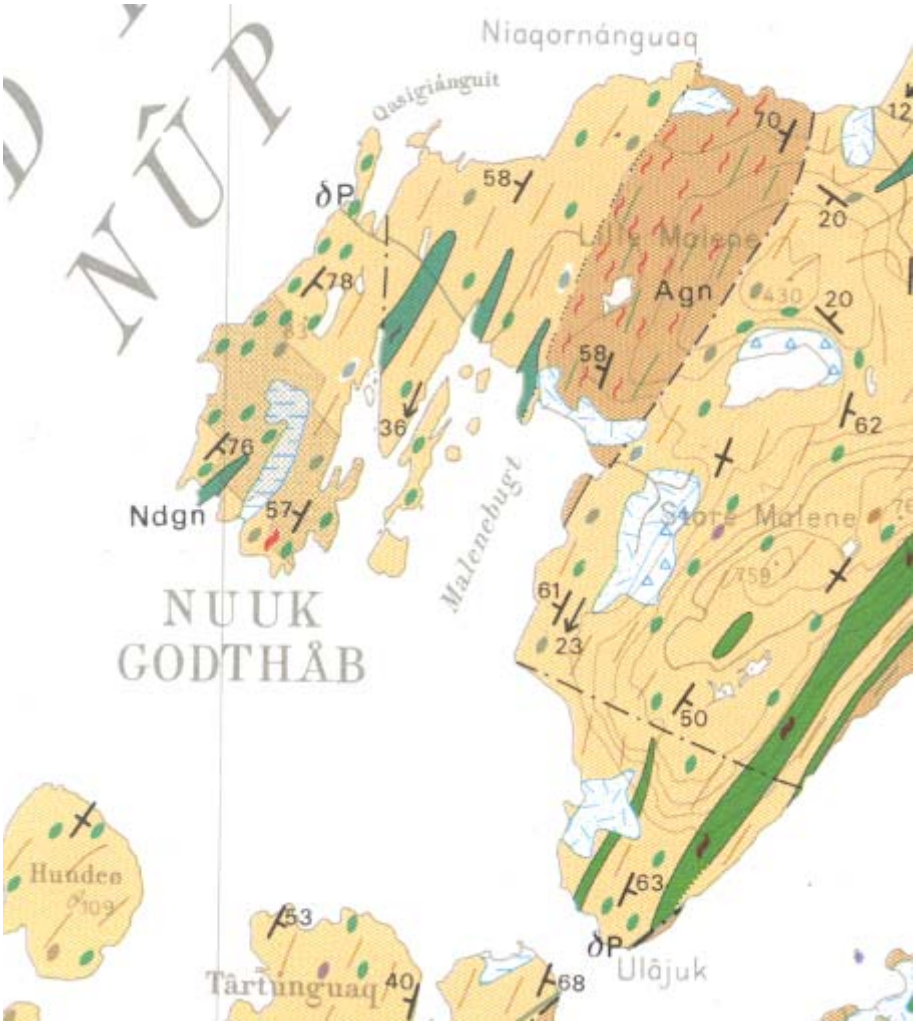

Figure 1. Geological map of the Nuuk area (from McGregor, 1993). Ngn: Nuuk Gneiss; Ndgn: Nuuk dioritic gneiss and Metagabbro; Agn Amitsoq gneiss. Stippled lines: faults.

The light grey gneiss is grey or light reddish grey. It is sometime migmatitic and has generally a weak foliation defined by biotite. It always appears as a massive rock (Figure **2**).

Figure 2. Grey gneiss with lenses of amphibolite.

The Banded gneiss is composed of alternating bands of grey gneiss, amphibolite and metagabbro (Figure **3**). It occurs as smaller units in the grey gneiss.

Figure 3. Banded gneiss at the road cut on Borgmester Annitap Aqquserna.

In the Nuuk area the foliation of the gneiss and fold axes all trend in about 30˚. On the geological map of the area two faults are shown. One is cutting the Store Malene or Ukkusissat striking in 130˚. Another is striking N-S in the central part of Nuuk (Figure 1).

3. Earlier investigations in the Nuuk area

In connection with planned tunnels and road cuttings in the Nuuk area toward Qinngorput and at Ukkusisat (Figure **4**e 4), investigations of the rock quality was made in order to estimate the stability of the rocks (Jakobsen & Karlsen, 2001, Jakobsen & Larsen 2004a, 2004b). In these investigations fractures and faults played a major role and they were systematically studied. The main results of these investigations are presented in the next paragraphs.

Figure 4 Geological map of the Nuuk area. The areas were earlier investigations has been carried out are indicated on the map with red circles.

3.1 Fractures

Fractures were mapped from orthophotos as well as along scanlines in the field at both the Qinngorput and the Ukkusissat localities (Jakobsen & Karlsen, 2001, Jakobsen & Larsen 2004a, 2004b).

3.1.1 Locality 1 (ridge next to Qinngorput)

At locality 1 four fracture systems are recognised. System 1 and 2 are closely spaced and strike respectively 130˚ and 105˚. They are steep fractures with an inclination of about 80˚

(Figure 5). The system 1 fractures occur more frequent than the system 2 fractures (Figure **8**).

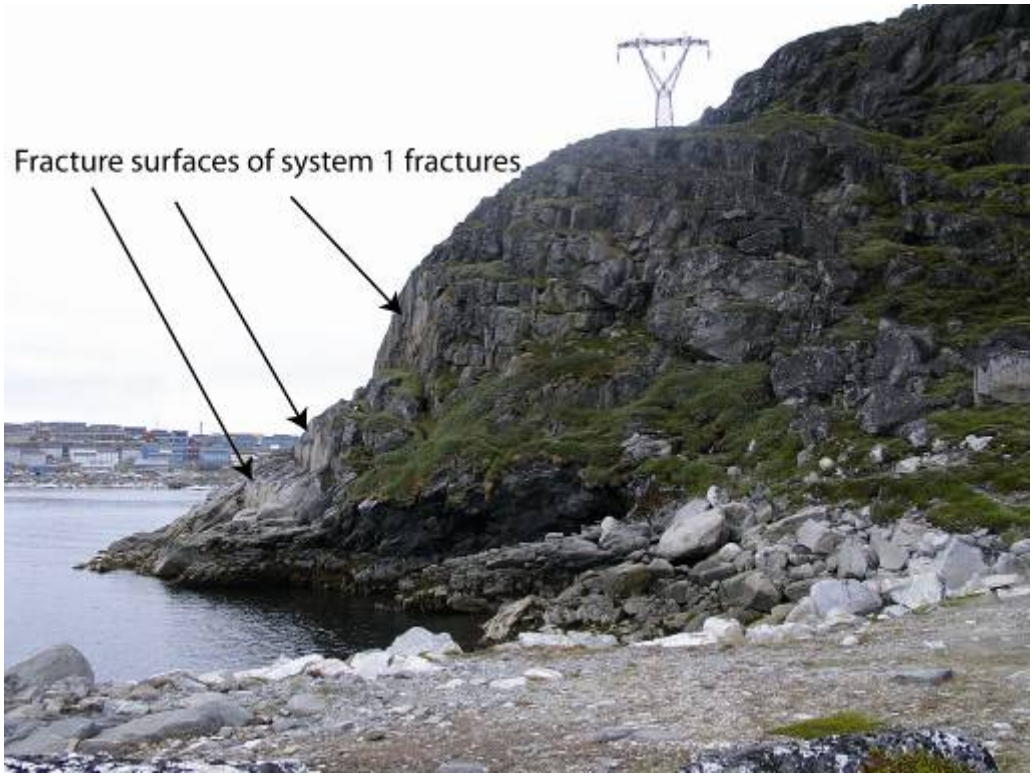

Figure 5. Large system 1 fractures towards Qinngorput.

The system 3 fractures are parallel with the foliation in the gneisses, which at the Qinngorput locality strikes about 30˚ with an inclination of about 70˚ (Figure **6**). The fracture intensity of the system 3 fractures is higher in the banded gneisses than in the grey gneiss, caused by the frequent change of lithology.

Figure 6. Banded Gneiss with steep system 3 fractures parallel to the foliation.

The System 4 fractures strike in about 30˚ with an inclination of about 22˚ (Figure **7**), which is nearly perpendicular to the foliation-parallel system 3 fractures.

Figure 7. System 4 fractures in grey gneiss.

Large fractures are drawn from orthophotos at this locality (Figure **8**). In this area it is mainly the system 1 and 2 fractures which can be outlined. The trace length is up to 52 m. Separation between fractures is up to 20 m (based on the contour interval).

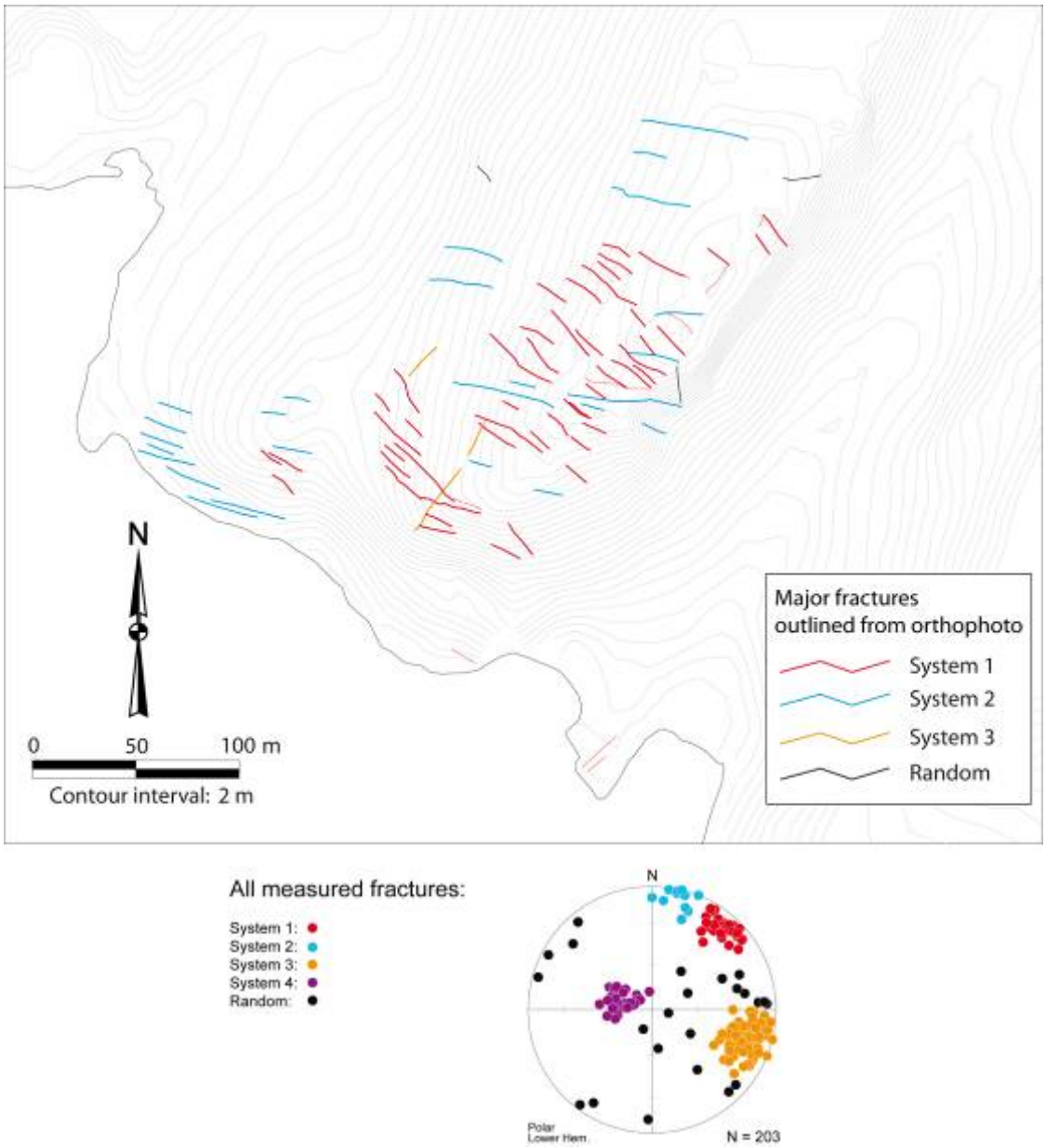

Figure 8. The Qinngorput lokality. The map shows the frature traces outlined from orthophoto. The stereoplot below shows the orientation of all fracture measured along scanlines in the area. (from Jakobsen & Larsen, 2004)

3.1.2 Locality 2 - Ukkusissat

At Ukkusissat the same fracture systems occur as at locality 1. The most prominemt fracture systems mapped from orthophoto are system 1 and 2, which are parallel to the faults/fracture systems in this area (Figure **9**). The system 3 fractures, which are parallel to the foliation, are difficult to recognise on the orthophoto, but they are recognised along the scan lines.

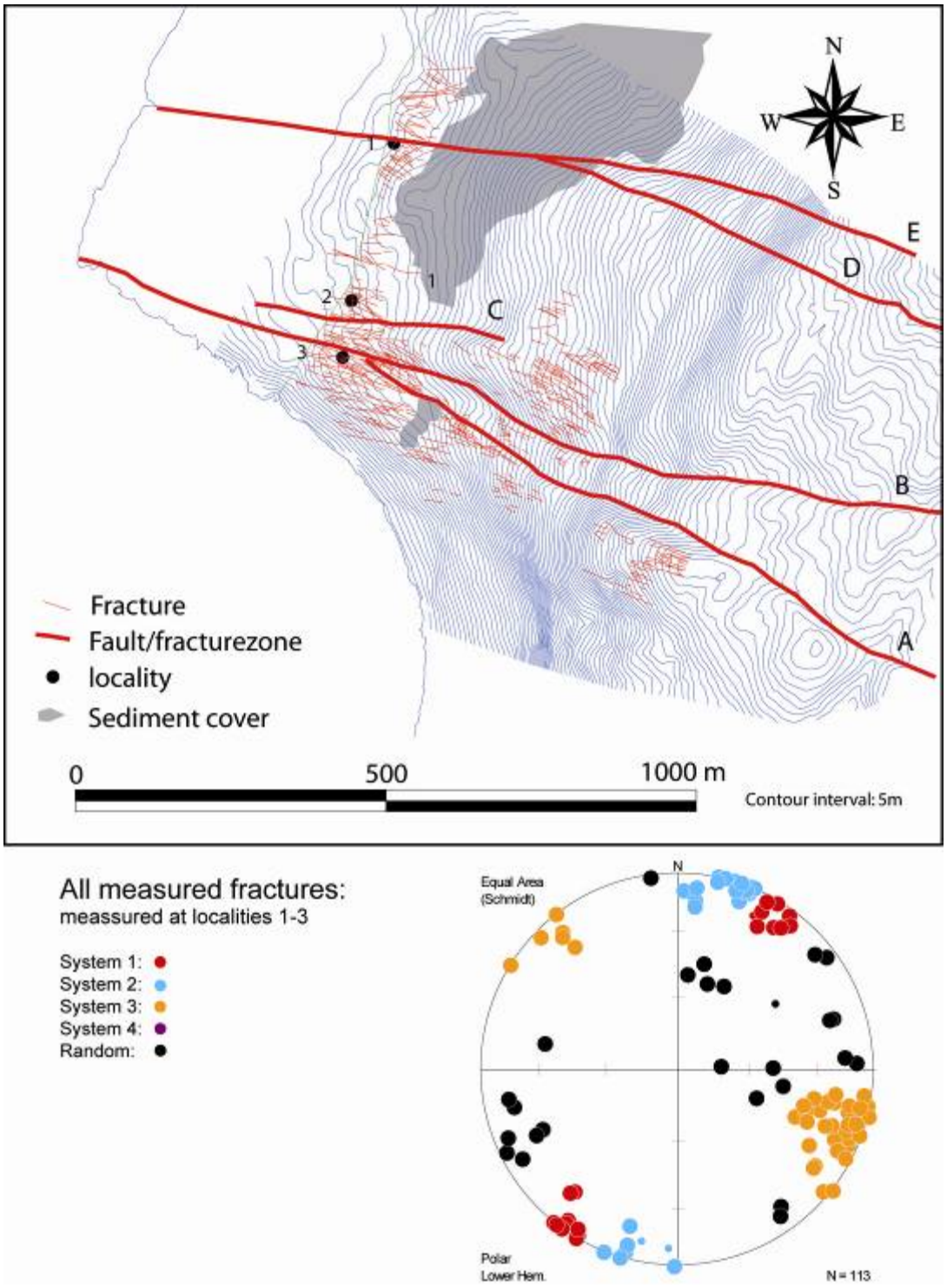

Figure 9. The map shows the SW part of Ukkusissat and adjacent area. Fractures are maped from orhtophotos along with faults and fracture systems. Fractures were measured along scanlines at three localities, and their orientation is shown on the stereonet below.

3.2 Faults and fracture systems

On the Geological map (Figure 4) a fault crosscut the southern part of Ukkusissat, striking N130˚. This fault corresponds to the fracture system A on Figure **9** and Figure **10**.

Figure 10. Areial photo of the southern part of Ukkusissat. The red lines outline major fault/fracture systems cutting across the Ukkusissat ridge.

Apart from zone A two other zones cut the ridge from coast to coast and up to about level 700 m, and they show a distinct morphological erosional features (Figure **11** and Figure **12**). Zone A can be followed for 2.3 km on land, and continues below sea level. Within the fracture systems the gneiss is heavily fractured and crushed

Figure 11. Oblique view towards the deeply eroded zones A, B and C.

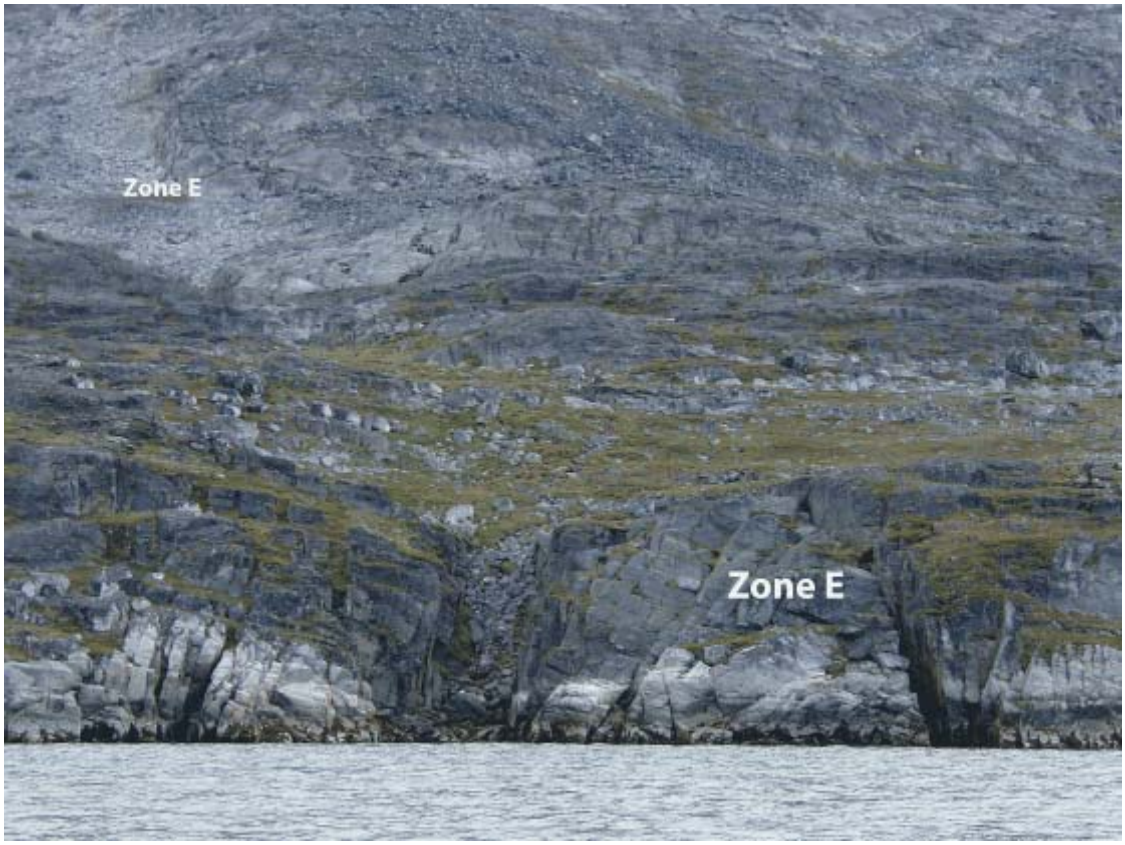

Figure 12. Oblique view towards the deeply eroded zone E

Figure 13. Heavily fractured and crushed gneiss within zone A at about 200 m of elevation.

Figure 14. Heavily fractured and crushed gneiss within zone E

4. Orthophoto interpretation in the area of interest

A preliminary analysis of structural trends along the coast is possible with the help of the published Orthophotos in Google Earth (Figure 14). The images show the presence of two orthogonal trends corresponding to the main structural trends. The first is coast-parallel (red) and the second one is fjord-parallel (yellow). At site b (Figures 14 and 16) there is an evident shear zone with brittle, not weathered deformation zone. This character could represent an indication of relative recent activity (compared to the basement rocks) of the fault zone. Fieldwork along those faults/fractures could reveal the kinematics and cross-cutting relationships useful in understanding recent movements together with an evaluation of the fractured rock mass along recently active fault zones.

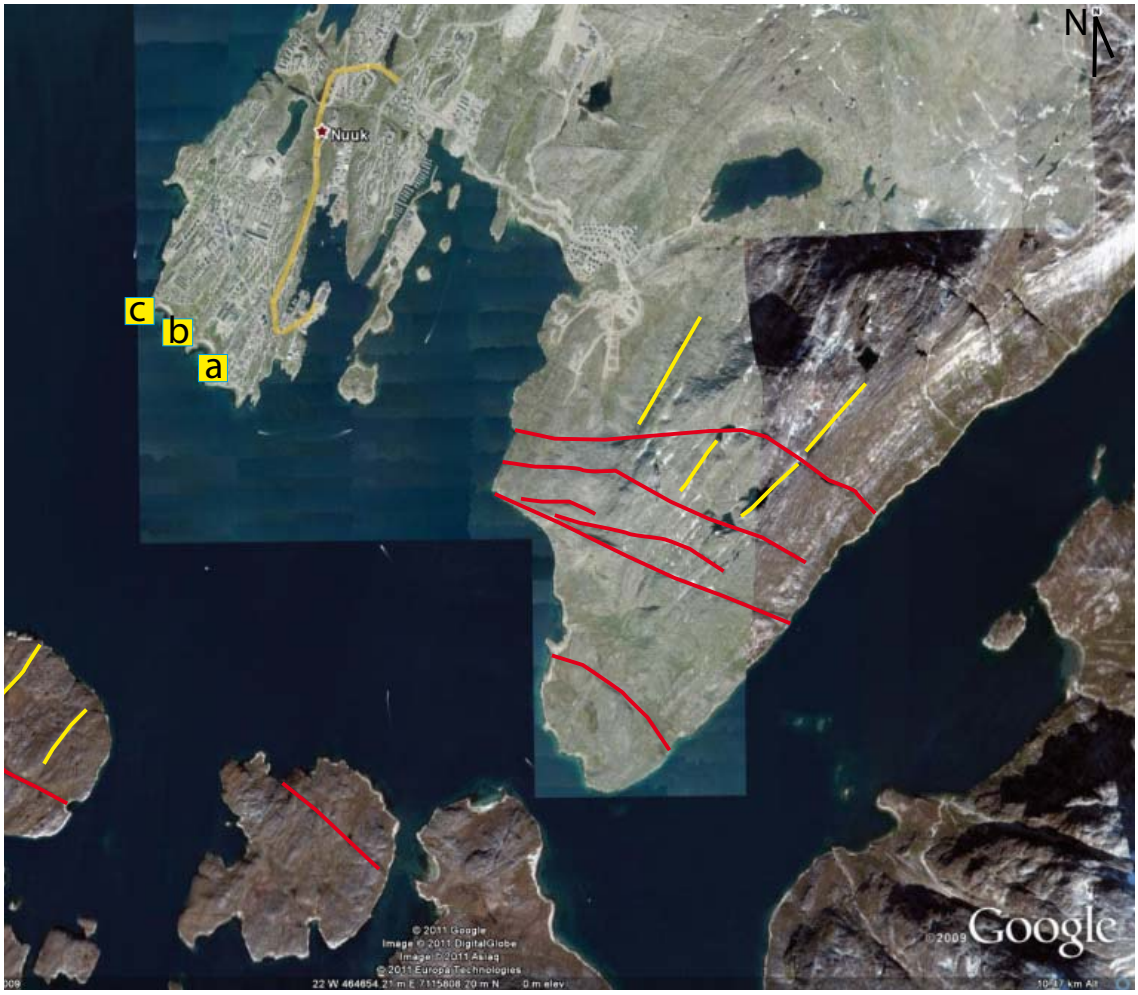

Figure 14. Orthophoto from Google Earth of the Nuuk area and detailed enlargements (yellow squares).

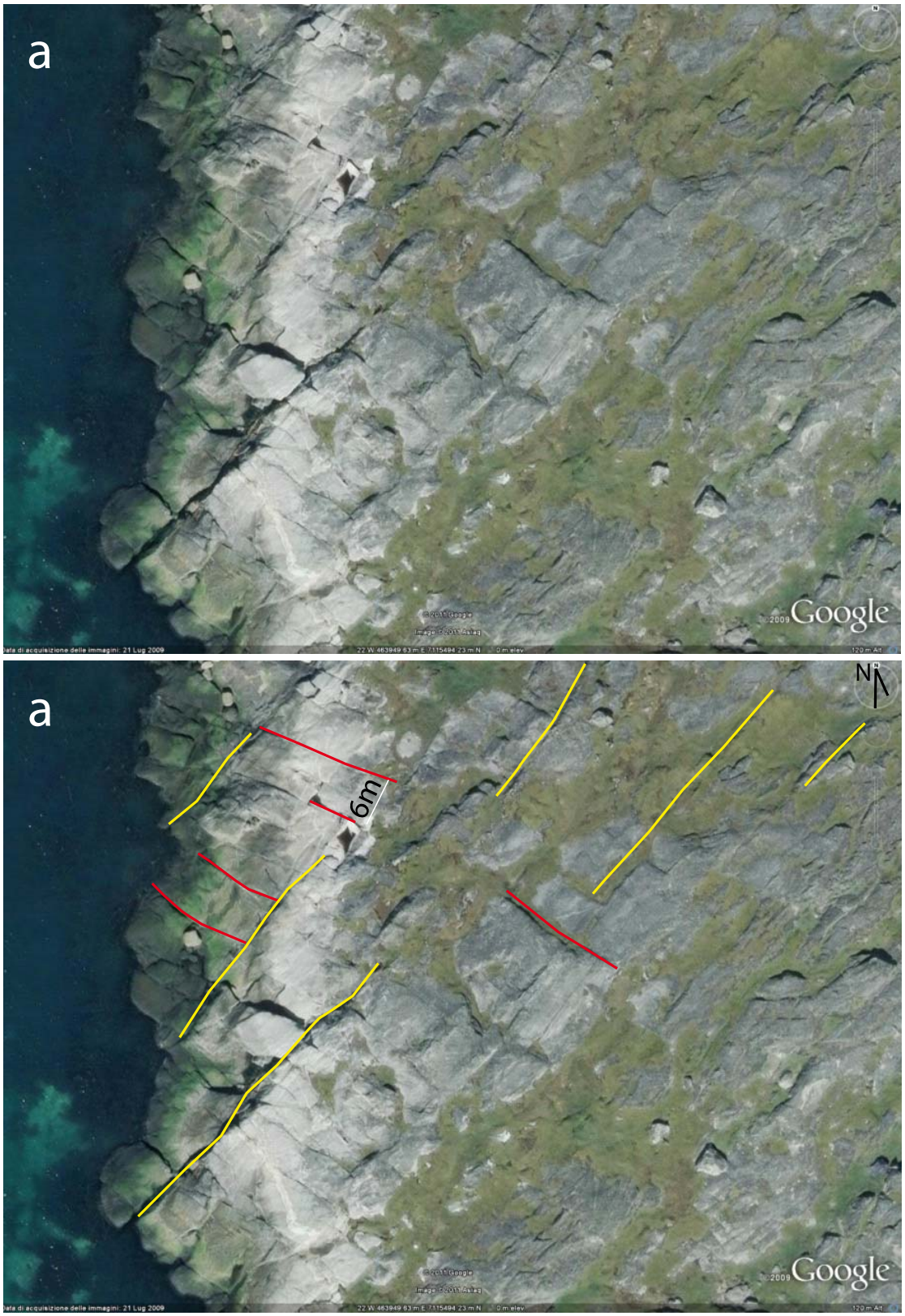

Figure 15. Enlargement-a from Figure 14. Fracture systems with orthogonal trends well developed along the coastline.

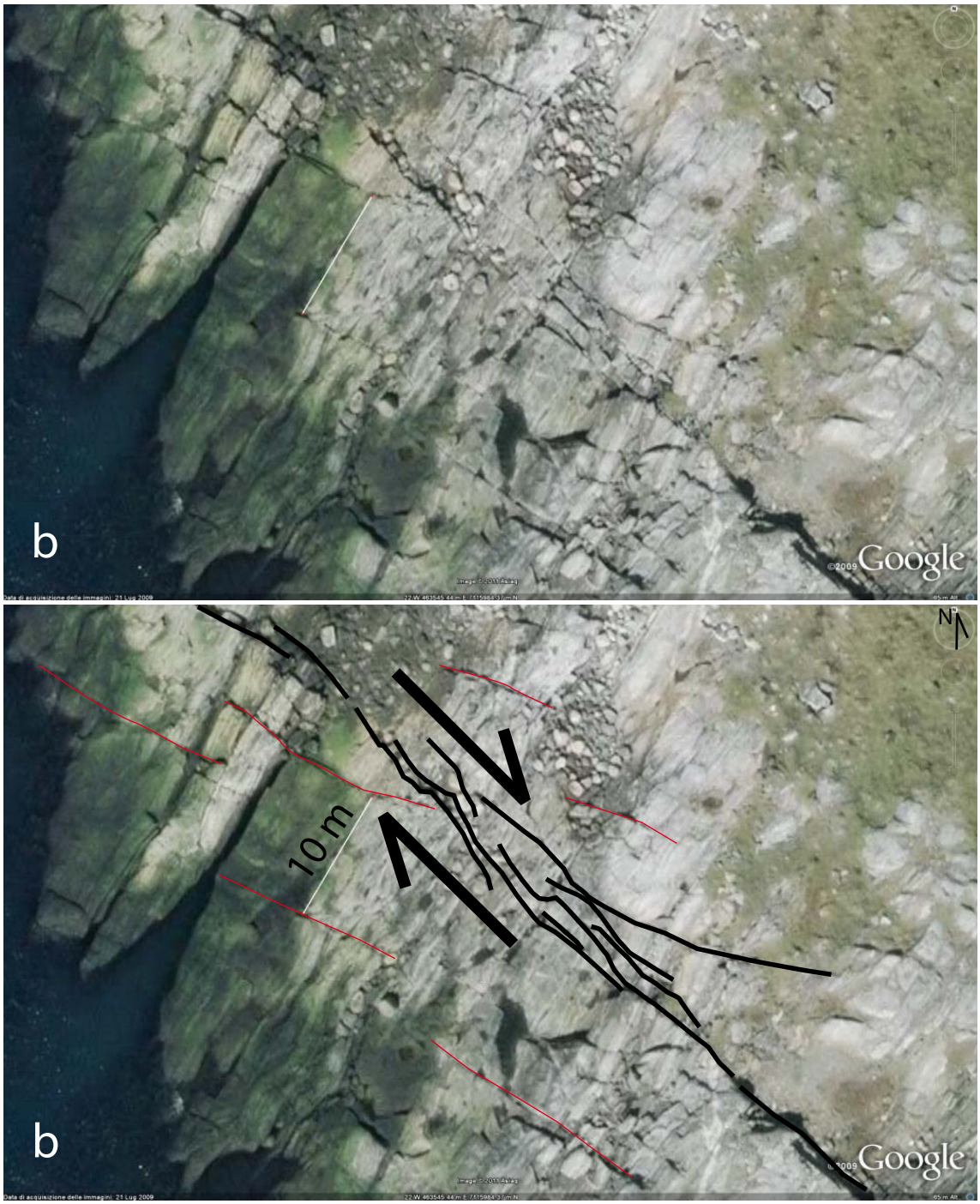

Figure 16. Enlargement-b from Figure 14. A coast parallel fracture system showing a brittle zone that could be interpreted as probably right-lateral fault zone. Such a brittle fabric could be related to recent movement along the contact.

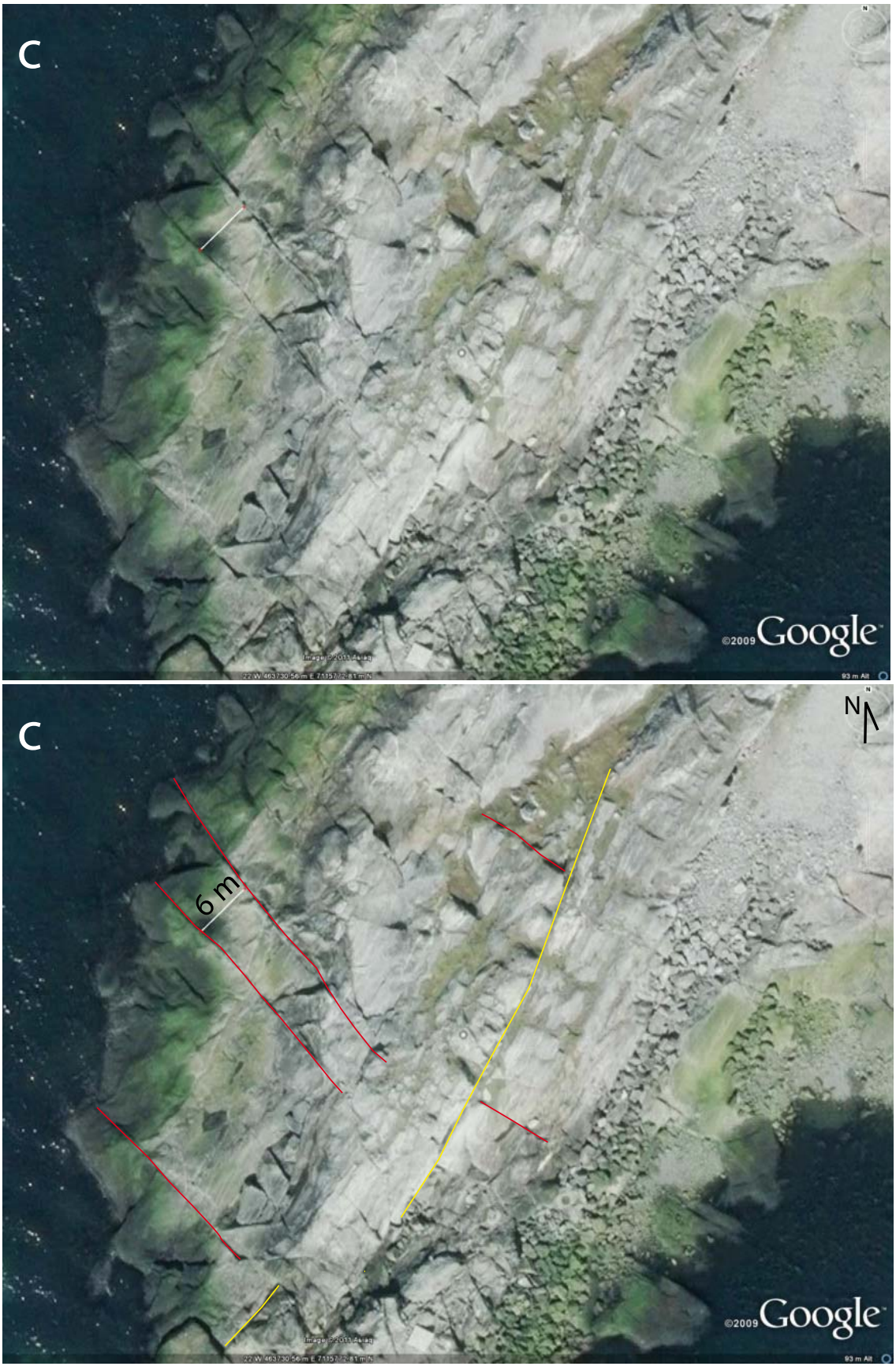

Figure 17. Enlargement-c from Figure 14. Fracture systems with orthogonal trends well developed along the coastline.

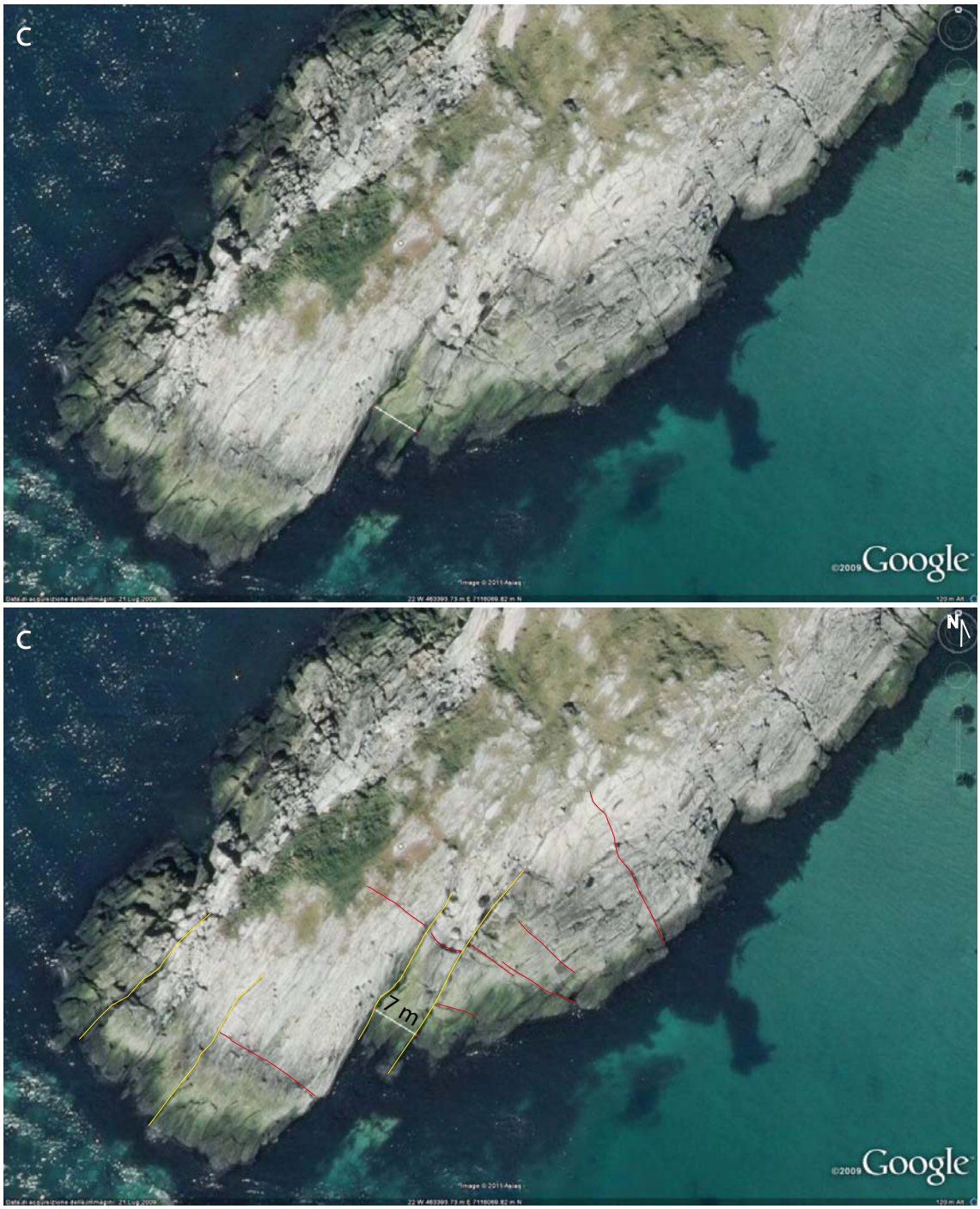

Figure 18. Enlargement-c from Figure 14. Fracture systems with orthogonal trends well developed along the coastline. The cross-cutting relationship between the two fracture system is not clear from orthophotos.

5. Discussion and recommendations

The faults and fracture systems cutting the Ukkusissat can be followed for at least 2.3 km laterally, and about 700 m vertically. The two fracture systems that are parallel with these faults are some of the dominating fracture systems through out the Nuuk region, indicating that the stress that caused the faulting has affected the whole area. After a preliminary interpretation of orthophotos it is possible to recognize the same pattern of faults and fractures. In particular:

- System 1 (Figs 8 and 9) corresponds to the coast parallel lineament depicted in Figure 16 (black lines);
- System 2 (Figs 8 and 9) corresponds to the coast parallel lineament depicted in FigureS 15-17-18 (red lines);
- System 3 (Figs 8 and 9) corresponds to the fjord parallel lineament depicted in Figures 15-17-18 (yellow lines);

The possible continuation of the faults seems to be just south west of area of interest. This would imply that the planned drillings would pass through a densely fractured or crushed zone(s).
On the geological map the rocks in the area of interest is the Nuuk Gneiss and a metagabbro. It is very important to have a detailed geological map of the area of interest, as the grey gneisses and the banded gneisses have very different geotechnical qualities. The alternating bands in the banded gneiss with very different lithologies might cause problems when drilling in them. The fracturing parallel to the foliation of the banded gneiss is also more dens than in the more massive grey gneiss. The shoreline at the area of interest, with peninsulas pointing in the same direction as the foliation, might be the result of differentiated erosion, controlled by the lithology.

Recommendations:

- A detailed Structural Geology study of the area of interest in order to get better information on fracturing at the site;
- A detailed Geological Mapping in the area of interest, in order to plan the best place to start drilling, and to estimate the best direction of drilling;
- A Geophysical investigation of the area covering the planned borehole lines as the faults might be situated off shore south west of area of interest. This could include a combined sidescan and sparker investigation. The side scan investigation would also give detailed information of the bathymetry.

6. References

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