DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2003/8

Dimension stone prospecting in West, South and East Greenland 2002

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Summary

A total of 16 localities have been examined for their properties for dimension stone in 2002. Twelve samples for evaluation of dimension stone quality are sampled. Nine dimension stone samples have been cut and polished and evaluated by RGS 90, (the largest producer of dimension stones in Denmark.

The focus has been on localities with low fracture densities, mainly the areas reported in Kalvig et al. 2002. The main goal has been to collect big samples and evaluate the areas for a potential dimension stone quarry.

The flame-structured migmatite from Seersinnilik in Nassuttooq is, according to RGS 90 the most promising locality for a dimension stone quarry in West Greenland examined durring this exploration.

Of the localities wisited in South Greenland the most promising localities for dimension stone quarrys are the two kakortokite types in the Illímaussaq intrusion and the red sandstone at Sillisit.

In East Greenland we only studied one locality in 2002 and the pale red granite which has a physical potential for a dimension stone production. However the rock type is already on the market. Accordingly this is second priority.

Figure 1. Collecting a rock sample with black powder in South Greenland.

Contents

Introduction

This report contains field observations, evaluation of potential dimension stone production from the areas, description of the polished slabs cut out of the samples, and recommendations for future work.

The objective was to collect large rock samples from specific areas, evaluate the areas and make contact to the industry, so that they would carry out cutting and polishing of the samples and evaluate the samples seen from their side.

The project is carried out by GEUS on behalf of Greenland Resources A/S.

Participants: Thomas V. Rasmussen (project leader) and Paarvo Härmä (Geological Survey of Finland), natural stone consultant.

Field period: 22/7-22/8 2002.

Local boat transport: Søkongen in West Greenland, J.F. Johnstrup in South Greenland and Ra VI in East Greenland.

All directions are given with reference to true North.

Structural data are given with dip direction.

Industry partners:
Råstof og Genanvendelses Selskabet af 1990 A/S, afdelingen for Granitprodukter (RGS 90).
Rabekkevej 1
Postbox 12
3700 Rønne
Denmark
Tlf.: +45 56 95 01 10
E-mail: dfg-granit@dfg-granit.dk
Homepage: www.dfg-granit.dk

Evaluation of the most promising dimension stones

From the observations in the field and the evaluation of the polished samples the most promising rocks for dimension stone are:

Locality 4. The flame-structured migmatite in Seersinnilik (Appendix A map A).

Positive features about the flame-structured migmatite:

- The structure and colour are attractiv on the market.
- The area is easy of acces.
- The rock type covers very large areas.
- Exfoliation benches are pronounced and they are economic to quarry from.
- There are diffrent types of the flame-structured migmatite in the area.
- Distances in direct line are ca 100 km to Sisimiut and 75 km to Kangerlussuaq.

Negative features about the flame-structured migmatite:

- There is a thin (maximum 2-3 m) overburden in places.

Locality 21. The red sandstone with sedimentary structures near Sillisit.

Positive features about the red sandstone:

- The sandstone can be polished.
- The colour is deep red.
- There are atttractive sedimentary structures in the sandstone.
- The rock type is rare on the dimension stone market.
- The logistics in the area are good.
- The area is easy of access.

Negative features about the red sandstone:

- Mining, cutting and polishing rocks consisting of almost pure quartz is expensive.
- There is a high fracture density.
- The overburden will be very thick due to the dipping layers.
- The best quality is 1,5 km from the shore.
- There is no large homogeneous volume documented.
- The sandstone is cut by a large number of dykes.

Locality 17. The two kakortokite types in the Illímaussaq intrusion.

Positive features about the two kakortokite types.

- There are two types within the same area.
- The logistics are very good already.
- There is no overburden.
- The rocks are broken up in dimension stone blocks.
- The colours are strong and well defined.
- Both types are unique and there is not any similar stone on the market.
- The area is easy of acces.
- Low radioactivity

Negative features about the two kakortokite types:

- On of the minerals (the red one) is eudialyte. Eudialyte means, soluble in water. According to J. C., Bailey, professor at Geological Institute in Copenhagen (personal communication) eudialyte is as soluble in water as marble.

- New Millennium Resources N.L., Australia holds an exploration licence (exclusive) that covers the area. The licence area covers 540 km² at Ilimmaasaq.

Locality 1. The charnockite on Uummannaq island (Rifkol).

Positive features about the charnockite on Uummannaq:

- There is no overburden.
- There is a good natural harbour.
- The exfoliation benches are pronounced and they are economic to quarry from.
- The logistics are relative good.

Negative features about the charnockite on Uummannaq.

- The Greenlandic whale hunters use the natural harbour for landing site for slanghtering whales.
- The colours and texture are not especially attractive for the market.

Locality 22. The pale pink granite on the cap 1,5 km east of Tiniteqilaaq.

Positive features about the pale pink granite.

- The granite is tacknically very sound.

- The exfoliation benches are pronounced and they are economic to quarry from.
- There is no overburden.
- The area is huge.
- There are other places nearby with sound granite.
- The logisitcs are good.

Negative features about the pale pink granite:

- Transport by ship is limited because of ice in the wintertime and the pack ice can cause trouble all year round.
- The granite type is already on the market and sold cheaply from China and other countries.

Evaluation of the less promising dimension stones

The less promising rocks for dimension stone based on field observations, the polished slabs and the evaluation by RGS 90, during this project are:

Locality 2. The Charnockite on Maniitsoq island.

Positive features about the charnockite on Maniitsoq:

- There is no overburden.
- The locality is near the shore.
- The dark greenish-brown colour and texture are attractive, according to RGS 90.

Negative features about the charnockite on Maniitsoq:

- The Charnockite is too fractured.
- The island is remote from local facilities.
- There is no natural harbour.

Locality 5-9. Grey rapakivi granite localities examined in South Greenland.

Positive features about the grey rapakivi granite in South Greenland:

- There is no overburden.
- The fracture-free rapakivi granite covers large areas.
- It is close to local facilities.
- All the localities are close to shore.

Negative features about the grey rapakivi granite.

- The biotite crystals are too coarse so it is impossible to make sharp corners on slabs.
- The colour and texture are too ordinary to be of market interest, according to RGS 90.
- The dimension stone market already has cheap similar products from China and Portugal.

Recommendation

The recommended next steps in prospecting for dimension stone in Greenland are: (1) Follow-up projects on the best types evaluated in this report and (2) Continued basic prospecting for dimension stones rocks in Greenland.

(1) The follow-up projects in the next season ought to bee concentrated in two areas: Nassuttooq (Nordre Strømfjord) and South Greenland.

Nassuttooq, because the flame-structured migmatite holds properties that qualified the rock type as a potential for dimension stone production according to RGS 90. In the Nassuttooq area the task will be to collect different kinds of the flame-structured migmatite especially the dark types, map the size of homogeneous and sound areas with black and red flame-structured migmatite. Because the industry are interested in this information's.

In South Greenland, at the Illiumausaq intrusion, there is a good potential for a unique type of dimension stone in the kakortokite, but the fracture-free areas have to be evaluated both at the head of Kangerdluarssuk and at the Tunulliarfik side.

RGS 90 is still interested in the red sandstone at Sillisit, but they want to see more samples with different colours from the deep red to pale red. This task will be easy to carry out in combination with the sampling and mapping of the kakortokite.

To improve the involvement from the industry a representative from the industry should be invited to Greenland to follow the next part of dimension stone project. The project will gain external evaluation and it will be easier to "sell " the idea of starting up a dimension stone industry after the industry have has their own man at the localities.

Further motivation of the industry has to be intensified by showing the polished dimension stone samples at conferences and by direct personal contact to potential dimension stone producers in the EU and Norway.

The dimension stones have to be tested for their physical and mechanical properties, but thisis expensive (c. 20.000 DKr for one total test set). It would be best if the initiatives to the tests are done by the industry, because it is their expertise and a way to show their commitment. It is definitely an advantage to have good test results to show to potential partners. According to A. Haumann, Technological Institute, Bygge og Anlæg the dimension stone products from the Nordic countries more often have better test results than South European stones, because nordic stones already has suffered and survived in a harsh climate.

(2) Continuation of basic prospecting for rocks with dimension stone qualities in Greenland is recommended, because of the present situation in the EU and USA. In both EU and USA the restrictions on mining are increasing, because of noise factors and local protests against expanding quarries and opening new ones. Also in developing countries the prices are going up because of changing labour politics. These factors make Greenland a more

and more interesting target area for the stone industry. But the industry will never know the possibilities in Greenland if the resources remain unknown.

The basic prospecting for rocks with dimension stone qualities in Greenland is recommended to be done in two steps:

1. The first step can be done by minor funding to follow the geological mapping and other geological exploration activities within areas were the logistics are relatively easy. By informing the geologists who are participating in activities in Greenland about what to look for in the field (massive blocks and colourful rocks), they should be able to point out interesting target areas for the next step in the basic prospecting.
2. Target areas can then be selected for an investigation like the present one.

Within the basic prospecting for dimension stones it will be a good idea to use the information from the Ujarassiorit, the mineral hunting competition in Greenland.

It is recommended that the knowen findings are shown on a web page together with description of the site and pictures of both the polished rock and the site.

West Greenland

Locality: 1, Uummannaq (Rifkol) (Appendix A map A)

Water depth: 5-7 m limit because of an underwater threshold outside the bay.
Sample GPS position: 67°57'468N 53°47'209W.

The target rock on Uummannaq is a post-tectonic charnockite on the central part of the island located by GEUS in 2001 (Kalvig et al. 2002) as a potential source for dimension stone. The Charnockite are white with black elongated spots including small red garnets. The white minerals are quartz and feldspar crystals of medium grain size. The black elongated spots consist of medium grain orthopyroxene crystals (Fig. 2).

The surface colour is reddish brown and the alteration depth is approximately 10 cm.
On larger surfaces the elongated black spots give an impression of a wavy pattern.
The elongated spots are strained in the approximate direction of 180°/23°.

Subhorizontal exfoliation fractures are pronounced in the area and they control the thickness of the benches. The exfoliation structure gives op to 2-meter high benches (Fig. 3).
The charnockite in this area is sound[1] and massive and is measured to cover an area of approximately 300-m x 1000m.

The spacing of the East-West going (90°-270°) vertical cracks are 2-25 meters and they are on the surface mainly controlled by the pronounced exfoliation structures (Fig. 3). Perpendiculars to the vertical fractures along the benches there are vertical cracks with spacing from 1-6 meters.

The topography in the area is relatively low and it will probably be a problem for traditional dimension stone mining, because the mine would soon bee under normal sea level (figure 3). To avoid this scenario we made a reconnaissance to the northern part of the island where the topography is high. In the northern part the charnockite is often very heterogeneous with a lot of inclusions, differences in mineral content and appearances. In a few small places in the northern part of the island the charnockite is homogeneous, massive and sound. But the overburden is enormous.

The sampling was made from the central part of the island and a ca. 150kg sample was brought out (Figs. 4, 5 and 6).

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[1] "Sound" means that the rock gives a characteristic clear resonance when you hammer on it.

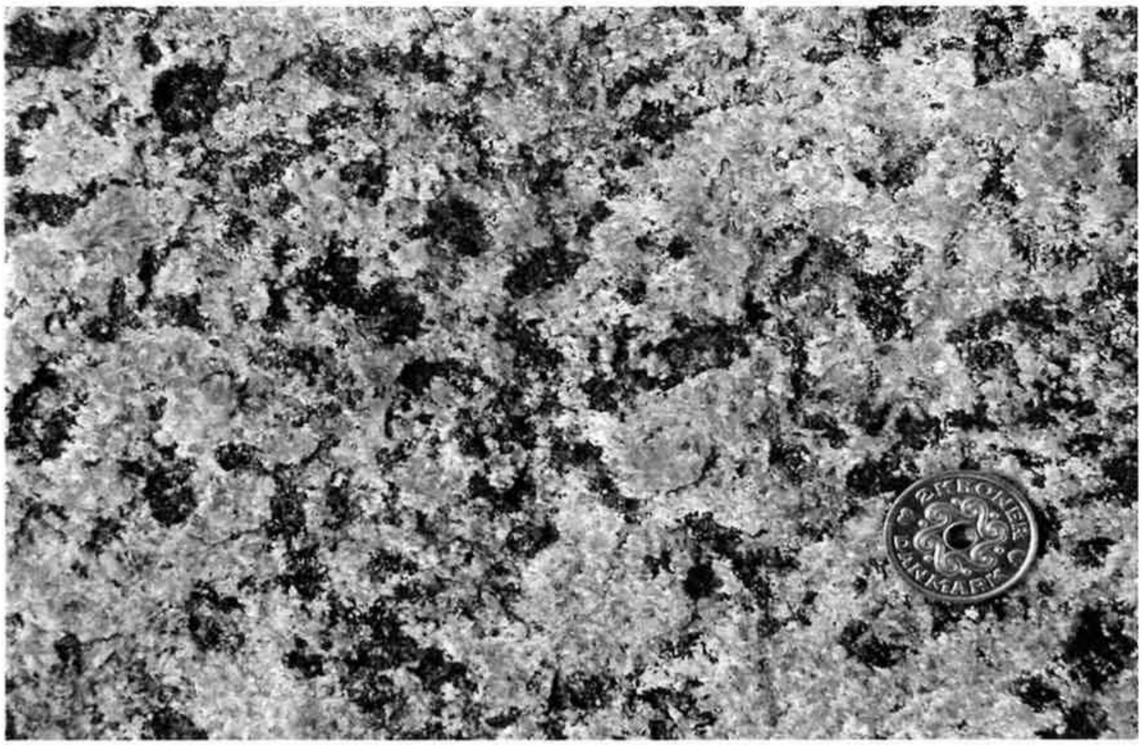

Figure 2. Close up of the charnockite on Uummannaq.

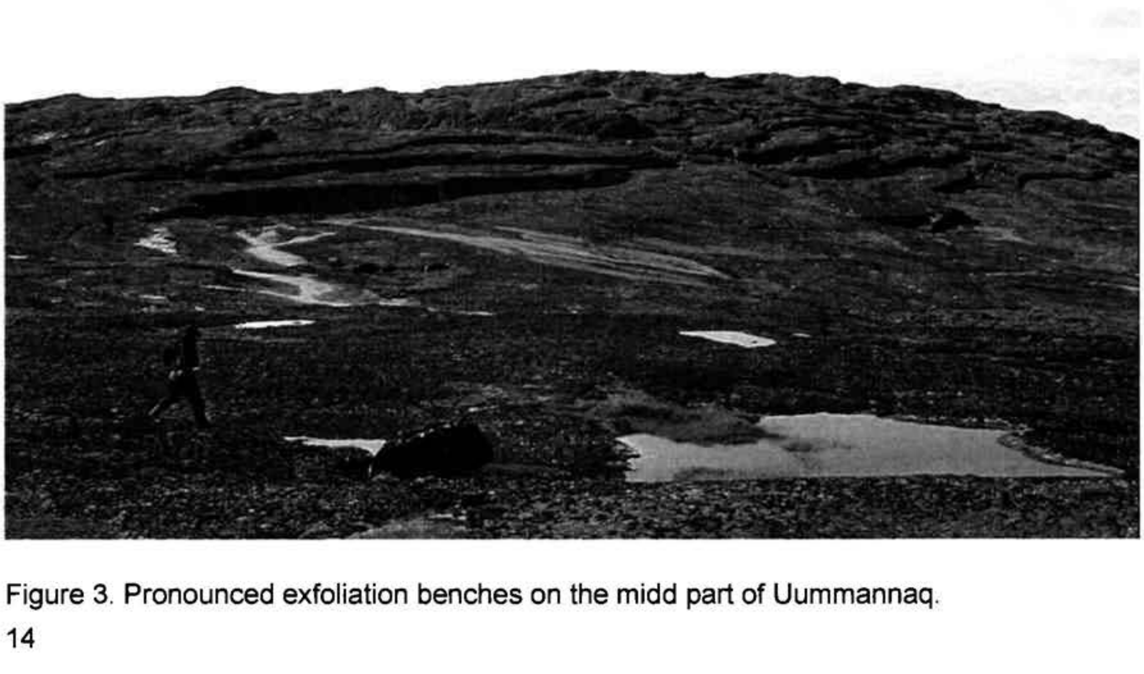

Figure 3. Pronounced exfoliation benches on the midd part of Uummannaq.

Figure 4. Sample site on Uummannaq after explosion.

Figure 5. The free primary block and the sampling site in the background.

Figure 6. Bringing the sample on board Søkongen.

The polished slab is fine and no fractures or cavities are observed on the surface. The colour is light brown with black spots and it has a homogeneous look (Fig. 7 next page).

Figure 7. Polished charnockite from Uummannaq. Width of foto: 20 cm.

On the way to Maniitsoq island we sailed near the shore of Uummannaq. First up to the northeastern part and then near the south and southwestern part to have a close look from the boat on the landing possibilities at other places. The conclusion is that the bay we anchored up in is the best natural harbour on the island (Appendix A map A).

Locality: 2, Maniitsoq island (Appendix A map A)

Water depth: 25 m, 30 m from land and the cliffs go steeply into the water.

Sample GPS position: 67°49'885N 53°49'719W.

The target rock on Maniitsoq island is a charnockite situated on the south side of the island located by GEUS in 2001 (Kalvig et al. 2002) as a potential source for dimension stone. The charnockite looks like augen gneiss with large rounded feldspar clasts surrounded by blueish quartz veins with minor small garnets (Fig. 8).

The surface colour is brownish-green (Fig. 9) and the alteration depth is approximately 40 cm.

The rock is "open"[1], at least near the surface for more than 1.5 m.

The entire island consists of this charnockite but the most massive parts are restricted to local areas divided by brittle faults. The fault directions are 80°/90° and 10°/90°. The local more massive areas are 100 x 100 m with fracture density of 5-7 m. The fracture directions in the more massive areas are sub parallel to the direction of the dominating faults.

It is very difficult to find a suitable place to take a good sample (Figs. 10 and 11), because of minute fractures which are not visibly before the sample actually breaks up.

[1] "Open" means that the rock has a lot of small fractures often in same direction internally in the minerals. This means that the rock is not sound.

Figure 8. The Charnockite with large rounded feldspar clasts surrounded by blueish quartz veins.

Figure 9. The surface colour is brownish-green and the free blocks are large but they are fractured by minute cracks.

Figure 10. Sampling site on Maniitsoq.

Figure 11. The primary block breaks along minute fractures.

The polished slab of the charnockite from Maniitsoq Island shows that there are too many fractures in the rock for making dimension stone of it (Fig. 12 next page).

Figure 12. Polished charnockite from Maniitsoq Island. On the polished surface it is clear that there are too many fractures for dimension stone production. Width of foto: 20 cm.

Locality: 4, Seersinnilik in Nassuttooq (Nordre Strømfjord) (Appendix A map A)

Water depth: 3-meter at high tide limit, because of an underwater threshold outside the bay.

Sample GPS position: 67°37'340N 51°47'257W.

The target rock is situated on the south side of Nassuttooq in the small bay Seersinnilik (Appendix A map A) located by GEUS in 2001 (Kalvig et al. 2002) as a potential source for dimension stone (Figs. 12 and 13).

The rock is a flame-structured medium to corse-grained red, black and white migmatite. The minerals in the flame-structured migmatite are quartz, alkali feldspar, plagioclase and amphibole (Figs. 13, 14, 15 and 16).

The flame-structured migmatite is exposed from the eastern cape of the bay to the opposite side of the river at the shoreline. 50 m inland to the south along the river, there is a small outcrop of massive, homogeneously pale red granite. Further to the south along the river the lithology changes to more migmatitic and partly banded and flame structured migmatite. In some places the migmatisation is so coarse that patches of black, white and red minerals are too big (200 cm x 200 cm) for dimension stone.

The dominant vertical fracture direction is parallel to the river valley (320°) and perpendicular to the valley (50°). 3 km to the south along the river valley exfoliation structures, that indicate a sound and massive rock, is observed.

The general fracture density is 3-6 meters, locally less or more.

Next to the river valley there is 1-3 meters of sedimentary overburden.

The sample collection is done near the shoreline from the flame structured migmatite.

Because of the underwater threshold outside the bay we made a small exploration for alternative landing sites where machinery can be landed. There are a number of places near the bay and the topography is flat along the coast.

On the way out of the fjord we saw several localities with exfoliation structures on the south side of the fjord in the Archean migmatite terrain. This indicates that there are very good possibilities for other places of interest for dimension stone prospecting.

RGS 90 is very interested in this kind of dimension stone, because the price on the market is high and there is only one place in the Nordic countries were it is in production. The industrial name is Halmstad granite and it is produced in Sweden. The price for the Halmstad granite is 10.000 – 12.000 Dkk per m^3.

Figure 12. The stream close to the sampling site at Seersinnilik. The stream has exposed the surface of the flame-structured migmatite.

Figure 13. The sampling site at Seersinnilik near the shore.

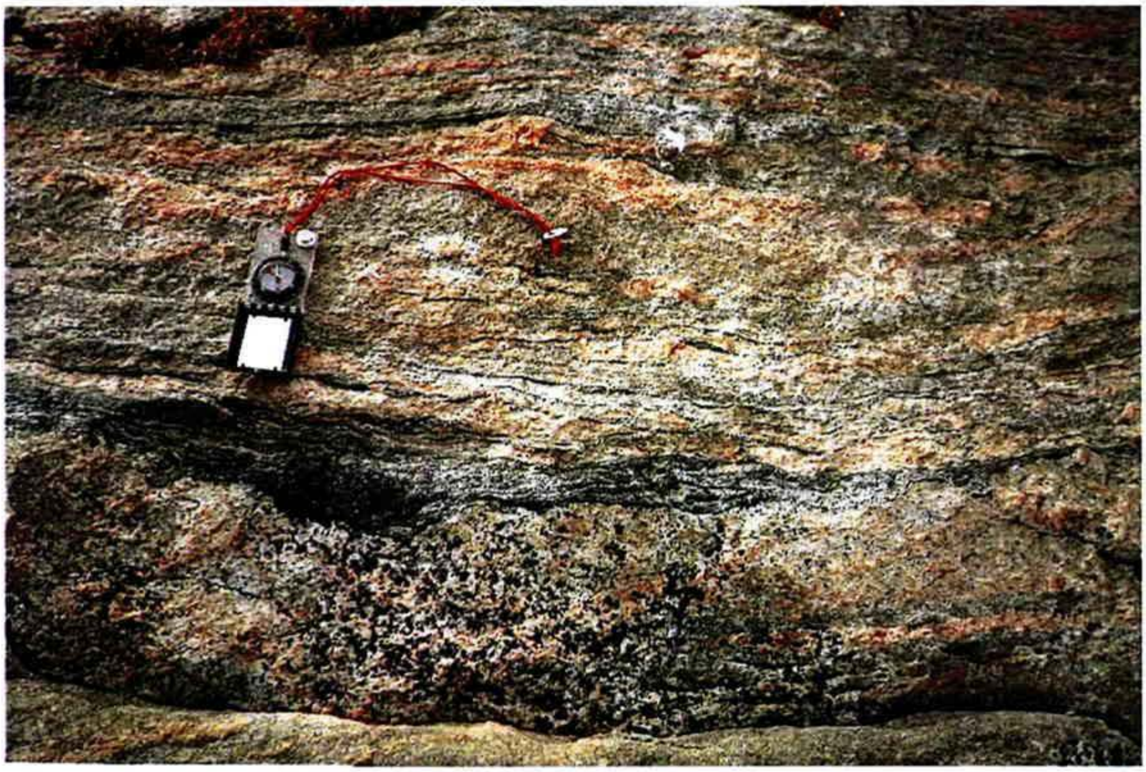

Figure 14. The flame-structured migmatite at Seersinnilik.

Figure 15. The flame-structured migmatite at Seersinnilik.

Figure 16. The flame-structured migmatite at Seersinnilik with a fresh sample next to the pencil.

The polished slab of the flame-structured migmatite is next to perfect (Fig. 17 next page). The colour is a little too light for the market, but the structure is a valuable feature. In the area there are a lot of varieties that are darker and redder.

Figure 17. Polished flame-structured migmatite from Seersinnilik. Width of foto: 20 cm.

South Greenland

Locality: 5, Annikitsoq (east of Morujunnguaq) (Appendix A map C)

The first target area in South Greenland is a locality in the bay east of Morujunnguaq on Annikitsoq (Fig. 18) recommended by Gothenborg et al. (1994).

The bedrock in the area is a grey coarse-grained post-tectonic rapakivi granite with cm sized biotite crystals. With a quick reconnaissance we concluded that the locality was too broken up in two directions.

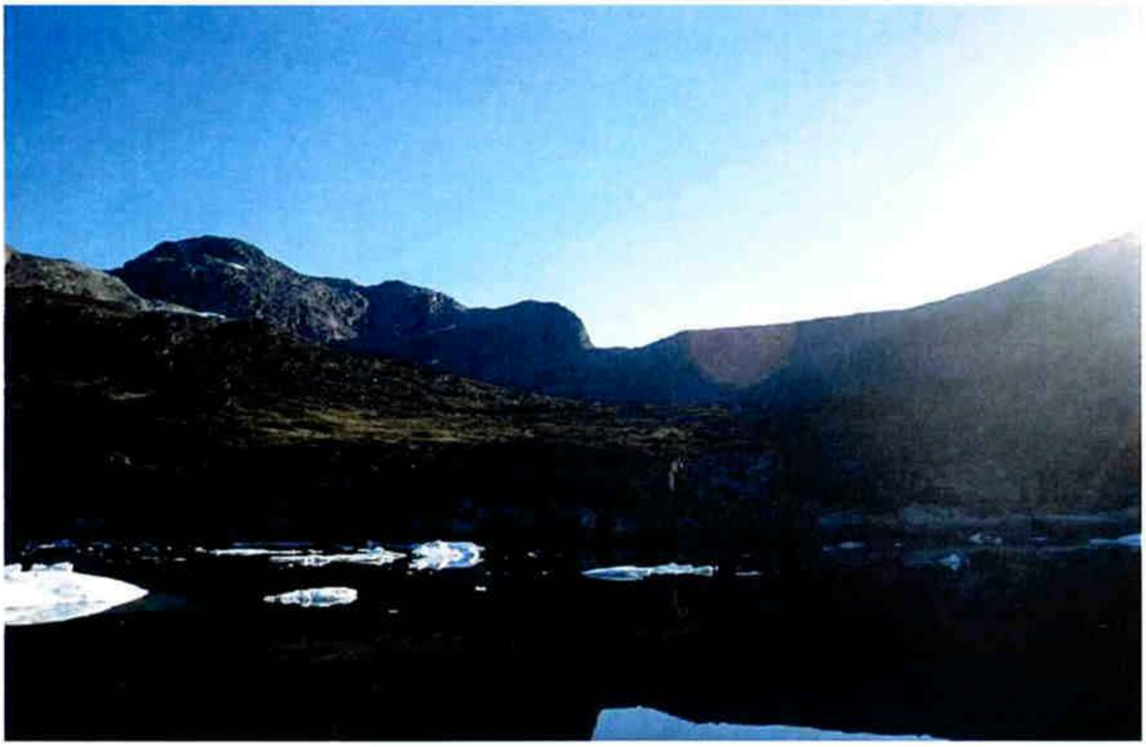

Figure 18. The locality at the bay east of Morujunnguaq on Annikitsoq.

Locality: 6, Annikitsoq (Qasigissat Nuua)

Sample GPS position: 60°03'742N 44°06'283W.

Water depth: 17 m, 5 m from the coast.

The next locality is also recommended by Gothenborg et al. (1994).

The place is located on the opposite side of Annikitsoq at Qasigissat Nuua (Figs. 19 and 20). The granite here is a grey massive homogeneously coarse-grained biotite-rich rapakivi granite with feldspar crystals up to 7 cm in size, both with and without rapakivi texture. The vertical fracture density is 5 – 7 m orientated 140° and 50°. The rapakivi granite is open with a close pattern of microfractures. The surface colour is light greenish brown and the alteration colour of the feldspar is pink and green. The alteration depth is c 40 cm.

2 samples were prepared with explosives and chisel. The biggest sample was left on the locality for later pickup by helicopter (Fig. 20). We brought the smaller sample with us as a backup if the helicopter transport failed.

It turned out that the backup sample was a good idea, because the helicopter pickup was delayed until late November. So the smaller sample has been used for the preparation of the polished slab (Fig 21).

Figure 19. Preparation of the "small" backup sample at Qasigissat Nuua.

Figure 20. The big sample at Qasigissat Nuua prepared for helicopter sling.

From the surface of the polished slab of the grey rapakivi granite it is clear that there are too many fractures and the biotite crystals are too big for dimension stone production. Another negative feature seen on the polished surface is the brown spots that originate from the decay of radioactive elements (Fig. 21).

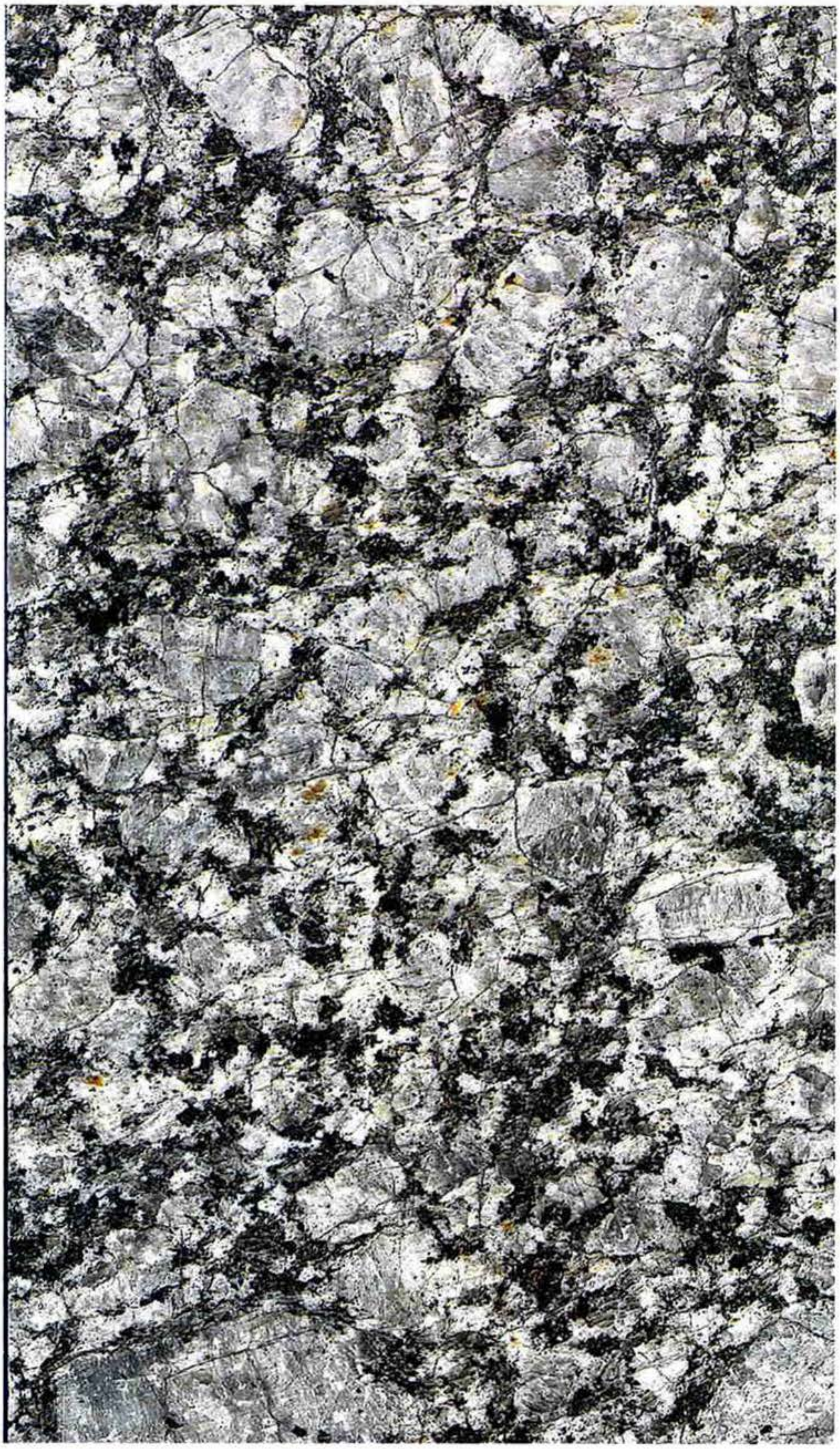

Figure 21. Polished slab of the grey rapakivi granite, fractures and brown spots are pronounced. Width of foto: 15 cm.

Localitet: 7, Annikitsoq (Morujunnguaq) (Appendix A map C).

Sample GPS position: 60°06.638"N 44°15.194"W.

Water depth: 17 meter outside the bay at the cap and there is 4 meter in the bay.

The bedrock at Morujunnguaq is the same biotit rich grey rapakivi granite as at Qasigissat Nuua. The only difference is that the vertical fracture density is between 6-20 m in the direction 286°N and 4-10 m in the direction 10°N. There are pronounced exfoliation structures with 2.5 m high benches. The rapakivi granite is very well exposed and the topography makes the area easy accessible (Fig. 22).

The locality at Morujunnguaq is the best place for mining the grey rapakivi, both because of the quality of the rapakivi granite and proximity to Aappilattoq.

Figure 22. The rapakivi granite is very well exposed and the fracture density is low at Morujúngnaq.

Locality: 8, Tasiusaq (Appendix A map C)

GPS position: 60°11'709N 44°48'779W.

The rapakivi granite is the same grey type as the other places, but with a significant amount of xenolites. The exposure in the area is too low to give an appropriate estimate of the fracture density, but some exposures have 4x5 m surfaces free of fractures (Fig. 23).

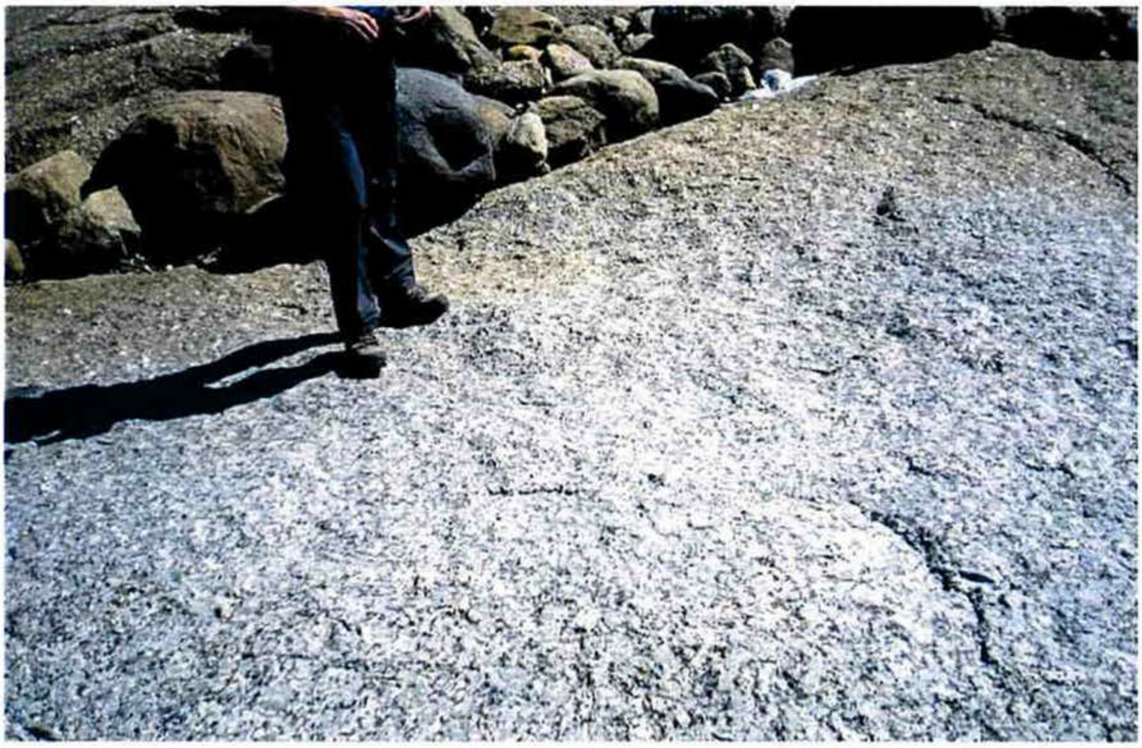

Figure 23. One of the rare small exposures at Tasiusaq.

Locality: 9, Qunnermiut (Appendix A map C)

Sampel GPS position: 60°26'150N 45°14'943W.

The grey rapakivi granite is like the other places, but with significant lager biotite (1-3 cm) crystals and the alteration depth is 50 cm or more. It is very difficult to collect a fresh sample (Fig. 24). In all outcrops there is observed xenolites from centimetres to metres in size were observed.

The locality is totally unqualified for dimension stone production.

Figure 24. The rapakivi granite at Qunnermiut is very weathered.

Locality: 10, Illorpaat (Appendix A map C)

Sample GPS position: 60°28'060N 45°21'186W.

The rapakivi granite on the locality is of the same quality as at Qunnermiut and is totally unqualified for dimension stone production.

Locality: 16, Killavaat Alannguat (Kringlerne) (Augite syenite) (Appendix A map B)

The syenite that borders the Julianehåb batholith is not suitable for dimension stone production because of the high fracture density (max 2x3-m surfaces without fractures) and the coarse grain size (Fig. 25).

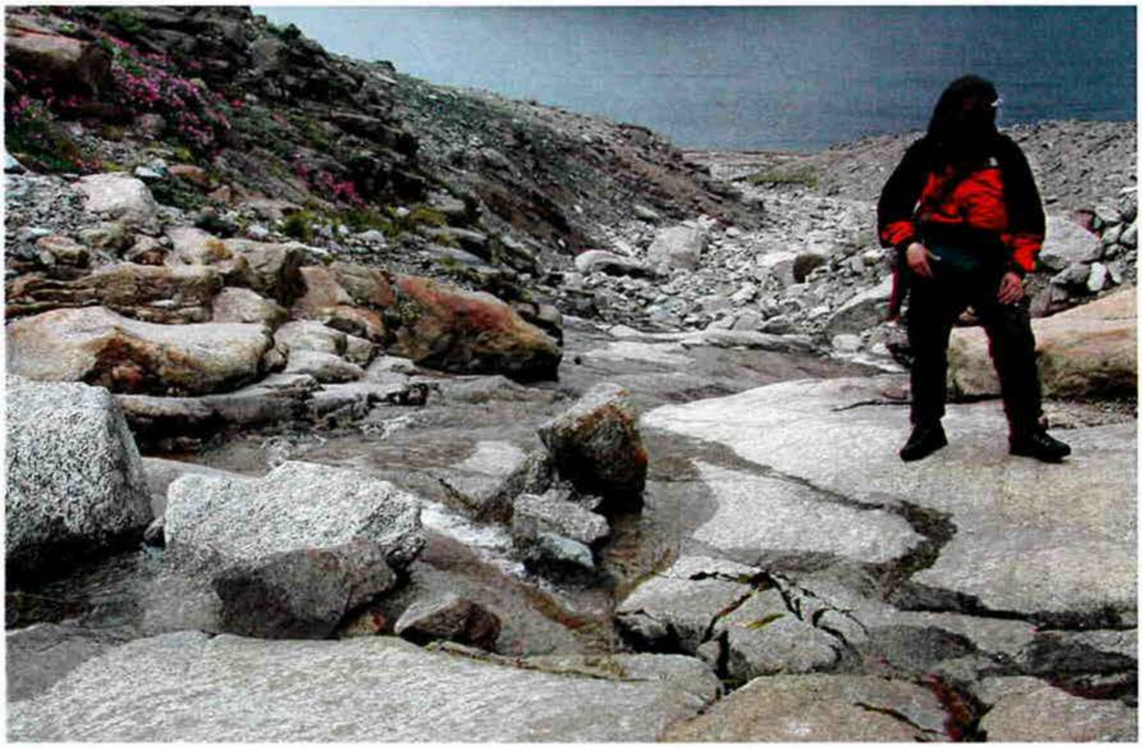

Figure 25. The syenite that borders the Julianehåb batholith.

Locality: 17, Killavaat Alannguat (kakortokite)

Sample GPS position: 60°52'108N 45°52'023W (dark type).
Sample GPS position: 60°52'061N 45°52'295W (light type).

The medium grained kakortokite is in places massive homogeneous and sound. Exfoliating structures produce 2 m high benches and the fracture density is 4-6 m, making up 6x4x2 m blocks with right angles (Fig. 26). There are two types of the medium grained kakortokite: a dark and a light, both types are sampled. The colour of the kakortokite is a mixture of red, black and blueish-white, were the light type has a smaller content of dark minerals. The pronounced colours are an advantage for a possibly dimension stone mine. The dark minerals are aegirine and arfvedsonite; the red mineral is eudialyte, the bluish-grey mineral is nephline and the white laths are feldspars. There are several other exotic minerals in the kakortokit not mentioned here. The radioactivity from kakortokite is not higher than from normal granite. The Uranium content is 20.6 ppm and the thorium content is 59,4 ppm in the red part (eudialyte) of the kakortokite, whereas a typical alkali granite has 44.1 ppm U and 123 ppm Th (Bailey et al. 2001).

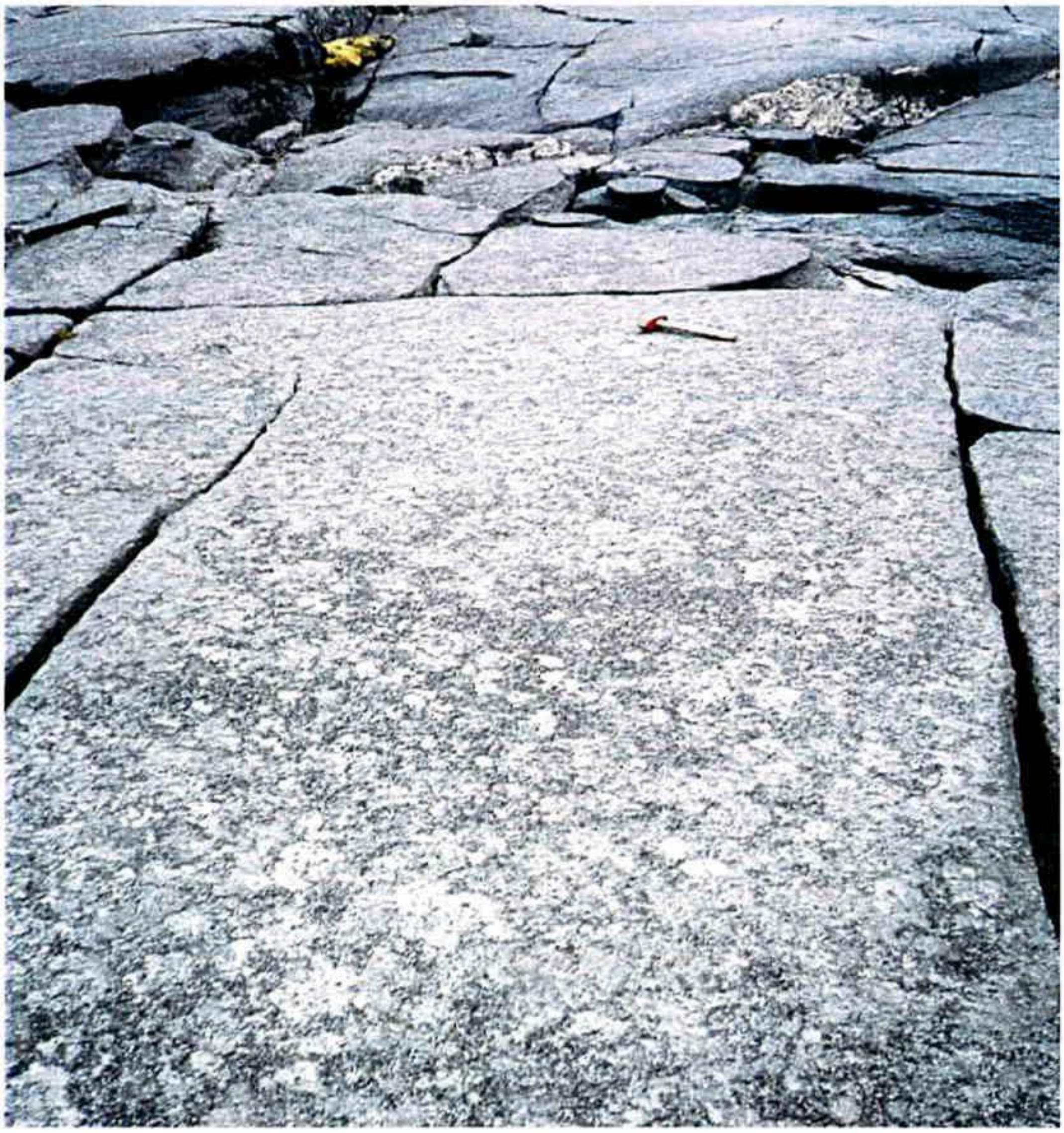

Figure 26. The medium grained dark kakortokite in large blocks with right angles.

The polished slab of the dark kakortokite is without errors and so far it is suitable for dimension stone production. The dark colour and the homogeneous look are an advantage for the market (Fig. 27).

The polished slab of the light kakortokite has some minor cavities on the polished surface and these features can lower the value of the stone (Fig 28).

Figure 27. Polished dark kakortokite. Width of foto: 15,5 cm.

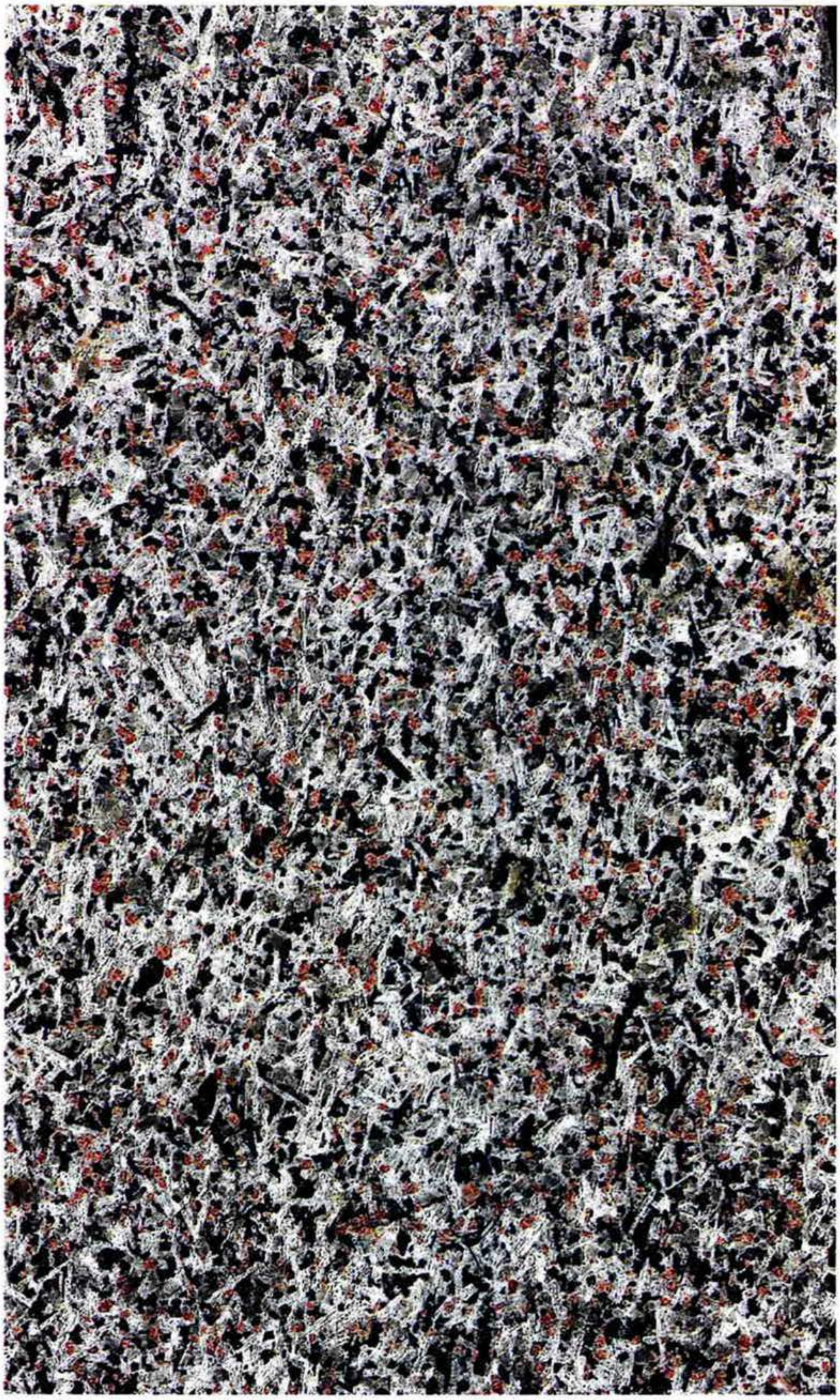

Figure 28. Polished light kakortokite. Width of foto: 15,5 cm.

Locality: 18, Mouth of Kangerluarsuk (naujaite) (Appendix A map B)

GPS position: 60°53'453N 45°50'920W.

The naujaite is coarse-grained and the minerals are mostly in red, black and white clusters (Fig. 29). The surface is very weathered and it was impossible to collect a big sample. On the surface the naujaite looks sound, but it is very open and breaks easily.

Figure 29. The coarse-grained naujaite with red, black and white minerals in clusters.

Locality: 19, Mouth of Kangerluarsuk (lujavrite).

Sample GPS position: 60°53,235N 45°50'276W.

The lujavrite is a dark green with black spots medium grained rock (Fig. 30). The rock is massive and the fracture density is in places 2-6 meters, but a cover of boulders made a fracture density estimate very difficult.

According to Bailey et al. 2001 the lujavrite is radioactive and this feature disqualified the rock as a possible dimension stone.

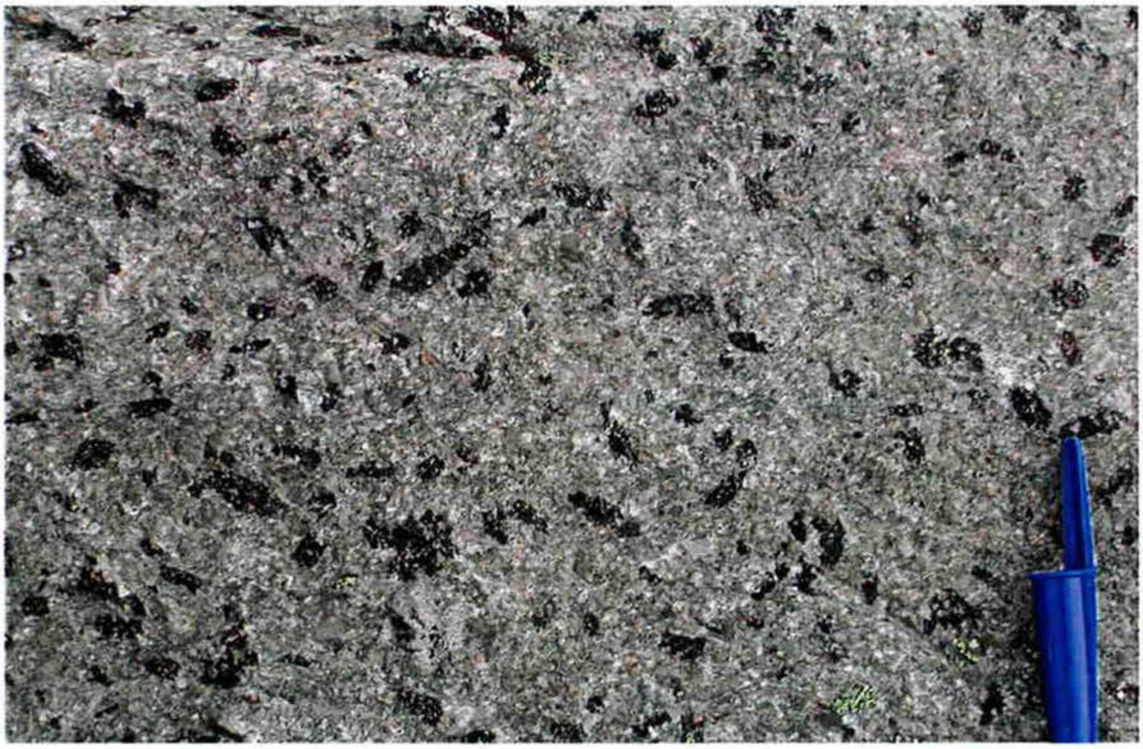

Figure 30. The dark green medium grained lujavrite with black spots.

Locality: 20, 15 km Southwest of Sillisit (Appendix A map B)

GPS position 61°03'583N 45°32'707N.

The target rock is the sandstone in Eriksfjord Formation.

The red sandstone at this position looked sound from the distance (Fig. 31) but at closer observation showed that it is very fractured and the layer of red sandstone disappears under 0.5 km overburden of flood basalts and conglomerates.

Figure 31. Large overburden and too high fracture density in the Eriksfjord Formation.

Locality: 21, Sillisit (Fig. 41 and Appendix A map B) (Fig. 32)

Sample GPS position 61°03.288N 45°32.901W (Sandstone with reductions spots).
Sample GPS position 61°03.947N 45°32.496W (Deep red with structures).

The name Sillisit means whetstone in greenlandic.

The locality at Sillisit is also recommended by Gothenborg et al. (1994).

The access to the red sandstone (called Igaliko sandstone) at Sillisit is good because there is a network of local roads in the area (Fig. 33).

The red sandstone is well known for its pale reduction spots (Fig. 34), but these are only fund at one locality and are related to the dyke that cuts the sandstone. At other localities were the red sandstone is cut by dykes the sandstone is totally white at the dyke margins (Fig. 35).

The colour varies from light red to deep red and there are sedimentary structures in all the observed localities (Fig. 36). In some outcrops near the shore dark spots are evenly distributed in the red sandstone.

The sandstone forms beds that dip 5-15° to the west. In between the sandstone beds are beds of conglomerate (figure 37) and flood basalt layers.

The fracture densities limit the block size to a maximum of 1x1x0,4m. The thickness of the individual sandstone beds controlled by sedimentation varies from 1 – 40 cm (Fig. 38) with dense vertical fractures.

The dip of the beds limits the amount of free material, because the overburden increases quickly if the mining direction is in the dip direction.

The best type of sandstone in the area is found 1,5 km northwest of the farmhouses, and this sandstone is deep red with sedimentary structures (Fig. 39).

Figure 32. Sillisit with JH Johnstrup as a small red spot. The locality with the reduction spots is the red outcrop to the left at the coast.

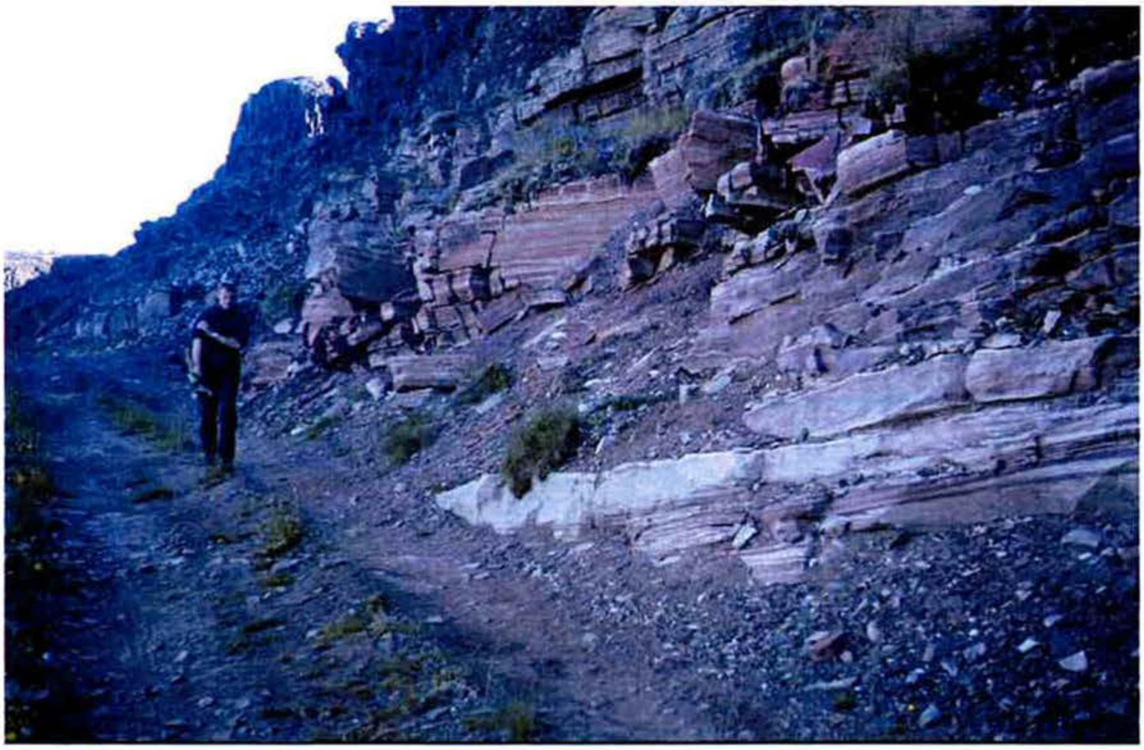

Figure 33. A local road along a profile with red and pale-red sandstone in the Sillisit area.

Figure 34. The locality with the white reduction spots in the red sandstone in the Sillisit area.

Figure 35. Dyke that cuts the red sandstone with pronounced contact reduction of the sandstone in the Sillisit area.

Figure 36. Deep red sandstone with sedimentary structures in the Sillisit area.

Figure 37. Conglomerate layer in the Sillisit area.

Figure 38. Red sandstone near the coast. The sedimentary beds control the subhorizontal cleavages.

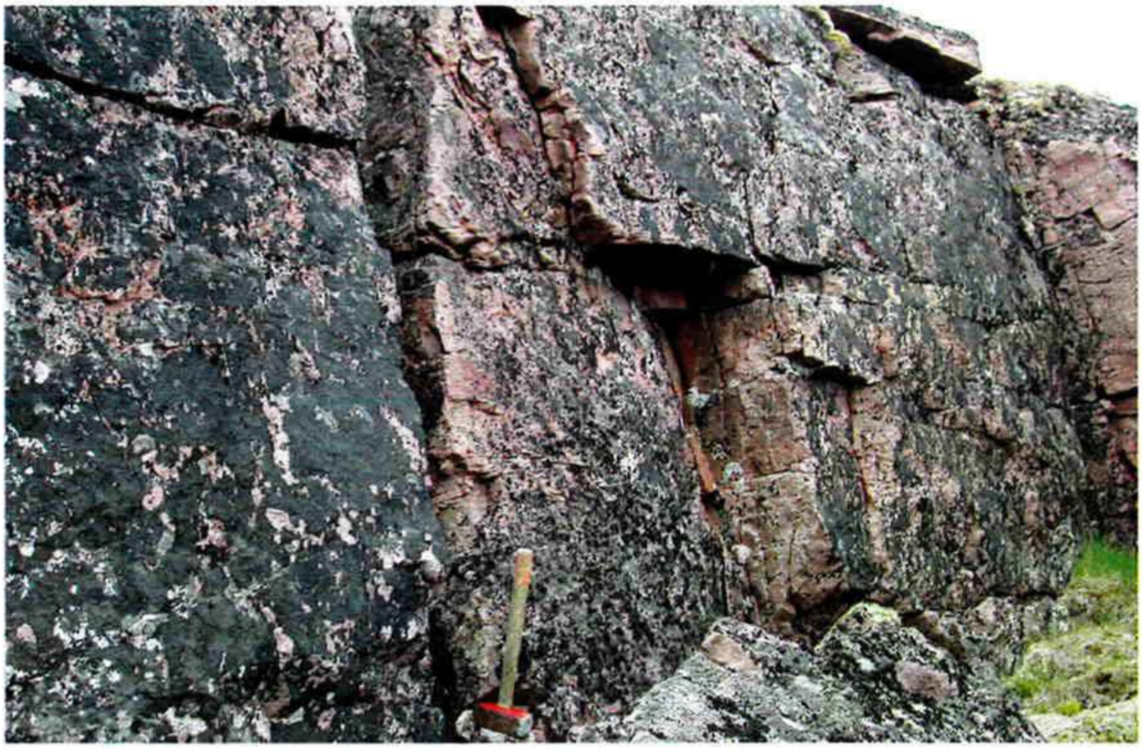

Figure 39. Deep red sandstone in the Sillisit area with sedimentary texture in relative large blocks 1,5 km from the coast.

The polished slab from the red sandstone has too many fractures for dimension stone production (Fig.40). Beds or blocks with fewer fractures are difficult to find, because the space between fractures is often smaller than 30 cm and hidden in the bed or block. However, there are blocks without fractures, like the polished slab of the red sandstone with reduction spots (Fig. 41). Both samples were collected with the same method and no fractures were observed in either of two blocks. Note the pretty sedimentary structures in Fig. 40.

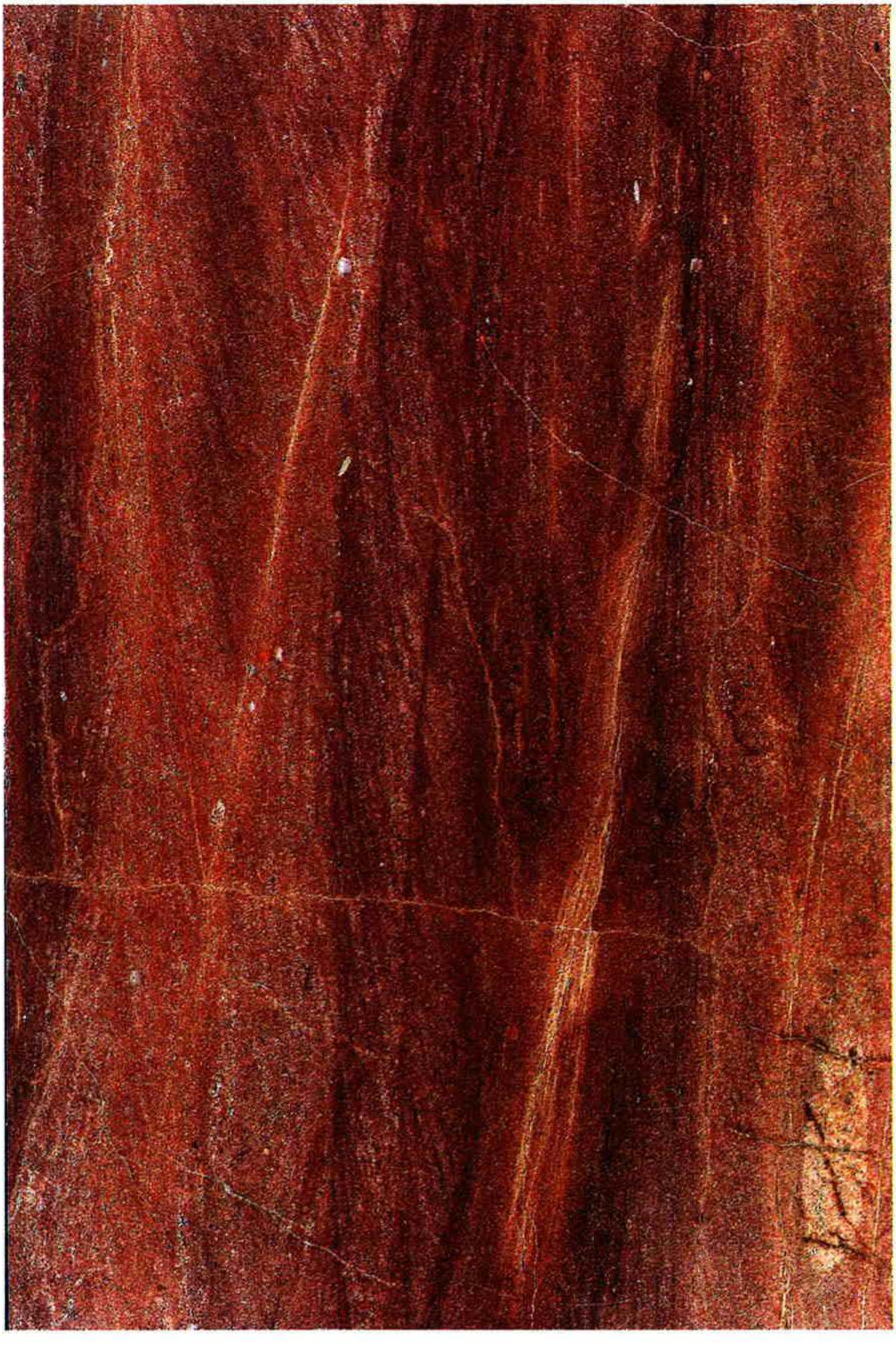

Figure 40. Red sandstone from Sillisit. There are many fractures in this particular slap but there are beds or blocks with less fracture density (Fig. 41). Width of foto: 20 cm.

Figure 41. Polished slab of the red sandstone with pale reduction spots from Sillisit. No fractures are observed on the polished surface. Width of foto: 20 cm.

Some of the dykes in the area are reddish with randomly distributed 0.5 – 1 cm large, white plagioclase phenocrysts in a fine-grained matrix (Fig. 42). The dykes that cut the sandstone are commonly 3 – 5 m wide and vertical. The fracture density in some of the dykes is low and they are very sound. It can be impossible to distinguish the dykes from the red sandstone even from a close distance, because of the similar colour.

Figure 42. Dyke with white plagioclas phenocrysts.

East Greenland

Locality: 22, 1,5 km east of Tiniteqilaaq.

Sample GPS position: 65°52'747N 37°43'425W.

Water depth: 7 m, 20 m from the shore. The cliffs dip steeply into the water.

The target area is the cape 1,5 km east of Tiniteqilaaq (Fig. 43).

The rock type at the cape is pale pink medium-grained, massive, homogeneous, sound, biotite alkali feldspar granite.

The dominating fractures follow the orientation of the massive benches around the cape. These fractures are interpreted as controlled by exfoliation and major fault systems.

Vertical fractures that cut the granite are observed at several places, but they are spaced with more than 4m (Figs 44 and 45), and the main direction is in between 45° and 52°.

The pronounced exfoliation structures show benches up to 6m high, and fracture-free surfaces in the area are up to 60x60 m^2 (Figs. 44 and 45). The horizontal fractures are totally dominated by the exfoliation in the area and the spacing between the horizontal fractures varies from 1 m at the top of the cape (50 m) to 6.5 m at sea level (Fig. 46).

The total area with the sound pale pink granite is very large and continues to the east for more than 2 km. To the south the sound granite continues about 1 km to the other side of the bay. The sound pale pink granite continues also to the north, but it is cut by a major fault 500 m from the sampling site (Fig. 47).

The polished slab of the pale red granite is homogeneous, free of sulphide minerals and sound (Fig. 48).

Figure 43. The cape 1,5 km east of Tiniteqilaaq.

Figure 44. The fracture density is generaly more than 4 m (Kalvig et al. 2002).

Figure 45. Fracture-free surfaces with pronounced exfoliation structures (Kalvig et al. 2002).

Figure 46. High benches near the shore (Kalvig et al. 2002).

Figure 47. The sampling site near the cape 1,5 km east of Tiniteqilaaq.

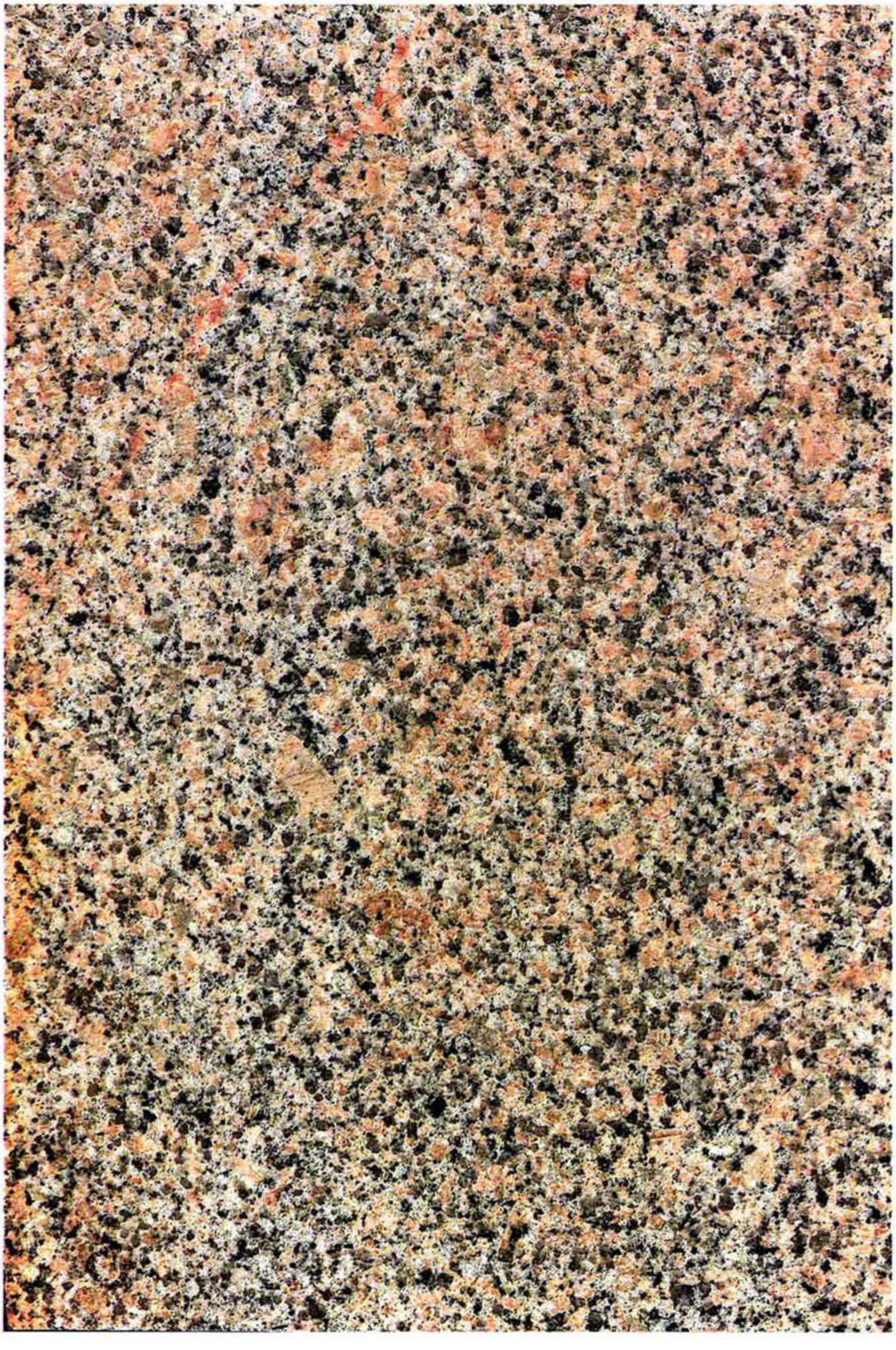

Figure 48. Polished pale red granite from the cape 1,5 km east of Tiniteqilaaq. Width of foto: 20 cm.

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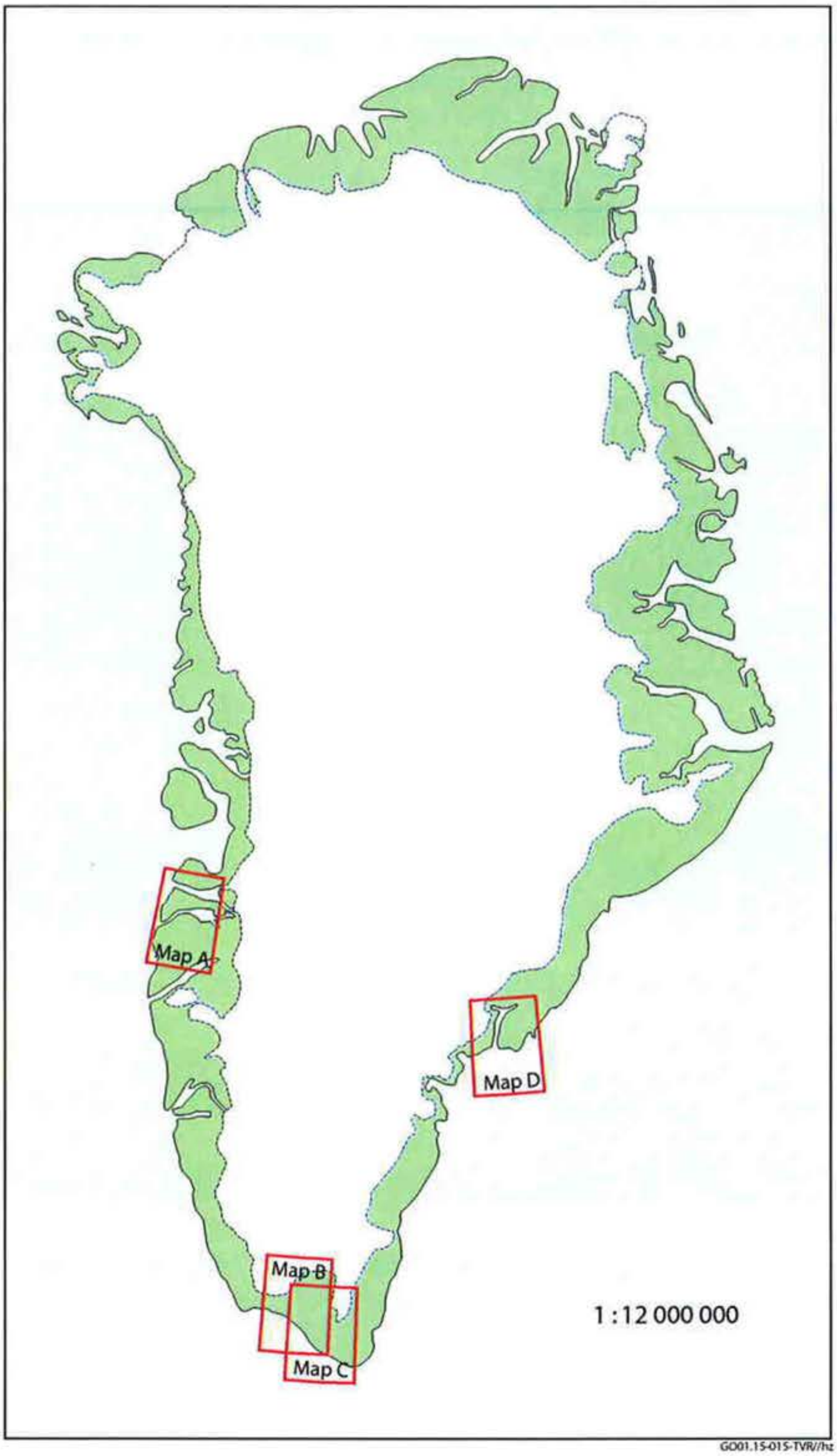
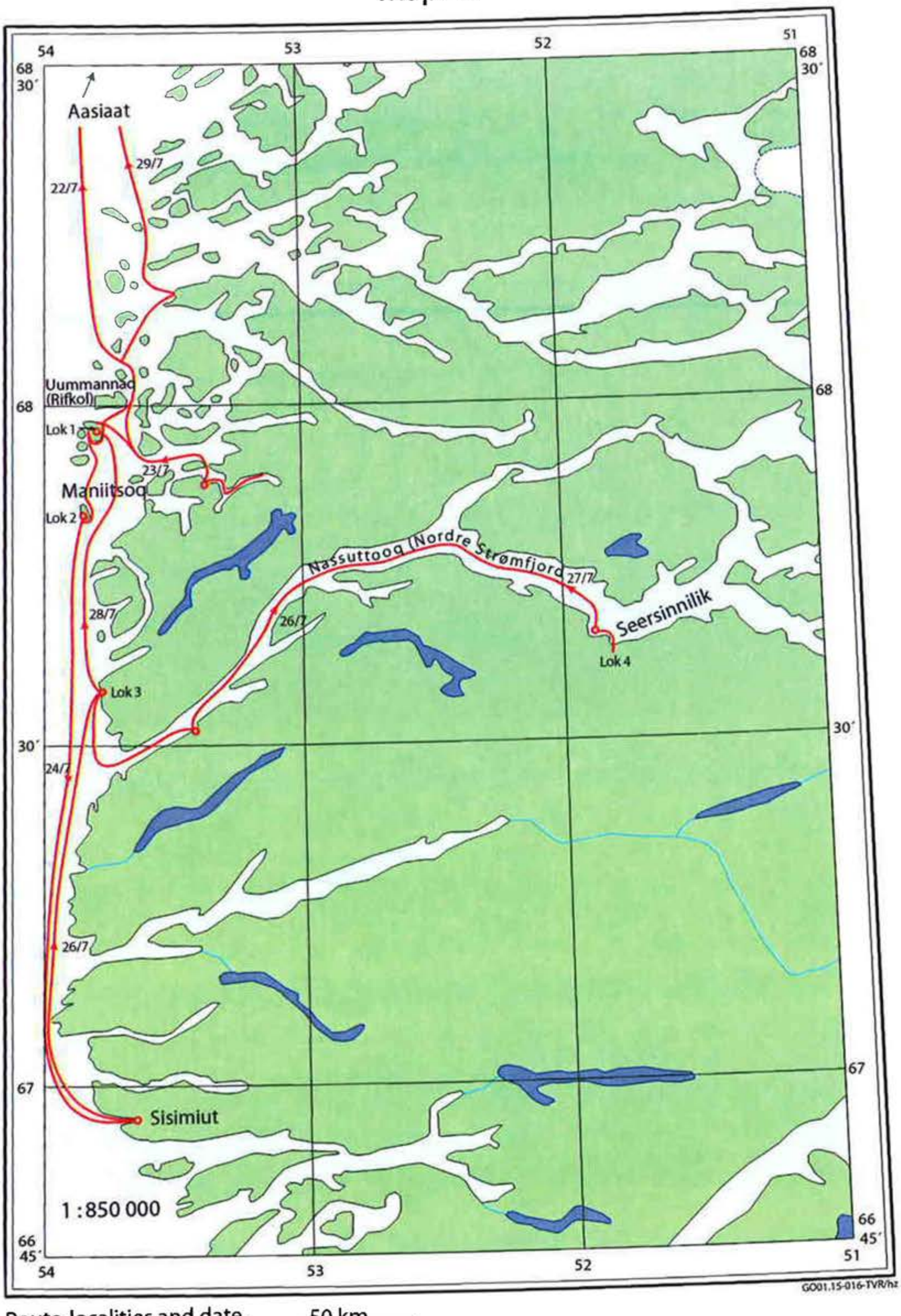
Appendix A. Index map of Greenland and local maps A - D

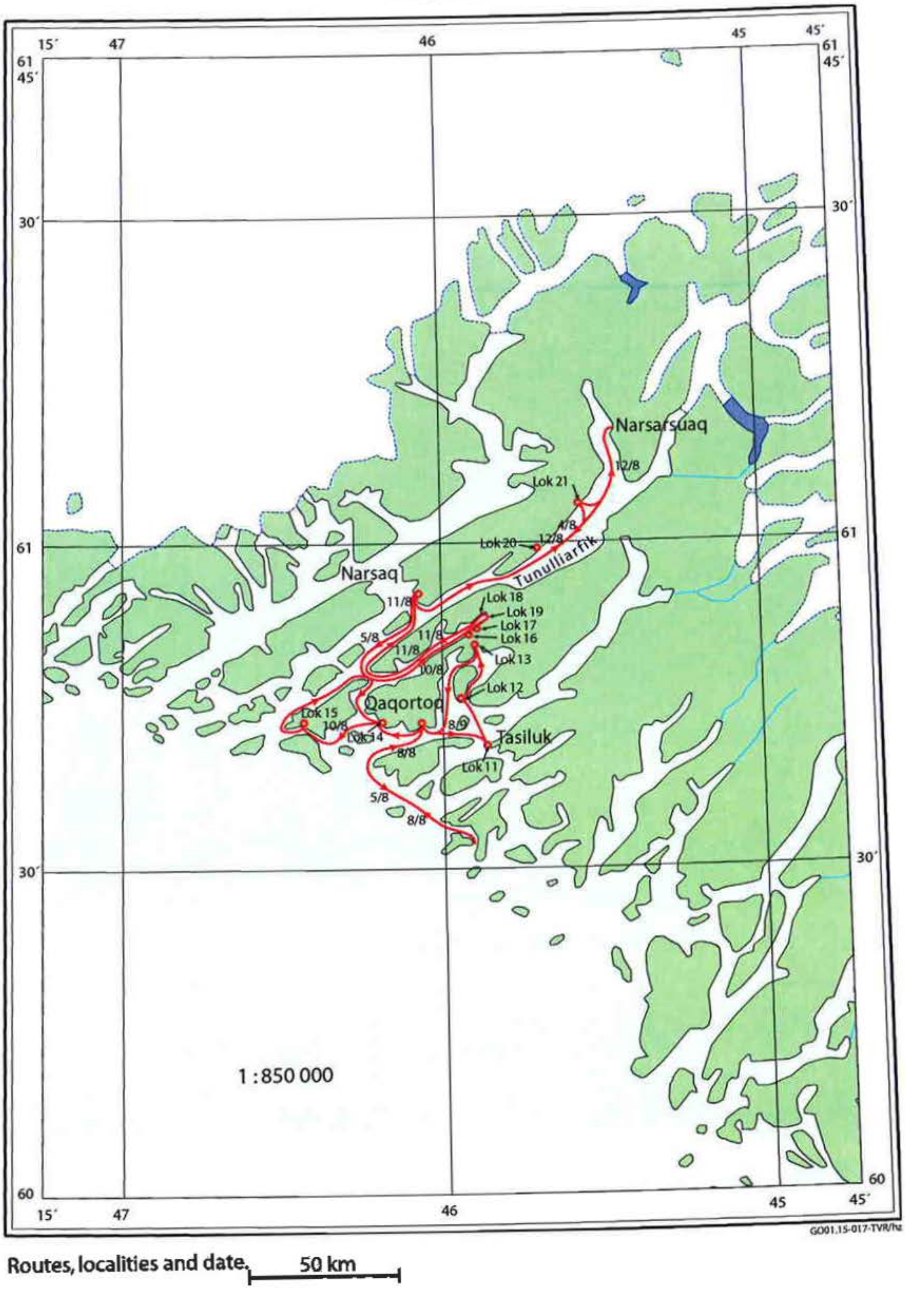


Map. A



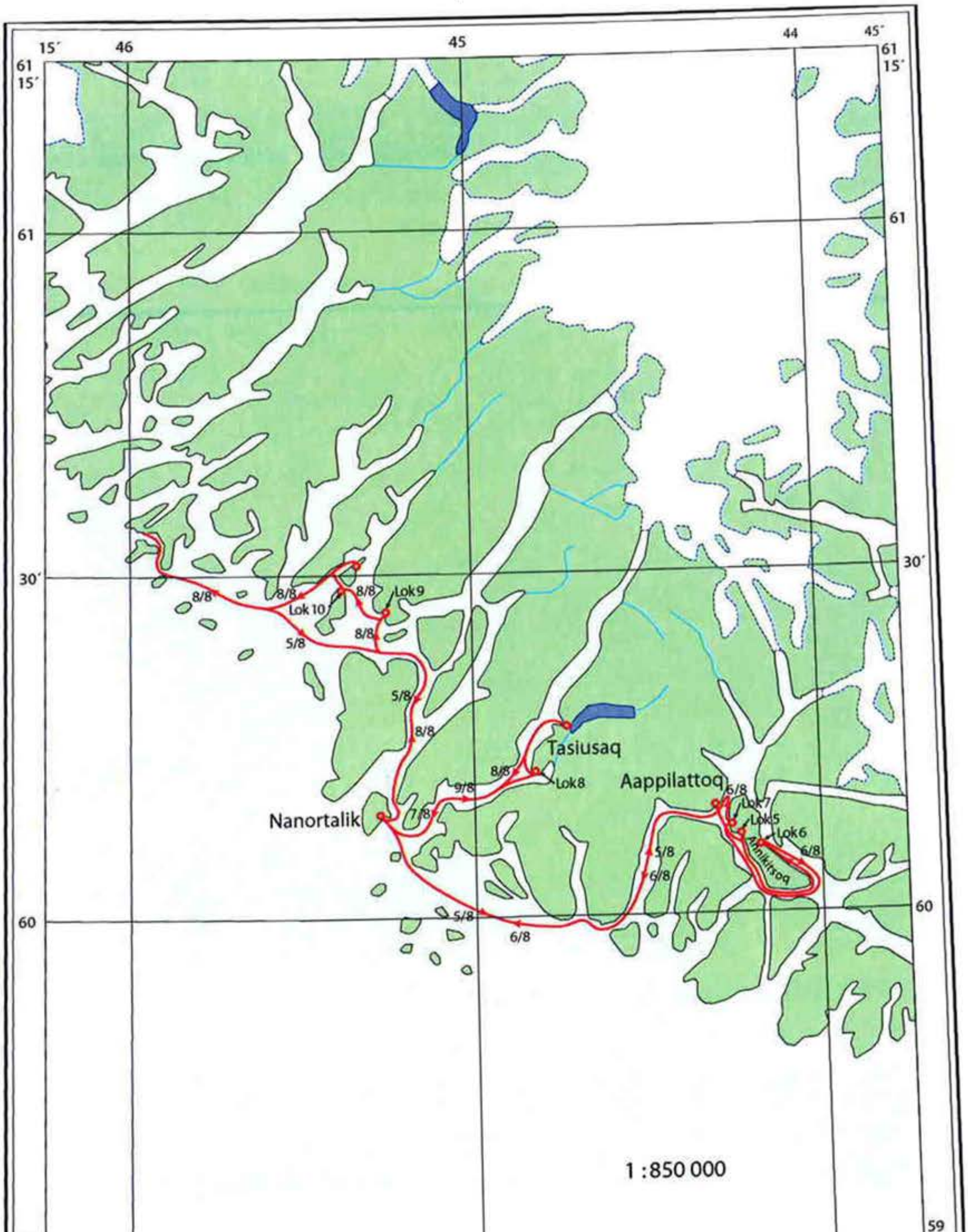
Route, localities and date. 50 km

Map. B



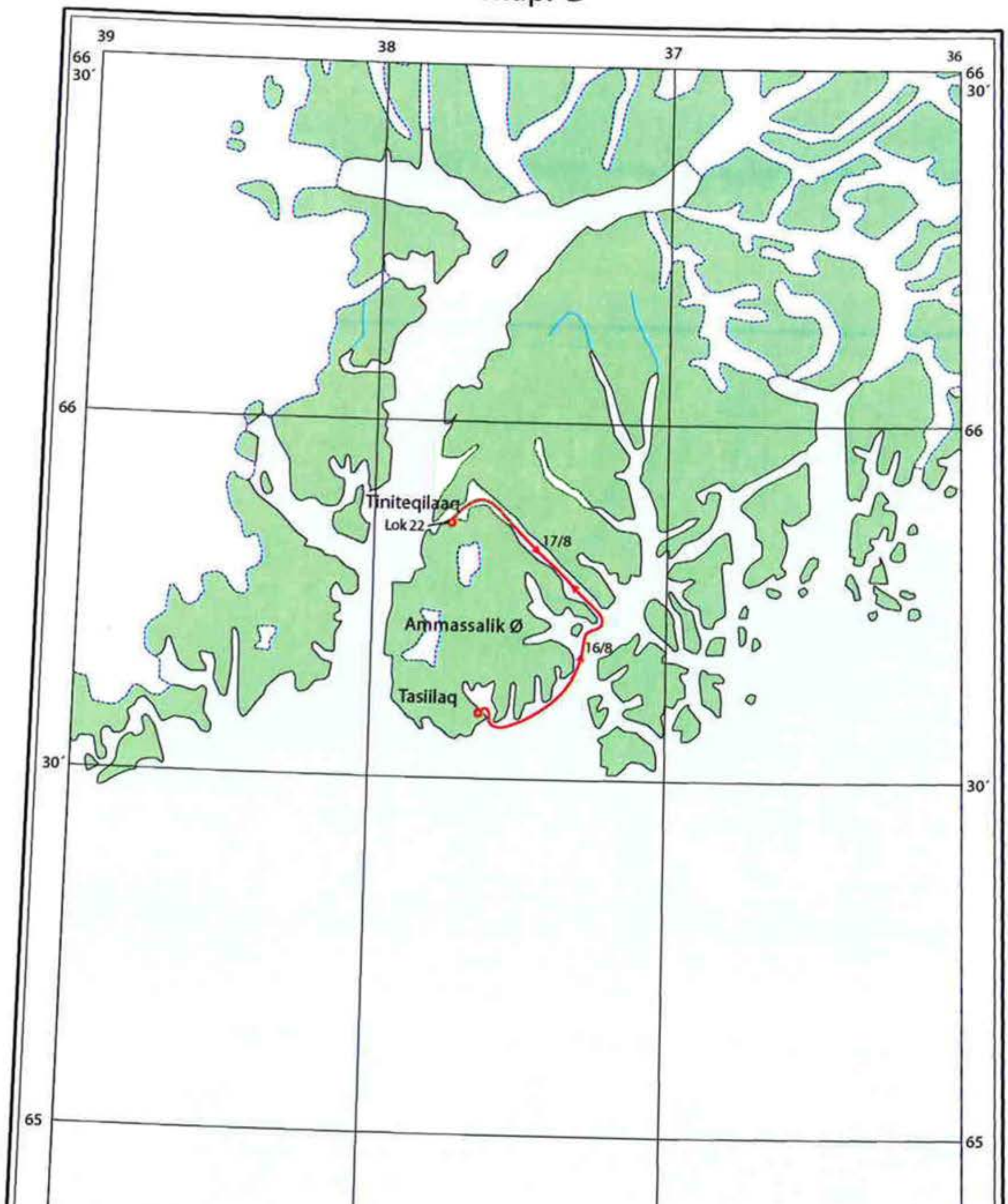
Routes, localities and date. 50 km

Map. C



Routes, localities and date. 50 km

Map. D



Routes, localities and date.