DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2003/107

Dimension stone prospecting in West and South Greenland 2003

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GREENLAND RESOURCES A/S

Northern Periphery

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Introduction

This report contains field observations, evaluation of potential dimension stone production from the visited areas, description and evaluation of the polished slaps of the samples and recommendations for future work of prospecting which were carried out in central West Greenland and South Greenland. The project is being carried out by GEUS and Greenland Resources A/S on behalf of Greenland Resources A/S and partly financed by the EU Northern Periphery Project under the project "Promotion of natural stone industri in the northern areas (PNASTINA). The objective was to follow up on observations made and data collected by Rasmussen (2003) by collecting large samples from specific areas and finding localities that can be used for quarrying dimension stones with high values on the international market.

Participants: Thomas V. Rasmussen (project leader from GEUS), Mac Person (assistant), Hans Kristian Olsen (senior geologist from Greenland Resources A/S).

Field period: 13/7-6/8 2003.

Local transport: Søkongen in West Greenland and J.F. Johnstrup in South Greenland combined with zodiacs.

The Prospecting in central West Greenland started in Aasiaat and finished in Sisimiut. And the prospecting in South Greenland started Narsaq and finidhed in Narsarsuaq.

All directions are given with reference to true north. Structural data are given in the format of strike and dip.

Industry partners:
Råstof og Genanvendelse Selskabet af 1990 A/S, afdelingen for Granitprodukter (RGS 90).

Contents

Summary

The primary target areas during the dimension stone prospecting operation in summer 2003 were the outer part of the Nassuttooq area in Central West Greenland, the Eriks Fjord Formation and the two Kakortokite types in the Ilimaussaq alkaline complex in South Greenland. The aim was to follow up on the observations and data collected in 2002 (Rasmussen 2003).

A total of 27 dimension stone localities have been examined in the summer 2003. During this period 22 samples have been collected for evaluation of dimension stone quality.

The focus has been on localities with low fracture densities and rock types with high potential market prices, mainly in the areas reported by Rasmussen (2003). Another significant factor in the selection of localities has been the proximity of infrastructure. Large samples were collected to evaluate areas for a potential dimension stone quarry. Selected large samples have been cut and polished and evaluated by RGS 90. The final selection of the large samples for cutting and polishing was done by RGS 90 in co-operation with the author.

West Greenland

In 2002 one large sample from flame-structured garnet biotite gneiss was collected in Seersinnilik in Nassuttooq. The sample was cut and polished by RGS 90 and assessed as having a high market value. A similar rock in production in Sweden has a value of approximately 10.000 DKr per m^3. Therefore we aimed to find more of the flame-structured garnet biotitie gneiss in 2003 closer to local infrastructure. During the 2002 fieldwork several localities with exfoliation, unbroken shorelines and sound rock of high market value were identified. The main aim in 2003 was to find a good location with a sound rock of high market value as close as possible to existing infrastructure and local settlements. Therefore the outer part of the Nassuttooq area was chosen as the main focus area in West Greenland for the dimension stone prospecting project in 2003.

Locality 1: 2 km Southeast of Kangaatsiaq

Water depth: unknown. There are some skerries in the area but they are well known to the local people.

Sample GPS position: 68°18'729N 53°23'302W.

The target locality in the Kangaatsiaq area is a pale red mega-crystalline granite. The granite is lineated along its margins with a more granular texture within the main body of the intrusion. Only the lineated parts of the granitic body are accessible from the sea and thus for logistic reasons are the only areas of interest. It is these areas that are the focus of the discussion below. The colour is ordinary. There are several thin pegmatitic veins that cut through the granite and the biotite grains define a weak foliation (figure 1). The pegmatitic veins will be a potential problem during production and the biotite foliation can cause critical weakness in platy products and on corners of normal products. The fracture density varies from dense up to 3 metres. There is a clear exfoliation with up to 2 metre benches. The exfoliation indicates that the fracture density is lower at deeper levels (5-20 metres down). The low-lying topography in the area (figure 2) provides relatively easy access at several places for establishing harbour facilities and it is possible for a medium size ship to dock directly to the cliffs in this area (Hans Myrup - Søkongen skipper, pers comm., 2003).

Figure 1. *The lineated granite near Kangaatsiaq. The granite is cut by several thin light pegmatits.*

Figure 2. *The lineated granite near Kangaatsiaq with a orange tent in the middel of the picture. The relative low topography makes access easy to the area.*

The main reason for choosing the area for dimension stone prospecting was the potential for finding granite with low fracture density and close to Kangatsiaq, which has the necessary infrastructure.

One sample (nr 0301) weighing 69 kg was collected from the lineated granite.

The sample is evaluated by RGS 90 and they concluded that it is not suitable for production.

Locality 2: Seqqorsua

Water depth: steadily deepening to 7 metres, 30 metres from land.

Sample GPS position: 67°45'875N 52°22'244W.

The rock type at this locality is a flame-structured, fine to coarse-grained biotite gneiss. The rock is characterised by millimetre to centimetre-scale dark reddish and light layering. Folded layering defines the flame structures (figure 3 and 4). The rock type is similar to the flame-structured sample collected in 2002 (Rasmussen, 2003; see locality 4). The fracture density of north-south trending vertical fractures is 7 to 10 metres. The general orientation of the weak foliation is 80° vertical and a few foliation-parallel fractures were observed. Exfoliation structures with up to 2 metre benches are pronounced in the area (figure 3). The locality is 50-75 wide from south to north at the water line and continues for approximately 10 km to the west.

Figure 3. *Looking West along the foliation at locality 2. The arrow points at a ca 2-meter high exfoliation bench.*

Figure 4. *The fracture density at locality 2 is low and the flame-structure very clear.*

One sample (nr 0302) weighing 213 kg was collected from the flame structured biotite gneiss.

The sample is cut and polished by RGS 90 (figure 5). Dimension stone experts from the Nordic countries have evaluated the polished sample to be suitably for production because it is lighter than similarly products all ready on the marked and there is a demand for this rock type for the production of desktops.

Figure 5. *The polished sample from locality 2 at Seqqorsua in Nassuttooq.*

Locality 3: Seqinniuitsup nuua

Water depth: steadily deepening to 13 metres, 20 metres from land.

Sample GPS position: 67°44'495N 52°43'644W.

Superficially the orthopyroxene gneiss at the locality appears a perfect candidate for dimension stone production. The rock type is fine to coarse-grained with dark and light bands in a vertical foliation that strikes 90°. Several pegmatites cut the foliation (figure 6) and there are enclaves of dark and light patches up to 1 m^2 in extent. However the surface is rusty and discoloured by sulphate-rich minerals. The most positive attribute of the rock is the fracture density, which is more than 10 metres over a large outcrop (2 x 5 km) (figure 7 and 8). In places the banding is folded into flame-structures. It was difficult to collect a good sample because the upper 30 to 40 cm is crumbling disintegrating and breaks along hair fine fractures.

Figure 6. *Locality 3. Orthopyroxene gneiss with light pegmatites cutting the foliation.*

Figure 7. *The orthopyroxene gneiss at locality 3 with a man for scale in the circle.*

Figure 8. *Orthopyroxene gneiss at locality 3 with low fracture density.*

One sample (nr 0303) weighing 43 kg was collected from the orthopyroxene gneiss.

Locality 4: Little bay on the East side of the mouth of Nassuttuutaa

Water depth: In the bay there are skerries and the water depth is about 10 metres, 30 metres from land. There are good anchorages outside the bay.

Sample GPS position: 67°42'937N 52°49'710W.

This outcrop of flame-structured biotite gneiss is dominated by pronounced (up to two-metre high) exfoliation benches (figure 9). The rock is massive and sound with a vertical foliation oriented 070°. Red and light layering with some black streaks is folded into flame-structures (figure 10). The fracture density is more than 10 metres and locally several fractures occur within a few metres. The fractures are foliation-parallel. Close to the waterline there is a single fault oriented 160°/90°. No other similar features were observed. A few deformed pegmatites cut the gneiss. On the north side of the bay it is possible to land heavy vehicles and a dirt road could easily be constructed direct to the outcrop.

Figure 9. *Pronounced exfoliation benches at locality 4. In the centre of the picture there is a man for scale.*

Figure 10. *A close up picture of the flame-structured biotite gneiss at locality 4.*

Two samples (nr 0304 and nr 0305) weighing 130 kg and 132 kg were collected from the flame-structured biotite gneiss.

Both samples are cut and polished by RGS 90 (figur 11 and 12). Dimension stone experts from the Nordic countries have evaluated the polished samples and like the sample from locality 2 at Seqqorsua in Nassuttooq the two samples are of the light colloured flame structured type that are popular as desktops.

Figure 11. *Polished slab of sample 0304.*

Figure 12. *Polished slab of sample 0305.*

Locality 5: East side of the mouth of Nassuttuutaa

Water depth: approximately 10 metres, 20 metres from land.

Sample GPS position: 67°43'235N 52°51'156W.

Locality 5 is flame-structured biotite gneiss with red and dark folded banding (figure 13 and 14). A few deformed pegmatites cut the gneiss. No exfoliation was observed and along the coastline ½ km north south and 1½ km inland the rock is very massive and sound with a fracture density greater than 25 metres parallel to the foliation (70°/90°) (figure 15). There are some local enclaves of larger patchy neosome and paleosome (up to 2 m^2). Sampling was difficult because of the low fracture density. There is easy access to the area as the topography is low and a ship can sail direct to the low dipping shoreline. Locality 5 can also be used to access locality 4.

Figure 13. *Looking down on the flame-structured biotite gneiss at locality 5.*

Figure 14. *The flame-structured biotite gneiss at locality 5 in a vertical profile.*

Figure 15. *The shoreline at locality 5. A man for scale is standing in the circle.*

One sample (nr 0306) weighing 179 kg was collected from the flame-structured biotite gneiss.

The sample is cut and polished by RGS 90 (figure 16) and it is darker than the other flame-structured biotite gneisses in the area. According to the dimension stone experts from the

Nordic countries, the demand for this kind of rock is high, but it is already in production in several places so the price competition is too high for a greenlandic production.

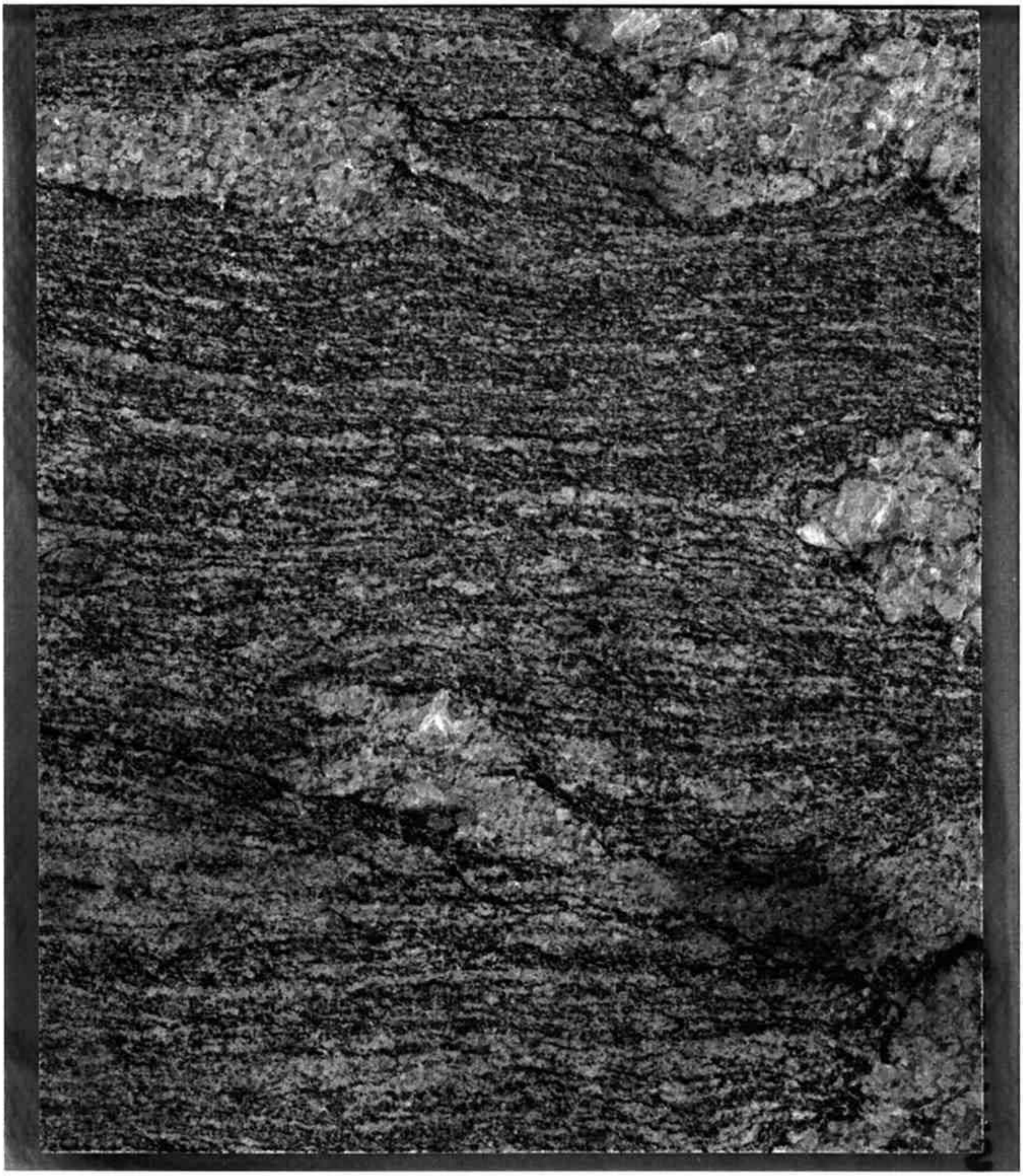


Figure 16. *The polished slab from sample 0306.*

Locality 6: Niaqornarsuaq

Water depth: steadily deepening to 10 metres, 30 metres from land.

Sample GPS position: 67°42'926N 52°58'098W.
The rock at this locality is a massive and sound flame-structured biotite gneiss. Thin deformed red and black bands define the banding (figure 17 and 18) . There are some small (ca 30 x 30 cm) deformed enclaves of green actinolite. The fracture density is higher than 10 metres and the fracture direction is 080° vertical. The foliation is also vertical and strikes 080°. Exfoliation is pronounced at this locality, forming 3 metre high benches (figure 19). The bay in which this locality occurs has a good anchorage and ship to shore access is possible via direct docking against the cliffs. The topography is low and will not cause problems for heavy vehicles.

Figure 17. *The flame-structured biotite gneiss from locality 6.*

Figure 18. *Closeup of the flame-structured biotite gneiss from locality 6.*

Figure 19. *The flame-structured biotite gneiss from locality 6. The arrow points at a ca 2-meter high exfoliation bench.*

One sample (nr 0307) weighing 124 kg was collected from the flame-structured biotite gneiss.

Figure 20. *The polished slap of sample 0307.*

Locality 7: Tasiusaq

GPS position: 67°27'703N 53°40'467W.

The orthopyroxene gneiss is full of north south and east west oriented vertical fractures (figure 21). The lithology was not sampled because, with the high fracture density, it was impossible to collect a block large enough for a dimension stone test.

Figure 21. *Heavy fractured orthopyroxene gneiss at locality 7.*

Locality 8: 2 km West of Tiggaat

Water depth: steadily deepening to 30 metres, 30 metres from land.

Sample GPS position: 67°30'286N 53°27'407W.

This was the first locality visited in Nassuttooq in which we observed massive rock with clear exfoliation structures. The lithology is an orthopyroxene gneiss with a fracture density greater than 25 metres (figure 22). The rock is lineated with a gentle dip to the north (10°). The surface shows rusty patches (figure 23) and the outer-most parts of the rock (40 cm) are open and crumple easily. Access to the locality is difficult because the topography is steep, which limits the possibilities for a production site.

Figure 22. *Massive orthopyroxene gneiss at locality 8.*

Figure 23. *The surface of the orthopyroxene gneiss is full with rusty spots.*

One sample (nr 0308) weighing 203 kg was collected from the orthopyroxene gneiss.

The sample is cut and polished by RGS 90 (figure 24) and evaluated by dimension stone experts from the Nordic countries. The green collour in the rock caused most attention and according to the Finnish dimension stone experts there is at least one major producer who wanted to know more about the posibilities for production of the orthopyroxene gneiss.

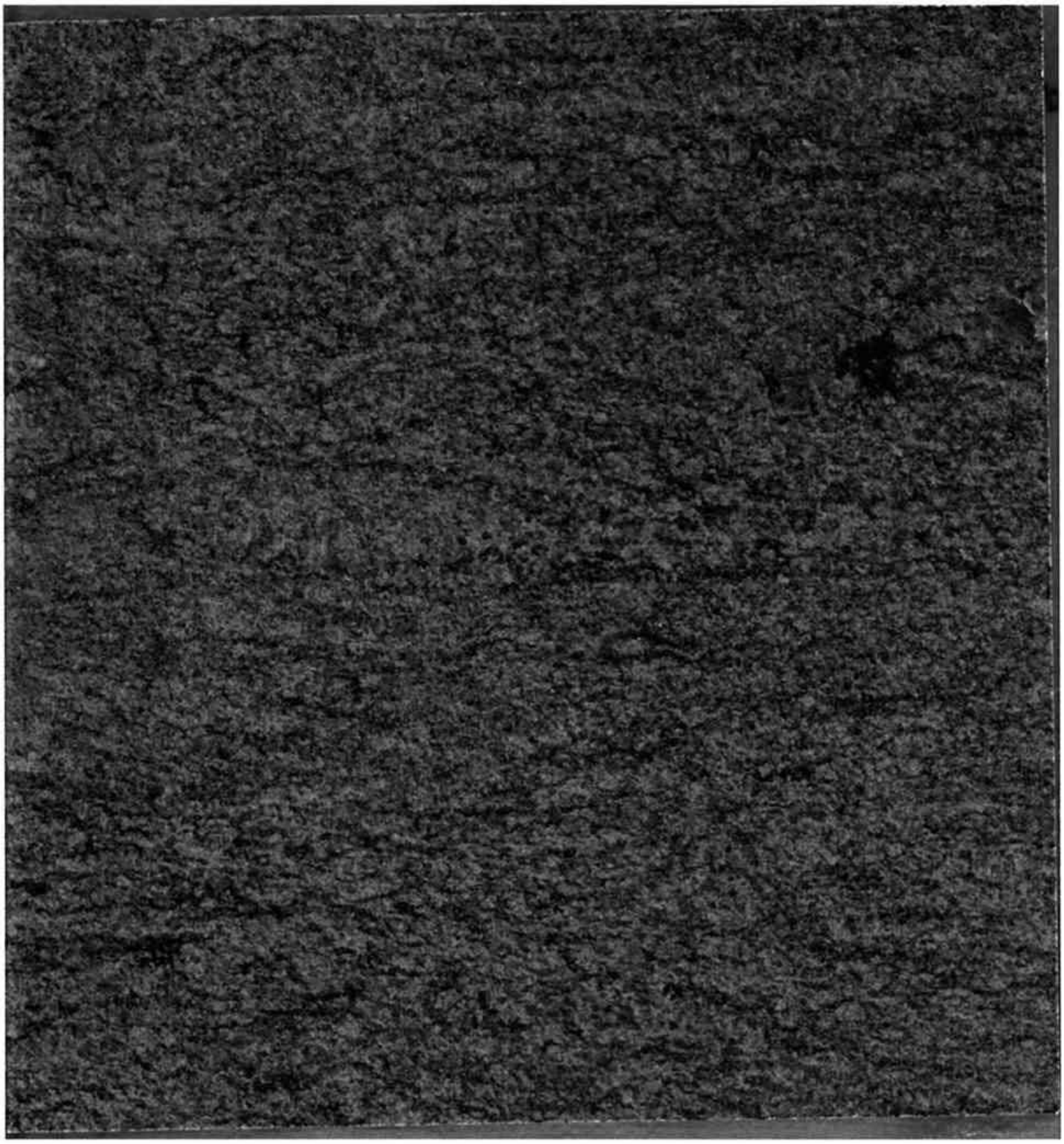


Figure 24. *The polished slap of sample 0308 from locality 8.*

Locality 9: Tiggaat

Water depth: steadily deepening to 50 metres, 30 metres from land.

GPS position: 67°30'764N 53°25'791W.

As for locality 8, the lithology here is an orthopyroxene gneiss, however this locality is more accessible (figure 25). The surface shows the same features: rusty spots (figure 26) and open structures down to approximately 40 cm. No sample was collected because sample nr 0308 is representative of this rock type.

Figure 25. *Locality 9 with better access to the orthopyhroxene gneiss.*

Figure 26. *The orthopyroxene gneiss at locality 9. Like all the other orthophyroxene localities the surface have rusty spots.*

Locality 10: 4 km East of Tiggaat

Water depth: unknown.

GPS position: 67°32'865N 53°19'102W.

Orthopyroxene gneiss (eg. sample 0308) crops out along the coast from Tiggaat to this locality. The gneiss at this locality is still massive with a low fracture density (figure 27), but also with the rusty spots and the open crumpled surface. No sample was collected from this locality.

Figure 27. *Massive orthopyroxene gneiss at locality 10. In the circle there is a man for scale.*

Locality 11: South side of Eqalugarsuit

Water depth: steadily deepening to 50 metres, 30 metres from land with indications of skerries near the shoreline.

Sample GPS position: 67°34'739N 53°09'444W.

This is a good locality for the orthopyroxene gneiss (figure 28). The rock is similar to locality 8 but the access is good and the fracture density greater than 25 metres. The aerial extent is very large - at least 4 x 4 km.

One sample (nr 0309) weighing 218 kg was collected from the orthopyroxene gneiss.

Figure 28. *Locality 11 from where sample nr 0309 is collected. The orthopyroxene gneiss is massive with the same type of rusty and open surface.*

The sample is cut and polished by RGS 90 (figure 29) and evaluated like sample 0308 by the team of dimension stone experts from the Nordic countries. At least one major dimension stone producer from Finland are intersted in knowing more about the orthopyroxene gneiss.

Figure 29. *Polished slab of sample nr 0309.*

Locality 12: South side of Eqalugarsuit 2 km further out

Water depth: steadily deepening to 50 metres, 30 metres from land with indications of skerries near the shoreline.

GPS position: 67°34'064N 53°12'229W.

This is a very massive orthopyroxene gneiss with an extremely low fracture density (figure 30). Rusty spots occur on the surface, as for all the other orthopyroxene gneiss localities. No sample was collected.

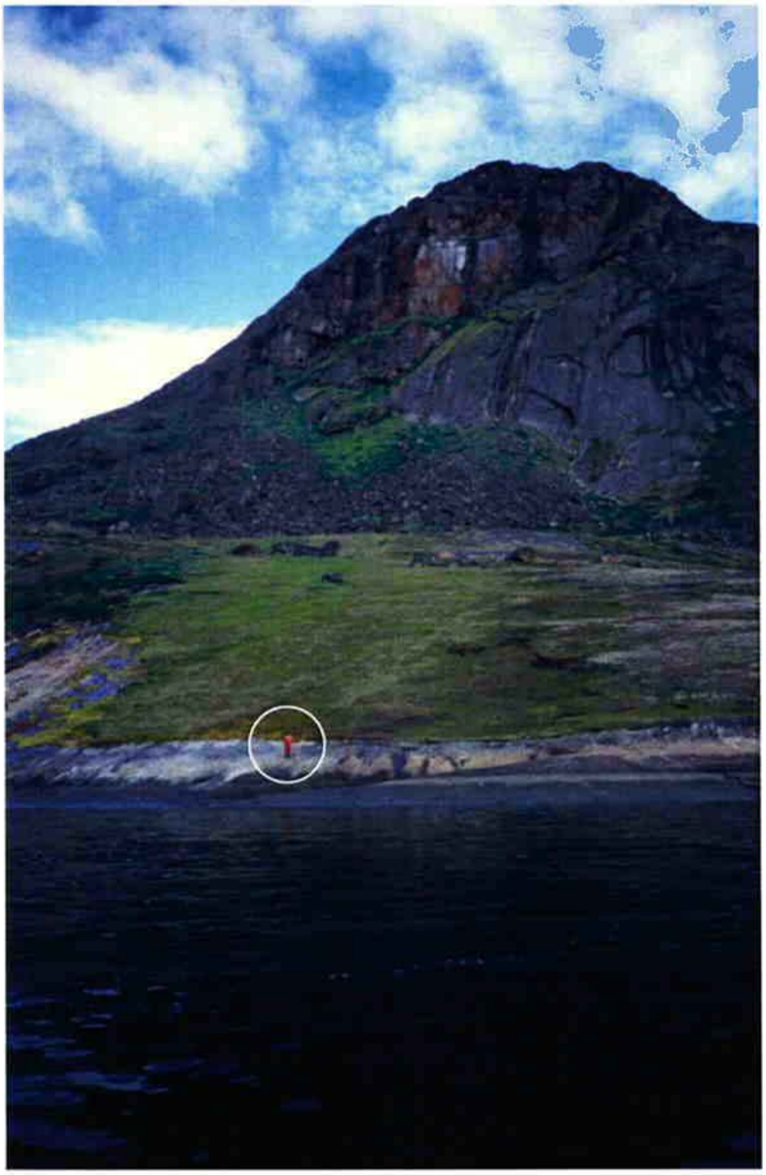


Figure 30. *Mega massive area with the orthopyroxene gneiss at locality 12.*

Locality 13: North side of Kangerluarsuk

Water depth: at least 7 metres, 10 metres from land.

GPS position: 67°40'276N 52°58'495W.

This is a biotite gneiss with a well-defined foliation, often with associated fracturing. There is a tendency to migmatisation at the contact with the orthopyroxene gneiss. The biotite gneiss unit is 50 metres wide. Away from its margins the lithology is homogenous with a strong vertical foliation that strikes 090. No samples were collected because the schistosity along the foliation is high and disqualifies the rock for dimension stone production.

Locality 14: South side of Kangerluarsuk

Water depth: 15 metres, 30 metres from land, but only 2 metres, 10 metres from land.

Sample GPS position: 67°40'050N 52°57'153W.

This is a heavily-folded medium to coarse-grained garnet biotite quartz gneiss (figure 31, 32 and 33). The high content of garnet gives the rock a purple coloration (figure 33 and 34). The biotite content is critical because it is coarse-grained and concentrated in layers that reduce the bending strength of the stone. The fracture density is relative high, generally between 2-3 metres perpendicular to the foliation (080°/90) (figure 31). The locality is small - 30 x 400 metres - but there are several very large areas of the same rock type north of Nassuttooq that could be of more interest. A sample was collected from this locality no other outcrops of this special rock type were accessible in the area, but with the knowledge that there are other localities where the garnet biotite quartz gneiss can be found.

One sample (nr 0310) weighing 219 kg was collected from the garnet biotite quartz gneiss.

Figure 31. *Locality 14 with the garnet biotite quartz gneiss.*

Figure 32. *The heavy folded garnet biotite quartz gneiss.*

Figure 33. *The heavy folded garnet biotite quartz gneiss.*

The sample is cut and polished by RGS 90 (figure 34) and evaluated by the team of dimension stone experts from the Nordic countries. According to the team of dimension stone experts from the Nordic countries this rock type is all ready in production in India and therefore will it never be posibly with a compeditive production of it in Greenland.

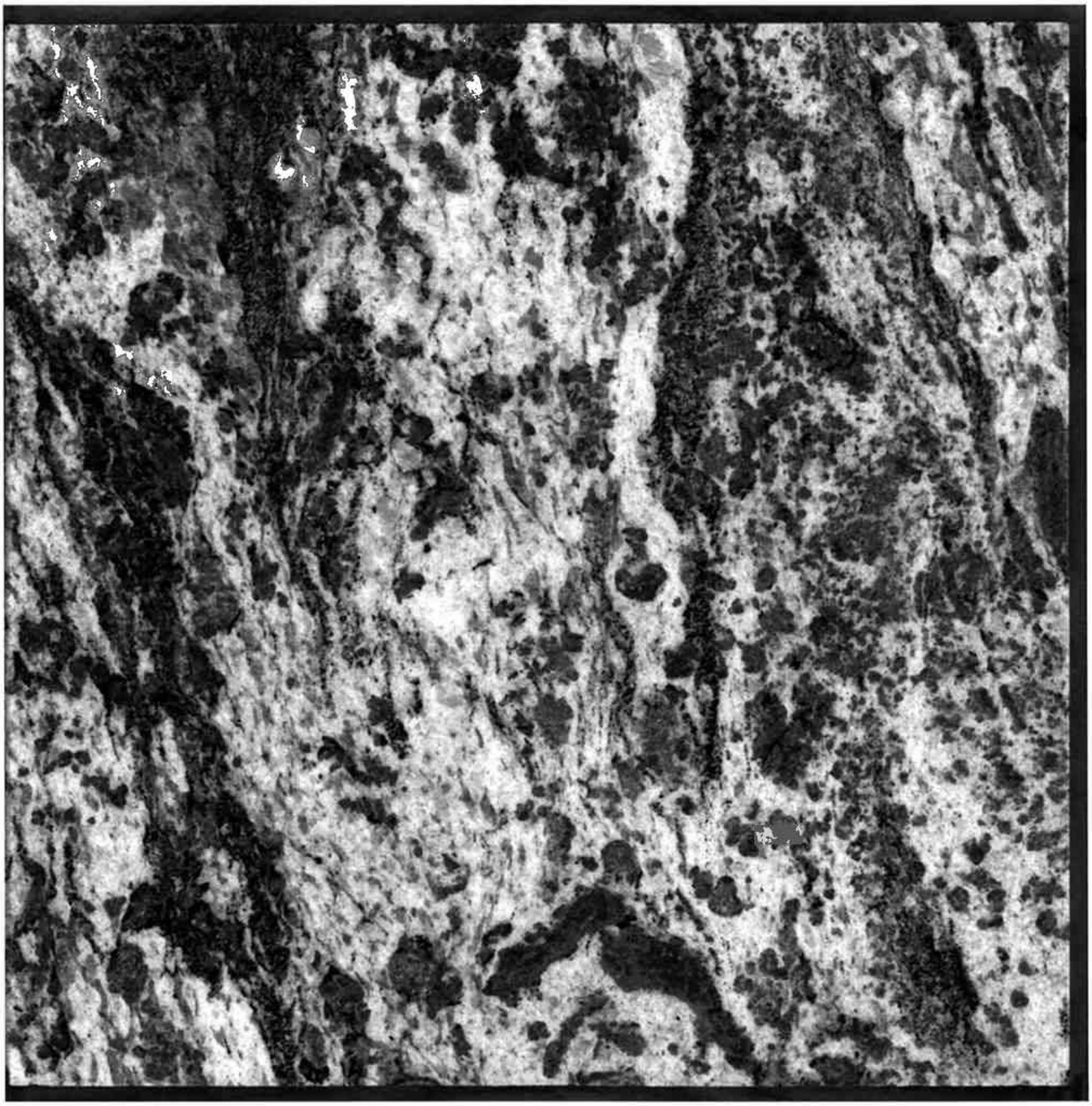


Figure 34. *The polished slap of sample nr 0310.*

Locality 15: Little bay on the North-West side of Nassuttuutaa

Water depth: 15 metres, 20 metres from land with some skerries near the shoreline.

GPS position: 67°43'828N 52°45'162W.

The rock type is the same as for locality 4. The flame-structured biotite gneiss is exposed over 50 metres along the shoreline and the fracture density is more than 10 metres (figure 35). The lithology forms the core of a large scale fold structure which closes about 500 meters inland with a vertical axial plane that strikes east-west. Small-scale folds of layering throughout the area are probably parasitic on the larger-scale fold structure. The aerial extent is relative small and access with vehicles is limited by the high topography 100 metres inland. No samples were collected because the two samples from locality 4 are representative of the lithology at this locality.

Figure 35. *Locality 15 with the flame-structured biotite gneiss that continue the unit from locality 4 on the other side of the fjord. There is a red man for scale in the circle.*

Locality 16: Head of Nassuttuutaa

Water depth: 6 metres, 30 metres from land with some skerries near the shoreline.
Sample GPS position: 67°43'249N 52°41'352W.

This is a flame-structured fine to coarse-grained biotite gneiss with red, light and black bands. In places it is highly migmatitic (figure 36 and 37). The foliation strikes 76° vertical and there may be some weakness along the foliation indicated by loose blocks with foliation-parallel planar surfaces (figure 36). Perpendicular to the foliation the fracture density is greater than 25 metres and the fractures are vertical. The area is restricted to a ca 100 metre wide zone that runs 1.5 km east-west. The topography is low-lying. A few deformed and undeformed pegmatites cut the biotite gneiss.

One sample (nr 0311) weighing 271kg was collected from this locality.

Figure 36. *Flame-structured biotite gneiss at locality 16.*

Figure 37. *Closeup picture of the flame-structured biotite gneiss at locality 16.*

The sample is cut and polished by RGS 90 (figure 38) and evaluated by the team of dimension stone experts from the Nordic countries. According to the team of dimension stone experts from the Nordic countries the less pronounced flame-structure and more strait foliation in the gneiss is a negative feature because it is difficult to use as flagstone and tile.

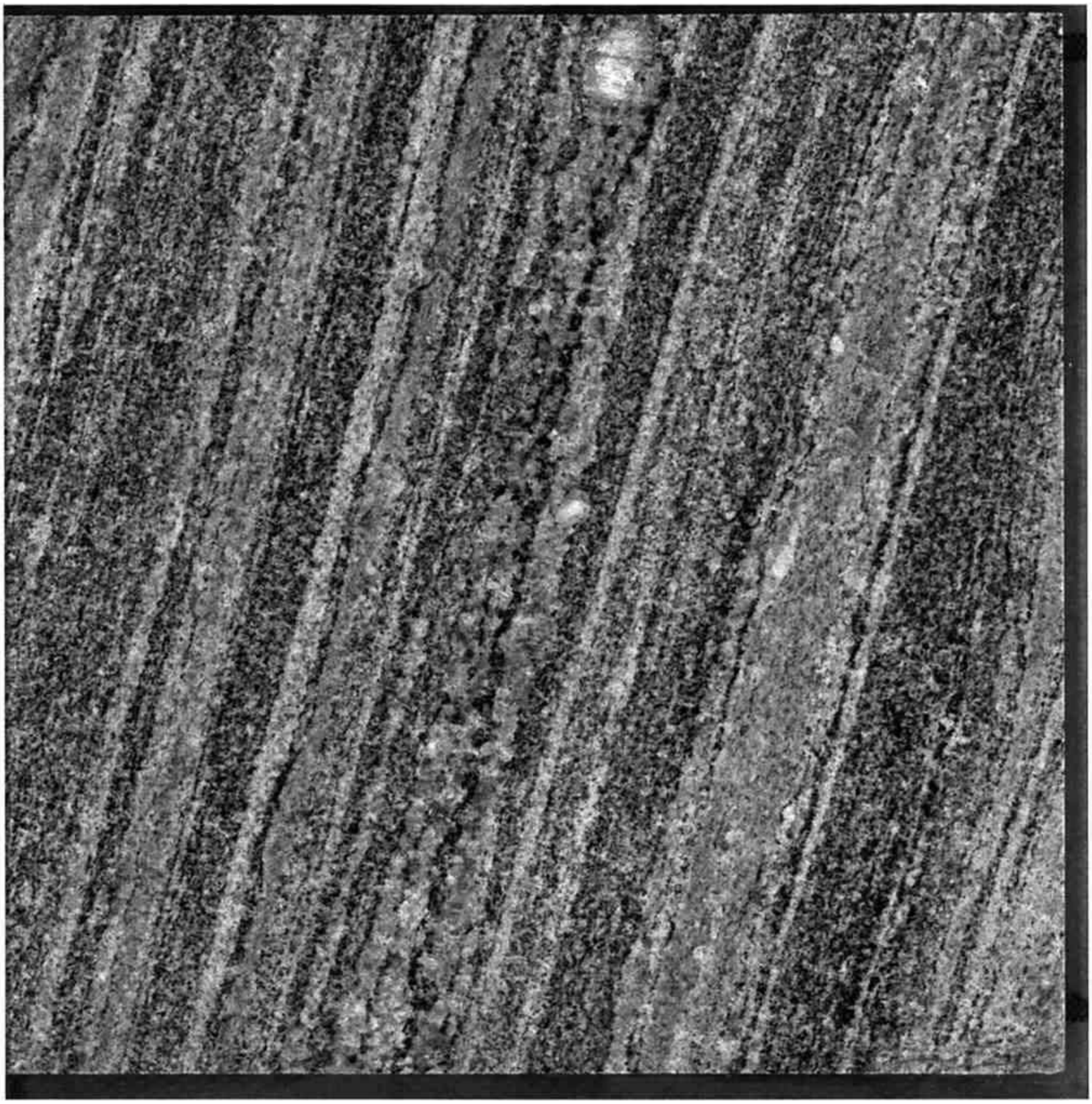


Figure 38. *The polished slap of sample nr 0311.*

Locality 17: 3 km West of Qaarsoq

Water depth: Unknown.

GPS position: 67°44'578N 53°01'667W.

The locality is less than 50 m wide and comprises flame-structured garnet biotite gneiss (figure 39 and 40), which in some places is black and deep red (figure 41). The fracture density is 4 metres at a maximum and often more dense. No sample was collected from the locality because many better localities with the flame-structured garnet biotite gneiss were visited in the area.

Figure 39. *The flame-structured garnet biotite gneiss at locality 17 with a relative high fracture density.*

Figure 40. *Closeup picture of the flame-structured biotite gneiss at locality 17.*

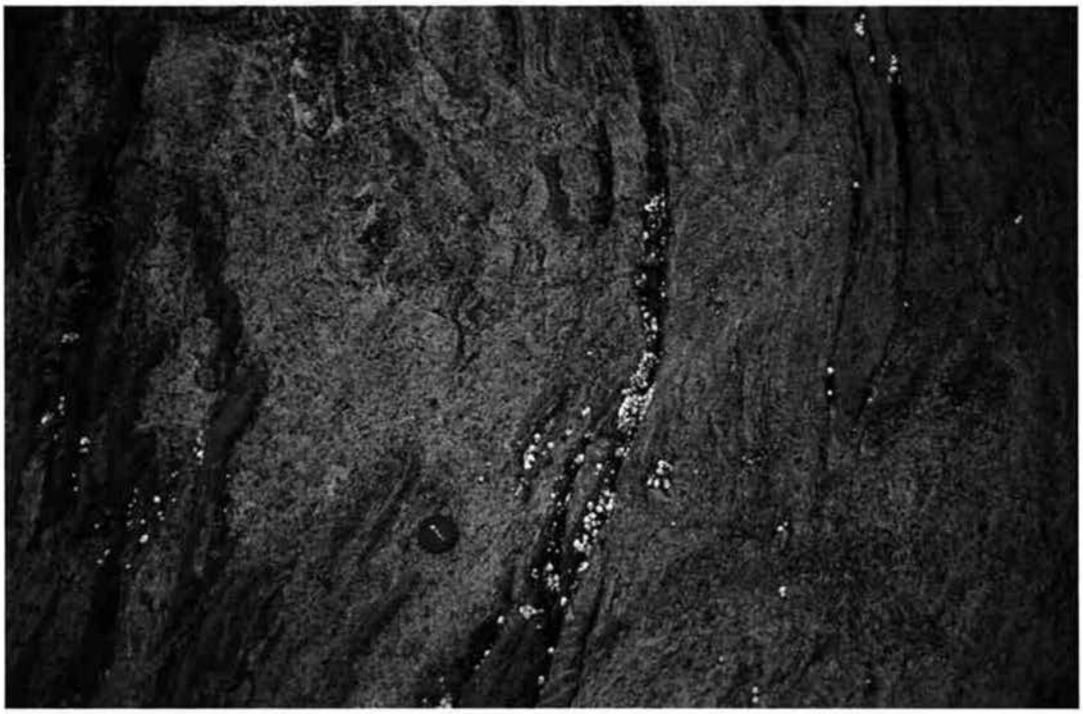


Figure 41. *Closeup picture of the red and black flame-structured biotite gneiss at locality 17.*

Locality 18: Qeqertarsuaq

Water depth: Unknown, but there are several skerries and no good possibilities for establishing a harbour because the shoreline is very exposed to the western wind.

Sample GPS position: 67°47'308N 52°39'963W.

The lithology here is a leucocratic garnet biotite gneiss (figure 42), partly migmatitised and with foliation defined by thin bands (less than 1 cm thick). There are several enclaves of decimetre-scale black amphibolite, randomly distributed through the outcrop, and rusty patches are common. The fracture densities are mostly greater than 4 metres to a maximum of 7 metres. Exfoliation structures in the leucocratic garnet biotite gneiss were observed, indicating that the locality is sound. The area with leucocratic garnet biotite gneiss is limited to the costline for about 500 meter and only 30-40 meters inland.

One small sample (nr 0312) weighing 43 kg was collected from the leucocratic garnet biotite gneiss.

Figure 42. *The leucocratic garnet biotite gneiss at locality 18.*

Locality 19: Qatsissut Kitaatungaat

Water depth: 20-30 metres, 30 metres from the shoreline. In general the bay is a good anchorage.

Sample GPS position: 67°43'473N 52°10'223W.

This lithology is a flame-structured biotite gneiss with dark red and black thin deformed bands (figure 43). The general orientation of the foliation is 90°/90° and the fracture density is a maximum of 5 metres perpendicular to the foliation. The locality is unfortunately small (figure 44), only about 20-metres wide and ca 500 metres long. Quarrying at this locality would have problems with seawater infiltration because the topography is less than 10 metres above sea level. The ship to shore access possibilities are very good in the area.

One sample (nr 0313) weighing 194 kg was collected from the gneiss.

Figure 43. *Closeup of the red and black flame-structured biotite gneiss at locality 19.*

Figure 44. *Locality 19 were the biotite gneiss runs along the coast in a thin (20-30 meter) unit. The double white arrow marks the outline of the unit.*

The sample is cut and polished by RGS 90 (figure 45) and evaluated by the team of dimension stone experts from the Nordic countries. According to the team of dimension stone experts from the Nordic countries the less pronounced flame-structure and more strait foliation, like at locality 16 (sample 0311) in the gneiss is a negative feature because it is difficult to use as flagstone or tile with a texture like that.

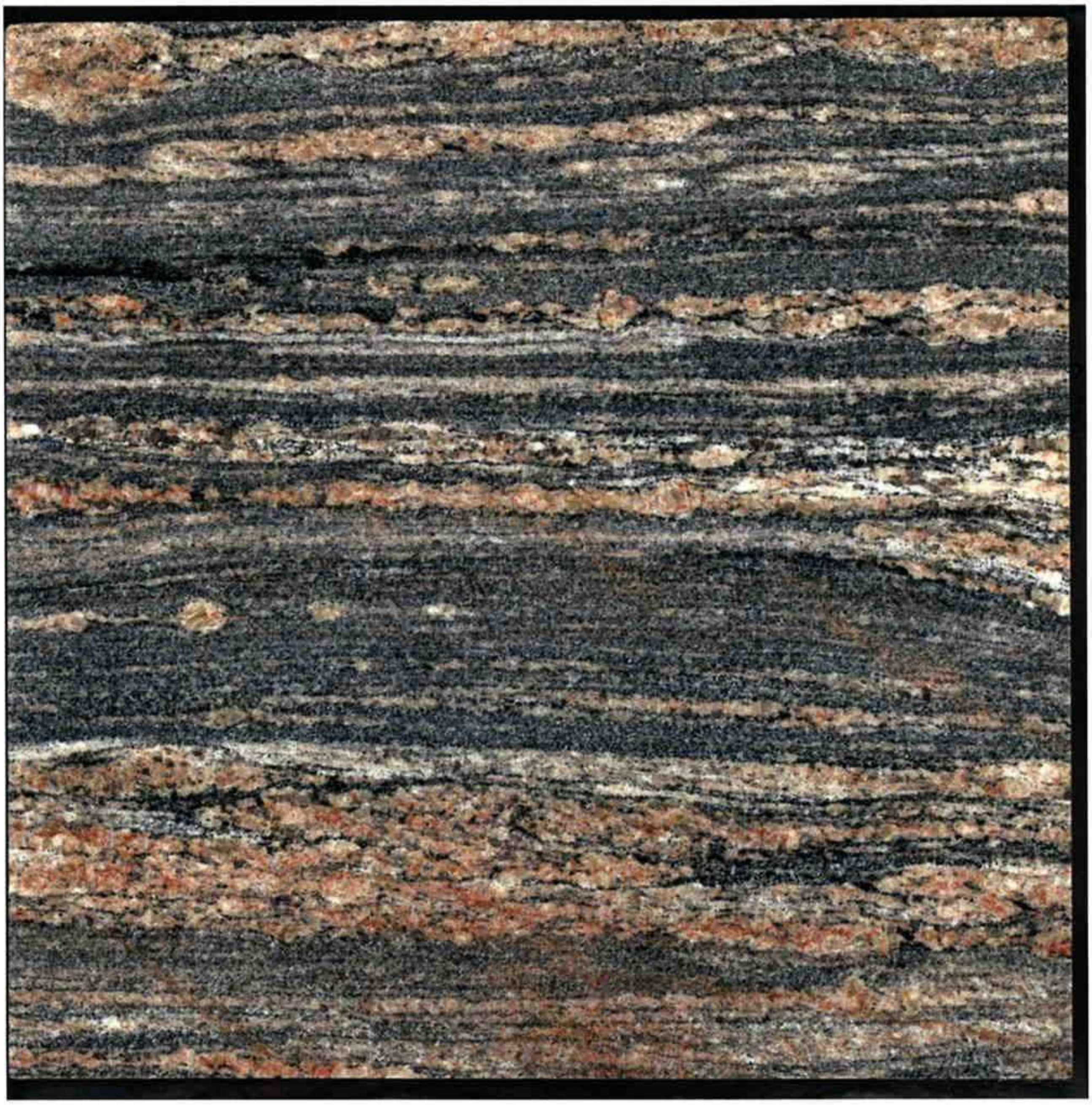


Figure 45. *Polished slab of sample nr 0313.*

Locality 20: Qatsissut Kitaatungaat

Water depth: The same area as locality 19 (20-30 metres, 30 metres from the shoreline. In general the bay is a good anchorage).

Sample GPS position: 67°43'015N 52°11'727W.

At this locaity the lithology is a foliated red gneiss with black bands (figure 46 and 47). The locality is about 150 metres wide at the shore line and continues inland for more than 300 metres under vegetation and a thin layer of Quaternary cover.

One sample (nr 0314) weighing 125 kg was collected from the gneiss.

Figure 46. *Foliated red gneiss with black bands at locality 20. In the background the Quaternary cover dominates the area.*

Figure 47. *Closeup of the red and black biotite gneiss at locality 20.*

The sample is cut and polished by RGS 90 (figure 48) and evaluated by the team of dimension stone experts from the Nordic countries. The light flame-structured biotite gneiss is positiv evaluated by both the industry and the team of dimension stone experts because the light flame-structured type are not normal on the marked like the more darker types.

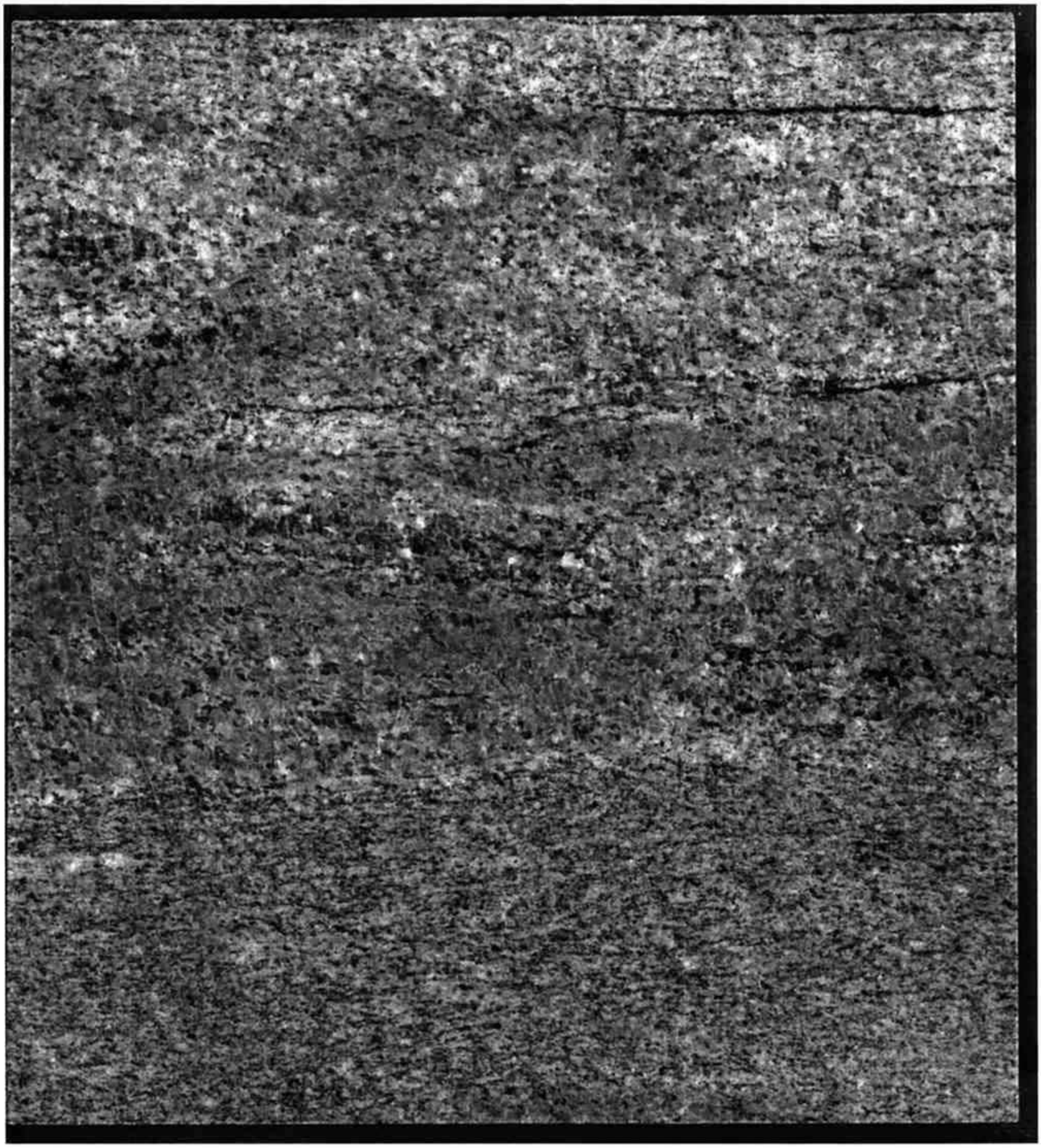


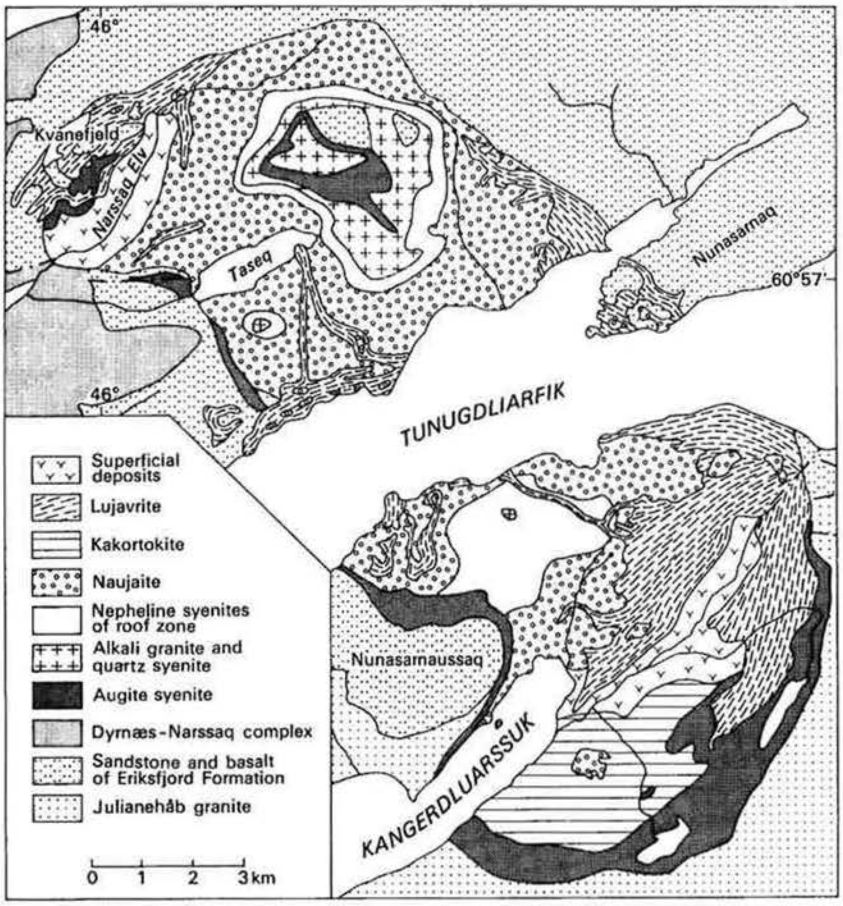
Figure 48. *The polished slap of sample nr 0314.*

Dimension stone prospecting in South Greenland

The purpose for the dimension prospecting in South Greenland was to follow on observations and sampling by Rasmussen (2003) at Kringlerne and at the Erik Fjords Formation by bulk sampling some specific rock types that can be suitable for quarrying dimension stones.

Prospecting and bulk sampling was done in following areas:

1) Kringlerne (black and white kakortokite)
2) Tuttutooq (syenite)
3) Tupersuatsiaat (naujaite)
4) Sillisit (red and blue-green sandstone)



Simplified geological map of the Ilímaussaq intrusive complex. After Ferguson (1964).

Figure. 49. *Simplified geological map of the Ilímaussaq alkaline complex after Geology Greenland Surv. Bull. 190, 167 pp.*

Locality 21: The southern coast of Kangerluarsuk at "Kringlerne"

Location: Sample 0315: Dark kakortokite (figure 50): 60° 52´2´´N 45° 52´6´´W

Sample 0316: Light kakortokite (figure 51): 60° 52´9´´N 45° 52´8´´W

Description: The visible subhorizontal layer of kakortokites consist of blocks of different sizes where the sides or joints are approximately at right angles to each other. Exfoliations joints are also visible along the horizontal plane (See fig. 52 A and B).

The depth of the kakortokites is less than 1 meter in this area and therefore limit the potential quarry blocks.

The rocks does take a good polish to yield an usual and attractive pattern suitable for decorative applications. The polished slabs has attracted great interest at the Nordic Stone 2003 Fair in Turku, Finland.

Access: Kringlerne is easily accessible by boat and ship and ship of minor tonnage can navigate at the inner part of the fjord.

Rock type:

Name: Agpaitic nepheline syenite

The kakortokites belongs to the Ilímaussaq alkaline complex, which is one of a number of instrusive complexes in the Gardar igneous province. The type locality consists of several types of agpaitic nefeline syenites. The agpaitic phase comprises a roof of series, a floor series and an intermediate sequence of rocks.

Colour: Black variety depending on the content of arfvedsonite and the white variety depending on the content of alkali feldspar.

Texture: The kakortokites are coarse-grained with a pronounced foyaitic texture. They show a pronounced, almost horizontal layering and lamination caused by the alternation of layers of different mineralogy.

Grain size: Medium - Coarse grained.

Mineralogy: One of the most common rock types is kakortokite, which belongs to the exposed part of the floor series and is made up of a layered and laminated series of kakortokite with the major minerals alkali feldspar, nepheline, aegirine, arfvedsonite and eudialyte.

The lowermost visible part is made up of centimetre-thick layer with varying content of mafic minerals, feldspar and eudialyte. It displays though structures and cross-bedding and is overlain by a series made up of 29 three-layer units, each about 10 m thick and made up of a lower black layer rich in arfvedsonite and an upper much thicker layer rich in alkali feldspar. Between these layers, there is often a thin red layer rich in eudialyte. The black, red and white layers pass gradually into each other, whereas the black layers are separated from the underlying white layers by sharp contact.

Structure: The visible layers dip gently to northwest, striking east-west.

Joints: In the area without rock boulders it was possible to see subparallel joints perpendicular to the layering, spaced approximately 10 cm – 1 m.

Positive Features: Close to coast and infrastructure at Narsaq

Unique and attractive peculiar rock type, tecture and colour.

Negative Features: The layering and lamination of the kakortokite and the joint density will limit extraction of large quarry blocks.

The dipping of the exposed outcrops at the coast will probably create difficulties with quarrying.

The kakortokites has also been jointed by the east – west trending faults that penetrates Kringlerne.

Figure 50. *Polished dark kakortokite from the Ilímaussaq alkaline complex.*

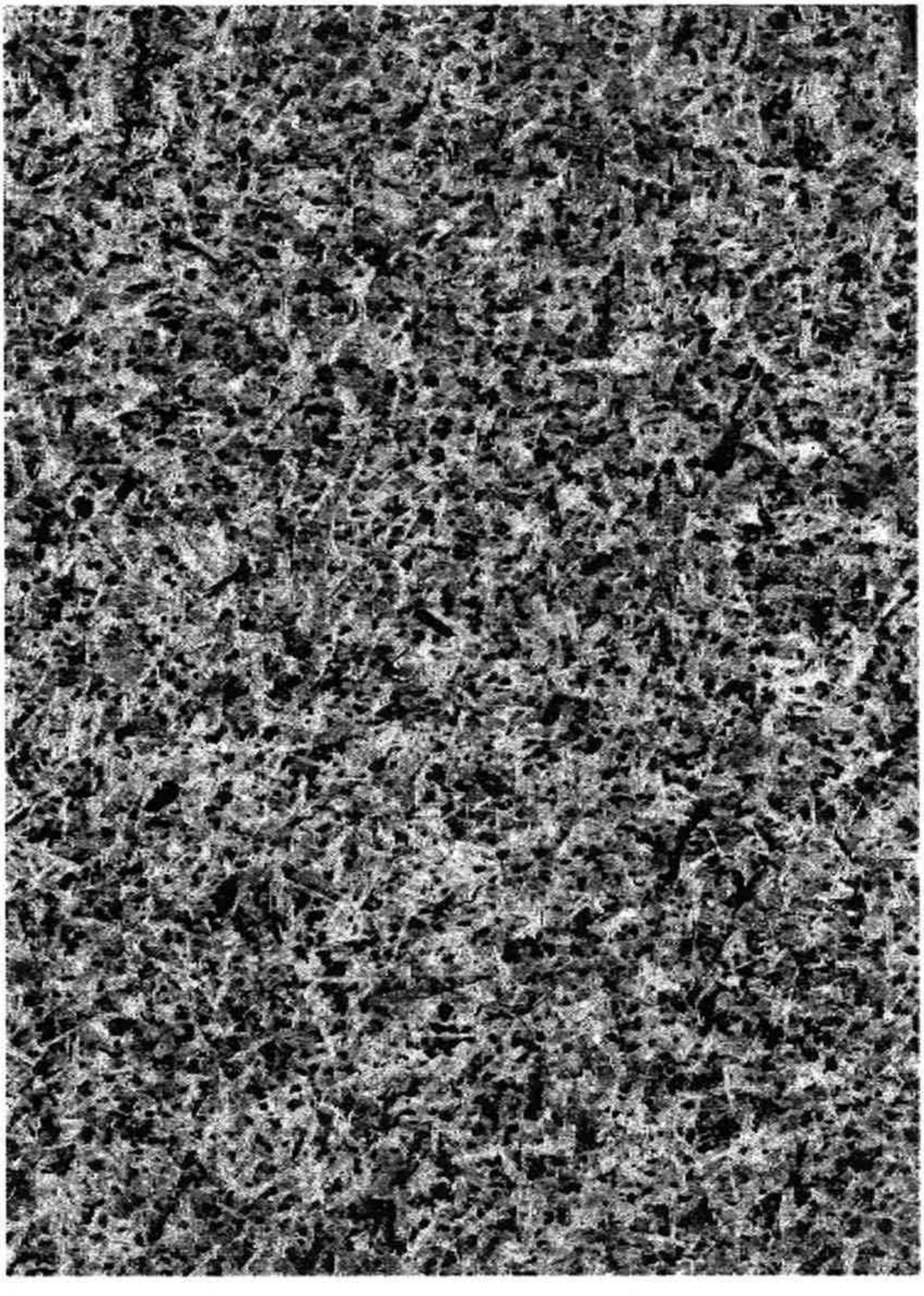


Figure 51. *Polished light kakortokite from the Ilímaussaq alkaline complex.*

Figure 52 A. *Kakortokites blocks of different sizes where the sides or joints are approximately at right angles to each other. Exfoliations joints are also visible along the horizontal plane. The layering of the kakortokites is visible in the background of the picture.*

Figure 52 B. *Close-up picture of the perpendicular jointing of the kakortokites in figure. 50 A.*

Locality 22: Tuttutooq - Sissarluttoq

Location:	Tuttutooq – Sissarluttoq
	Sample 0317 (figure 53): 60°53´58´´N 46°10´44´´W
Description:	The syenites in this area belongs to the Gardar province.
Access:	Sissarluttoq is only accessible by minor ship due to the low depth of the bay.
Rock type:	
Name:	Syenite
Colour:	White - Gray
Texture:	Equigranular - Coarse grained
Grain size:	Coarse grained.
Mineralogy:	Feldspar, augite, olivine, magnetite.
Structure:	The syenite complex has an excessive joint density which precludes extraction of larger blocks (figure 54).
Positive Features:	Close to coast and infrastructure at Narsaq.
Negative Features:	Excessive joint density and high content of magnetite.
	The Sissarluttoq bay prevents navigations by larger ships.
Comments:	The syenite is not suitable for dimension stone quarrying.

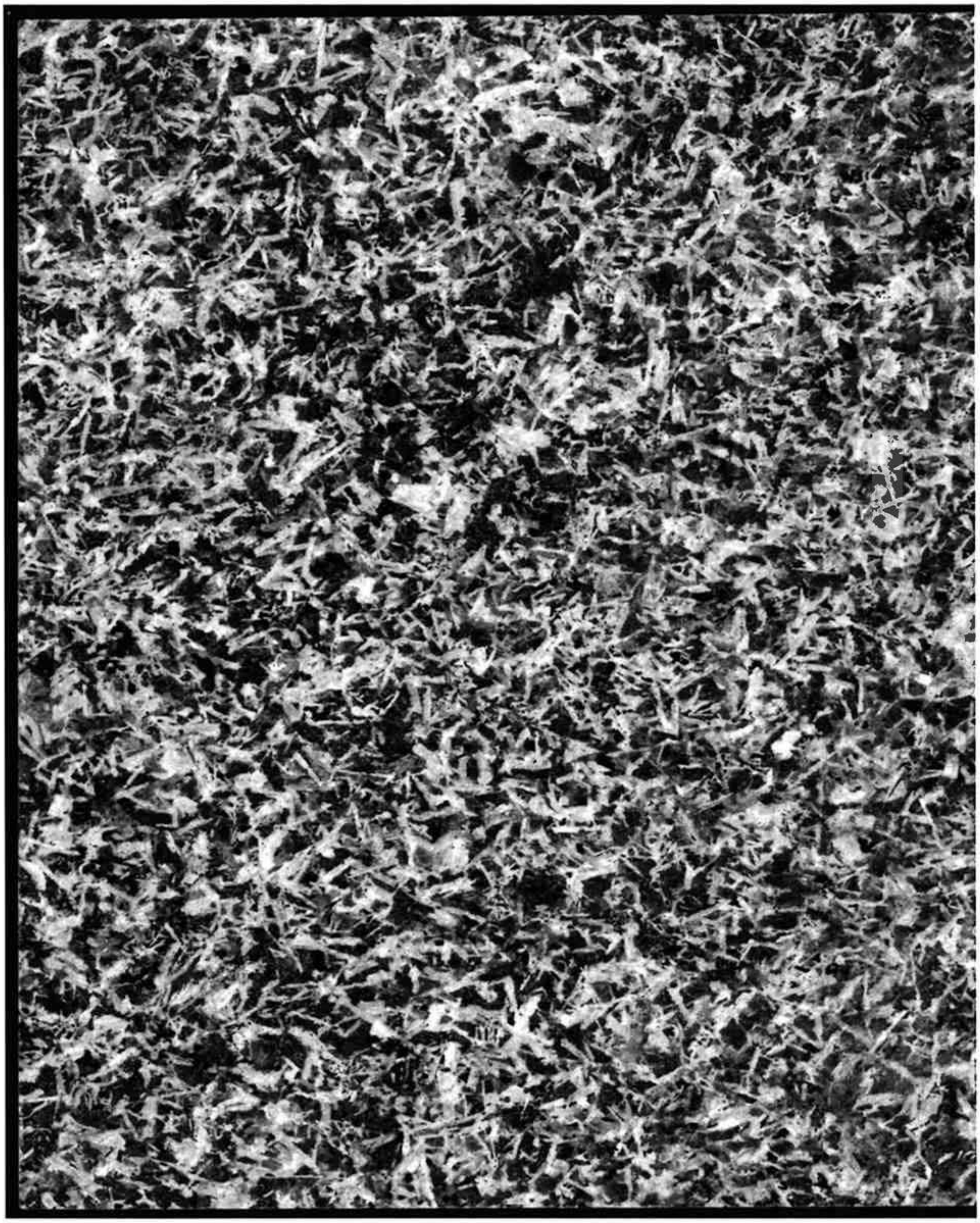


Figure 53. *Polished syenite from Tuttutooq.*

Figure 54. *The syenite at Tuttutooq is strongly weathered and many tight joint in several directions.*

Locality 23: Tupersuatsiaat – Naujaite

Location: Tupersuatsiaat – The southern coast of Tunulliarfk

Sample 0318: 60°53´3´´N 45°50´4´´W

Description: Naujaite is well exposed at the southern side of the Tunulluarfik fjord and is one of the major rock types that constitute the Ilimmaasaq complex.

Access: Tupersuatsiaat is easily accessible by ship.

Rock type:

Name: Naujaite

Colour: A mixture of white, green, red, black colours.

Texture: The naujaite is a very coarse-grained nepheline syenite with a peculiar poikilitic texture: small crystals of sodalite are enclosed in the other minerals of the rock.

Grain size: Coarse - pegmatitic.

Mineralogy: The naujaite normally consist of sodalite, nepheline, eudialyte, microcline microperthite, aegirine and arfvedsonite. The eudialyte is present in large grains with numerous inclusions of sodalite.

Structure: Due to the coarse grained texture, strong weathering and jointing it was difficult to get a representative bedrock sample of the rock type.

Positive Features: Close to coast and infrastructure at Narsaq.

Flourescent

Negative Features: The rock is strongly weathered and makes it difficult to evaluate the jointing of the rock.

Comments: According to Gothenborg et al. (1994) naujaite has previously been studied by Intergeo-Exploration Company but without positive results.

Figure 55. *The polished Naujaite with the spectacular red poikiloklastic eudialyte.*

Locality 24: Igaliko – Igaliko sandstone

Location: Igaliko – Igaliko sandstone

60° 52´9´´N 45° 52´8´´W

Comments: The prospecting for the Igaliko Sandstone has previously been initiated for the purpose as a dimension stone by the Danish company Geokon A/S, but was never accomplished as the municipality of Narsaq would not give the company an approval for the project.

The sandstone unit at the western side of the inner part of Igaliko Fjord was visited, but no bulk samples was sampled in this area due to very tight jointing and thin layering of the sandstone (figure 56 and 57).

Figure 56. *Reddish sandstone unit at the western side of the inner part of Igaliko Fjord.*

Figure 57. *Reddish sandstone unit from figure 54 with a notably cavernous weathering pattern which may reflect a high content of carbonate derived form the underlying volcanic unit.*

Locality 25: Sillisit – Spotted Igaliku sandstone

Location:	Sillisit - 61° 03´40´´N 45°34´0´´W
Description:	The type locality of the Igaliku sandstone was revisited and occurs in a 15-10 m thick bedded outcrop at the beach few kilometres south east of the sheep farm at Sillisit (figure 58, 59 and 60). The sandstone is overlain by a thick basalt layer and continues at a sub horizontal level further north.
Access:	There is a good access to the site from land.
Rock type:	
Name:	Igaliku Sandstone
Colour:	Dark violet (purple) to reddish and yellowish beige in alternating thin horizons.
Texture:	Very closely spacing of joints and fractures along the layering.
Grain size:	Fine – medium grained.
Mineralogy:	Quartz
Structure:	Ripple marks and cross bedding and white spots. Further inland the sandstone appears as massive without structures.
Positive Features:	The sandstone is a competent rock type with exciting sedimentary features.
Negative Features:	The thick basalt cover and the flooding of the location at high tide makes this difficult to establish a quarry.
Comments:	The prospecting for the Igaliko Sandstone has previously been initiated for the purpose as a dimension stone by the Danish company Geokon A/S, but was never accomplished as the municipality of Narsaq would not give the company an approval for the project.

Figure 58. *Sillisit with the type locality of the Igaliku sandstone.*

Figure 59. *Thin bedded sandstone at the type locality at Sillisit.*

Figure 60. *Close-up view of the spotted Igaliku sandstone at Sillisit.*

Locality 26: Sillisit Itinnerat – Igaliku red sandstone

Location:	Sample 0319 – Red-purple sandstone: 61° 03´55´N 45°33´59´´W
Description:	Red-purple homogeneous sandstone The type locality of the Igaliku sandstone was revisited and occurs in a 15-10 m thick bedded outcrop at the beach few kilometres south east of the sheep farm at Sillisit (figure 61, 62 and 63). The sandstone is overlain by a thick basalt layer and continues at a sub horizontal level further north.
Access:	There is a good access to the site from land.
Rock type:	
Name:	Igaliku Sandstone
Colour:	Dark violet (purple) to reddish and yellowish beige in alternating thin horizons.
Texture:	Very closely spacing of joints and fractures along the layering.
Grain size:	Fine – medium grained.
Mineralogy:	Quartz

Structure:	Ripple marks and cross bedding and white spots. Further inland the sandstone appears as massive without structures.
Positive Features:	The sandstone is a competent rock type with exciting sedimentary features.
Negative Features:	The thick basalt cover makes this difficult to establish a large quarry.
Comments:	The prospecting for the Igaliku Sandstone has previously been initiated for the purpose as a dimension stone by the Danish company Geokon A/S, but was never accomplished as the municipality of Narsaq would not give the company an approval for the project.

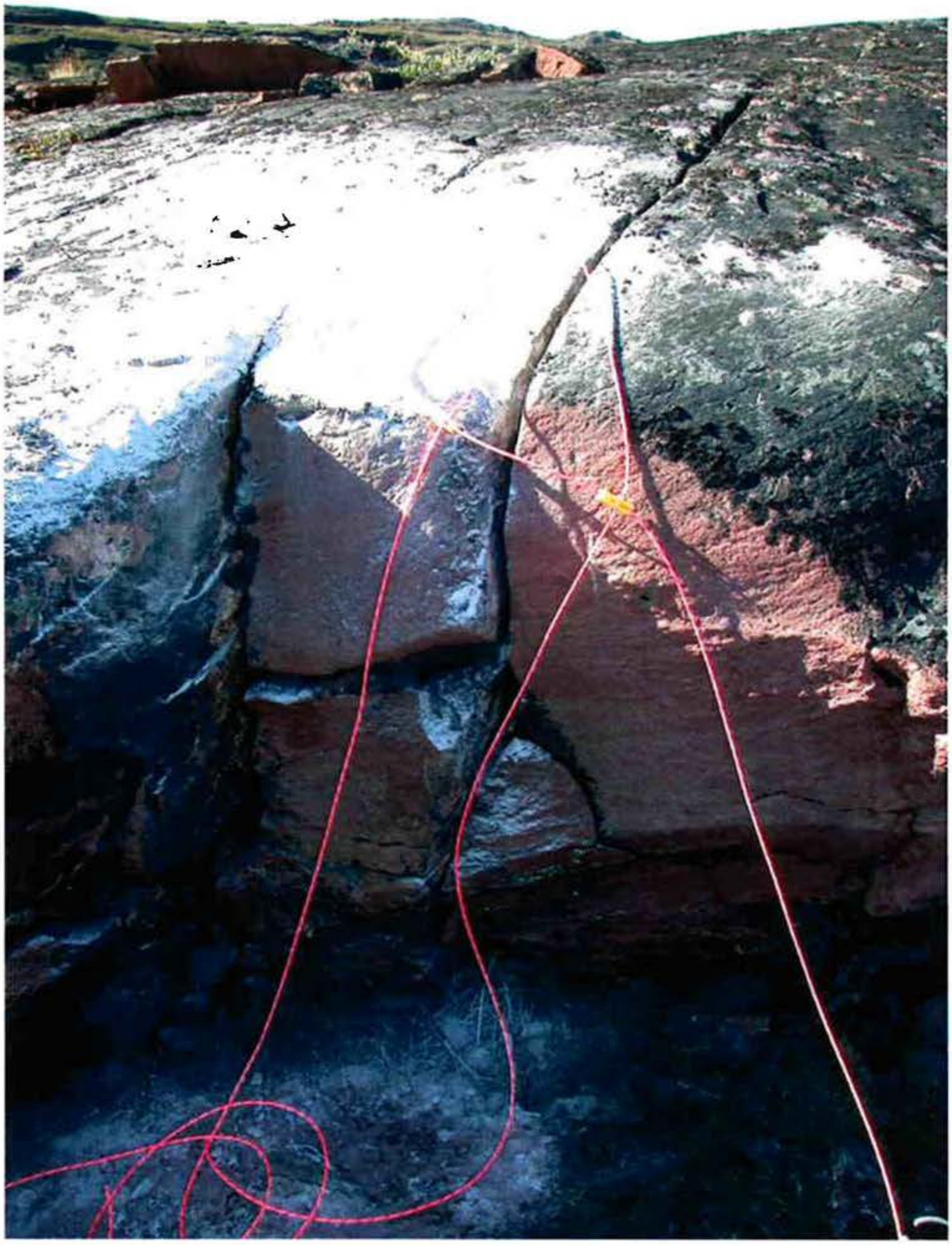


Figure 61. *Red – purple sandstone ready for blasting.*

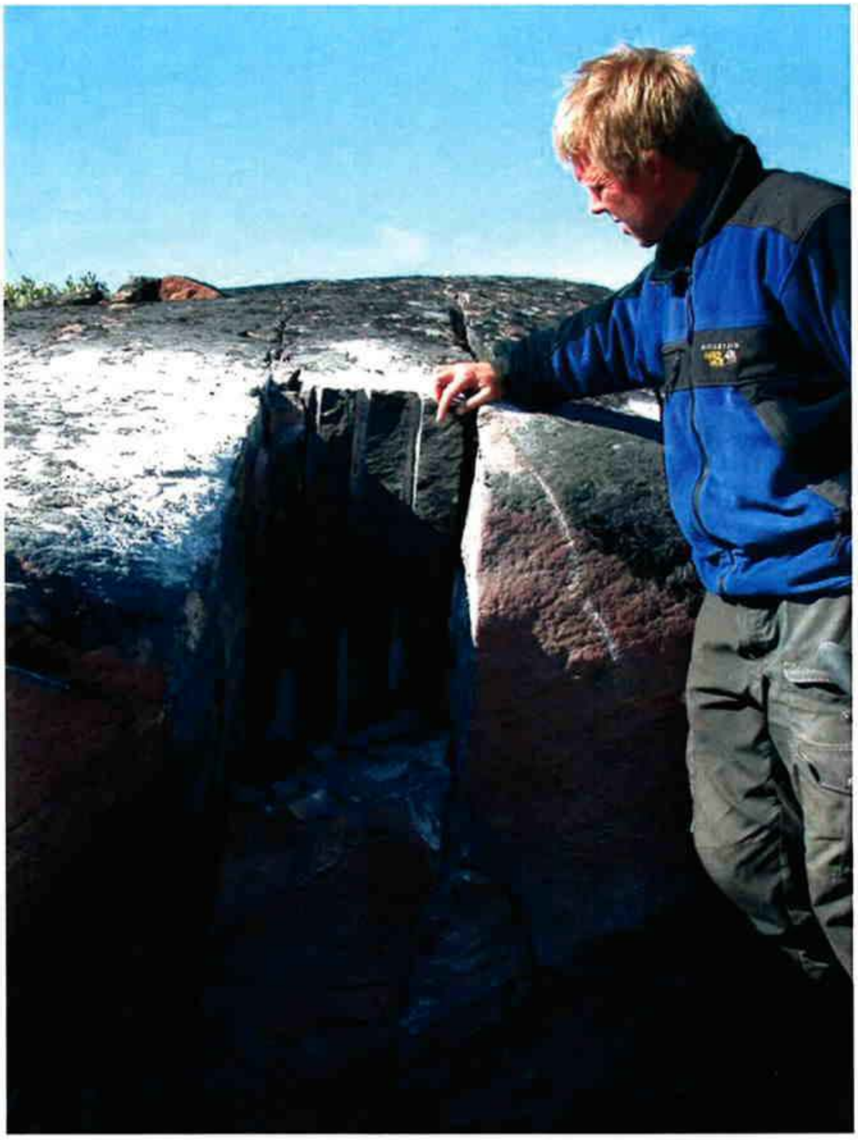


Figure 62. *The red – purple sandstone after blasting.*

Figure 63. *Polished red – purple sandstone from Sillisit.*

Locality 27: Sillisit Itinnerat – blue-green quartzite

Location: Sample 0320 – Blue-green quartzite: 61° 04´16´´N 45°35´41´´W

Description: Blue-green quartzite. The type locality of the blue-green quartzite found at several places within the red igaliku sandstone often in conection to cross cutting mafic dyks.

Access: There is a good access to the site from land.

Rock type:

Name: Contact metamorphosed Igaliku Sandstone (figure 64).

Colour: From blue-green to pale green.

Texture:	In general the blue-green quartzite are more massive than the red sand stone because there is no horisontal layering and the vertical fractures are more spaced than in the red sandstone.
Grain size:	Fine.
Mineralogy:	Quartz
Structure:	Massive.
Positive Features:	The quartzite is a competent rock type with exciting colours (figure 65).
Negative Features:	At Sillisit the thick basalt cover makes this difficult to establish a large quarry. But the blue-green quartzite found at several places within the red igaliku sandstone and some of them are more accessible. More prospecting has to be done to find the best place for mining it.

Figure 64. *Sharp irregular contact between reddish Igaliko sandstone and blue-green quartzite.*

Figure 65. *Blue-green quartzite from Sillisit.*

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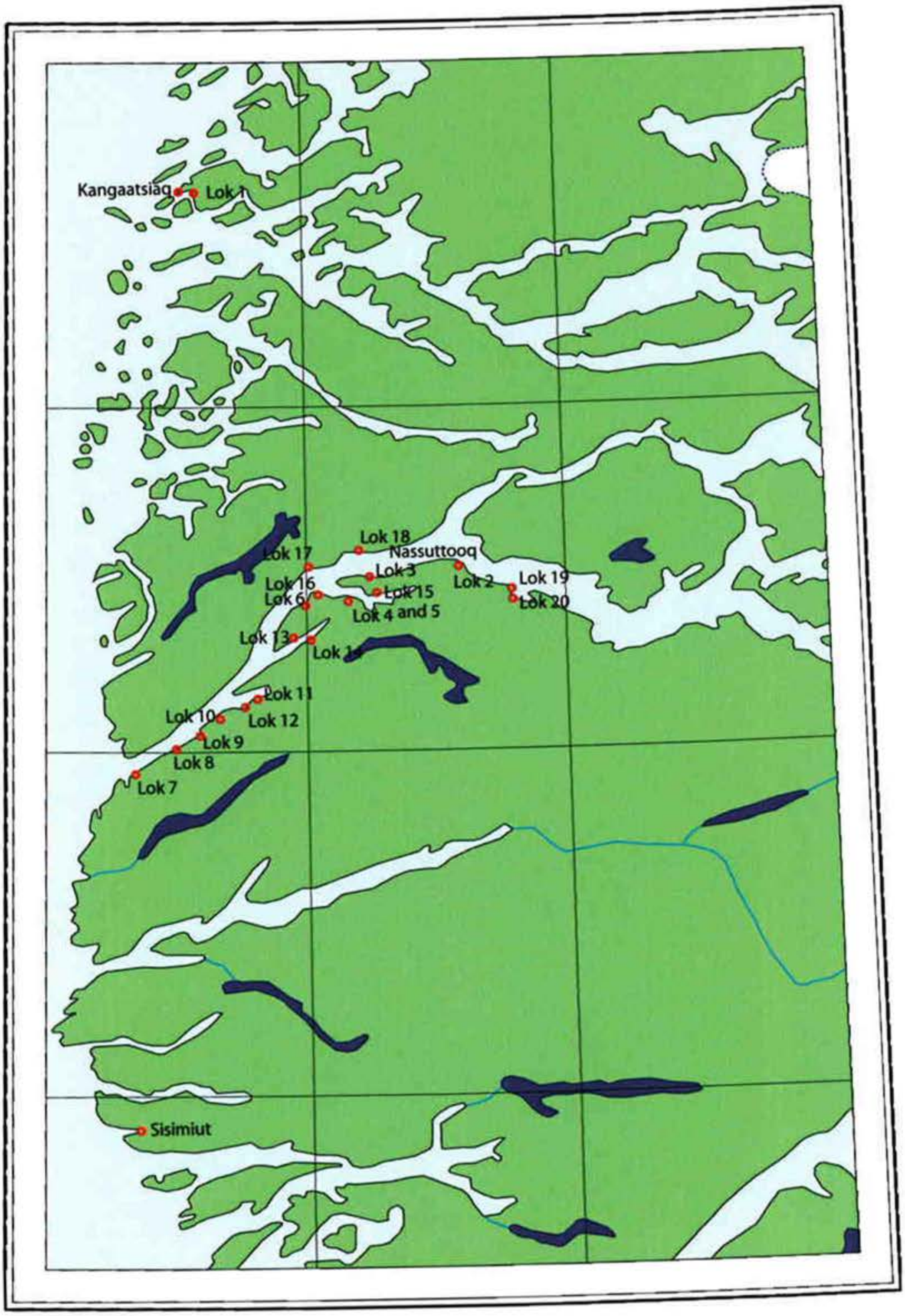
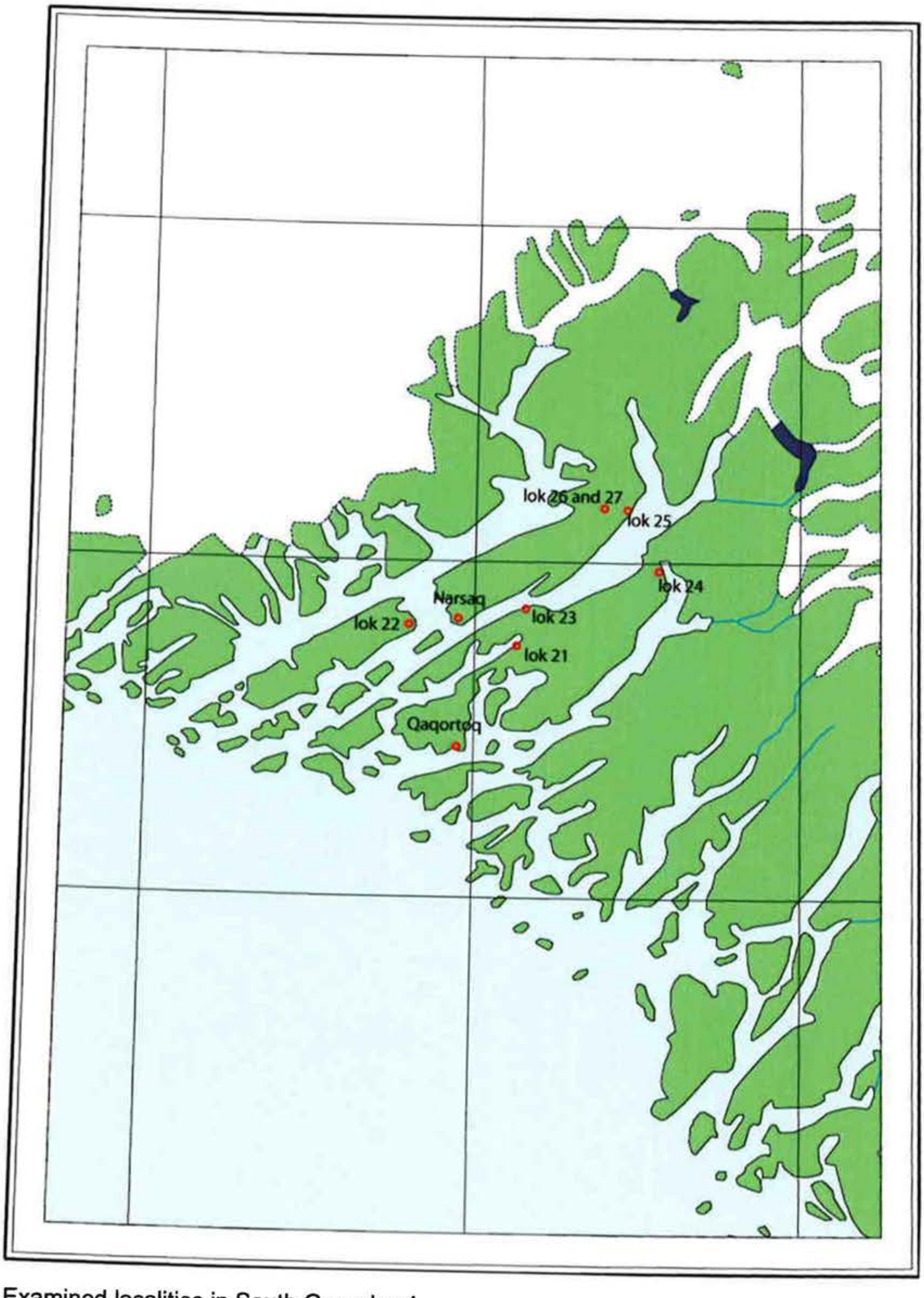
Appendix A Index map of Greenland and local maps A and B

Map A.



Examined localities at Kangaatsiaq and Nassuttooq.

Map B.



Examined localities in South Greenland.