DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2017/42

2014 Field report - investigations of the metamorhic rocks in the Tasiilaq area, South-East Greenland (SEGMENT-project)

Vincent J. van Hinsberg & Majken Djurhus Poulsen

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1. Preface

This report is a report of the field work from the 2014 field season in South-East Greenland that was organised under the joint GEUS-MMR ‘SEGMENT’-project (2009-2016), and that focused on reassessing the geology and mineral potential of the area between 62°30’N and 66°30’N. The main results of the SEGMENT-project are reported in Kolb et al. 2016 [Kolb, J., Stensgaard, B.M. & Kokfelt, T.F. Danmarks og Grønlands Geologiske Undersøgelse Rapport 2016/38, 157 pp.].

2. Field report for Team 6

This report lists the observations, and data collected by the members of field Team 6 during the 2014 SEGMENT expedition to South-East Greenland. The field team consisted of Majken D. Poulsen (MADP) – GEUS, Vincent J. van Hinsberg (VIVH) – McGill University, Canada and Lærke L. Thomsen (LLT) – Government of Greenland. This team was in the field from the 16th of July 2014, until the 6th of August, with LLT leaving on the 24th of July and MADP staying on until the 9th of August.

Vincent van Hinsberg prepared this report with help from Majken D. Poulsen.

3. Introduction

Fieldwork was conducted in South-East Greenland as part of the SEGMENT project from different field camps directed from a base camp located in Kuummiut. Please see Figure 1 for location of the area. The team operated from five camps spread out over the field area and from base camp for the last days; see Figure 2 and Table 1. Camp 4 was shared with Team 4/11 (Kristoffer Szilas (KSZ) – Stanford University, USA, Jonas Tusch (JOT) – Universität zu Köln, Diogo Rosa (DRO) – GEUS, and Nicolas Thebaud (NTH) – University of Western Australia) and camp 5 with Team 2 (Annika Dziggel (ADZ) and Sacha Müller (SMU) – Rheinisch-Westfälische Technische Hochschule Aachen, Germany). MADP helped DRO and Jonas Petersen (JPET) – Government of Greenland with panning for gold at streams on the island of Qianarteq during the last day of her stay.

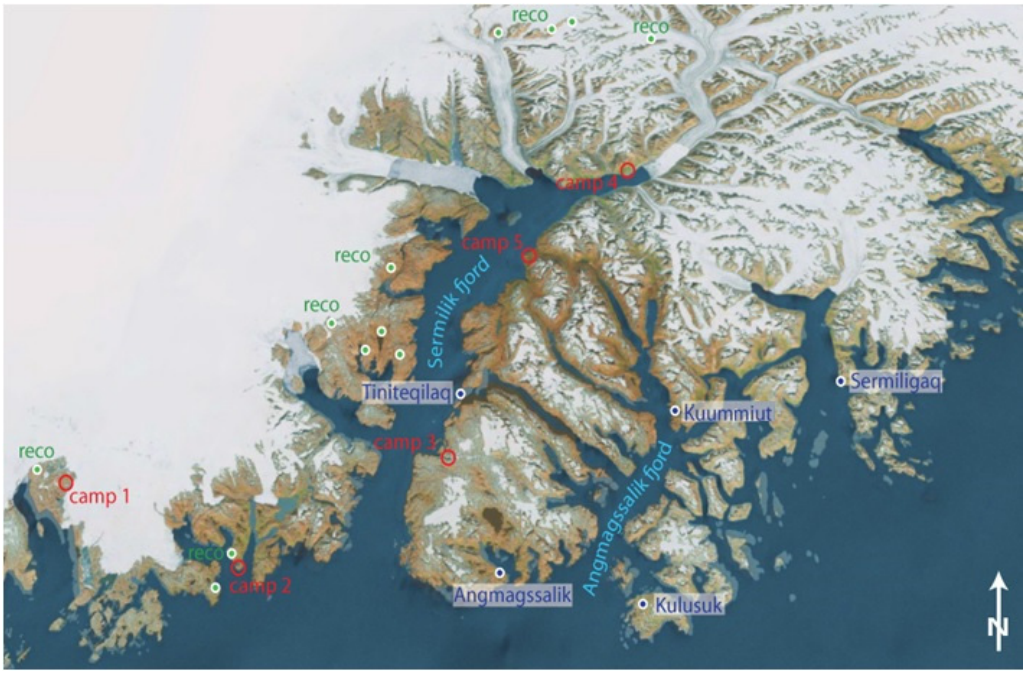

Figure 1. *Pseudo-topographic overview satellite image of the field area with approximate locations of the different camps and reconnaissance stops.*

The main goals of the fieldwork were to:

1. Characterise the occurrences of corundum in the field area, their geological and geochemical setting in contrast to South-West Greenland occurrences, and identify the process(es) involved in its formation.
2. Investigate the “metasedimentary” units in the south and north of the field area and establish:
    a. whether they represent true sediments
    b. what protolith they represent
    c. whether the units in the north and south are the same
3. Investigate specific mapped units to establish whether they have been mapped correctly and how they fit within the understanding of the regional geology:
    a. anorthosite units in the centre and north of the area

b. the diorite complexes in the south and southwest

4. Establish the regional metamorphic grade in the field area and its gradient from south to north, focusing on aluminous units.
5. Describe the geology in and around local communities to put together field guides for use by schools and potentially tourists.

Table 1. *Details of the camps.*

Camp no.	Date	Locality	Lat. (N)	Long. (W)
Camp 1	July 16-21	Diorite-granite complex in southwest	65.72000	39.12167
Camp 2	July 21-14	Ujarassiorit ruby-corundum locality	65.61556	38.47500
Camp 3	July 24-27	Northern contact of Angmagssalik intrusion	65.77278	37.77250
Camp 4	July 27-30	Metasediments north of Sermilik Fjord	66.35013	37.08290
Camp 5	July 30-Aug 2	Triple metasediment band at Cap Nûk	66.16500	37.49528
Camp 6	Aug 2-6	Base camp in Kuummiut		

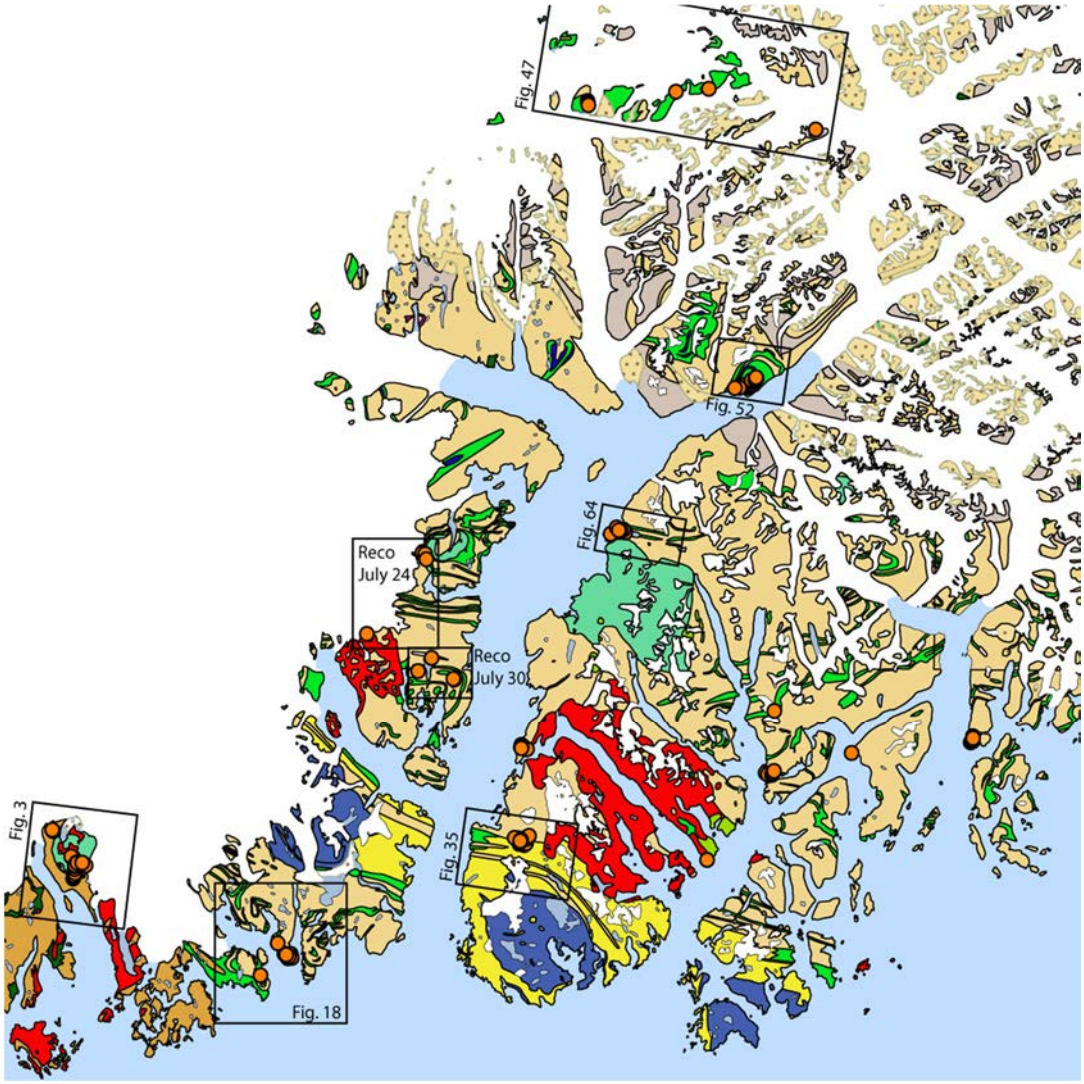

Figure 2. *Geological map showing the station locations discussed in this report (orange dots). The black boxes and the corresponding figure number indicate detailed maps of the various camps. Base geology from GEUS.*

4. Summary of main findings

4.1 Goal 1 – Corundum occurrences

Several occurrences of ruby-corundum were investigated, with a main focus on the occurrence on a small island off Immikkeerteq (on old maps it's spelled with old Greenlandic spelling Ingmikêrteq), which was found as part of the Ujarassiorit mineral hunt project (Nattivit occurrence). Additional, new ruby-corundum occurrences were found at camp 1 and in a continuation of the Ujarassiorit occurrence at camp 2.

All occurrences share the same characteristics: ruby-corundum occurs where late-stage felsic pegmatites crosscut and interact with metamorphosed ultramafic rocks. A progressive metasomatic replacement of the pegmatite takes place with well-developed mineral zones, culminating in a biotite zone, followed by a zone with black amphibole + pink to purple ruby-corundum. This sequence has been found as a concentric arrangement around the pegmatite dyke, as well as along the pegmatite dyke with metasomatism increasing as the dyke protrudes further into the meta-ultramafic. Ruby-corundum is rare, but large (locally up to 5 cm in diameter), anhedral in shape with minimal fracturing. Its concentration in a few large grains suggests that metasomatic replacement took place when element mobility was high. The source of the aluminum appears to be pegmatite plagioclase with removal of silica by interaction with the ultramafic as the mechanisms leading to Al_2O_3 saturation.

The process of formation is local and linked to element exchange between ultramafic rocks and late-stage pegmatite dykes. Both these lithologies are common throughout the field area, and metasomatic reaction zones between them are ubiquitous. However, most of these do not reach the final black amphibole + ruby-corundum stage, and instead develop only up to the biotite mineral zone. Even where ruby-corundum was observed, most reaction zones in these localities do not advance to this stage.

Earlier stages of pegmatite activity did produce metasomatic reaction zones, but these are wider and not as focused, leading to only limited element enrichment. The ultramafic rocks are boudinaged in the entire area, and most often, the host rocks are amphibolites and felsic TTGs. The interaction between the felsic gneisses and the ultramafic rocks does not seem to be the trigger for the corundum-forming processes. This suggests that element mobility was less punctuated in these cases, possibly as a result of limited fluid availability.

Nonetheless, the style of metasomatism observed at the ruby-corundum localities is common in the field area, especially in the south, and we therefore conclude that although ruby-corundum is rare, it could be widespread. Any exploration effort should focus on localities where ultramafic units are cut by late-stage pegmatites.

4.2 Goal 2 – Metasedimentary units

Lithologies presented on the geological map as metasedimentary units vary significantly in their appearance, composition and mineralogy. In the south, the defining characteristic appears to be a rusty weathering colour, generally accompanied by the presence of mica. In the north, there is greater variety in lithologies, with the presence of marble and quartzite in addition to rusty lithologies. Graphite is very common in these units in both the centre and north of the field area, but also occurs in the south. A distinct, coarse-grained, green, unit in the south may be a calc-silicate, which could indicate that carbonate was present in the south as well, although much less abundant.

Our observations indicate that several of the lithologies mapped as metasediments by J.C. Escher in 1989-90 (GGU, Skjoldungen 1:500 000) in both the north and the south are in fact altered primary lithologies from amphibolites to TTGs. Alteration is especially prevalent along regional scale structures, and is commonly accompanied by sulphide and/or graphite formation, which in turn leads to rusty weathering. An alteration origin for these units seems to be more prevalent in the south. However, lithologies with a likely sedimentary protolith have also been observed, and we include the marble and quartzite units of camp 4 under this category, as well as the highly aluminous schists of the nunataks in the far north. For the camp 4 marble and quartzite, Team 11 prefers an alteration origin, and further work is needed. Where lithologies are likely of sedimentary origin, deformation is commonly concentrated in them, making use of the abundance of platy minerals. This suggests that some of the "alteration-lithologies" around regional structures could alternatively represent focusing of deformation into a metasedimentary unit.

A range of samples were taken to verify whether these units represent true sediments or rather alteration zones. We do note differences in lithology characteristics among the south, north and far-north nunataks. Marbles are common in the north, but absent in the south (except for possibly as minor calc-silicates), and we would more readily attribute lithologies to an alteration origin in the south. The metasediments on the far north nunataks are massive, highly aluminous units that resemble typical meta-pelites. This sequence can be explained in several ways, from three distinct units, one or more of which could be the result of alteration of magmatic precursors, to a gradual change in composition in one sedimentary unit. To resolve this requires age information, identification of protoliths, and reconstruction of P-T-X history, which will be researched in collaboration with Team 4.

4.3 Goal 3 – Specific units: anorthosites and diorite

The published geological map lists several anorthosite localities in the field area, two as thin bands in the south, and one as a larger unit in the far north. All were visited. The two thin bands consist of a single dismembered layer of a maximum original thickness of approximately one meter, now present as boudins up to one meter in size enclosed by well-foliated TTG (Tonalite–trondhjemite–granodiorite) gneiss. The mineralogy of the boudins is plagioclase and green to black amphibole, both as megacryst aggregates. They represent a unique lithology that can be traced easily despite its small dimensions. It is similar in appearance to lithologies in the Fiskenæsset anorthosite complex, but occurs on a completely different scale

here. It does represent a mappable unit, but anorthosite is not an appropriate designation, especially in relation to the massive Fiskenæsset complex. It is a coarse-grained gabbroic unit, peculiar in its appearance and preservation, but no evidence was found to link it to a large magmatic complex. Nonetheless, samples were taken to investigate this unit further.

The larger anorthosite in the far north was found to be a true anorthosite, composed dominantly of megacrysts of plagioclase with smaller green amphibole. The plagioclase was light purple to grey in colour. It outcrops on a sharp peak that did not permit access, so only float could be investigated. It appears to have sharp contacts to the enclosing rocks, which could unfortunately not be accessed. No other occurrences of this material were observed in the surrounding nunataks, nor were any dark mafic rocks that we expected to accompany such an anorthosite body. Samples were taken for geochemistry to characterise it, and geochronology to establish the age of this anorthosite and its place in the regional geological history.

Several diorites were studied, starting with the diorite body in the southwest. According to the geological map, this body was similar to the metadiorites in the centre of the field area. However, we found an intrusive complex with minimal deformation disturbance, which contrasts sharply with the characteristics of the metadiorites further north. The basement of the area consists of well-foliated upper-amphibolite facies TTGs and amphibolites with ultramafic and calc-silicate lenses. This basement is intruded by two subsequent pulses of diorite, a coarse-grained and a fine-grained variety. The coarse-grained diorite coats rafts of basement and appears to predate the fine-grained diorite, although both were molten at some point because they show mingling textures. A subsequent granite melt intrudes this sequence producing spectacular intrusion breccias. The final stages of this magmatic system consist of intrusion of pegmatite dykes that cut all lithologies.

The metadiorites in the centre of the field area west of Sermilik Fjord (unit di_2) are true metadiorites with a well-developed foliation. They are identical in appearance and mineralogy to metadiorite layers interbedded with TTGs at camp 3.

We conclude that the diorite-granite body in the southwest is a different, and more recent magmatic generation than the metadiorites of the di_2 assemblage. It could be part of the di_1 sequence, although we have not studied the di_1 unit in any of its mapped localities. We have taken samples for geochemistry and geochronology to establish the age of this body and how it fits in the regional geological history.

4.4 Goal 4 – Regional metamorphic grade

The metamorphic grade of the area represents upper amphibolite to granulite facies conditions, with local anatexis in felsic, water-rich units. In the north the presence of kyanite suggests relatively high pressures, and kyanite is also abundant in the Kaneertivit area the Northern nunataks in the Switzerland area (reco 3). These conditions are overprinted in a wide variety of events at different metamorphic conditions. Contact metamorphism can be observed around the large intrusions, as well as around early pegmatitic dykes on the far north

nunataks where it leads to sillimanite replacing kyanite. Sillimanite around camp 4 could suggest a higher temperature regional metamorphism in this area compared to further north, or contact metamorphism.
Both regional and local retrogression is observed, with chlorite replacing amphibole along veins and faults at all camps, muscovite replacing sillimanite at camp 4, and muscovite and chlorite appearing in deformation zones, such as at camp 5. The original mineral paragenesis may be completely replaced, or remnants can be abundant.

Samples have been taken throughout the field area as a basis for constraining the P-T conditions, and any regional trends. Focus will be on aluminous units, with Team 2 focusing on (ultra)mafic lithologies and high-pressure rocks.

4.5 Goal 5 – Outreach

Five communities (Kuummiut, Tiniteqilaaq, Sermiligaaq, Kulusuk and Tasillaq) were visited and their local geology observed and sampled to act as a basis for a local outreach field guide. MADP and VIVH visited the first three villages together; MADP visited the latter two.

All villages presented interesting geology at minimal distance from the village with different highlights from intrusion relations and contact metamorphism (Tiniteqilaaq) to deformation and metamorphism (Kuummiut) to an igneous fractionation series (Sermiligaaq). Samples were taken to add P-T and age information, as well as compositions and (thin-section) photographs to these field guides.

The aim is to produce a field guide for use in the local schools with background information on geological processes and features, and an excursion guide for tourists.

5. Field observations and data

5.1 Camp 1. Diorite-granite intrusive complex

Campsite just north of a lake on a nice flat area with polished slabs and boulder fields. Next to small a river fed by melting ice. Good spot for camping. The station locations for camp 1 are seen in Figure 3.

Goals: - investigate the diorite complex and its relationship to its basement
- check the anorthosite band in the TTGs north of this diorite

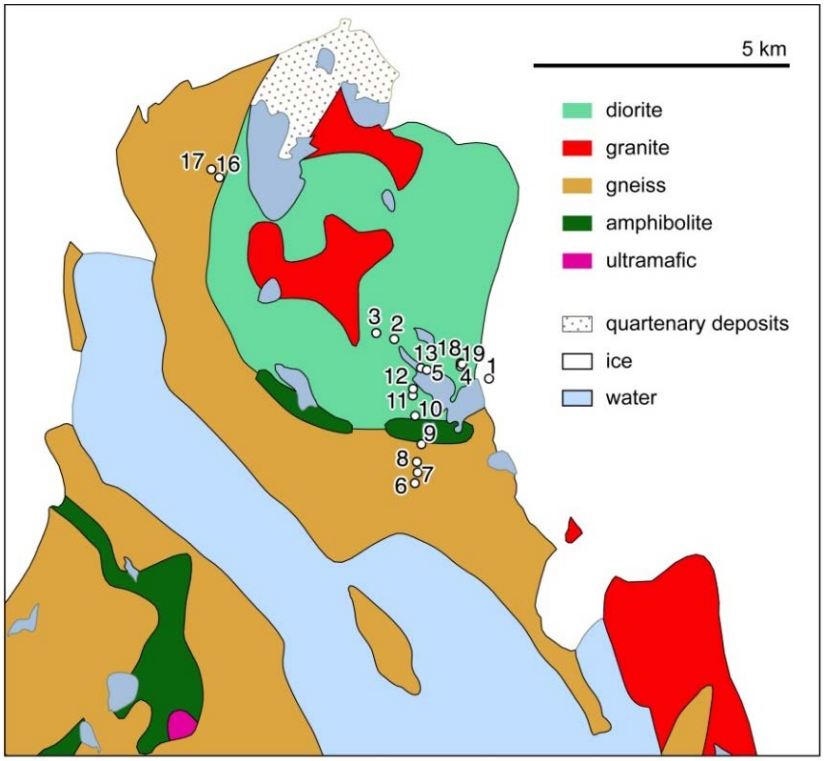

Figure 3. *Geological map showing the station locations for camp 1 (geology taken from GEUS interactive 1:500.000 geological map of Greenland). See Figure 1 and 2 for location of camp 1.*

5.1.1 July 17

Sunny in the morning, overcast in the afternoon. Went towards the Inland Ice in the morning, lunch at camp and then to the central granite in the afternoon.

Station: 14vivh001
Coord: 65˚ 43.053 N
39˚ 06.617 W

Loose boulder of ultramafic with metasomatic veinlets cutting through it (Figure 4). The best-developed veinlet is 2 cm wide with a bleached brown outer rim, white to beige inner amphibole rim with dark green amphiboles within it, and where widest has a small ruby inside (0.5 cm diameter), see Figure 5. Other veinlets only have the brown rim with dark green amphibole +/- chlorite in core. One of these latter veins transitions along strike to plagioclase in core.

Several orientations of veinlets in the block, crosscutting, but no real age progression.

Looks like fluids getting in and forming metasomatic rims along the fluid pathways, possibly related to felsic intrusive to which the plagioclase belongs?

Local rocks are well-foliated amphibole gneisses.

- Sample: **526701** - sample of second type of veinlet with plagioclase
- Photos: 123-124 - overview pictures
  125-127 - detail with tip of pen pointing to ruby

Blocks continue up the hill. Some nice coarse-grained green to brown UMs. Still veinlets, but not the ruby bearing type and no rubies found. Two generations of veinlets: older wider generation with brown leaching, beige amphibole and dark green amphiboles up to 3 cm in length. These are crosscut by younger veinlets of finer-grained green amphibole and chlorite. No outcrop, but many blocks and ranging in size from 2 x 2 x 2 m to dm scale.

On the way back to camp passed through diorite and granitoid. The diorite is fine-grained dark grey with mm-sized plag and amphi/px, the granitoid white to grey with mm-sized plag and qtz and minimal dark minerals (looks like amphibole). A little coarser-grained than the diorite. Both contain rafts of the amphibole gneisses, and granitoid also has rafts of the diorite. Most of these are angular. Locally there is a thin (10 cm wide) rim of coarser-grained and lighter coloured melt on the gneiss rafts in diorite, and this melt is mingling with the diorite. Could be partial melting of the rafts? Elsewhere also mingling, but no rafts. Rafts in general are angular.

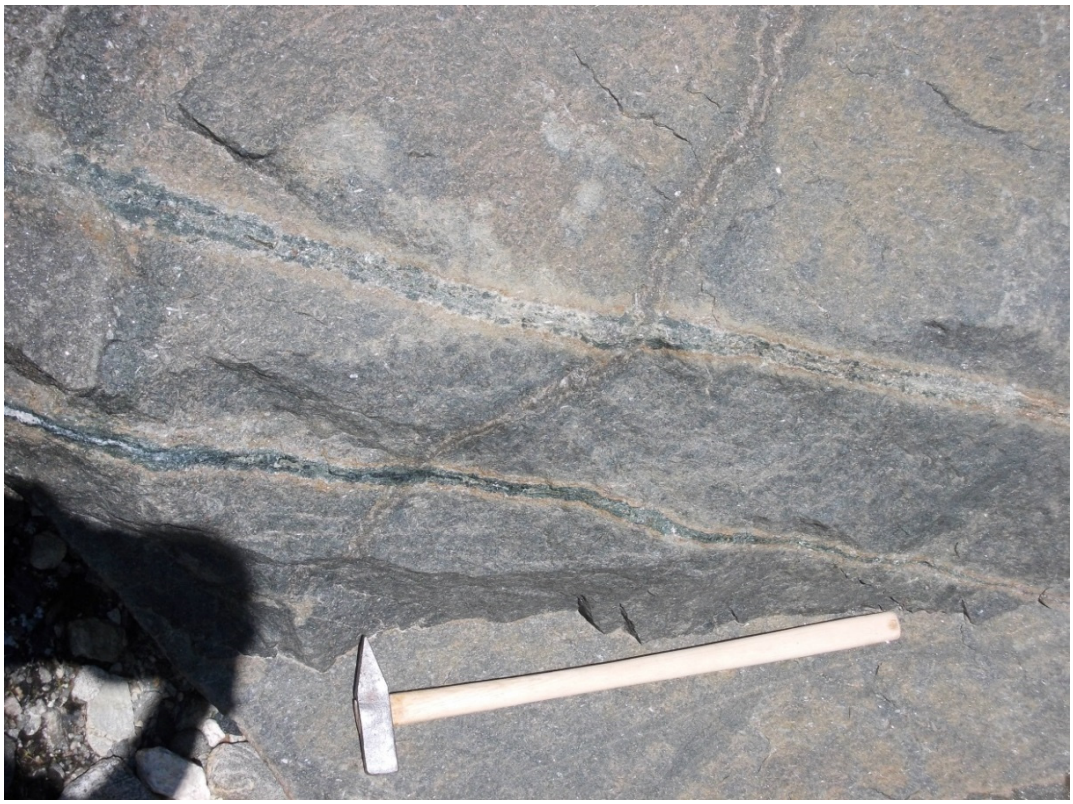

Figure 4. *Metasomatic reaction veins in ultramafic metamorphic rock (photo 123).*

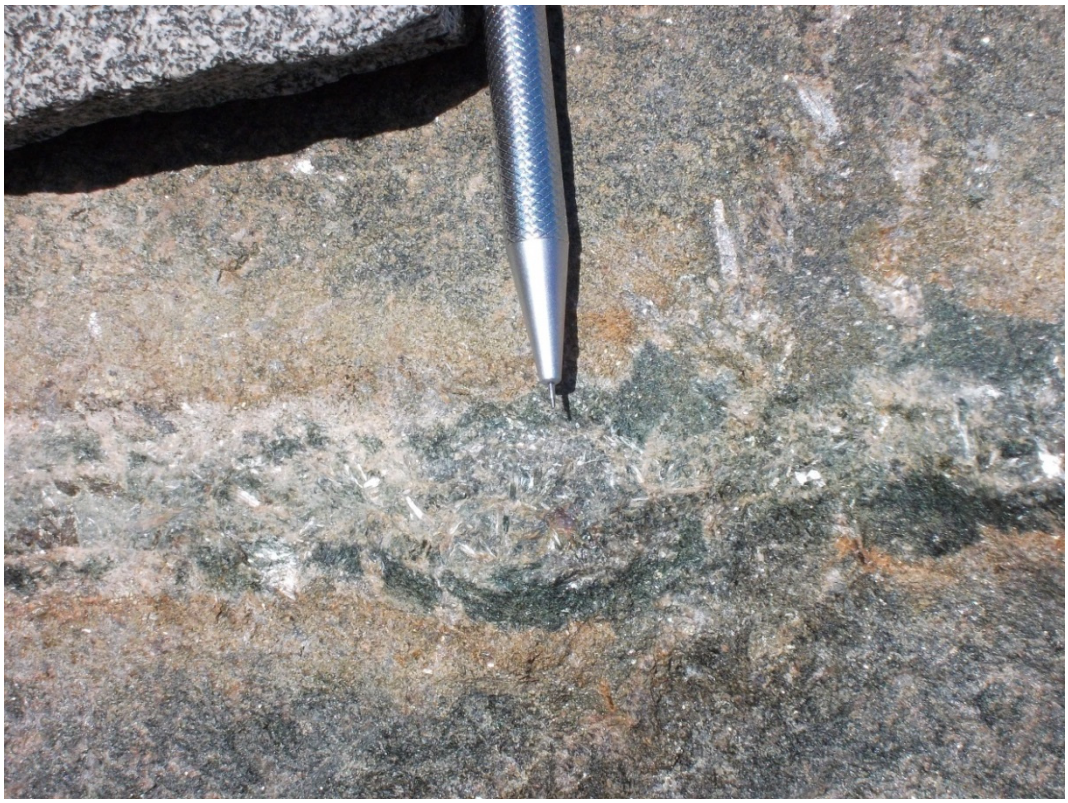

Figure 5. *Pink ruby in the centre of metasomatic vein in ultramafic metamorphic rock (photo 126).*

Station: 14vivh002
Coord: 65˚ 43.565˚ N
39˚ 08.929 W

Metasomatic reaction rim between diorite with large (2–3 mm diameter) magnetite grains (unusual, diorite away from this does not have these) and coarse-grained green amphibolite (Figure 6). Rim contains plag and brown biotite as well as a blue glassy mineral. Looks like quartz but the blue colour is intense and consistent. Could be a metasomatic mineral; sapphire? No cleavage and fatty lustre. Sampled to do mineral ID.

Outcrop is small (1 m) and reaction zone is thin (5 cm). The magnetite in the diorite is also related to the metasomatism and because these are randomly distributed and there is no fabric, it would appear that exchange happened when diorite was still liquid. Also lots of magnetite in the gneiss.

Figure 6. *Metasomatic reaction rim between diorite and coarse-grained green amphibolite basement.*

• Sample: **526702** - for mineral ID

Station: 14vivh003

Coord: 65˚ 43.651 N
39˚ 09.372 W

Sample of the granitoid taken well within the area mapped as granitoid. Have seen much more of this granitoid on the way from camp to this station as dykes and larger bodies. The boundary is therefore not abrupt as drawn on the map, but rather diffuse with granitoid intruding the other units (Figure 7). Even in this area there are still abundant rafts of gneiss and diorite.

- Sample: **526703** - representative sample for geochronology and geochemistry
- Photos: 130 - mingling
  131-132 - intrusion breccia of granitoid with diorite rafts

5.1.1.1 Overview July 17

Area consists of metamorphic basement with strongly foliated and tightly folded felsic gneisses and amphibolites, often alternating at dm to 10s of m scale. Composed of amphi, plag and qtz. Within also a variety of other lithologies: 1. Calc-silicates up to 2 x 5 m with green cpx and red garnet masses; 2. Meta-gabbro with coarse-grained elongated plag phenocrysts; 3. Layered dark green amphibole/pyroxene + plag gneiss with lots of magnetite, and 4. UM lenses from fine-grained to coarse-grained (cm scale minerals). The UMs have blackwall reaction rims around them with px, amphi or bt. These also develop metasomatic veinlets when interacting with more recent felsic intrusives + fluids to form amphibole + plag +/- px +/- chl and locally ruby.

This basement is intruded by a fine-grained dark grey diorite, mostly as larger bodies but locally as dykes. Contains lots of basement fragments towards station 14vivh001 from camp, but 'clean' in interior towards the central granitoid. Locally partial melting (?) of the basement rafts is observed with subsequent mingling of these melts. This partial melt has same mineralogy as diorite, but is coarser-grained and has much more plag. In interior the diorite also shows mingling with this lighter coloured coarser melt, but here no rafts.

A second much coarser grained 'diorite' is present in central part of the body. Its relation to main diorite is conflicting: locally it appears to mingling with the main darker diorite, at other times it is present as angular blocks in diorite. Could be multiple pulses?

Final stage is very white 'granite' with plag + qtz, minor amph/bt (mostly amph). No obvious K-spar although there is K-spar in pegmatitic veins that crosscut the granitoid. The granitoid is full of blocks of both basement and diorite, mostly angular but locally somewhat rounded. Blocks vary in size from meter to centimeters. Central area has large granite body; elsewhere it is mostly present as dykes -> boundary on map does not represent actual contact: is diffuse rather than sharp. At very end, coarse-grained (crystals up to 10 cm diameter) plag-K-spar-qtz pegmatite dykes up to 50 cm wide. They crosscut everything with sharp, mostly straight contacts. Often plag + K-spar on rim, qtz in core.

Figure 7. *A) Mingling in dark grey dioritic melts (top of photograph), which are cut by later felsic melt along brittle fractures (photo 130). B) Intrusion breccia of felsic melt into diorite with brittle fractures (photo 131).*

5.1.2 July 18

Went south of camp to look at the contact between the intrusive complex and its southern host rocks, including the nature of the amphibolite lenses of the map.

Station: 14vivh004
Coord: 65˚ 43.208 N
38˚ 07.309 W

Outcrops around camp: flat area between the lake and snow covered slope on other side. Four different units:

1. Basement of amphibolite gneiss ranging from amphibole dominated to white-grey plag-qtz dominated. Well-foliated and locally intensely folded.
2. Three bodies of rounded UM, ~4 m long and 2–3 m wide. No fabric internally. Dark green internally, brown on weathering surface. One of these has well-developed blackwall of dark amphibole, and all show crosscutting, metasomatic veinlets. Part of basement. See also station 14vivh019.
3. Diorite, fine-grained, grey. No internal fabric. Contains rafts of basement and is itself present as rafts in granitoid (Figure 8). Rafts are angular. There is also a coarser-grained variety of this diorite, locally mingling with the fine-grained one. This coarser-grained one also coats most of the basement rafts: appears that this melt brings in the basement rafts.
4. Granitoid, light in colour, medium-grained (2 mm scale). Last event with rafts of diorite and basement, and diorite + basement. Even later pegmatite dykes cut everything.

Some alignment in one part of the granitoid just south and east of camp, with alignment of minerals and flattened and aligned rafts of diorite.

Figure 8. *Granitoid with alignment of minerals and flattened rafts of diorite.*

Station: 14vivh005
Coord: 65˚ 43.232 N
38˚ 08.337 W

Ridge of brown weathered amphibolite gneiss with yellow staining on cracks. Ridge is about 50 m long, 15 m wide and 4 m high. Sampled to check mineralisation. The ridge sits in between diorite and granitoid, with granitoid full of rafts of basement and diorite. This ridge is likely a raft as well.

• Sample: **562704** - mineralisation check

Station: 14vivh006
Coord: 65˚ 42.025 N
38˚ 08.779 W

Edge of the intrusive complex on slope towards the fjord, a few hundred meters beyond where the contact is drawn on the map. Consists of nicely foliated TTG gneiss with cm-sized augen of plag and boudinaged felsic layers. Mixed in is amphibolite, dark green to black in colour with amp + plag. Also locally strong folding at cm to m scale, although not at station.

Contact is gradational with dykes of granitoid into the TTG and amphibolite. Granitoid itself appears different from the one in the centre of the complex (see below). In the distance there appears to be a large UM body in the TTG gneisses.

• Sample: **562705** - sample for PT
• Structure: foliation 340/48 (dip direction, dip)

Station: **14vivh007**
Coord: 65˚ 42.136 N
38˚ 08.686 W

Large in-situ slab of polished granitoid on way back into complex. Very siliceous appearance with almost glassy appearance of fresh surface. Grey on fresh surface, white with mm-sized phenocrysts of plag on weathered surface. No fabric. Very minor dark minerals (= amphibole). Locally with pink K-spar.

From previous station: TTG + amphibolite basement intruded by coarse-grained diorite that looks similar to the coarse-grained diorite of the interior. This is a thin band (~10 m wide) and then in turn this is intruded by the granite of station. Abundant small to large fragments of the diorite and basement in the granite at contact.

• Sample: **562706** - for geochronology and geochemistry

Station: 14vivh008
Coord: 65˚ 42.254 N
38˚ 08.679 W

Large glacially polished outcrop of the coarse-grained diorite (Figure 9), nicely homogenous here. Locally cut by small granite dykes. From last station to here: a large raft of amphibolite followed by a pink pegmatite dyke ~2 m wide with epidote veining, and then the fine-grained diorite (see overview picture on tablet). From stream to station, the outcrops are the coarse-grained diorite.

Sample is characteristic for the coarse-grained diorite and it is assumed that is the same of the coarse-grained one that is mingling in the interior. Also shows mingling here.

• Sample: **562707** - sample for geochronology and geochemistry

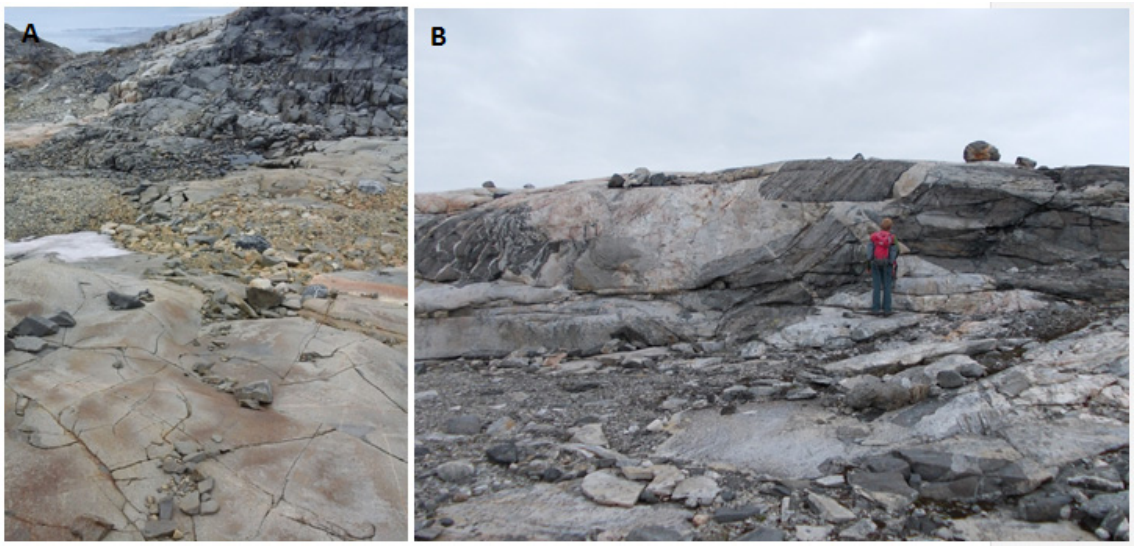

Figure 9. *A) Glacially polished outcrop of coarse-grained diorite. B) Outcrop with large rafts of partially rotated amphibolite in the coarse-grained diorite.*

Station: 14vivh009
Coord: 65˚ 42.435 N
38˚ 08.517 W

Sample of very dark amphibolite, roughly at location of amphibolite on the map. Although the shape and inferred relations are incorrect on the map, the body is indeed there. However, it is not the start of the basement, nor a separate basement unit, but rather a very large raft in the intrusive complex. It has a very sharp contact to the granitoid to the N. Almost black in colour, composed of amphibole (>95%) and minor plagioclase. It is well-foliated and isoclinally folded.

This amphibolite is part of the basement. Only at station is it dominated by amphibole, elsewhere proportions of plag and amphibole vary. It is cut through by TTG dykes that now have a shallow angle to the overall foliation, so it appears these dykes were parallelised in later

deformation event. Both the amphibolite and TTG dikes are folded. The amphibolite is oldest here, followed by TTG. This is probably true for whole basement sequence here.

The lens is cut by granitoid dykes and is also locally brecciated by intrusive. The granitoid appears to dome here and slope down towards the fjord. Could this be the roof of the intrusive complex? That would explain the size of the raft and the many dykes and brecciation.

• Sample: **562708** - sample for geochemistry and P-T

Station: 14vivh010
Coord: 65˚ 42.736 N
38˚ 08.593 W

Layer of light green material in amphibolite basement with metasomatic replacement (Figure 10). The green rock is fine-grained and does not have a fabric but the enclosing amphibolite has good foliation. Minerals are pale grey (plag?), and pale green (px?) with metasomatic replacement in bands up to 5 cm wide to black amphibole and biotite, both large (several cm).

Unclear what this material is, but it forms a continuous zone in the amphibolite for at least 50 m. Could be a calc-silicate layer.

• Sample: **562709** - sample for mineral ID

Figure 10. *Possible calc-silicate layer in amphibolite basement with light green mineral (not yet identified). Sampled as 562709.*

Station: 14vivh011
Coord: 65˚ 42.954 N
38˚ 08.603 W

Dry riverbed leading down to lakes and camp. Medium grained granitoid of interior all along valley floor with large section (raft ?) of well-foliated very white TTG gneiss within it.

• Sample: **562710** - sample for geochron and geochem

Station: 14vivh012
Coord: 65˚ 43.015 N
38˚ 08.562 W

Orange brown weathered zone in amphibolite-cut-by-diorite raft in granitoid (Figure 11). Raft is ~3 x 4 m in size. Alteration zone with sulphides that give the orange brown staining is irregular with patches ~20 cm wide. Contains abundant (30%) sulphides interstitial to amphibole matrix.

• Sample: **562711** - outcrop sample of sulphide-bearing zone
562712 - float sample approx. 50 m down slope, which has similar sulphides
• Photos: 136-137 of basement at station

Figure 11. *Large block of amphibolite basement cut by diorite and enclosed in granitoid. The rusty-brown weathered zones contain abundant sulphides (sampled as 562711).*

Station: 14vivh013
Coord: 65˚ 43.201 N
38˚ 08.175 W

Fine-grained diorite as large rafts up to 10 x 10 m in granitoid. Also rafts of basement in the diorite rafts and as separate rafts in the granitoid (Figure 12). The basement rafts have a rind of coarser-grained diorite that is mingling with the fine-grained diorite. The coarser-grained melt is lighter in colour.

- Sample: **562713** - typical fine-grained diorite
- Photos: 145, 147, 148

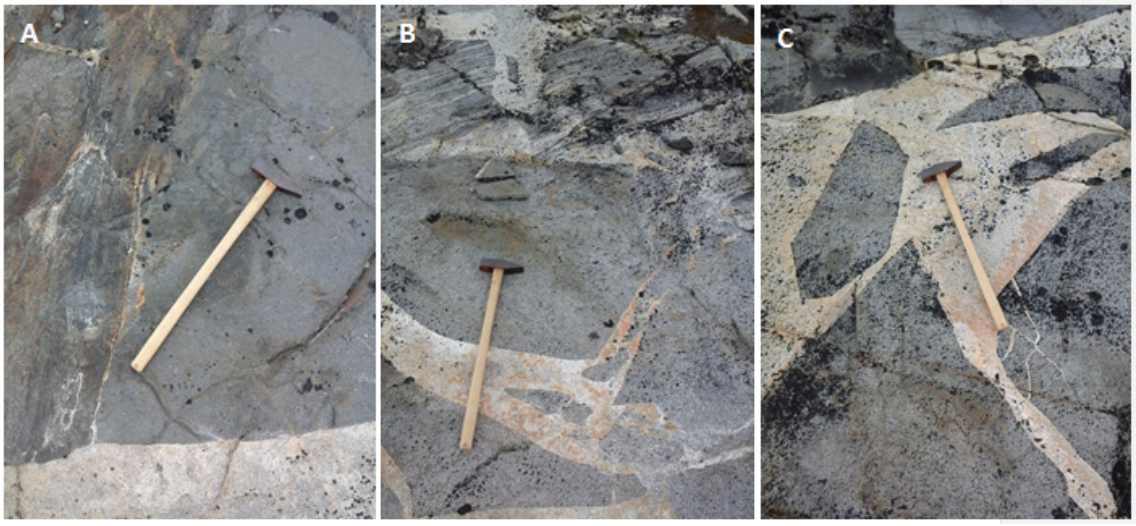

Figure 12. *Fine-grained diorite rafts in granitiod. A) Very sharp contact between amphibolite basement and diorite, with both being cut by later granitoid. B) Coarse-grained diorite cut by granitoid. C) Finer-grained diorite with slightly darker colour cut by granitoid.*

5.1.3 July 19

Overcast in the morning, a little rain during the day, sunny in the evening. We went to the ruby/sapphire site from the Ujarassiorit mineral hunt with Vittus Sakæussen by boat via Tasi-ilaq. On return to camp had a reco stop with helicopter to check on anorthosite layer in TTG gneiss of northern contact of intrusive complex.

Station: 14vivh014
Coord: 65˚ 37.262 N
39˚ 29.132 W

Approximately 40 cm sized metasomatic band in UM with cm-sized purple to pink rubies in black-amphibole core (Figure 13). Pale brown coarse-grained (5 mm sized grains) UM with px and within this series of metasomatic veinlets up to 40 cm wide. These branch out and do not seem to be crosscutting. Characteristic series of mineral zones in veinlets, but not all have all the mineral zones (Figure 13). Mineral zones from outside to core:

1. Pale beige fibrous amphibole? ~4 cm wide with fibres growing perpendicular to vein walls;
2. Brown rim of ~0.5 cm thick; Light green fine-grained amphibole/pyroxene grading to dark green amphibole (coarse-grained with grains up to 4 cm long);
3. Several cm thick friable band of pure biotite;
4. Coarse-grained black amphibole (up to 6 cm long) with locally large irregularly shaped pink rubies up to almost 4 cm in size.

The rubies are irregular in size and some have rim of biotite around them with flakes growing out perpendicular to ruby surface.

In enclosing gneiss, there is a non-foliated late pegmatite with plag - K-spar - qtz: likely source of the fluids/melts for the metasomatism and the K for all the biotite.

• Sample: **526714** - core zone with several rubies for fingerprinting
• Photos: 174-181

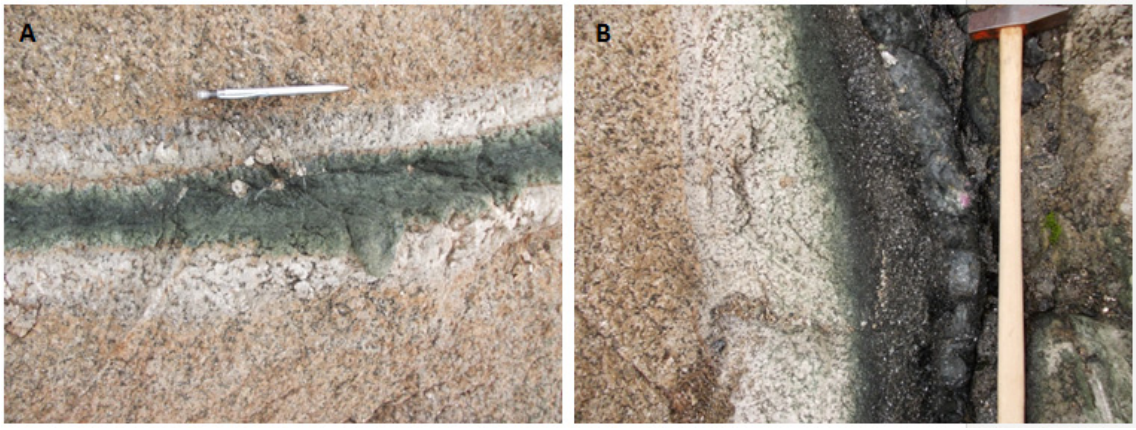

Figure 13. *Metasomatic reaction band in ultramafic rock with concentric mineral zones; A) Ruby/sapphire-absent veinlet, consisting of pale beige fibrous amphibole and a brown rim of ~0.5 cm thick followed by light green fine-grained amphibole/pyroxene grading to dark green amphibole. B) The green zone is thinner here but grades into a black core zone consisting of pure biotite, locally enveloping a black amphibole + pink ruby zone (photo 178 and 181).*

Station: 14vivh015
Coord: 65˚ 37.221 N
38˚ 28.837 W

Continuation of the UMs continues from the small island (Vittus-ruby island) until the larger island across from the water (Immikkeerteq island) and East of station 14vivh014. UMs in two distinct bands going up the mountain, boudinaged into lenses. The bands appear roughly parallel to the foliation in the enclosing gneisses. The northern one is the same as the UM that contains the rubies, the southern one is also represented on the small island as a continuous UM band that runs across the island. The southern UM looks different in that it is full of large (up to 3 cm diameter) round, black porphyroblasts. On weathered surface it looks brown and almost like garnet, but black in fresh section: opx? Ruby bearing one does not

have this so must be a different composition. The northern UM on big island has similar metasomatic veinlets as on small island, but mineral zone 5 is missing.

The area in between the two UM bands has pale green gneiss.

Figure 14. *Greenish ultramafic rock with abundant (ortho-pyroxene?) porphyroblasts.*

Station: 14vivh016
Coord: 65˚ 45.463 N
39˚ 12.972 W

Helicopter –reco to small bands of anorthosite lenses close to the inland ice in the bottom of Isortoq fjord. The lenses are marked on the 1:500.000 map from Escher 1989-90 as rather big lenses, but are exaggerated on the geological maps. Field observations show
TTG gneiss, well-foliated and very light in colour. Contains lenses of up to 50 cm in length and 30 cm in width of amphibole-plagioclase rock (Figure 15). This band with lenses is about 2 m wide and none is found elsewhere. They consist of 5–10 cm sized rectangular to rounded plag masses with qtz inclusions surrounded by mass of dark green to black amphibole. Very different from the material around. Could be the anorthosite that is referred to on the map. If so, is a minor component of the gneiss.

• Sample: **526715** - sample of the 'anorthosite' lens for geochem and PT

Figure 15. *Leuco-gabbroic layer in TTG consisting of large rounded, light-coloured masses dominated by plagioclase enclosed in dark green to black amphibole (photo Vivh-Loc-16-No-1 and 2). A) Small pods of amphibolite and what is possibly referred to on the old maps as anorthosite. B) Close-up photo of the small pods of 'anorthosite' in the TTG.*

Station: 14vivh017
Coord: 65˚ 45.559 N
39˚ 13.158 W

On way back to helicopter (= north towards the ice) pass through TTG gneisses cut by 2 m thick pegmatite with nice graphic intergrowth of feldspar and quartz. After this a ~20 m thick meta-gabbro (Figure 16), medium grained (2–3 mm sized grains of amphiboles and plagioclase). Fabric aligned with foliation in TTG gneisses.

• Sample: **526716** - representative meta-gabbro for geochemistry and PT

5.1.3.1 Overview July 19

Ruby occurs in metasomatic veinlets in UM with beautiful metasomatic mineral zoning. Very regular and consistent between veins. Ruby in innermost zone with black amphibole. This zone is rarely present. Two foliation parallel horizons with UM lenses both on the small island with the ruby locality and on the other side of the water on the bigger island of Immikkerteq. The southern horizon consists of medium grained green UM homogenous in appearance; the northern one has large (2–3 cm sized) orange weathered, green to black in fresh surface grains of garnet? or pyroxene? that stand out from green matrix. This one seems to have a different style of metasomatism. The area in between consists of well-foliated gneiss with bands of pale green fine-grained material, dark, almost black amphibole bands and bright green bands of amphibole or pyroxene (will go back to check mineralogy – see July 23). This could be calc-silicate. Locally there are pockets of biotite in this. The horizons are continuous for at least 100 m along strike.

Figure 16. *Medium-grained meta-gabbro with laths of amphibole and plagioclase.*

The only rocks that had an 'anorthosite' affinity in the TTGs were a black massive metagabbro and a horizon in the pale felsic TTG gneisses with large lenses of almost undeformed plag + amphi. The plag was present as balls or rectangular crystal masses with dark green amphibole filling in the matrix around them. The proportions of plag and amphibole varied, and some were almost completely amphibole. The large plagioclase masses looked a little like some of the plagioclase balls of the Fiskenæsset anorthosite complex. The horizon itself was narrow, but it did appear to be continuous. The 'anorthosite' predates the TTG gneisses they sit in and their deformation. Will need to be confirmed in analyses.

5.1.4 July 20

Sunny with light wind. Lots of bugs. Investigate the UMs close to camp followed by camp move to Immikkeerteq island next to island with rubies.

Station: 14vivh018
Coord: 65˚ 43.246 N
38˚ 07.296 W

River next to camp, just downstream of ice patch with small lake. Next to UM and flowing over boulders. First order stream, approx. 20 m in length between ice and larger lake. Many of the boulders are rusty stained. Some of these contain sulphides with malachite staining.

• Sample: **553300** - sediment sample from small river next to camp

Station: 14vivh019
Coord: 65˚ 43.232 N
38˚ 07.263 W

UM lens within sheared and foliated gneiss that wraps around it. In pressure shadow limited blackwall formation. Elsewhere around lens this appears to be sheared off and is intruded by granitoid. No reaction rim on granitoid contact but magnetite layers in gneiss and lots of cm-sized veinlets with surrounding metasomatism in UM. Several orientations of veinlets, but all appear contemporaneous. Veinlets have an outer rim of green amphibole, inner rim of black amphibole and then plagioclase core (Figure 17). Or, outer rim of green amphibole, inner biotite, core of large black amphibole. Latter ones often grade to ones with plag core along the veinlet, which we interpret as going towards the source of the fluid/melt that produced the metasomatism.

UM is green to blueish grey in colour on fresh surface and dominantly composed of serpentine + magnetite. Weathers to lumpy brown: pseudomorphs after original minerals preserved in weathering surface?
Next UM at the river at station 14vivh018 is similar but has a well-developed blackwall consisting of a 20 cm zone with large grains of black minerals (opx?) as seen at station 14vivh015 around the serpentine + magnetite UM, then a 1 m thick irregular black amphibole + plag zone and next thin mm- to cm-sized veinlets rimmed by magnetite 'bleeding' into the host enclosing basement gneiss.

• Samples: **562717** - UM
562718 - magnetite bearing gneiss from contact
562719 - plag bearing metasomatic veinlet
562720 - veinlet without plagioclase

• Photos: 231-233 - overview photos showing the blackwall zones

5.2 Camp 2. Ruby occurrences around Immikkeerteq Island

Flat area on top of island Immikkeerteq next to lake (Figure 18). Nice soft flat area large enough to put all the tents and set up the radio. Beautiful view over the fjord and towards the glacier. Problem is lack of water, because small animals in lake water. However, there are ice patches on island and (very) small streams sourced from these.

Goals: - detailed study of the UMs, metasomatism and origins of the rubies
- check the geology of the island, in particular the metasediments and their contact to the gneisses

Figure 17. *A) Metasomatic veins in ultramafic rock with core of plagioclase and amphibole B) Metasomatic veins in ultramafic rock with pegmatite mineralogy in core (plagioclase, feldspar? and quartz) C) Overview photo of ultramafic rock and blackwall zone close to notebook in the photo (photo 231 shown here).*

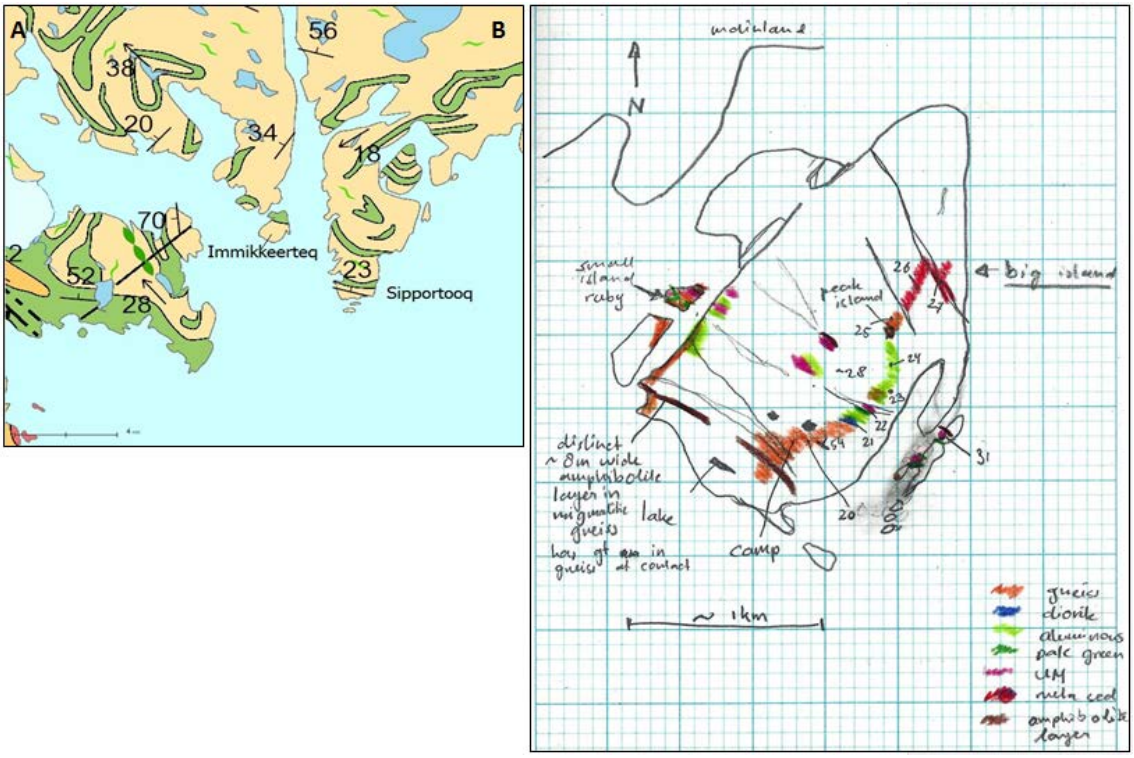

Figure 18. *Camp 2 A) Geological map of Immikkeerteq (see Figure 1 and 2 for the location of this map) and B) a sketch map showing station numbers and geology of Immikkeerteq for July 21 transect.*

5.2.1 July 21

Sunny and hot. Little wind and lots of bugs. Will transect the island to get an overview of the geology and check out the metasediments.

Station: 14vivh020
Coord: 65˚ 36.943 N
38˚ 28.429 W

Outcrop next to lake and east of camp, continuous to west of camp. Rocks consist of well-foliated felsic gneiss full of disseminated stringers of pegmatite or partial melt? Very regularly spaced. These stringers are foliated and folded as well, but they postdate the host gneiss and crosscut its foliation, albeit at shallow angle. Locally the stringers are associated with black amphibole lenses; could be partial melt and restite?

- Sample: **562721** - for geochem and geochron
- Foliation: 036/54 to NE dip direction/dip

Figure 19. *Folded bands of felsic melt and restitic? amphibolite in TTG. These crosscut the TTG foliation at shallow angle, indicating that these are intrusive into the TTG (photo Vivh-Loc-20-No-3).*

Station: 14vivh021
Coord: 65˚ 36.973 N
38˚ 28.244 W
Coord: 65˚ 36.988 N (exact location for sample 562723)
38˚ 28.171 W

Dark grey fine-grained meta-diorite intrusion into the migmatitic gneisses (Figure 20). Contains amphibole, plagioclase and quartz. Also contains several small melt stringers, derived from surrounding gneiss? This would indicate that migmatisation postdates the intrusion. The diorite is foliated but the fabric is less pronounced. The diorite is ~7 m wide.

A light coloured coarse-grained felsic unit with abundant garnet follows this unit. It is well-foliated, ~4 m wide and contains plag, qtz, and locally very large garnet (up to 2 cm diameter). Some rusty staining with minor sulphides interstitial to the metamorphic minerals.

This unit is in turn followed by a dark garnet-amphibolite. Sub-mm sized grains of plag, amph, gt +/- qtz.

- Samples: **562722** - garnet bearing felsic unit for PT
  562723 - garnet-amphibolite for PT
- Foliation: 040/60 NE dip direction /dip
- Photos: 246 - photo of the felsic garnet-bearing unit

Figure 20. *A) fine-grained meta-diorite intruding into migmatitic gneiss (562723). The gneiss is visible in the top right corner. B) Narrow band of meta-diorite with large garnets intruding into migmatitic gneiss (sampled as 562722).*

Station: 14vivh022
Coord: 65˚ 37.015 N
38˚ 28.110 W

Outcrops in a narrow valley. Up to this position still the garnet-amphibolite. In valley, pale green metasomatic rock enclosing large lenses of brown-green UM. Pale green rock contains

plag, pale green mineral, bright green amphi? or px?, and lenses of pure biotite. The pale green mineral has well developed cleavage and looks like feldspar. Locally the rock is well-foliated, elsewhere it is patchy.

In the valley also a sheet of very light coloured pegmatite with plag, K-spar, qtz, approx. 2 m wide. Closer to pale green rock this pegmatite also contains the pale green mineral (green K-spar?). The pegmatite is clearly part of the metasomatic zone around the UM.

The UM is massive and unfoliated. Occurs as lenses along the foliation from the top of the mountain down to the coast and continues on the small islands in the fjord.

Towards the E the UM is bounded by reaction zone with large porphyroblastic crystals of black mineral (brown on weathered surface) in the UM, as also seen at station 14vivh015. This is followed by a coarse-grained black amphibolite that grades into amphibolite full of leucosome stringers. Looks similar to the gneiss at camp, but here much more amphibole.

- Photos: 248 - pale green grains in pegmatite
  247 - reaction zone on UM

Station: 14vivh023

Coord: 65˚ 37.076 N
38˚ 28.024 W

Outcrop of garnet-amphibolite with leucosome stringers, same as at station 14vivh022. The stringers are aligned to the foliation and to a large extent define the foliation. Part of the outcrop is stained with an intense bluish green material. Too blue for malachite? Ni? (Figure 21).

Further to the west the amphibolite continues and is full of crosscutting (at shallow angle) leucosome stringers, and locally contains garnet.

- Sample: **562724** - green staining on amphibolite for mineralisation check
- Photo: 252 - view out to small islands off the coast with two UMs. Peninsula in fore-ground.

Figure 21. *Staining on amphibolite of light greenish blue mineral, could be malachite. Sampled as 562724.*

Station: 14vivh024
Coord: 65˚ 37.158 N
38˚ 28.097 W

Still same amphibolite at this station as at 14vivh023. No garnet. Full of leucosome stringers. Amphibolite is steeply dipping at this locality.

• Foliation: 024/76 NE dip direction/dip (overall foliation as wavy at station)

Station: 14vivh025
Coord: 65˚ 37.183 N
38˚ 28.152 W

Outcrop on top of the mountain at highest point on the island (Figure 22), where there is a transition from the dark amphibolite to much more felsic and lighter coloured gneiss. Also more resistant to weathering. Isoclinally folded with fragments and layers of amphibolite within it. Nice double fold with staining on the face at station. Similar in colour to sample 562724.

Figure 22. *Glacially polished outcrop on summit of island with transition from mostly amphibolite (right) to more felsic gneiss (left). The face shows a double isoclinal fold marked by layers of dark amphibolite in the lighter coloured gneiss.*

Station: 14vivh026
Coord: 65˚ 37.279 N
38˚ 28.125 W

Outcrop on E end of the island. From last station: felsic gneiss as at last station up to a narrow valley that cuts the whole island. After that: muscovite-bearing gneiss. Very light in colour with plag, qtz and musc, locally almost pure quartzite. Within it pieces of more mafic composition with green amphibole.

At station: plag-qtz-bt gneiss. No internal foliation in the rock, but there is a fabric to the overall material from biotite rich bands where biotite is aligned. No musc at station, but musc bearing gneisses are in package.

Station: 14vivh027
Coord: 65˚ 37.259 N
38˚ 27.943 W

Outcrops along narrow valley that crosscuts the island on its eastern end (different one from that mentioned at station 14vivh026). Consists of muscovite-biotite gneisses, locally green amphibole lenses, and calc-silicates with abundant epidote. Also a unit that looks like a quartzite (Figure 23): almost pure qtz with minor musc. It is unclear what made the valley. It is very regular. The foliation is strongly folded here so it appears that the valley cuts the foliation.

• Sample: **562725** - sample of quartzite and musc gneiss

Figure 23. *Outcrop of quartzite with minor muscovite in a foliation-parallel eroded-out valley on the eastern tip of the island. The quartzite displays a strong foliation and is intensely folded.*

Station: 14vivh028
Coord: 65˚ 37.095 N
38˚ 28.340 W

UM band on ridge back towards camp (Figure 24). Has dark amphibole rim on eastern contact that grades into amphibolites with leucosome stringers. Other units between last and this station are the same as those observed on transect this morning.

Figure 24. *Ultramafic band (reddish surface weathering) on the Immikkeerteq island. The view is towards the small island with Vittus Sakæussens' ruby find. The ultramafic rocks represent a boudinaged dyke or sill and continue onto the small island.*

5.2.2 July 22

Overcast. Little wind and lots of bugs. By boat to small ruby island (Vittus' Ujarssiorit 2009 ruby locality) and to other spots around the fjord. Skipper is Danny Heimar.

Station: 14vivh029 = 14vivh014
Coord: 65° 37.262 N
39° 29.132 W

UM body with ruby (see detailed map Figure 25). (A) Small body, about 3 m wide and 8 m long, elongated to the foliation of the enclosing gneisses with a metasomatic reaction zone of pale green well-foliated gneiss with a crosscutting contact to the amphibolites with leucosome stringers that host the UM bodies. En echelon there is another UM body (B), mostly buried beneath soil, 4 x 5 m in size. This package is cut by late crosscutting coarse-grained pegmatite with plag - K-spar - qtz, pinkish orange on weathered surface. Within the UM a network of veins with metasomatic reaction rims. Very regular mineral zoning although not all veins have the complete series of zones. UM B has different vein mineralogy with asbes-

tos? fibres in core, oriented perpendicular to the vein walls. This UM also has a well-developed metasomatic rim to the enclosing amphibolite with leucosome stringers: pale green gneiss. Can still recognise the original foliation of the amphibolite in this green gneiss, including the leucosomes, but the leucosomes appear to have been leached of silica leaving blueish transparent plag? This pale green unit appears to be the metamorphic exchange between amphibolite and UM, whereas the veinlets in the UM represent interaction with melt/fluid from the pegmatite.

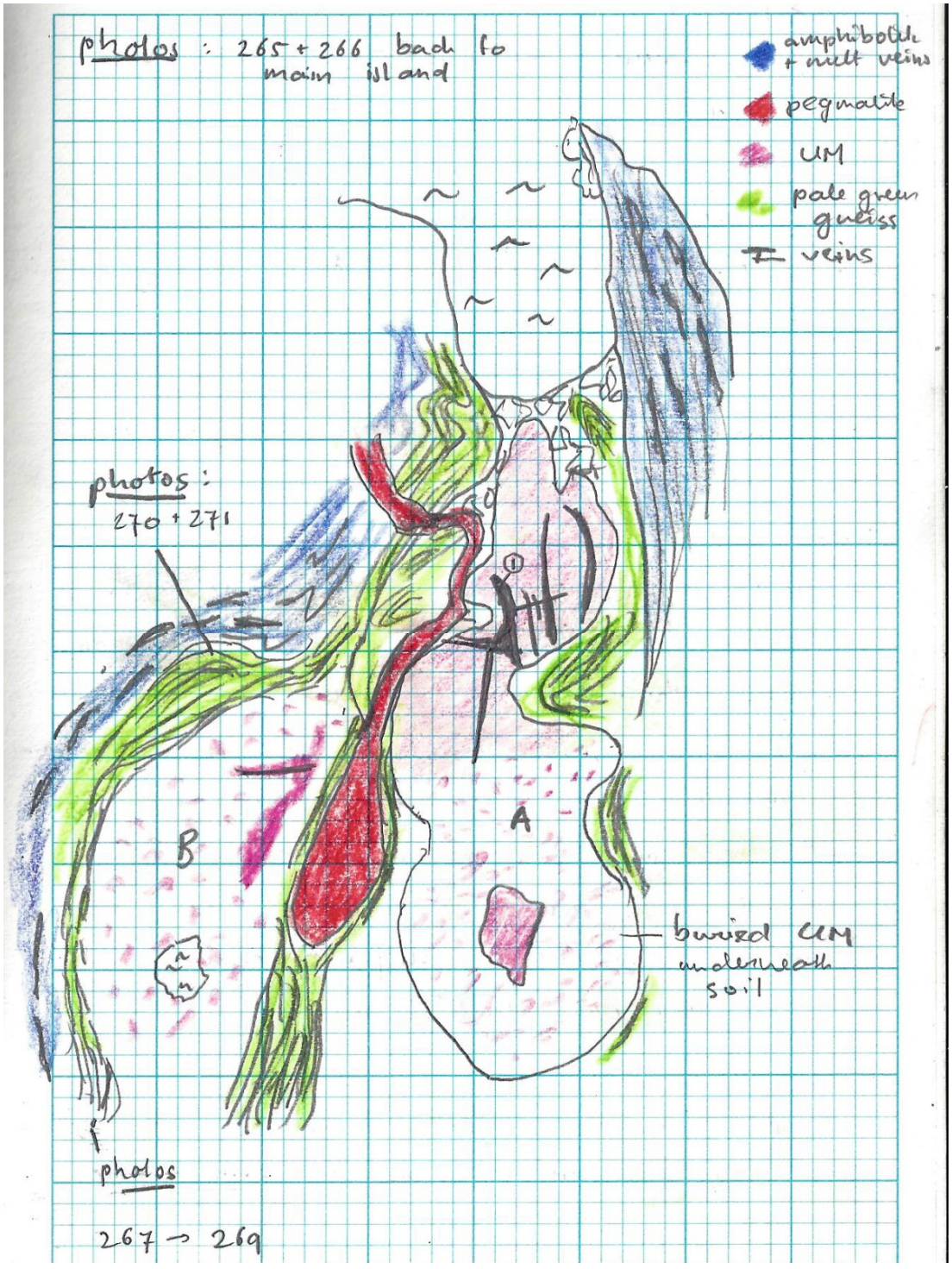

Figure 25. *Sketch geological map of UM bodies at northern end of Vittus' ruby island.*

Best-developed veinlet (1) consists of (see Figure 26):

- 5–8 cm core of black amphibole (up to 4 cm in length), biotite and locally purple to pink massive ruby (irregular in shape, but appears to be unfractured, up to 3 cm in size).
- 6 cm of pure biotite, randomly oriented and with 2–3 mm sized grains.
  - 4 cm of bright green amphibole grading into the next zone.
- 10–15 cm of white fibrous mineral with green amphibole. Retains the UM fabric although the fibres are aligned perpendicular to the vein wall.
- brown fine-grained UM with the fibrous mineral still in it. Grades irregularly into UM core.
- core of the UM consists of finegrained green matrix with brown mineral and dark transparent porphyroblasts (probably opx).

Sampled for mapping of element transport and mineralogy, as well as fingerprinting of the rubies.

• Samples: **562727**
-1 - float with rubies for fingerprinting
-2 - in-situ ruby bearing zone
562728 - biotite layer
562729 - green amphibole layer grading to zone with fibrous white mineral
562730 - UM with fibrous white mineral
562731 - least affected UM

• Photos: 265-266 - view towards main island (Immikkeerteq) (

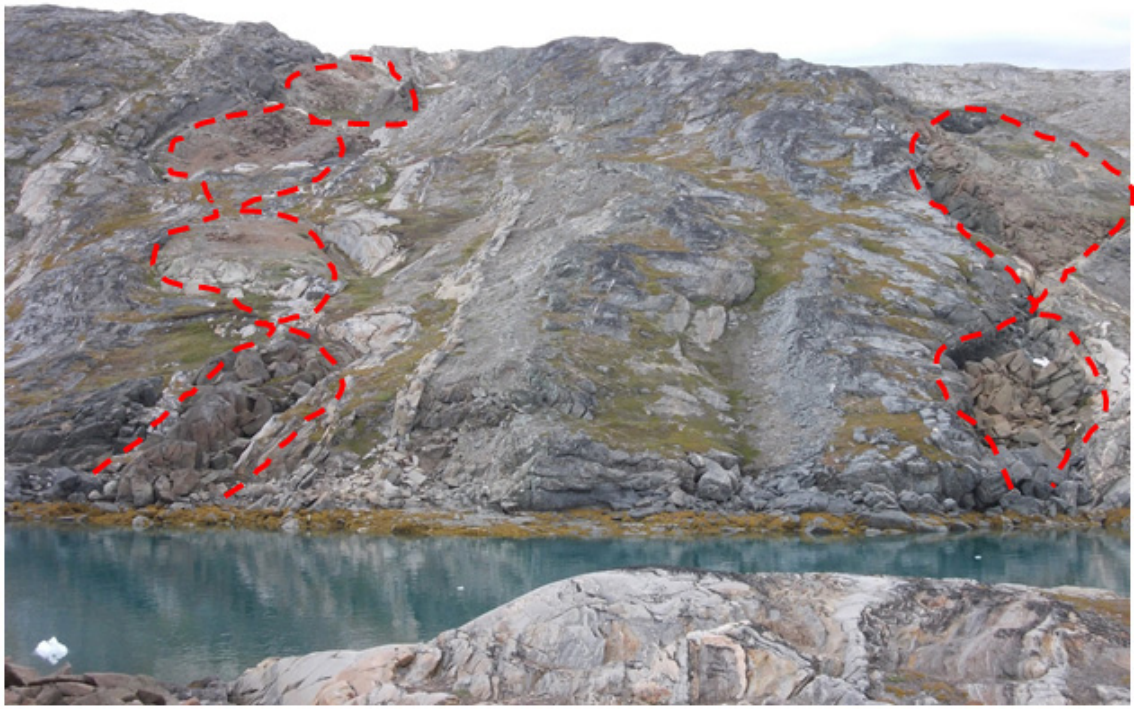

Figure 27)

267-271 - pale green gneiss (Figure 28)
272-273 - overview of veinlet (Figure 26)

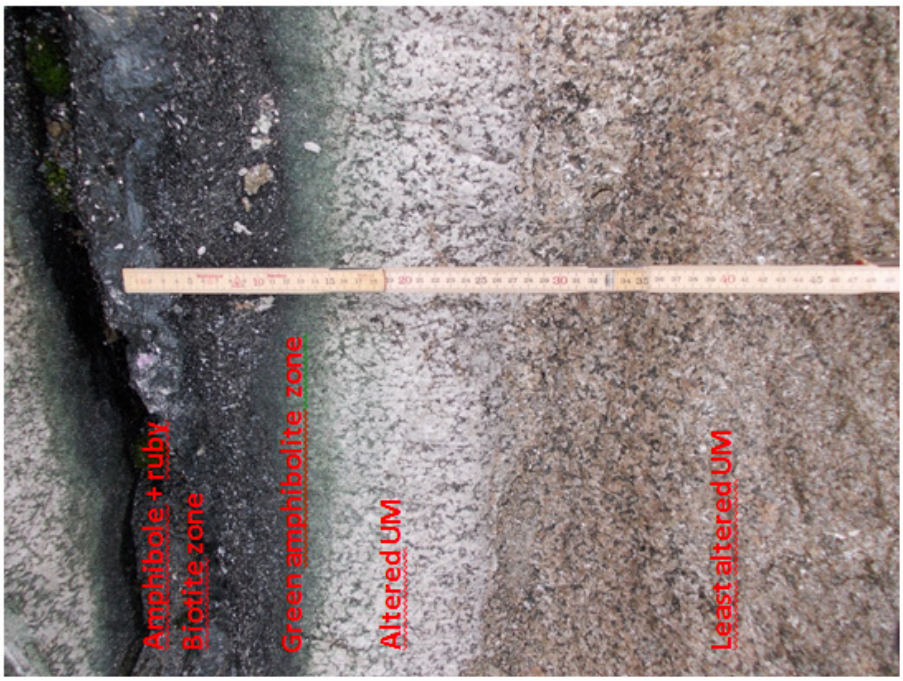

Figure 26. *Overview of the metasomatic veinlet, from the black amphibole and ruby-bearing core (left side), to the biotite zone, dark green amphibole zone, light coloured altered ultramafic rock and the least altered ultramafic rock on the right.*

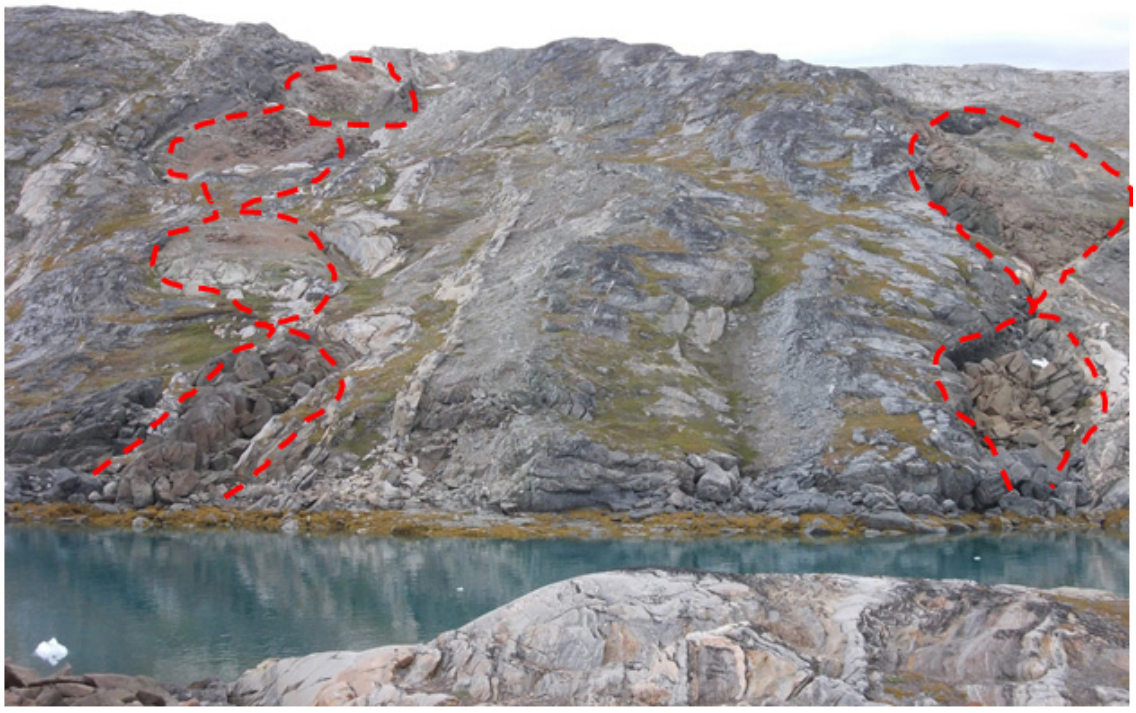

Figure 27. *View from the small ruby island towards Immikkeerteq, showing the two bands of ultramafic boudins (brown with blocky weathering). On left foreground one of the UMs on ruby island is just visible, which connects to the left band on Immikkeerteq (photo 266).*

Station: 14vivh030
Coord: 65˚ 37.247 N
39˚ 29.034 W

Second band of UMs to the east of first band. Also continues on the big island and can be traced all the way to the top of the mountain. Different appearance: coarse-grained, more massive and less veins. Also very large black porphyroblasts of up to 4 cm diameter. These are rounded and full of inclusions.

There is no reaction zone on this UM, absolutely nothing. So this contrasts sharply with UM (A) and (B). Just a very dark amphibolite on the east side of the body but nothing on the western contact. On western contact outcrops of well-foliated garnet amphibolite. Composition of UM or its host must have been quite different to explain contrast.

UM has a green matrix with brown and green minerals (ol and px?) and then a fibrous/platy mineral (serpentine?). Overgrowing this are the large round porphyroblasts, likely of opx (Figure 29).

- Sample: **562726** - float of ruby bearing rock next to UM (C)
  562732 - UM
  562733 - garnet amphibolite for PT
  553298 - sediment sample from sand-sized sand beach next to UM
- Photos: 255-264 - UM + its setting

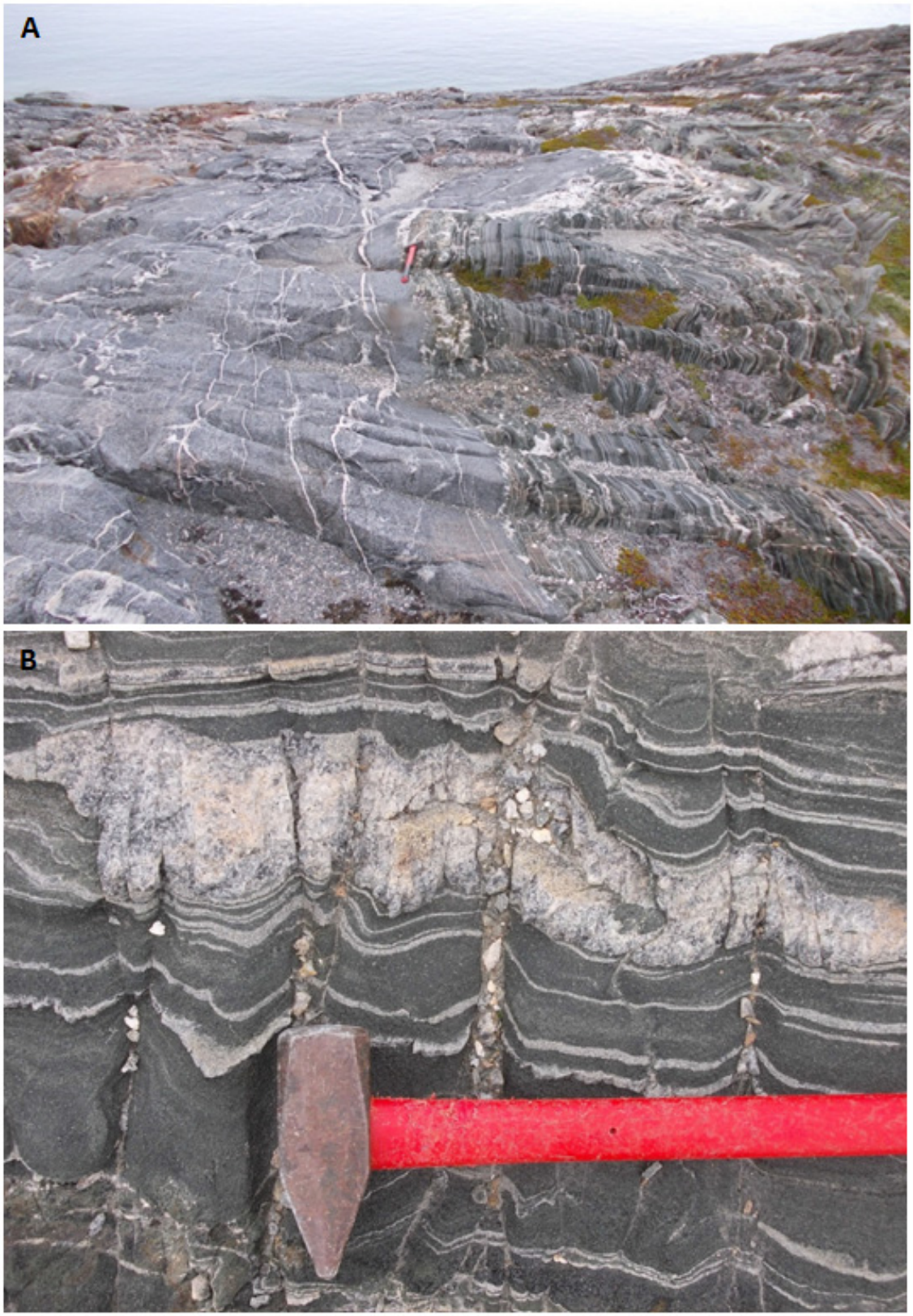

Figure 28. *A) Migmatitic gneiss on the left side of the photo and green, banded gneiss to the right, which appears to crosscut the migmatite. B) Close-up photo of the green gneiss outcrop (calc-silicates?)*

Figure 29. *Large round porphyroblasts of opx? In an ultramafic rock (photo 255).*

Station: 14vivh031
Coord: 65˚ 37.033 N
39˚ 27.825 W

Second UM band (eastern band) on small, elongate island off the south-eastern coast of the big island of camp. No reaction zone whatsoever on this UM. On western contact to garnet amphibolite full of leucosome stringers (Figure 30), on eastern contact to dark amphibolite without garnet. Western UM band is also present with extensive pale green metasomatism of the garnet amphibolite.

Station: 14vivh032
Coord: 65˚ 37.033 N
39˚ 27.825 W

Crosscutting fine-grained mafic dyke ~N-S orientation with vertical dip.
• Sample: **562734** - for geochron
• Dyke strike: N-S

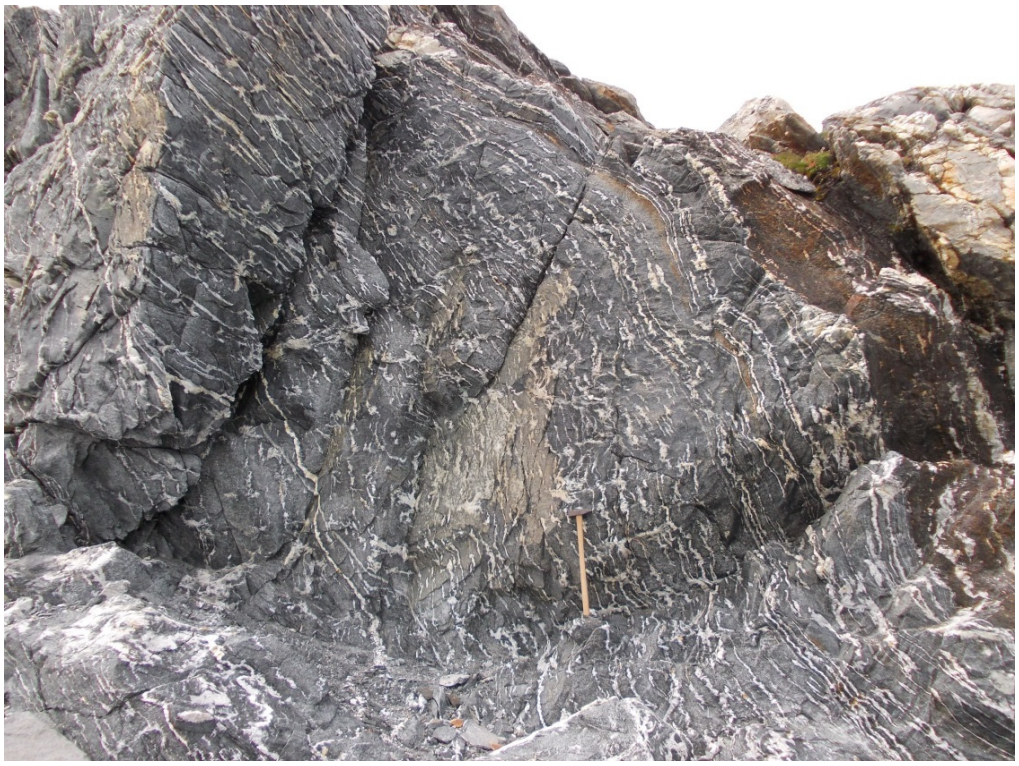

Figure 30. *Outcrop of garnet amphibolite basement full of leucosome stringers.*

Station: 14vivh033
Coord: 65˚ 38.019 N
39˚ 30.421 W

Dyke on mainland, at least 20 m wide and can be traced all the way up the mountain. Dyke is present on the geological map on both sides of the fjord. It is very vegetated compared to the other lithologies. Brown weathering. Coarse-grained, strongly magnetic. Mineralogy is pyroxene, magnetite, with garnet?

Vertical dyke with a strike of 038.
• Sample: **562735** - for geochron
• Dyke strike: 038

Station: 14vivh034
Coord: 65˚ 35.568 N
39˚ 33.334 W

Stream on mainland to the SW of Immikkeerteq island. The stream forms the boundary between light-coloured well-foliated gneisses and rusty brown weathered 'meta sediments' (geological map has boundary wrong). 'Meta sediments' are biotite gneiss. Fine-grained with well-developed foliation, although no continuous foliations planes of biotite (not enough biotite). Looks very similar to the material at station 14vivh026.

• Sample: **553299** - stream sediment sample

5.2.3 July 23

Cold night, but some sun in the morning. Look at the UM bands on Immikkeerteq in detail and see if these also contain ruby corundum.

Station: 14vivh035
Coord: 65˚ 37.173 N
39˚ 28.897 W

Lowermost UM of the southern band (see Figure 16 for sketch). Complex outcrop of UM and its host rocks. UM is medium-grained with brown (opx?) porphyroblasts. Massive with no internal fabric although some of the brown grains occur in a network of connecting veins. The UM is cut by ~10 cm wide veinlets with metasomatic mineral zoning, similar to zoning at ruby locality but core zone is missing and biotite layer is thin. So the metasomatic zoning is the same as the one on the ruby locality (station 14vivh014), but the core zone is missing as is also the case for most of the veinlets at the ruby locality. Sheet of pegmatite next to UM: likely source of the metasomatising liquids.

Southern contact consists of black amphibolite with minor plagioclase and locally on contact biotite. This grades into the amphibolite with leucosome veinlets as found elsewhere on the island. South eastern contact is complex and consists of diffuse metasomatic zone of pale green gneisses with pockets and lenses of fibrous brown mineral and biotite. This occurs together with coarse-grained layer of metasomatised pegmatite? Contains plagioclase and large grains (up to 8 cm in length) of pale green feldspar like mineral. Could be aegerine? Also locally green amphibole. This pegmatite must predate the metasomatism and is not the same age as the pegmatite on the contact presently. The pale green rocks are well-foliated, but mineral alignment mostly follows the metasomatism. Green 'pegmatite' is almost parallel to the foliation. Pale green rock could be calc-silicate in which case it might have been more susceptible to metasomatism than the amphibolites on the other contact?

Rocks dip shallowly away from the UM with two open folds involving gt-amphibolite and gneiss with garnet up to 8 cm in diameter. Foliation steepens to the UM and near vertical at the UM band. Flattens out again on the other side of the UM. These rigid boudins clearly control deformation here. They are boudinaged into lenses along the strike of the band.

Detailed stratigraphy west to east to the UM band (Figure 31):

- Gneiss with leucosome veinlets as at camp
- ~6 m of fine-grained amphibolite
- ~2 m of felsic gneiss with very large garnets
- ~20 m of fine-grained amphibolite with garnet
- Pale green metasomatism zone
- UM
- Amphibolite with leucosome veinlets

• Samples: **562740** - green gneiss
562741 - UM

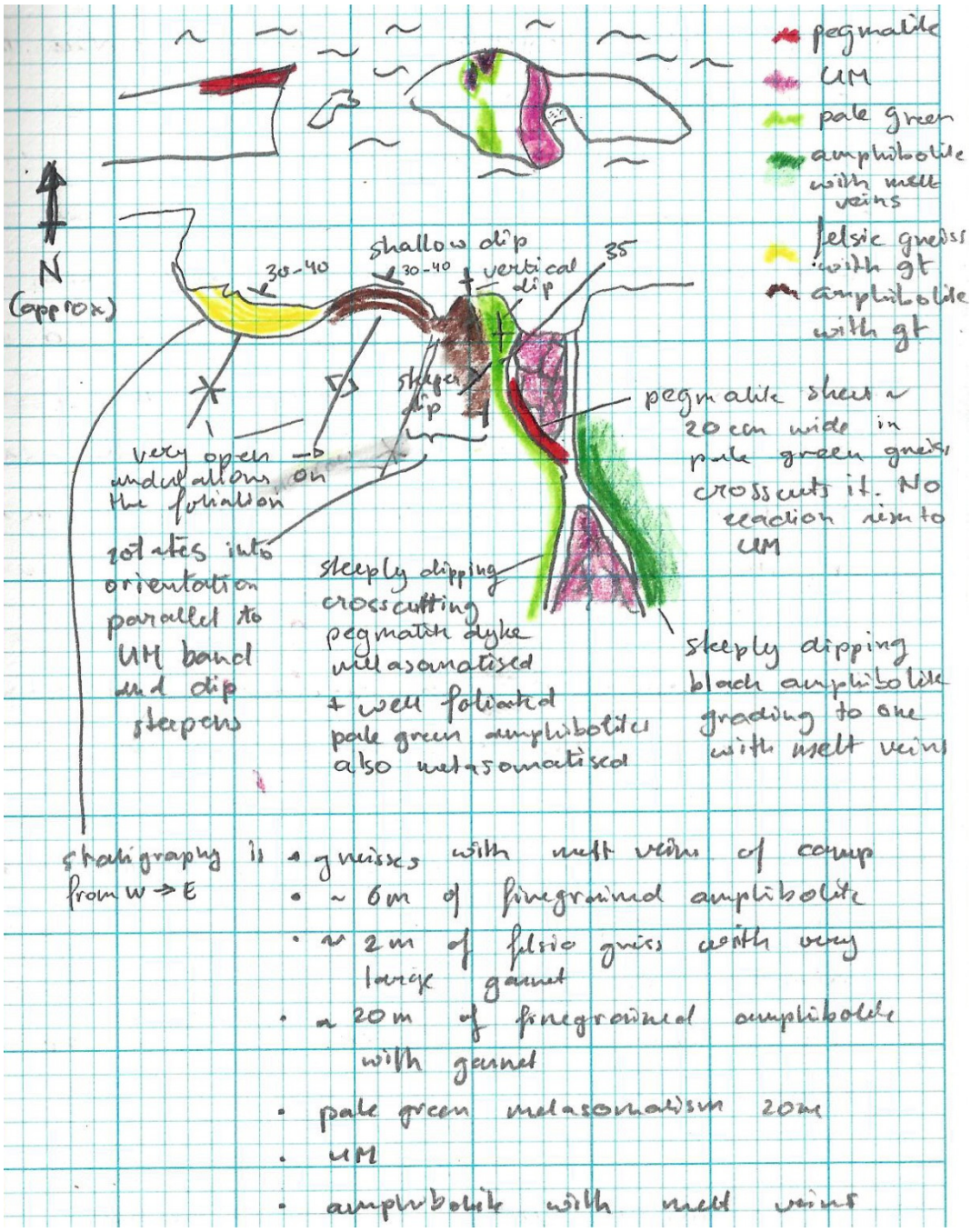

Figure 31. *Sketch showing the geology of the western shore of Immikkeerteq island in relation to the small ruby-bearing island. The UM band drawn on Immikkeerteq connects to the western UM outcrops on the small island.*

Station: 14vivh036

Coord: 65° 37.120 N
39° 28.770 W

Green 'pegmatite' a little further up the hill. Very large green radiating crystals of aegerine? Or simply K-spar? With plag. At station a pink colouration of the clear grains. Could be thulite (pink epidote).

• Sample: **562736** - sample of pink material for mineral ID

Station: 14vivh037
Coord: 65˚ 37.088 N
39˚ 28.268 W

UM on top of the mountain with metasomatic veinlets, one with cm-sized purple to pink rubies. Mineral zoning is the same as for the ruby locality on the small island (14vivh014), but now there is also zoning along the veinlet from pegmatite to black amphibole + ruby + biotite. In the UM enclosing the veinlet the same concentric zoning as observed elsewhere is found, from inside outwards: biotite -> bright green px -> green px + white fibrous mineral -> UM.

At this locality it is obvious that the pegmatite is the source of the metasomatising fluids/melts and that metasomatism takes place with the enclosing UM perpendicular to the pegmatite, resulting in changes in mineralogy along the pegmatite, which we interpret as changes in the direction of dyke propagation (Figure 32A and Figure 32B). In this case, ruby forms at the end of the dyke from the most metasomatically altered melt/fluid (Figure 32C). Hence, no regional metasomatism, but very localised. Further evidence that this is not metasomatism post-intrusion comes from the characteristics of the rubies; these are rare, large, irregularly shaped rubies, rather than dispersed equally distributed small ones.

• Samples: **562737** - ruby-bearing veinlet
562738 - pegmatite part of the veinlet
• Photos: 276 - overview of eastern band

Up to this point a series of UM lenses with pale green sequence on northern contact and amphibolite on southern contact, with a ~20 cm pure black amphibole rim at contact. These UM lenses belong to the northern band of UM lenses, whereas the one at station is part of the southern band. So can have rubies in both bands by the same process.

On way down to coast along southern band: Several lenses of UM, one very large, cut by pegmatite dykes that are up to 3 m wide (but most much thinner). In the UMs metasomatic veinlets with roughly the same orientation as the pegmatites. These veinlets show the same metasomatic mineral zoning as seen before, but no rubies were observed. Otherwise they are identical to the one on the top of the mountain, so there is lots of potential here. The UMs have a very sharp contact to white felsic gneisses on northern contact, more gradual contact to amphibolite with leucosomes on southern contact. southern contact also often has biotite + green amphibole layer at actual contact. Where the UMs are boudinaged out, the white gneisses and amphibolite are in direct contact. This stratigraphy is very different from that in the northern UM band, so they appear to be two distinct bands and not a tectonic repetition or folded sequence.

General orientation of the pegmatites is: strike 50 degrees, dip ~70 to SE

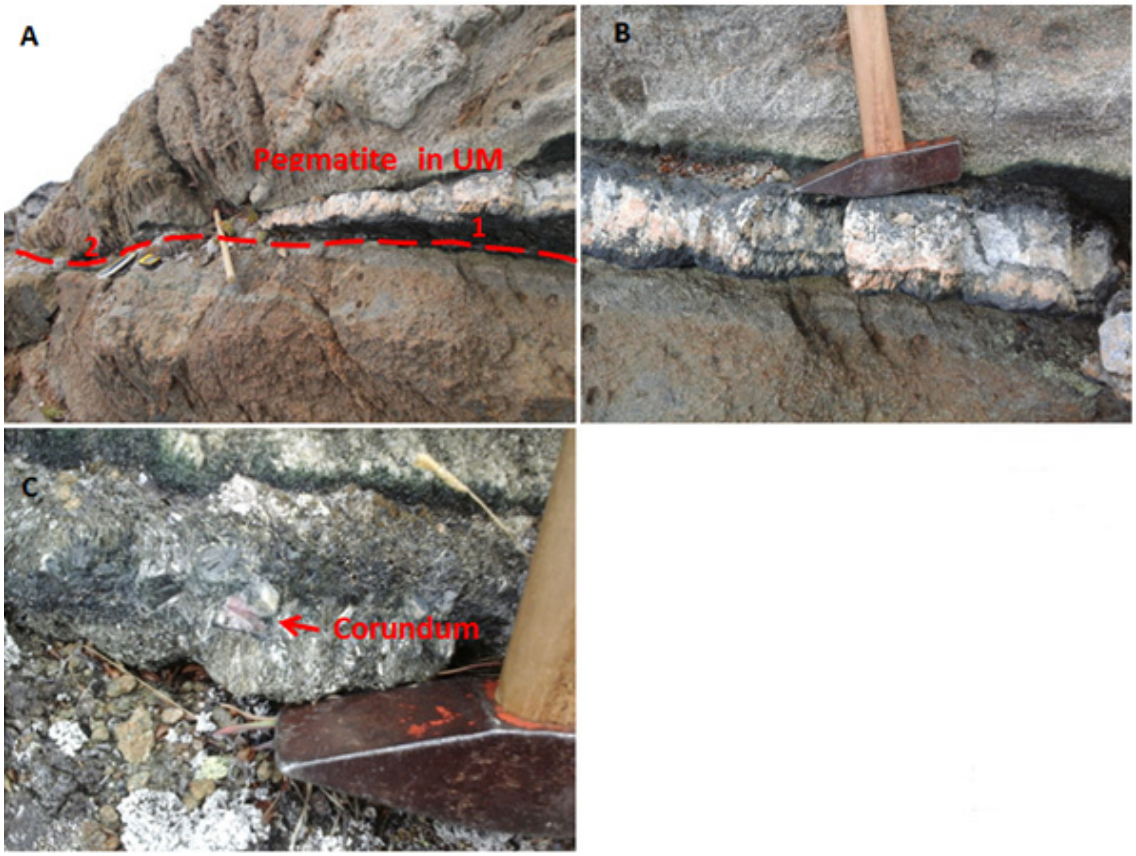

Figure 32. *A) Metasomatised pegmatitic vein in ultramafic rock on Immikkeerteq. Metasomatism increases from 1 to 2 with loss of quartz and feldspar, and eventually black amphibole and corundum form. B) Close-up of part 1 of the pegmatite. C) Close-up of part 2 showing the black amphibole and light pink to greyish coloured corundum.*

Station: 14vivh038
Coord: 65˚ 37.188 N
39˚ 28.764 W

UM in southern valley, second one up from coast. Very weathered. Extensive pale green alteration of the UM itself cut by pure white veinlets with colourless to white fibrous minerals aligned perpendicular to vein walls. On some of the white surfaces idiomorphic elongate brown transparent crystals. Not clear what they are: check.

• Sample: **562739** - metasomatic veinlet with different style of mineral zoning

UM in southern valley at the coast (= station 14vivh015). This one is full of porphyroblasts of opx? Just as its counterpart on the other side of the water on the small ruby-bearing island. It has ~2 m of felsic gneiss on its southern contact before the black amphibolite -> *the UM band is crosscutting the stratigraphy, or the gneiss has intruded into the amphibolites with UM bands.* No reaction rim on the felsic gneiss at all: is opx in UM the reaction product?

• Photos: 277 + 278 - looking S

5.2.3.1 Summary camp 2

The observations at station 14vivh038 show that the southern UM band crosscuts the foliation, albeit at shallow angle, and could therefore be an ultramafic sill or dyke. It is markedly different in composition, texture and mineralogy (i.e. porphyroblasts) from the northern UM band, and this is not a repetition of the southern UM band. Views from the helicopter strongly suggest that the northern band also crosscuts the foliation, and that these two bands thus represent two parallel sills/dykes of ultramafic material, unless the gneiss is intruded into the amphibolites and UM bands and therefore is not following the stratigraphy.

The UMs were subsequently deformed resulting in boudinaging and a steepening of the foliation in the enclosing gneisses towards the rigid UM bodies.

Late-stage crosscutting pegmatites chemically interact with the UMs resulting in formation of metasomatic reaction rims along and enclosing the pegmatite dykes. This develops in both UM types. At its most extreme, it results in formation of ruby corundum in the core of the metasomatic band.

Reco

Reconnaissance by helicopter to diorites west of Sermilik fjord to compare these to the diorite investigated in camp 1. These should be the same unit/generation according to the geological map. For location of the stops made during this reco, see Figure 2.

5.2.4 July 24

Sunny and hot. Camp change and reco with Bo Møller Stensgaard and Jakob Lautrup, GEUS.

Station: 14vivh039
Coord: 66˚ 07.702 N
38˚ 06.630 W

Meta-diorite in TTG gneisses (Figure 33). Has a very nice foliated texture defined by thin 5 mm by 5 cm lenses of plag + qtz in darker matrix with amphi + bt + minor, large, garnets. The TTG cuts into the diorite so postdates the intrusive. Contact has layer of pegmatite melt and a few rafts of meta-diorite.

• Sample: **562742 -** meta-diorite sample for check against diorite in south

Station: 14vivh040
Coord: 66˚ 07.608 N
38˚ 06.069 W

Garnet kyanite gneiss on other side of the lake from station 14vivh039. Coarse-grained with garnets up to 3 cm in diameter and nice splays of beige kyanite. Rusty weathered and in between TTG gneisses. Meta-carbonate skarn next to it. Strongly suggests this to be a

metasedimentary succession (Figure 34). Consists of 20 cm large pale green minerals, dark green amphibole intergrown with it and bright blue mineral (apatite?). The pale green mineral is likely a calc-silicate mineral (wollastonite?).

Pale green mineral looks similar to the pale green layer seen in between the amphibolites in camp 1 as well as the pale green 'pegmatite' next to the UMs in camp 2. Check this!

• Samples: **562743** - kyanite-garnet gneiss for PT
562744 - skarn for PT

Figure 33. *The metadiorite at station 14vivh039 has a foliation defined by light coloured lenses with plagioclase and quartz.*

Station: 14vivh041
Coord: 66˚ 07.226 N
38˚ 05.819 W

Meta-diorite with well-developed foliation and tightly folded. Contains plag, qtz, gt and amphibole. It is cut by pegmatite dykes up to 2 m wide which contain rafts of the meta-diorite. Sampled to compare against the meta-diorite of camp 1.

• Sample: **562745** - compare against the other diorite

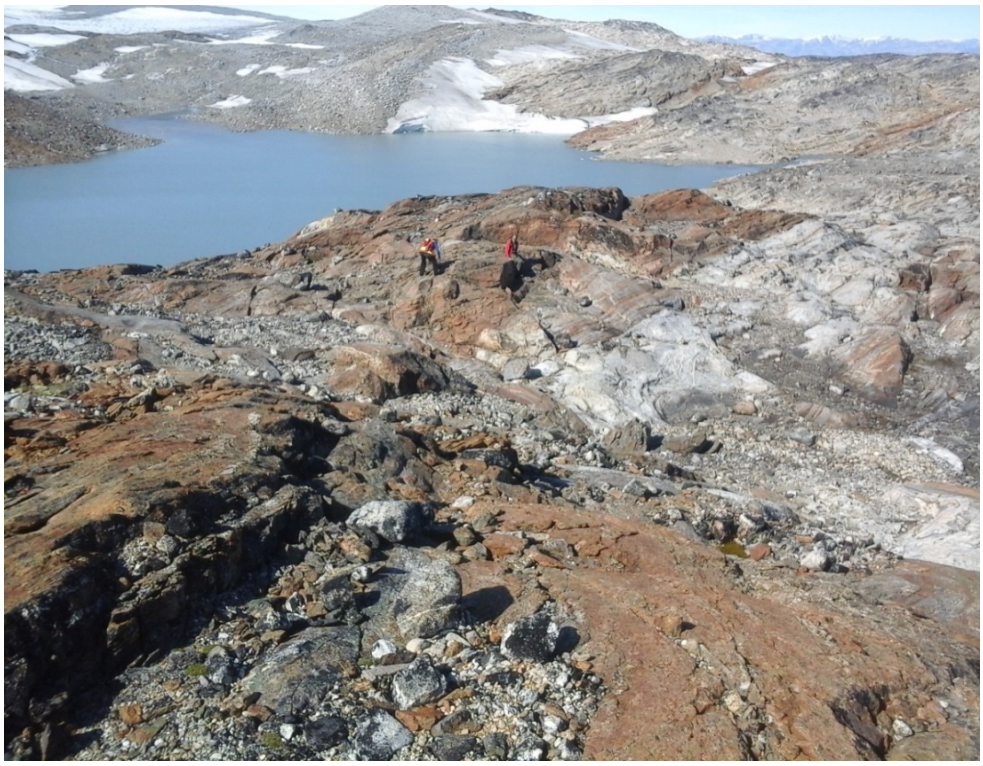

Figure 34. *Possible metasedimentary succession within TTG gneiss.*

Station: 14vivh042
Coord: 66˚ 01.464 N
38˚ 16.413 W

Flat outcrop on little plug high above the ice and lakes bordered by steep cliffs on all sides. Consists of green brown UM as marked on the printed geological map: needs to added back to electronic version. Cut by pegmatite dykes up to 1 m wide without a clear reaction zone -> minimal interaction between UM and pegmatite. UM is coarse-grained with 5 mm sized grains.

• Sample: **562746** - UM on top of plug for geochemistry

5.3 Camp 3. Metasediments at the northern contact of of Angmagssalik intrusion

Next to lake and river in the middle of the mountains (Figure 35). Beautiful spot with nice flat gravel area, and beach next to the river. Snow patches around for fridge. In walking distance lots of good geology. Only downside is that it is shaded from the late afternoon and then gets very cold. Great camp spot nonetheless.

Goals: - Check the anorthosite band of the geological map
- Investigate the contact between gneiss and anatectites
- Check for evidence of proposed orogenic suture zone

- *Check metasediments at coast and/or granite contact in interior* (neither locality visited, because of early camp move owing to helicopter availability)

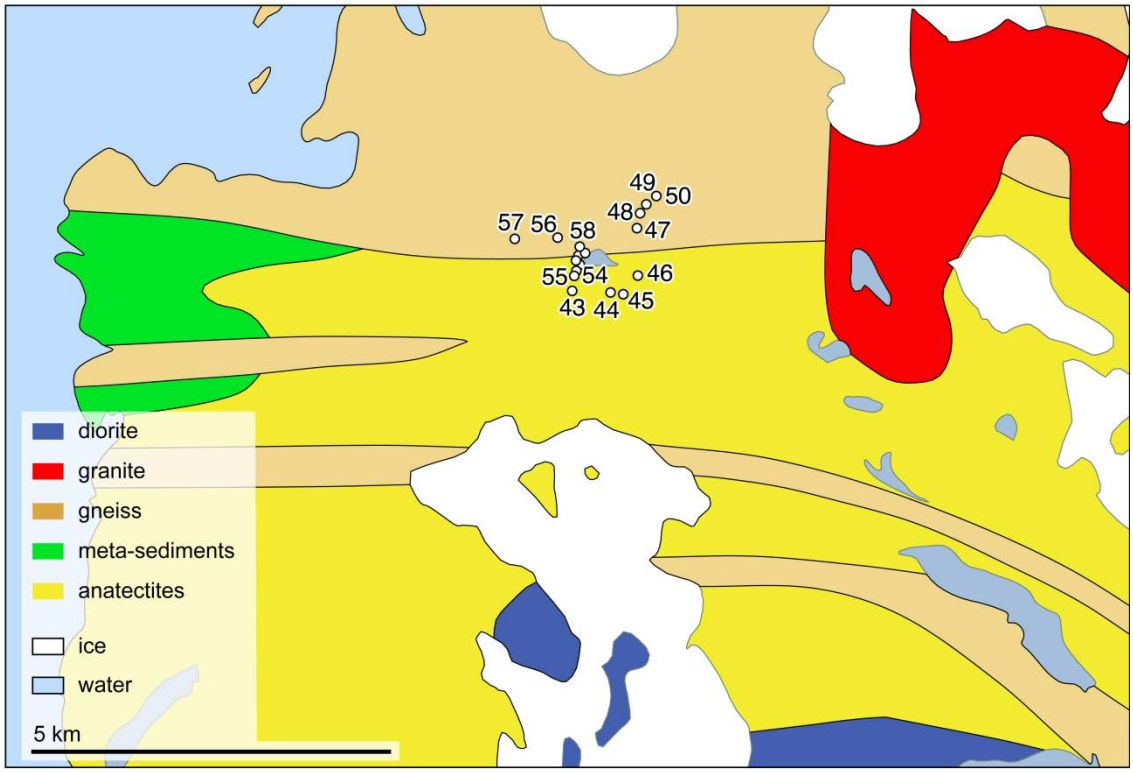

Figure 35. *Geological overview map of the area around camp 3 at the boundary between the anatectites related to intrusion of the diorite, and the basement gneiss. Station numbers where samples were taken are shown. See Figure 1 and 2 for the location of this map.*

5.3.1 July 25

Sunny with a little breeze. Will work around lake and camp to get an overview of the local geology.

Station: 14vivh043
Coord: 65˚ 46.176 N
37˚ 46.493 W

From camp to the south. Rocks consist of well-foliated gneisses, variable in composition from very felsic to amphibolite (Figure 36). Often contain lenses of one another as well as lenses of other materials such as fine-grained TTG. These are cut by melt veins from fine-grained pegmatite to very coarse-grained white pegmatite with bt flakes of 5 cm length and white plag grains of 8 cm length. Very little quartz in the coarse-grained pegmatite. Gneisses are full of garnet up to 5 cm in diameter. This is the zone of anatexis around the diorite intrusion in the south.

- Sample: **562747** - garnet bearing gneiss sample for PT
- Foliation: 001/82 N dip direction/dip

Figure 36. *Well-foliated gneiss, variable in composition from felsic to more mafic and with abundant lenses of other material including calcsilicate and aluminous units.*

Station: 14vivh044
Coord: 65˚ 46.122 N
37˚ 45.817 W

To the east of previous locality -> gneisses with lots of garnet, well-foliated. They contain 5-10 cm wide grey dykes that crosscut the foliation, but are themselves also affected by deformation. Also lenses of these -> boudinaged? Within this sequence lenses of ~10 m wide and 30 m long of very rusty weathered material (Figure 37). Full of garnet (up to 80%) with bt and qtz. No obvious reason for the staining and no sulphides observed. Could these be restites from partial melting?

At station pegmatite intrusion brecciated lens of garnet amphibole rock in garnet bearing gneiss. Nicely intergrown garnet and amphibole.

Sampled both the gneiss and the amphibolite to compare PT estimates.

• Samples: **562748** - amphibolite for PT
562749 - enclosing gneiss for PT

Figure 37. *Garnet-amphibolite lens in TTG brecciated by later pegmatite intrusion, which itself is now also foliated (photos Vivh-Loc-44-No-1 and 2).*

Station: 14vivh045
Coord: 65˚ 46.098 N
37˚ 45.584 W

Gt-bt gneiss with kyanite and sill? on biotite planes. Kyanite is beige to blue, nice crystals with good cleavage. Sill is as fibrous masses on biotite planes. Sits in coarse-grained meta-granite like rock with only weak foliation interbedded with more mica rich well-foliated material. This is a key sample to study relation between sillimanite and kyanite: which came first? Could be contact metamorphic replacement of sillimanite after kyanite.

• Sample: **562750** - two large pieces and one small with blue kyanite

Station: 14vivh046
Coord: 65˚ 46.213 N
37˚ 45.277 W

Massive coarse-grained (5 mm diameter grains) meta-igneous rock with plag, green amphibole rimmed by bt, qtz and garnet, with garnet concentrated in and along leucosome veinlets. Proportions suggest a dioritic composition (Figure 38).

Figure 38. *Coarse-grained meta-igneous rock possibly of dioritic composition.*

Station: 14vivh047
Coord: 65˚ 46.570 N
37˚ 45.196 W

5 m wide well-foliated green gneiss with abundant epidote, plag and pink K-spar. Nice continuous layer that forms green scree slope on the mountain to the west.

Are supposed to be in the normal gneisses now according to the geological map, but the contact is gradational, although there is less to much less garnet here, rocks show more parallel foliation, and there are less leucosome veinlets. Would also expect a gradational transition from gneiss to anatectic gneisses.

Station: 14vivh048
Coord: 65˚ 46.678 N
37˚ 45.104 W

Pseudotachylyte (or ultracataclasite) in garnet-bearing gneiss (Figure 39). Braided with locally pale grey melt. At narrowest point about 2 cm wide, widest about 20 cm of interconnecting fractures. Displacement along the pseudotachylyte is ~3 m sinistral as seen from marker beds, especially light grey dyke. The pseudotachylyte can be traced along strike. There is no indication of reworking or retrogression of the pseudotachylyte or too fine grained to be able to see with loupe and therefore suggesting it to be young.

Very nice pre-metamorphic mafic dyke in the gneiss, which has now been smeared out in the foliation (photo 324).

- Sample: **562751** – pseudotachylyte in gneiss
- Orientation pseudotachylyte: Strike 42 degrees, dip ~vertical
- Photos: 325-327, 332 - overview of pseudotachylyte
  324 - pre-metamorphic dyke

Station: 14vivh049

Coord: 65˚ 46.745 N
37˚ 44.975 W

Well foliated sequence of meta-leucogabbro with ~50% amphibole and 50% plag with within this, lenses up to 40 cm diameter of plag masses with interstitial dark green amphibole (Figure 40). Also lenses up to 2 m long of almost pure dark green amphibole + minor plag. In gneissic layers there are also leucosomes with abundant garnet, some of which are very large (5 cm diameter). The garnet is not restricted to the leucosomes but also in lenses with dark green amphibole, biotite and magnetite.

This is what is mapped as the anorthosite/leucogabbro band. It is indeed a leucogabbro and shows some resemblance to the lenses of plag + amphi seen at camp 1 during the reco NW of camp. However, could simply have been a coarse-grained leucogabbro.

- Sample: **562753** – sample for geochemistry and geochronology to check if this is anorthosite or a leucogabbro

Figure 39. *Pseudotachylyte in TTG gneiss with the two hammers showing offset (photo 334).*

Station: 14vivh050
Coord: 65˚ 46.790 N
37˚ 44.771 W

Rocks are very fractured between station 14vivh048 and 14vivh050 with lots of brittle offsets, mostly as normal faults and many tens of pseudotachylytes. Largest ones are 3-4 cm in thickness at narrowest point with light grey melt. All braid around blocks of host rock. Cut through the gneiss and the late pegmatites that cut the gneisses, so a young feature.

- Sample: **562752**
- Foliation in gneiss: 018/90 dip direction/dip
- Orientation pseudotachylyte: strike 72 degrees, dip vertical
- Photo: 338 - overview

Figure 40. *Leucogabbro lense with large plagioclase grains in a foliated meta-gabbroic rock. The lenses are up to 40 cm in diameter. The meta-gabbro host ranges from amphibole-dominated to leuco-gabbro. The lenses are somewhat similar to those observed at station 14vivh016 and may represent what is referred to as "anorthosite" on the old geological map, although the unit is not as well-defined as the map suggests.*

5.3.2 July 26

Sunny in the morning, then fog drifting in from the west. Sunny again from ~9:30. Outcrops around camp and to the NW towards Sermilik fjord.

Station: 14vivh051
Coord: 65˚ 46.370 N
37˚ 46.296 W

Outcrop next to lake just below camp. Sequence of gneisses with lenses of dark amphibolite, diorite and a UM body, all on 10 m scale. These are cut by pegmatites up to 40 cm wide, very white in colour with plag, bt, K-spar and minor qtz. Grain size is very big, up to 10 cm diameter. Rusty weathered zone in this sequence of ~4 m wide can be traced up the mountain along strike. Locally intense alteration producing a yellowish green sericitised zone with lots of sulphides (Figure 41). On the mountain along strike there is an old GGU sample marker: 217455.

The UM is cut by small pegmatite veins with minimal metasomatic reaction zone: mm thick layer of biotite.

Further to the south next to stained zone, nice leucogabbro with ~50% plag and 50% amphibole. Folded here, but elsewhere massive. Looks very similar to the leucogabbro seen at station vivh049.

• Samples: **562756** - UM
562754 - sulphide bearing zone hosted in meta diorite
562755 - leucogabbro

Figure 41. *Gneiss with alteration zone with abundant sulphides. Sampled as 562754 and previously sampled further up the slope along strike as 217455. The sample no. was written on orange flagging tape and could possibly have been from NunaMinerals or other mineral exploration companies. .*

Station: 14vivh052
Coord: 65˚ 46.422 N
37˚ 46.309 W

Outcrop north of camp of weakly foliated meta-granitoid with intrusion breccia of mafic melt (Figure 42), which is now almost pure black amphibole. No obvious deformation of the amphibole breccia so intrusion after deformation, but still metamorphosed, so metamorphism postdates the intrusion. Lens of meta-gabbro within the meta-granitoid that is also cut and brecciated by the mafic melt. Meta-gabbro + meta-granitoid cut by light grey fine-grained dyke ~10 cm wide that shows some deformation, but still clearly crosscuts the foliation. Looks dioritic in composition. Meta-granitoid contains a raft of foliated gneiss within it. Final stage

is white coarse-grained bt-plag pegmatite that cuts everything including the amphibole breccia. So complex sequence of events here:

- Oldest: foliated basement gneiss
- Meta-granitoid and meta-gabbro

Deformation

- Dioritic dyke

Deformation

- Mafic breccia

Metamorphism

- Youngest: undeformed pegmatite

• Samples: **562757** - mafic melt and gneiss host

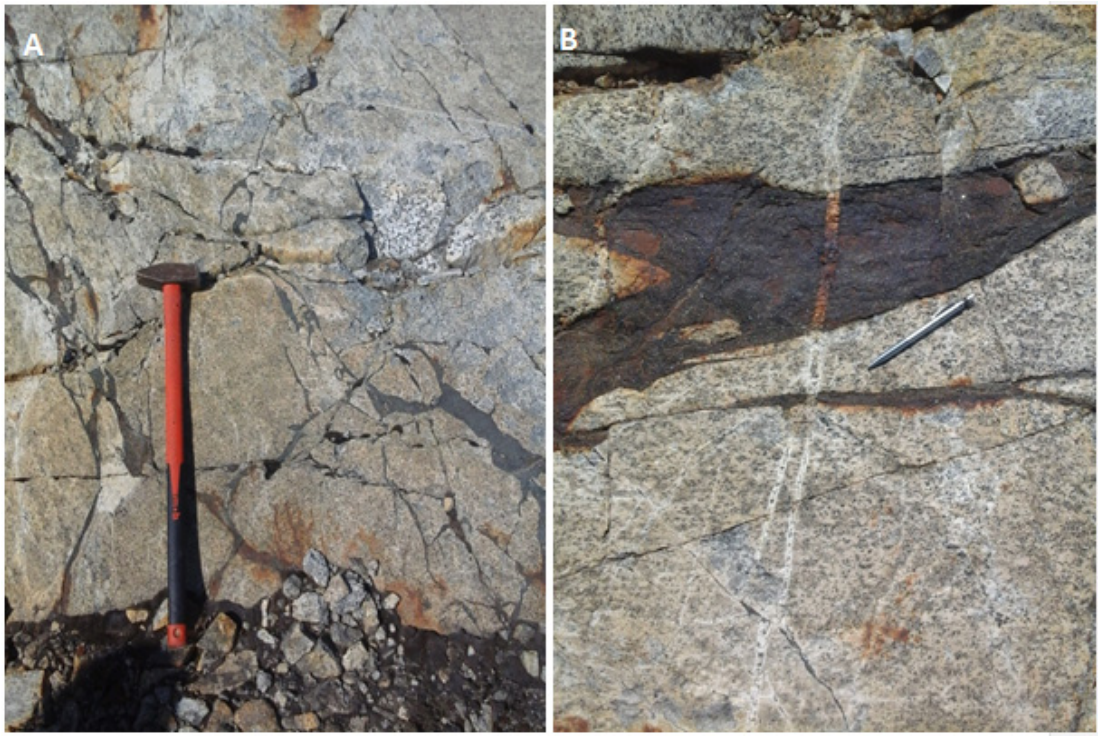

Figure 42. *A) Brecciated granitoid rock with intrusion of small amounts of mafic melt. B) Meta-gabbro within meta-granitoid cut by thin dyke (~10 cm).*

Station: 14vivh053

Coord: 65˚ 46.447 N
37˚ 46.228 W

Outcrops on lakeshore to the north of camp. Rocks become progressively more sheared towards the north. Initially massive meta-granitoid and gabbro/leucogabbro with only weak foliation (Figure 43), then these are cut into lenses separated by shear bands and finally augengneiss with very persistent and parallel foliation.

At station: blocks of gneiss with layers and lenses of amphibolite cut by m wide dyke of lighter-grey diorite with garnet-plag leucosomes inside it. This dyke then accommodates the shearing and now has good foliation, aligned leucosomes and it folds around the more mas-

sive lenses of gneiss and gabbro. Shear bands are cut by the bt-plag pegmatite, so the shearzone was active before pegmatites. This pegmatite sampled at previous station.

Augengneiss has strong and very parallel foliation with stretched quartz ribbons and abundant cm-sized augen. Augen are amphibole as well as plag/qtz.

- Sample: **562758** – augen gneiss for Nynke Keulen (GEUS)
- Foliation: 011/82 N dip direction/dip

Figure 43. *A) meta-granitoid with gabbro/leucogabbro parts with sharp contact to a shear band. B) The shear band is cutting though the gabbro.*

Station: 14vivh054
Coord: 65˚ 46.314 N
37˚ 46.382 W

Outcrop south of camp of shear zone + later reactivation. Shear zone consists of lenses of coarse-grained unfoliated leucogabbro (amphi + plag) cut by shear bands of felsic gneiss with garnet (Figure 44). Some of the shear bands have quartz veins along them.

This old shear zone is cut by an irregular greenschist facies shear band that narrows and widens. It consists of chl + pinkish carb sections and epidote-quartz-plag parts, with the later probably representing the retrogression of the leucogabbro. Both this one and the older one show pinch and swell textures.

- Sample: **562760** - sample of chl-carb unit
- Foliation: 174/74 S chlorite foliation (dip direction/dip)

Figure 44. *Outcrop of shear zone consisting of mylonite braiding around lenses of coarse-grained unfoliated leucogabbro.*

Station: 14vivh055
Coord: 65˚ 46.280 N
37˚ 46.430 W

Stream sediment from the stream that passes camp, downstream of the lake. Third order river on rocks and boulders.

• Sample: **553297** - stream sediment sample

Station: 14vivh056
Coord: 65˚ 46.578 N
37˚ 46.638 W

Outcrops of well-foliated orthogneiss in river valley to the NW of camp. Very light coloured rock dominated by plag, qtz and K-spar with pockets and lenses of green mica (chl?). If indeed chlorite then strongly retrogressed. Mica and quartz define the foliation with qtz elongated into ribbons. No garnet in this rock, but the enclosing gneisses have abundant garnet.

• Sample: **562761** - sample for geochron and geochem
• Foliation: 344/86 N dip direction/dip

Station: 14vivh057

Coord: 65˚ 46.605 N
37˚ 47.413 W

Well foliated felsic gneiss on top of hill NW of camp, beautifully polished by the ice into smooth rounded hillocks (Figure 45). Very regular foliation that is completely straight. Cut by mafic dykes, now amphibolite which has been rotated into the foliation plane and boudinaged. Also late stage undeformed pegmatites with plag + bt rim and qtz + pink K-spar interior. Gneiss contains gt, bt, qtz, and plag.

• Foliation: 180/80 S dip direction/dip (varies around vertical)

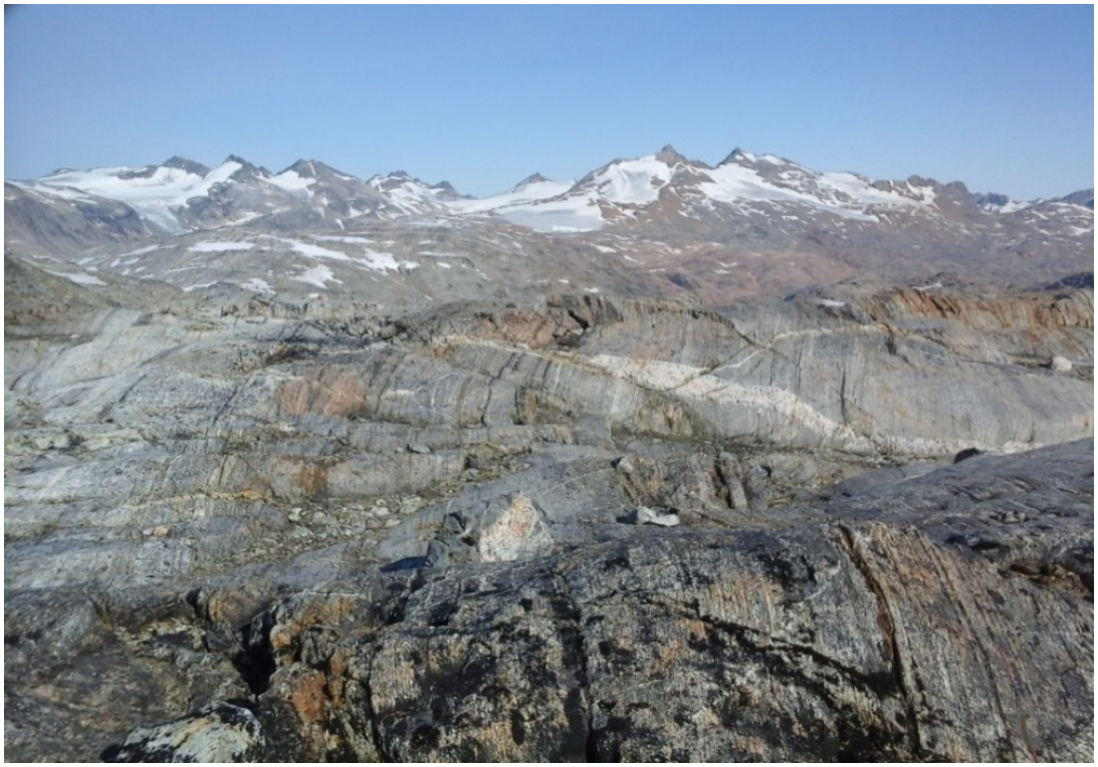

Figure 45. *Well foliated felsic gneiss here beautifully polished by glaciers into smooth rounded hillocks.*

Station: 14vivh058
Coord: 65˚ 46.483 N
37˚ 46.258 W

Stream to the north of camp flowing into the lake. First order stream ~1 m wide, 10 cm deep flowing on gravel and boulder field. Minor rusty weathered zone up the valley. Main lithology of river is the white orthogneiss. Almost all rusty zones are between this sample and sediment sample 553297 (14vivh055). Very little fine sediment at station.

• Sample: **553296** - stream sediment sample

Station: 14vivh059

Coord: 65˚ 46.392 N
37˚ 46.366 W

Epidote-quartz vein network at steep angle to the foliation, ~parallel to the orientation of the plag-bt pegmatite, but clearly its own event unrelated to the pegmatite. Braided vein network with angular fragments of epidotised gneiss within it. Epidote also 'bleeds' into the gneiss from the vein. Location is just north of camp (Figure 46).

- Sample: **562762** - sample of vein to check for mineralisation
- Vein orientation: strike ~E-W

Figure 46. *Epidote-quartz vein with open standing voids close to camp. Sampled as 562762.*

5.3.3 July 27

Sunny with some clouds coming in from the coast. Camp move to north to meet up with Team 4 and reco on nunataks.

Reco

Metasediments on northern nunataks (Figure 47 and Figure 2) for comparison with the metasediments of the Isertoq area and the metasediments of camp 4 and 5. Also investigate the anorthosite tip on nunatak as on geological map and compare with anorthosites of camp 1 and 3. Stations are shown in Figure 20.

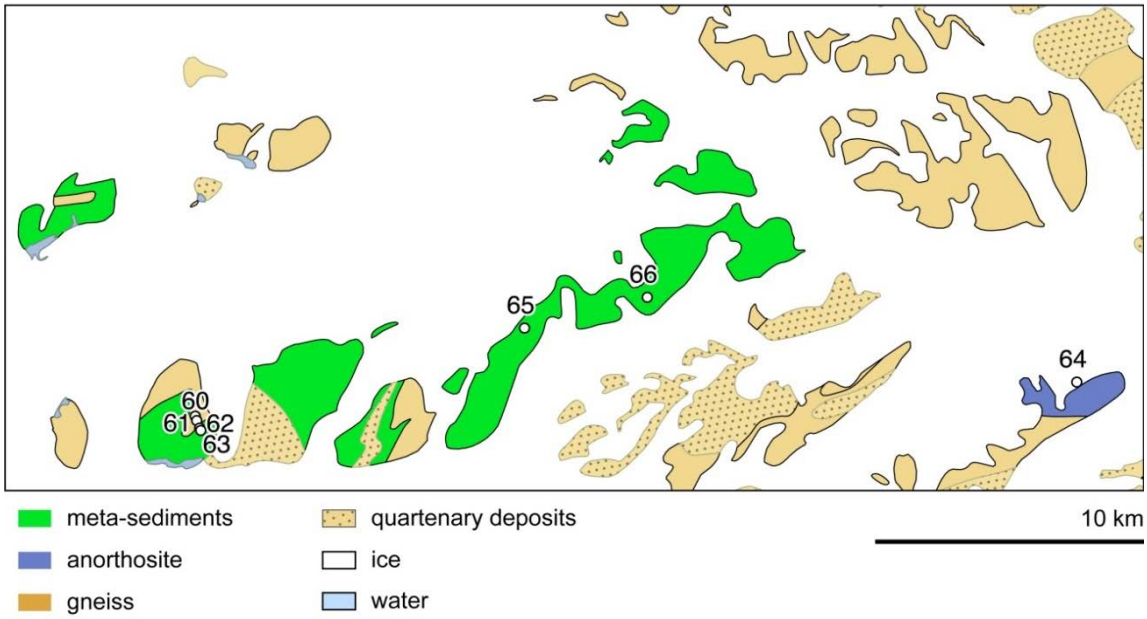

Figure 47. *Geological map with station numbers for the reco on July 27. See Figure 1 and 2 for location of this map.*

Station: 14vivh060
Coord: 66˚ 41.921 N
37˚ 38.146 W

Large (3 x 4 m) float of gt-sill schist with very large garnets (2–3 cm in diameter). Also contains biot, plag and qtz. Sill as fibrous masses and larger grains. Beautiful rock.

• Sample: **562763** - Gt-sill schist for PT

Station: 14vivh061
Coord: 66˚ 41.829 N
37˚ 38.088 W

Gneiss outcrops on slope away from the central valley. Well-foliated plag, bt, gt, qtz, sill gneiss with abundant boudinaged quartz veins. Veins are at shallow angle to the foliation. Mineralogy is the same as the previous sample, but the rock has a gneissic appearance at this station. Within it well-foliated layers of amphibolite.

• Foliation: 318/65 (wavy foliation) ddd

Station: 14vivh062
Coord: 66˚ 41.666 N
37˚ 38.000 W

Still the same gneiss with abundant quartz veins and same mineralogy. Starting to develop gneissic banding. Strongly folded at station (Figure 48A). Qtz, sill and plag in the felsic bands and bt, gt and sill in the dark bands. Within the gneisses a large lens of amphibolite, which has an alteration zone around it. It has rusty weathering and contains abundant graphite (Figure 48B). Surfaces of up to 10 x 10 cm of graphite and veinlets of graphite in the altered rock, now a schist, as well as small idiomorphic flakes within it. Graphite is associated with quartz and the altered rock looks sericitised.

• Sample: **562764** - graphite bearing alteration zone
562765 - gneiss for P-T

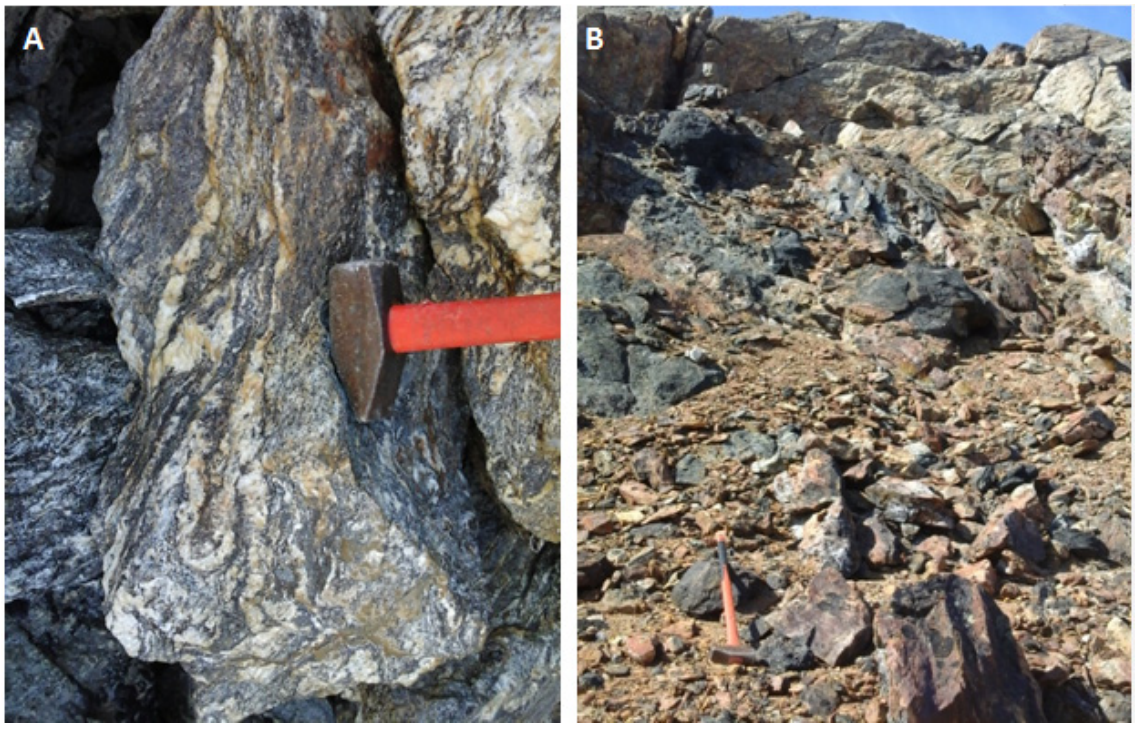

Figure 48. *A) Strongly folded TTG gneiss with amphibolite and felsic bands. B) Rusty weathered alteration zone between amphibolite lens and host gneiss, with abundant graphite flakes and veinlets.*

Station: 14vivh063
Coord: 66˚ 41.621 N
37˚ 37.977 W

Lenses of almost pure sillimanite enveloping qtz + bt + plag segregations in gneiss (Figure 49). Rock is medium-grained bt-qtz-plag gneiss, locally with garnet, with lenses dominated by qtz + plag and very minor biotite. These lenses look like melt veinlets. It is these melt veinlets or segregations that are enveloped by sillimanite. The sillimanite occurs as massive white fibres up to 10 cm in length, aligned with the foliation.

• Sample: **562766** - massive sillimanite

Figure 49. *Massive sillimanite on the contact between pegmatite and host gneiss.*

Station: 14vivh064

Coord: 66˚ 40.236 N
37˚ 54.003 W

Anorthosite locality as indicated on the geological map. Very steep grey mountain in the ice connected to more yellowish gneiss part of the mountain. Stark contrast in colour compared to the surrounding rocks that clearly marks it out as something different. This end of the mountain is completely grey with no obvious structure to the anorthosite. The mountains on the other sides of the ice do not have the same unit exposed as determined from colour. Impossible to land on the mountain itself because too steep and lots of rock falls from steep slopes, so landed on moraine that comes down from minor glacier whose catchment is only the anorthosite, and which itself flows onto the large glacier. Can be certain that material in the moraine is only sampled from anorthosite. Still not the best landing site as glacier full of crevasses. This station is to the north of the anorthosite body with a ridge in between anorthosite and gneiss, so material is definitely local.

Anorthosite consists of very large blueish to purple, transparent crystals of plag (up to 5 cm diameter) with some green pyroxene with black rims. There is also some minor interstitial

sulphide and garnet(?). This unit is exposed in the rock face next to the moraine (see Figure 50). Second most common rock in the moraine is a well-foliated fine-grained variety of this which contains greener pyroxene and where grain size is max cm scale. There are also rounded blocks of gneiss, which could be from the gneiss that connects to the anorthosite on the other side of the mountain, or be float. The gneiss looks quartz-rich, has banding and is different from the TTGs further south. There is no sign of any mafic rocks on the moraine, in the mountain or in the surrounding peaks.

The unit has thus been mapped correctly as anorthosite. It is very different from the anorthosite in camp 1 or the leucogabbro in camp 3.

• Sample: **562767** - anorthosite
562768 - plag-amphibole gneiss
562769 - gneiss float

Figure 50. *Purplish blue anorthosite in outcrop on rock face just below hanging glacier (photo Vivh-Loc-64-No-1).*

Station: 14vivh065
Coord: 66˚ 42.817 N
37˚ 21.130 W

Outcrops of metasediments on the chain of nunataks of station 14vivh060 to 14vivh063. Kya-gt-bt schist/gneiss. Not well-developed banding but the rock is coarse-grained. Kyanite is blue and up to 2 cm in length, it is present in the qtz + plag bands. The dark bands are gt +

bt. Kyanite is in the foliation plane, but randomly oriented on this plane and there is no lineation.

• Sample: **562770** – sample for PT

Station: 14vivh066
Coord: 66˚ 43.107 N
37˚ 14.802 W

Outcrop in the middle of the metasediment nunatak to the east of the previous station. Gt-kya schist/gneiss with beautiful idiomorphic blue kyanite + biotite + garnet + plagioclase + quartz. This rock is cut by a pegmatite and at the contact this pegmatite has sillimanite at its rim: from conversion of kyanite in host rock? Could sillimanite be retrogressive after kyanite in these rocks as a result of later heating by pegmatite?

• Sample: **562771** - sample for PT and check for kya->sill overprint

Figure 51. *Aluminous schist with kyanite + biotite + garnet + plagioclase and quartz.*

5.4 Camp 4. Metasediments at Midgårdgletscher

Camp in valley on eastern limb of carbonate fold in metasediments (Figure 52 and Figure 2). Nice flat area behind moraine with lots of vegetation and small fast flowing stream (Figure

53). No bugs! Probably because it gets too cold at night. Good spot, but even better a little higher up to the west next to a lake. Joined camp with Team 4.

Goals: 1. Check out metasedimentary units and compare them to southern ones
2. Characterise meta-carbonates and associated sediments
3. Compare notes with Team 4 regarding the metasediments

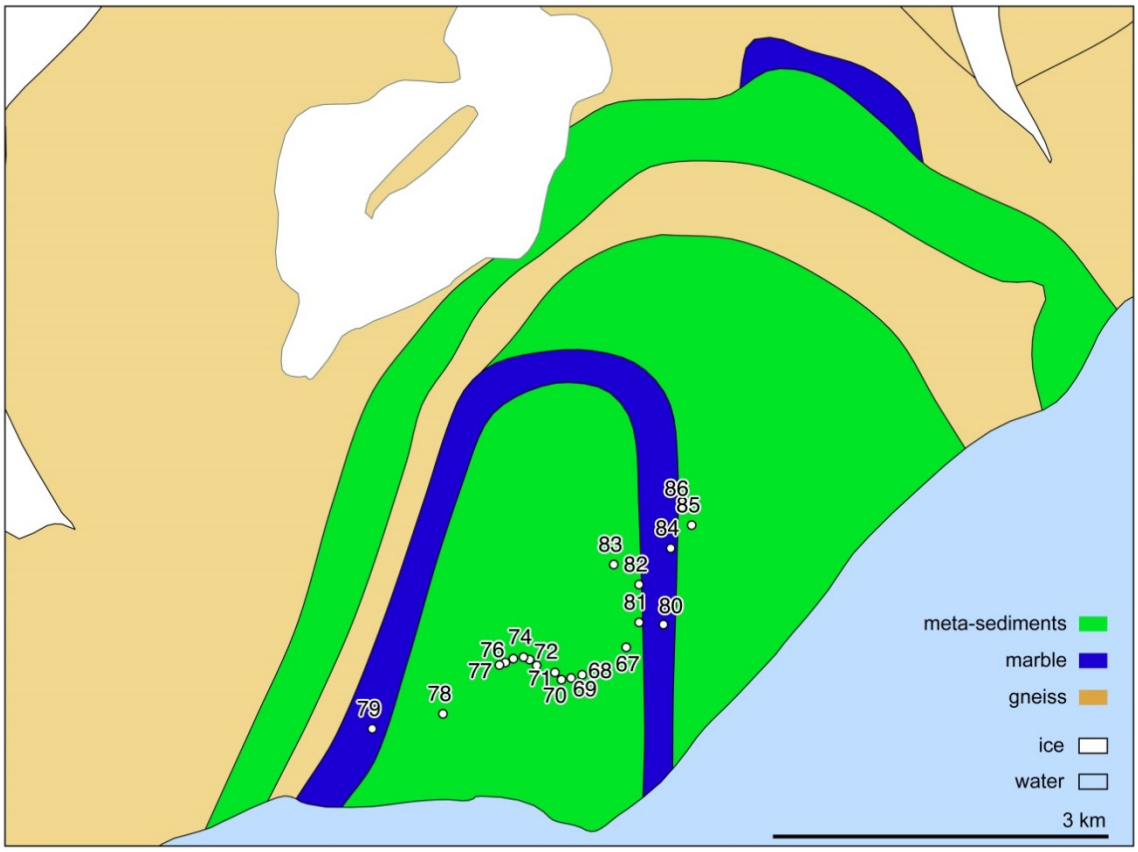

Figure 52. *Geological map of the area around camp 4 showing station numbers. Note that the fold indicated on this map was not found in the field. See Figure 1 and 2 for the location of this map.*

5.4.1 July 28

Sunny in the morning. Very cold at night. Still no bugs! Joined transect through this metasedimentary sequence with team 4.

Station: 14vivh067
Coord: 66˚ 21.010 N
37˚ 05.223 W

Outcrop just west of camp. Low grade biotite-chlorite schist with plag + qtz. The schist occurs within a rusty weathering zone that looks like a retrogression zone.

• Sample: **562772**
• Foliation: 305/78 wavy foliation that varies around vertical (ddd)

Station: 14vivh068

Coord: 66˚ 20.871 N
37˚ 05.913 W

Outcrop on hill further to the west. Well-foliated micaschist with bt + ms + plag + qtz and sillimanite intergrown with mica. The package also contains layers of fine-grained, very parallel-foliated garnet amphibolite. Outcrops are fresher than and not as affected by retrogression as at station 14vivh067. No chlorite.

• Sample: **562773** - gt-amphibolite for PT
• Foliation: 270/70 (ddd) in amphibolite

Figure 53. *View towards the N showing sharp lithological contact between rusty weathered (likely graphite-bearing) rocks to the E and dark grey amphibolites to the W.*

Station: 14vivh069

Coord: 66˚ 20.863 N
37˚ 06.022 W

Thick sequence of garnet amphibolite further towards the west up into the sequence. Well foliated. Mineralogy is amphibole, garnet, plagioclase, quartz.

Station: 14vivh070
Coord: 66˚ 20.870 N
37˚ 06.141 W

Top of hill between the two valleys. Up to this station garnet amphibolite, well-foliated and isoclinally folded. At station green, garnet amphibolite with calc-silicate layers that contain diopside (Figure 54).

• Sample: **562774** - sample for PT

Figure 54. *Green garnet-amphibolite with calc-silicate layers.*

Station: 14vivh071
Coord: 66˚ 20.910 N
37˚ 06.203 W

Slope on western valley with nice foliated garnet amphibolite with calc-silicate layers (Figure 55). Garnet amphibolite has on foliation plane randomly oriented cm long laths of quartz where quartz must be pseudomorphing something. Shape would suggest kyanite, but strange that it is replaced by quartz: check.

• Sample: **562775** - determine what pseudomorphs are

Station: 14vivh072
Coord: 66˚ 20.948 N
37˚ 06.412 W

Western valley just east of river. Good outcrops of garnet amphibolite with quartz lenses and veinlets. One of the samples has green amphibole enclosing quartz veinlet with graphite flakes inside the quartz.

- Sample: **562776** - graphite bearing quartz vein + amphibolite host
- Foliation: 290/76 (ddd)

Figure 55. *Nice foliated garnet amphibolite with calc-silicate layers.*

Station: 14vivh073
Coord: 66˚ 20.979 N
37˚ 06.503 W

River outcrop in western valley at small waterfall. Rocks consist of very hard silicified garnet amphibolite weathering into angular blocks. Cut at station by a late quartz vein with chlorite

+ epidote. Silicified amphibolite has very nice 30 cm wide shear zone in it with parallel foliation in core and then bending into the overall foliation (Figure 56). Shear zone has a N-S strike and near vertical dip.

• Sample: **562777** – sample of shear zone
• Foliation: 103/88 (ddd) in shear zone, so shear zone orientation

Figure 56. *Silicified amphibolite with an approx. 30 cm shear zone in the core which bends into the overall foliation.*

Station: 14vivh074
Coord: 66˚ 20.997 N
37˚ 06.542 W

Beige-yellow fine-grained layer in garnet-amphibolite sequence. Mostly fine-grained, but within this colourless to greenish fibrous mineral. Interbedded with quartz layers.

• Sample: **562778** - for mineral ID

Station: 14vivh075
Coord: 66˚ 20.995 N
37˚ 06.681 W

Back in micaschist with qtz, plag, bt and musc. Some relics of sillimanite being replaced by muscovite. Same as at station 14vivh068.

Station: 14vivh076
Coord: 66˚ 20.992 N
37˚ 06.773 W

Further up the valley. Same schists but locally with sillimanite porphyroblasts as nodules in bt-musc schist and on foliation planes. With bt, musc, plag and qtz.

• Sample: **562779** - sill nodules in schist

Station: 14vivh077
Coord: 66˚ 20.956 N
37˚ 06.835 W

Outcrop on saddle further to the west from last station. ~4 m wide felsic gneiss with augen of dark green amphibole (Figure 57). Amphibole augen contain small plag grains. Host gneiss is plag, qtz, bt + amphi. Sampled by KSZ for geochron.

Figure 57. *4 m wide felsic augen gneiss with dark green amphibole crystals.*

Station: 14vivh078
Coord: 66˚ 20.785 N
37˚ 07.596 W

West of western valley. Micaschist with sillimanite nodules as seen at station 14vivh076 (Figure 58). Thin horizon of only ~0.5 m width so maybe not porphyroblasts but replacement of something primary?

Just to the east of this station a retrogressed micaschist with graphite dispersed within it.

Figure 58. *Micaschist with sillimanite? Nodules.*

Station: 14vivh079
Coord: 66˚ 20.765˚ N
37˚ 08.455 W

Outcrops all the way towards the western contact of the metasediments. At station very light-coloured TTG gneiss with minor fabric in the scarce mafic minerals. Out of the schist sequence, so this may be part of the enclosing gneiss package. Up to here more micaschist occasionally sericitized with graphite and ~20 m wide garnet-amphibolite sequence. No signs of the carbonate and given the light colour of the gneiss here, it may have been mistaken for a carbonate. TTG gneiss sampled by KSZ for geochron.

5.4.2 July 29

Sunny but a thin layer of high clouds. Check out the sedimentary sequence to the east, as well as outcrops above camp to the north.

Station: 14vivh080
Coord: 66˚ 21.086 N
37˚ 04.900 W

Outcrops of garnet amphibolite on slope just to the east of camp. Well-foliated amphibolite with quartz layers (either segregations or sheared out quartz lenses/veins). Garnets have plag rims from retrogression. Mineralogy is amphi, plag, qtz, gt. 15 m to the N perpendicular to the strike there is sillimanite schist with nodules as seen at yesterday at 14vivh076.

• Foliation: 298/55 (ddd)

Station: 14vivh081
Coord: 66˚ 21.109 N
37˚ 05.245 W

A little north of camp along the valley of the river that runs next to camp. Package of rocks with rapidly changing lithologies (Figure 59). Felsic schist at the bottom followed by 30 cm thick schist with powdery beige to white weathering surface, followed by amphibolite, followed by garnet-bearing felsic gneiss. The weathering surface on the middle schist suggests carbonate inside, but the fresh surface does not show this obviously. Sampled to check.

• Sample: **562780** - felsic schist with carbonate?
562781 - gt bearing flesic gneiss for PT

Station: 14vivh082
Coord: 66˚ 21.262 N
37˚ 05.276 W

Float on boulder field north of camp. Sugary marble with idiomorphic mm sized flakes of graphite and bright green fuchsite (Figure 60). Block is ~50 cm in diameter and strongly weathered with calcite grains coming off like sugar. There are several creamy light green grains within the calcite matrix that could be diopside. There is a mica band within the marble with muscovite, locally bright green fuchsite and minor quartz. The mica band contains sulphides up to 1 cm in size. These are completely weathered to rusty brown iron oxide. Marble appears to preserve faint bedding in colour and mica.

• Sample: **562782**

Figure 59. *Well-foliated gneiss with rapidly changing composition. Appears to be carbonate-bearing.*

Figure 60. *Float of sugary-looking marble containing abundant flakes of graphite, fuchsite and minor pale green diopside.*

Station: 14vivh083

Coord: 66˚ 21.386 N
37˚ 05.329 W

Outcrops of bedded sugary light grey to beige marble above the scree slope (Figure 61) on which we found the marble float (sample 562782). ~25 m thick marble sequence interbedded with layered quartzite (layered on 2 cm scale) and cut by a quartz-graphite schist. The marble crops out just below rusty weathered schist with sericitisation which forms the mountain next to the marble outcrops. Quartzite could be meta-sandstone, but contains graphite, so could also be related to the fluids that brought in the graphite. Could graphite have formed from carbonate reduction? Would mean very reducing fluids -> should do C-isotopes on carbonate and graphite at this locality.

The marble looks sugary and looks the same as the float piece. There are lenses within it of opaque white material, blocky cleavage (~8 to 10 cm in length) -> calc-silicate? or dolomite? These occur within the bedding plane. Graphite schist cuts through the bedding.

The marble unit continues up the mountain and appears to crop out in the ridge to the west of the peak above camp. Although this confirms the presence of carbonate, the orientation and position do not agree with the geological map.

• Sample: **562783** - marble for C-isotopes
562784 - graphite-quartz schist within the marble for C-isotopes

View from helicopter on flight out on July 30 confirmed that carbonate is also present in the ridge west of the peak above camp and seems to continue on the rounded hill directly west of camp, even though we did not observe it during walking traverse. There is no evidence for any folding and the rocks seem to strike continuously from the ridge through the rounded hill to where we did our section. So the carbonate fold on the map does not exist, or has to close behind the scarp due north above camp. This scarp was visited by Team 11 who investigated this in detail.

Station: 14vivh084

Coord: 66˚ 21.414 N
37˚ 04.659 W

Outcrops just sticking through the soil and vegetation to the northeast of camp. Garnet amphibolite with plag rims on the garnet as at station 14vivh080, followed to the east by garnet bearing felsic gneiss similar to that at station 14vivh081.

• Foliation: 099/86 - foliation amphibolite (ddd)
312/80 - foliation gneiss

Figure 61. *A) The scree where sample 562782 was sampled. The lighter coloured rocks in the outcrops above consist of marble, and an about 2 m wide quartzite unit. B) The top of the peak was visible from the marble, with possible marble layers continuing to the top. C) Graphite-bearing lens of about 1 m length was found within the marble unit.*

Station: 14vivh085
Coord: 66˚ 21.512 N
37˚ 04.357 W

Outcrop on hill east of camp. Garnet bearing amphibolite with quartz veins. Medium-grained (mm sized grains). Well-foliated. Sampled for PT.

- Sample: **562785** - gt-amphibolite for PT
- Foliation: 093/70 (ddd)

Station: 14vivh086
Coord: 66˚ 21.593 N
37˚ 04.465 W

Outcrops a little further up the hill to the NW of previous station. Strongly folded basement gneisses with quartz veins that are isoclinally folded. The gneiss composition varies from garnet amphibolite to leuco-amphibolite to very dark amphibolite to TTG (last mostly as float). Amphibolite at previous station could be part of this sequence as well, as no contact was

seen, although there is no continuous exposure. This is true for complete sequence investigated today.

The gneisses are cut by felsic dykes that are now folded and almost parallel to the foliation. Sampled the gneiss for geochron, but it is quite mafic so may not yield zircon. Therefore also sampled the felsic dyke: will give a minimum age. Ages will help to figure out if this is still part of the metasedimentary sequence, or of its basement, and what their relative ages are.

• Sample: **562786** - gneiss for geochron
562787 - crosscutting felsic dyke for geochron

5.4.3 July 30

Reco

Overcast and very cold. Camp move today to shared camp with Team 2 + reco by helicopter to several Team 2 locations, including reco stop at possible ruby locality found by Team 2 suspected ruby locality.

Station: 14vivh087
Coord: 65˚ 58.854 N
37˚ 06.543 W

Outcrop on hill west of Sermilik Fjord. Rounded hill of dark massive garnet-amphibole rock with plag rims on garnet and green px in between the amphibole. Retrograded high-pressure rock. Cut by pegmatite dykes without deformation and by green amphibole retrogression zones. Also even later epidote + quartz veins. Sampled for study by Team 2.

• Sample: **562788** - high-pressure mafic rock with decompression retrogression

Station: 14vivh088
Coord: 65˚ 59.894 N
37˚ 04.108 W

Outcrop next to river feeding into big lake to the north of previous station. Rounded outcrop of massive green eclogite? Garnet - pyroxene rock with brown tremolite?, garnet and two green minerals One of the green minerals has no cleavage and is rounded: olivine? The other grades to black and has 120 degree cleavage so is amphibole. Rock is magnetic so it also contains magnetite. Enclosed by gneiss and on the contact it has a 1 m wide garnet-rich zone with garnet masses almost 10 cm thick. This seems to be the reaction zone between the mafic rock and the gneiss. Sampled by team 2 for study.

• Sample: **562789**

Station: 14vivh089
Coord: 65˚ 58.330 N
37˚ 59.707 W

Outcrop next to small lake with UM in middle of lake enclosed by gneisses. Outcrop is a low ridge next to the lake and lots of float in front of it. Small pegmatite dykes are cutting into it. Rocks are coarse-grained (up to 2 cm diameter grains) plag + qtz + green-blue kyanite + dark pink to red transparent grain. Red/pink grain is suspected to be ruby by Team 2, and they have named the locality ruby beach. The garnet is dark pink in colour and transparent and forms very nice crystals (Figure 62). Not always has cleavage and so looks like ruby in places, but locally in direct contact with quartz, so most likely all garnet. Some of these grains have an octahedral shape, which also suggests garnet. However, these rocks are the metasomatic reaction zone between UM and gneiss so it is not impossible that the red/pink grains are ruby [note: preliminary work after returning from the field confirms that these are garnet and not ruby].

The pegmatites show the same style of metasomatic mineral zoning as seen on the small island of camp 2 with large dark amphibole as pegmatite peters out and pure biotite zones, but here no rubies observed associated with these pegmatites and their metasomatic replacement. This also suggests that the pink/red grains in the main reaction zone are most likely garnet, because would otherwise have definitely expected ruby in these pegmatite metasomatism bands.

The rock is full of the garnet/ruby and it makes up about 50% of the rock. Some very nice crystals with few fractures and clear, so even if not ruby, these could still be suitable for cutting. There is also abundant kyanite in this rock, which is transparent colourless to blue and mm sized.

• Samples: **562790** - kyanite bearing garnet schist for PT
562791 - garnet schist without kyanite

Station: 14vivh090
Coord: 65˚ 58.382 N
37˚ 59.885 W

Outcrops of schists a little further up the hill from the lake. These have similar large pink grains of garnet/ruby with beautiful blue kyanite that forms plates of 2–3 mm thickness and >5 cm diameter (Figure 63). This is a very pretty rock! The pink grains are up to 8 cm diameter here. The schist unit is hosted by felsic gneisses and has rusty brown weathering. The grain size varies a lot over the outcrop in an irregular fashion and there is no clear foliation to this rock. From appearance of grains, garnet looks even more likely. Large grain size holds potential for looking at inclusion assemblages and investigating the prograde metamorphic history for this area.

• Sample: **562792** - sample for PT

Figure 62. *Aluminous schist with abundant pale pink clear garnet, locally making up 50 % of the rock.*

Figure 63. *Schists with large grains of garnet and pale-blue kyanite plates.*

5.5 Camp 5. Metasediments at Cape Nuuk

Camp on a very large flat plain east of Sermilik Fjord next to the southern river in this valley (Figure 64). The plain is great, but the river is milky white from suspended solids, not drinkable, and it is not possible to cross it without taking off your shoes. Better location is at smaller river to the south of this campsite. Plenty of flat space there as well and river is clear. Got a lift from Douglas Andersen in the evening to get water.

Goals: Check the metasedimentary units and compare these to the ones that we already visited in the north and south. 1989 GGU report mentions that there is carbonate here as well as abundant tourmaline. Tourmaline could help to distinguish sedimentary from hydrothermal origin for the aluminous schists.

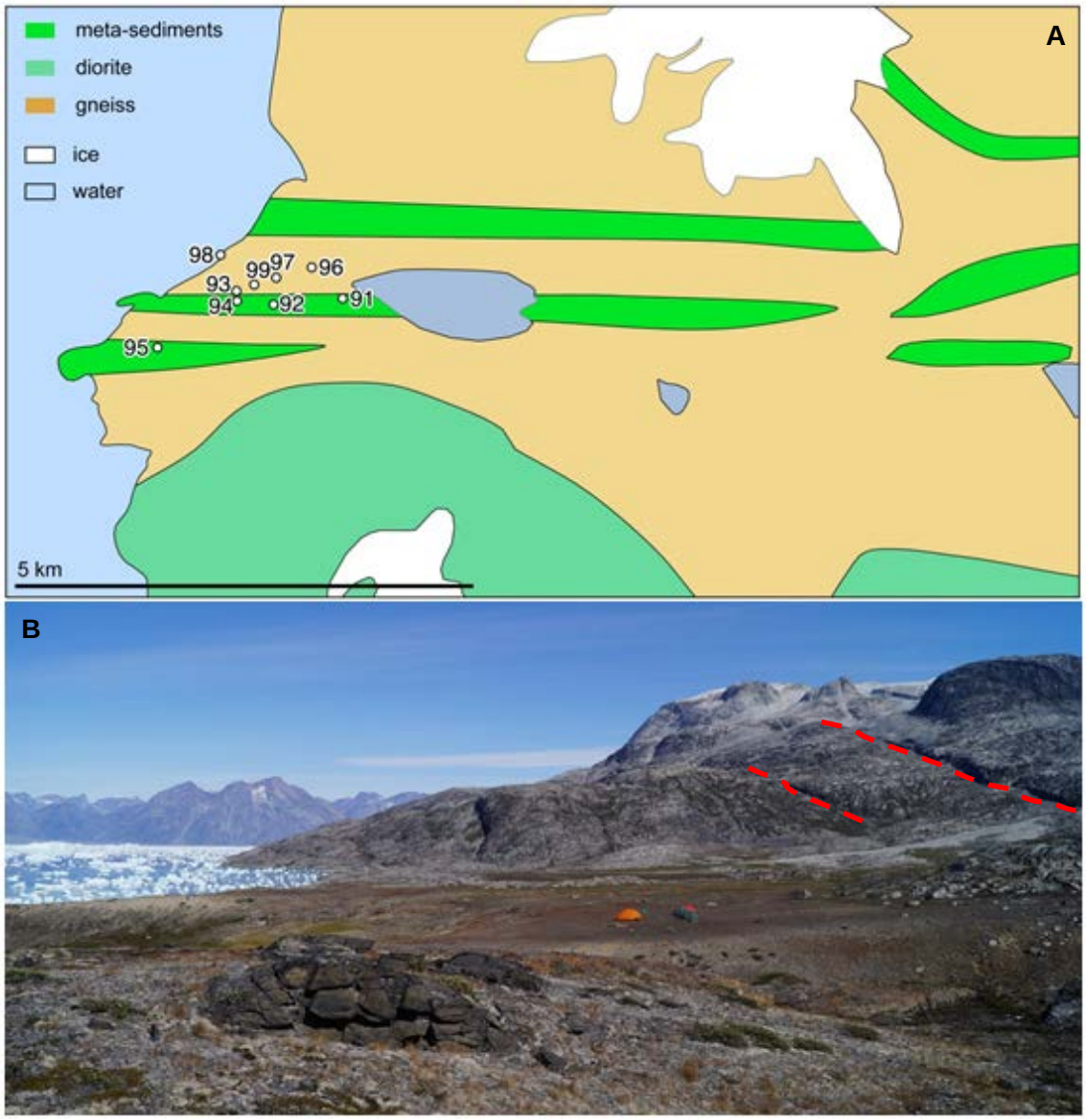

Figure 64. *A) Geological map (1:500,000) of the area around camp 5. See Figure 1 and 2 for the location of this map. The camp is at station 14vivh099. B) Photo showing the camp site and viewed with same orientation as the geological map . Note some fault planes suggested.*

5.5.1 July 31

Sunny but cold wind from the fjord. Will make a transect through the various metasedimentary lenses perpendicular to strike.

Station: 14vivh091
Coord: 66˚ 09.751 N
37˚ 28.503 W

Outcrops just south of river to SE of camp. Well-foliated biotite gneiss, light in colour. Biotite defines the foliation. It forms a thick succession ~E-W along the river and it crops out on both sides of the river at station.

• Foliation: 192/85 (ddd)

Station: 14vivh092
Coord: 66˚ 09.761 N
37˚ 29.514 W

Still in outcrops of well-foliated biotite gneiss south of the river. Locally leucogabbro amphibolite interbedded with it and quartz veins stretched out along the foliation.

• Foliation: 170/57 (ddd)

Station: 14vivh093
Coord: 66˚ 09.880 N
37˚ 30.013 W

Middle layer of metasediments (as on geological map) south of the river and just south from our camp. It forms a low, rounded ridge with a sharp boundary on western end where it is cut by a valley. The rocks on the other side of this valley are not the same even though the strike is identical -> strike-slip offset? At eastern end, the sequence crosses the river but then appears to disappear underneath the soil. This station marks the start of a detailed transect through this metasedimentary package:

- unit 1: biotite gneiss with boudinaged lenses of amphibolite within it. Approx. 40 m wide, but start not observed, so is minimum thickness.
- unit 2: aluminous schist with gt-bt-sill-plag-qtz. Sill as cm sized lenses and gt ~5 mm in diameter. Approx. 7 m wide.
- unit 3: back into biotite gneiss for ~2 m.
- unit 4: aluminous schist as before with biotite gneiss layers within it of ~20 cm width -> schist could represent alteration and hydration of the biotite gneiss: check! Approx. 3 m wide.

- unit 5: pure marble, approx. 3 m (Figure 65). Sugary grey to beige marble with no foliation or fabric within it. It has 2-3 mm sized calcite grains and small isolated graphite flakes within it.
- unit 6: calc-silicate rock, ~2 m wide, with a carbonate matrix and free-floating crystals of quartz, and green amphibole within this. It grades into a more massive calc-silicate. The calc-silicate contains beige diopside, green amphibole, qtz crystals, idiomorphic graphite flakes all in a matrix of calcite. These silicate minerals are free floating in the carbonate matrix and they stand out on the weathered surface. These silicates are concentrated in layers and define the foliation as ridges on the weathered surface. The marble and calc-silicates are cut by a ~30 cm wide pegmatite and very large (10 cm length) calc-silicate minerals develop in it, including a pale green one.
- unit 7: aluminous schist with 8 mm diameter garnet and sillimanite. This sample should be very good for PT as it must be calcic given that it is right at contact with the calc-silicate. The unit is approx. 5 m wide
- unit 8: garnet amphibolite, well-foliated with small red garnets. Within this is a 10 cm wide irregular quartz vein with rose quartz. Just the one vein has rose colour although there are many quartz veins in the amphibolite. The rose quartz is pale, but it is nice and large.

Hill is rounded and is sitting in flat marshy plain. En echelon, there are several more of these ridges, including the one behind camp and the one of station 14vivh095.

• Samples: **562793** - unit 4 and 7 for P-T
562794 - unit 5 for carbon isotopes
562795 - unit 6 calc-silicate
562796 - unit 8 garnet amphibolite for P-T
562797 - rose quartz
• Foliation: 182/90 (ddd) unit 1

Station: 14vivh094
Coord: 66˚ 09.819 N
37˚ 30.016 W

Station at end of section in flat plain that borders the ridge to the south. At station, a sequence of aluminous schists of ~20 m width followed by biotite gneiss with amphibolite lenses as at start of the section. There are still several irregular schist layers in the gneiss, which suggests that the schist might represent replacement or alteration of the gneiss, although there are no obvious crosscutting relationships. The gneiss is cut at very shallow angle to the foliation by a meta-mafic dyke of ~30 cm width. The schist has rusty-brown weathering.

• Sample: **562798** - check for tour
• Foliation: 355/85 (ddd)

Figure 65. *Outcrop with an approximately 3 m wide marble unit.*

Station: 14vivh095
Coord: 66˚ 09.615 N
37˚ 31.241 W

Metasedimentary layer of the geological map furthest to the south. Dominated by biotite gneiss with several ~40 cm wide calc-silicate layers similar to calc-silicate layers (unit 6) in the transect on the middle ridge. Similarly coarse-grained. Did not find the pure marble and exact stratigraphy is different from what was observed in the detailed transect. Also contains a ~10 cm wide sericitized zone with rusty staining. Cut by undeformed pegmatite.

• Pegmatite dyke orientation: 090/72

Unclear how the various metasedimentary ridges fit together. They are not as continuous as shown on the geological map and may be repeated by horizontal offsets, as also noted above for the middle layer which does not continue along strike west of the small sharp valley. However, stratigraphy in the various ridges is not exactly the same. Interestingly, the measured pegmatite has the kind of orientation that would fit with that required for the repetition, and this orientation is also seen in a sharp valley on the mountain north of the large valley

that hosts these metasedimentary units. The pegmatite could possible define a fault plane crosscutting the metasedimentary units, see figure 64 for the area, and the sharp valleys in figure 64B suggesting some major fault planes in the area.

5.5.2 August 1

Overcast but not as cold as yesterday. Bugs have arrived. Work along the ridge that runs across camp, both to the east and to the fjord in the west. Camp move to basecamp at 16:00.

Station: 14vivh096
Coord: 66˚ 09.954 N
37˚ 28.889 W

Ridge section on northern side of ‘canyon’ that cuts the ridge that runs east from camp.

Same kinds of rocks as seen yesterday in the detailed transect with well-foliated biotite gneiss, aluminous schists and boudinaged, 30 cm thick layer of calc-silicate. Stratigraphy is not the same as on the other side of the river and both cannot connect along strike unless there is a strike-slip offset in between.

Calc-silicate has porphyroblasts of elongate rectangular minerals. Also contains quartz and mica. Calc-silicate layer increases in thickness along strike to the east to ~5 m width with a 30 cm thick silicate layer in the middle. The calc-silicate varies from almost pure marble to thin foliation-parallel bands of calc-silicate to layers of mixed calcite + silicate minerals (Figure 66). Surface texture is similar to what seen on other side of the river with the silicate minerals sticking out of the weathered surface. No graphite observed in the carbonate. The large coarse-grained calc-silicate minerals are interbedded with marble in ~10 cm wide bands. These calc-silicate minerals are colourless, elongate transparent. Sampled for mineral ID.

Open fold in the marble sequence dipping to the east with foliations steepening towards the south. This kind of E-W folding might also explain the apparent offsets and repetition of the units here. The dips are shallow in the fold and then steepen to almost vertical and locally overturned to the south and in the canyon. The foliation also steepens to the north so it is only in the fold that they are shallow. There is some parasitic folding in the fold hinges.

Foliation along the double open fold from north to south (ddd):

094/16
148/20
173/25
002/40
048/27
004/63
004/80

See sketch map (Figure 67) for foliation locations.

• Samples: **562799** - calc-silicate
567001 - purest carbonate of this sequence
567002 - large calc-silicate minerals
• Foliation: 015/70 (ddd) in gneiss

Figure 66. *Silicate minerals standing out on the surface of the calc-silicate unit as a result of calcite being preferentially weathered out (photo Vivh-Loc-96-No-1).*

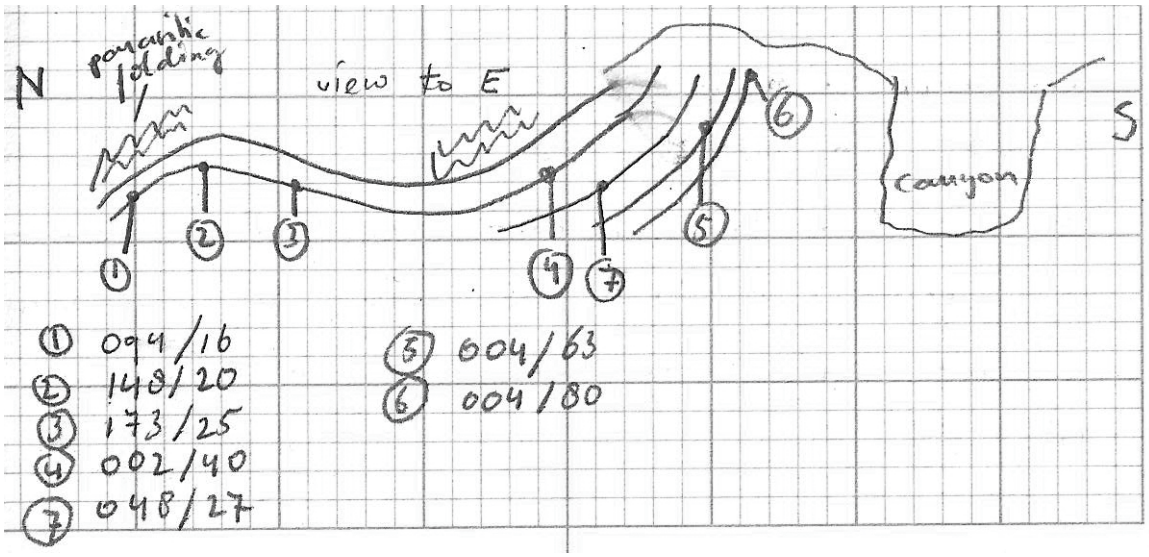

Figure 67. *Sketch of the fold in the marble sequence with locations of measurements.*

Station: 14vivh097
Coord: 66˚ 09.918 N
37˚ 29.406 W

Sericitized schist next to marble on low outcrops just north of camp. Fine-grained grey rock with rusty weathering. It is a calc-silicate rock with graphite and pale green diopside and actually contains little muscovite despite looking like the other sericitized schists that we have seen. Cm sized, almost completely oxidized sulphides in carbonate and especially in quartz lenses with calc-silicate minerals.

- Samples: **567003** - sericitized schist with graphite
  567004 – mineralised sample for DRO
- Foliation: 182/80 (ddd)

Station: 14vivh098
Coord: 66˚ 10.093 N
37˚ 30.162 W

Beautiful outcrops on coast of mylonite with boudinaged pegmatite dykes and black amphibolite within it (Figure 68). Pegmatite contains plag, qtz, bt and large pinkish orange K-feldspar crystals. It is parallel to the foliation and boudinaged and so intruded before the mylonite zone developed -> can use it to put max age on the shear zone. Gneisses are qtz, plag, amphi, bt with widely varying proportions of light and dark minerals.

- Samples: **567005** - mylonite
  567006 - pegmatite for geochron
- Orientation: 006/80 (ddd)

Station: 14vivh099
Coord: 66˚ 09.902 N
37˚ 29.729 W

Ridge just behind and to the east of camp. Core of it consists of a ~15 m wide well-foliated green calc-silicate schist with qtz, bt, green amphibole and green blocky mineral. It has a different green colour compared to the other calc-silicates and there are no marbles associated with this sequence and does not appear to be any calcite. Some biotite-gneiss layers within it as well at cm scale. Have not seen this unit in any of the other ridges.

- Sample: **567007** - calc-silicate

Figure 68. *Beautiful mylonite with boudinaged pegmatite.*

5.6 Camp 6. Basecamp in Kuummiut

Work from basecamp in school in Kuummiut.

Goals: Look at the geology around a number of settlements to make a geological guide and list of geological excursion stops for schools and tourists. Looked at Tiniteqilaaq, Sermiligaaq and Kuummiut together, MADP also visited Tasiilaq and Kulusuk.

5.6.1 August 2

Boat trip to Tiniteqilaaq with Karl and his wife. Overcast and a very cold wind coming from Sermilik Fjord, sunny in the afternoon.

Station: 14vivh100
Coord: 65° 53.552 N
37° 46.754 W

Touristic viewpoint above the town -> Tonalite-trondhjemite-granodiorite (TTG) gneisses with boudins of amphibolite (Figure 69) cut by undeformed pegmatite dyke dominated by large biotite (up to 4 cm long) and white plagioclase. This assemblage is characteristic for most of the town. Aside from beautiful views over Sermilik Fjord, this locality shows:

- Boudinaging by deformation of the amphibolite
- Crosscutting age relationship illustrated by the pegmatite dyke
- Folding of the foliation in the TTG
- Mafic and felsic lithologies

Sampled the TTG to get the age of the basement TTG gneiss for the guide.

• Sample: **567008** - sample for geochronology

Figure 69. *Tonalite-trondhjemite-granodiorite (TTG) gneiss with boudins of amphibolite.*

Station: 14vivh101
Coord: 65˚ 53.500 N
37˚ 46.546 W

Small rock quarry to the east of the lookout. Lens of gabbro in the TTG gneiss (Figure 70), partly silicified, with sericitized rim at contact with gneiss. Gneiss foliation folds around the gabbro lens. Sericitized gneiss contains quartz, feldspar, muscovite, biotite and small flakes of graphite, and has yellow to rusty brown weathering colour.

• Sample: **567009** - sericitized material

Figure 70. *Lenses of gabbro in the TTG gneiss. The gabbro has not been deformed. Note the small felsic melt stringers cutting into the gabbro and almost breaking more pieces off.*

Station: 14vivh102
Coord: 65˚ 53.360 N
37˚ 46.121 W

Outcrop at the water level on the fjord just to the east of the municipal waste dump. Still in the same meta-gabbro layer which is ~3 m thick and very continuous, although it is boudinaged and locally necked out. So not just a lense, but likely a sill. Here it is intruded by pegmatite with pieces of the gabbro rafted off into the pegmatite dyke. The meta-gabbro contains small red garnets and lenses of garnet. No garnet observed before: contact metamorphism? Unlikely to be from dyke, but are close to contact with granite.

Station: 14vivh103
Coord: 65˚ 53.310 N
37˚ 46.001 W

Pink granite sheets in the gneiss. Fine-grained granite. The gneiss does not show any clear signs of contact metamorphism, but its mineralogy would also not allow for that. This is essentially the contact between the granite and the basement gneiss. Individual contacts are sharp but overall this is a gradual contact with abundant dykes of granite and pegmatite in the gneiss-amphibolite basement.

Station: 14vivh104
Coord: 65˚ 53.312 N
37˚ 45.991 W

A little further to the east along the coastal path. Pink granite with above it epidotized gneiss with complex garnets up to 2 cm in diameter (Figure 71). These garnets look to be porphyroblasts from contact metamorphism. The epidotized gneiss is a thin layer of only ~40 cm wide. Sampled to determine P-T of intrusion or at least the contact aureole from garnet.

• Sample: **567010** - for thin section and PT

Figure 71. *Epidote gneiss with garnet up to 2 cm in diameter at the contact with the granite.*

Station: 14vivh105

Coord: 65˚ 53.241 N
37˚ 45.791 W

Outcrop of granite on point at end of path. Looks to be a camping site. Fine-grained white granite with coarser grained pegmatite parts and rafts of meta-gabbro (still the same layer as we have been tracing from station 14vivh101) and gneiss (hard to spot as its colour and mineralogy are the same as that of the granite) (Figure 72). No obvious signs of contact metamorphism in the rafts. Gneiss at contact with the granite is recrystallized with sugary quartz. Meta-gabbro at contact contains garnet.

Figure 72. *Raft of foliated TTG in fine-grained granite. Outlines are rounded (photo Vivh-Loc-105-No-2).*

Station: 14vivh106
Coord: 65˚ 53.262 N
37˚ 45.658 W

A little further along the coast from station 14vivh105. Very sharp contact between meta-gabbro and pink medium-grained granite -> meta-gabbro was intruded brittle, whereas the gneiss was ductile at time of intrusion (Figure 73). Meta-gabbro contains abundant garnet. Also raft of this in the granite. Good spot to end the walk with great views over the fjord and to the glacier in background. Alternatively, makes for a great lunch spot.

The granite at this location is a nice pink to orange colour and shows few fractures. Has potential as a building/ornamental stone, but not a large outcrop.

• Samples: **567011** - meta-gabbro for P-T
567012 - granite

Figure 73. *Very sharp contact between meta-gabbro and pink medium-grained granite.*

Station: 14vivh107
Coord: 65˚ 53.384 N
37˚ 46.661 W

Nice outcrop in town, a little downhill from café, of gneiss, well-foliated and felsic (almost looks like a quartzite), and meta-gabbro enclosed by it (Figure 74). These are cut by 5 cm wide pegmatite dyke with bt + plag + qtz +/- K-spar. Nice textures in the rock.

Figure 74. *Well-foliated and felsic rock (almost looks like a quartzite), and meta-gabbro enclosed by it. A pegmatite cuts the 2 lithologies.*

Station: 14vivh108
Coord: 65˚ 53.368 N
37˚ 46.773 W

Outcrop of ~2 m wide pegmatite in town with raft of gneiss within. (Figure 75) Has nice large feldspar crystals of up to 10 cm in size. In sun, can see the complete crystal light up at the same time. The large pegmatite is offset by a smaller one, which intrudes at a steeper angle than the main one.

On the road at this locality are pieces of almost pure graphite, and graphite in sericite-schist. This material looks very similar to that in the quarry of station 14vivh101.

• Sample: **567013** - graphite sample

Station: 14vivh109
Coord: 65˚ 53.384 N
37˚ 46.847 W

Outcrops of rusty weathered sericite schist next to and behind the school. Full of graphite and the same as the material sampled as 567013 (14vivh108). Continuing along this road towards the end of town there is a lot more of this material, both as float and in outcrop (Figure 76). Wherever there are rusty surfaces, there is abundant graphite. In fact, it is the graphite that gives it this appearance.

Figure 75. *A large pegmatite about 2 m wide that is offset by a smaller pegmatite.*

Figure 76. *Outcrop of massive graphite and sericite schist behind the school.*

Station: 14vivh110
Coord: 65˚ 53.310 N
37˚ 46.726 W

Outcrop of nice white plag + bt pegmatite dyke just next to the store, up the hill from the harbour (Figure 77). One dyke is ~20 cm wide with biotite grains up to 10 cm in length.

Figure 77. *Pegmatite dyke with white plagioclase and large biotite flakes. Several pegmatites similar to this are found in the area.*

Station: 14vivh111
Coord: 65˚ 35.368 N
37˚ 11.691 W

Outcrops at tip of the fjord south of Kuummiut with granite + gabbro. Granite is coarse grained with 2–3 mm-sized quartz, plag and K-spar. Cut by fine-grained aplite and pegmatite, both pink.

Next to it, silicified amphibole + plagioclase gabbro with some retrogression to chlorite. Greenish in colour. Gets darker in colour and more massive further away from contact to the north.

• Sample: **567014** - granite with aplite dyke

5.6.1.1 Overview August 2

Some really good geology in this town centred on three themes:

- *Age relations*: old basement with folding and boudinaged mafic dyke/sill crosscut by granite and associated felsic dykes. Crosscutting relations are clearly visible and rafts of amphibolite and gneiss can be found in granite at end of path
- *Effect of granite on host rocks* with contact metamorphism and development of garnet in the amphibolite
- *Graphite mineralisation*, especially nice next to the school with massive graphite and rusty weathering

Best route would be starting at the harbour and then taking the path to the east to the point. Unfortunately this goes past the garbage dump. At the point, there are great views over the fjord and to several glaciers -> good lunch spot. Then back to town to look at the graphite mineralisation and up to the viewpoint above Sermilik Fjord.

5.6.2 August 3

Visit to Sermiligaaq by boat with Karl and his wife. Sunny with high clouds. Not a lot of wind so bugs.

Station: 14vivh112
Coord: 65˚ 54.512 N
36˚ 22.976 W

Massive lens of dark meta-gabbro. Consists of two parts, one finer-grained amphi + plag and a coarser-grained one with abundant garnet. Contact between them is sharp (Figure 78). The garnet-bearing one has nice relict gabbroic texture. The meta-gabbro is enclosed in gneiss with well-developed foliation that folds around the meta-gabbro. Cut by m wide pegmatite and abundant quartz veins.

At station a good overview over the fjord and glacial landscape.

Figure 78. *Dark meta-gabbro of two types: a finer-grained amphibole-plagioclase variety in sharp contact with a coarser part with abundant garnets.*

Station: 14vivh113
Coord: 65˚ 54.589 N
36˚ 22.592 W

Outcrops along path up the mountain behind the cemetery. Path is mainly felsic gneisses but at station a boudinaged layer of garnet-amphibolite (Figure 79). Looks similar to that seen at station 14vivh112, but no gabbroic texture here. Contains black amphi, garnet and green clear mineral -> cpx? The green clear mineral is especially abundant around and close to quartz veins in the amphibolite. Cut by ~1 m wide pegmatite, which is coarse-grained and white in colour.

Approx. 20 m to the left of path at station there is a nice reaction zone between amphibolite and pegmatite with lots of biotite forming. Biotite appears to be at the expense of garnet in the amphibolite (Figure 79). Biotite as nests up to 1 cm in diameter.

• Sample: **567015** - sample of amphibolite for PT

Figure 79. *Garnet amphibolite.*

Station: 14vivh114
Coord: 65˚ 54.637 N
36˚ 22.643 W

Outcrops on top of the mountains just above the town. Gneisses, well-foliated, white in colour with boudins of plag-amphi fine-grained amphibolite (Figure 80). Cut by pegmatite dykes, some of which are in foliation although still crosscutting, but at very shallow angle. Some of the pegmatites are also boudinaged.

Lots of different lithologies in the gneiss from felsic to leucogabbro to coarse-grained black amphibolite to fine-grained amphibolite to pegmatite.

- Sample: **567016** - gneiss for geochron
- Foliation: 312/70 to N (ddd)

Figure 80. *Outcrop of well-foliated gneiss with boudins of fine-grained amphibolite.*

Station: 14vivh115
Coord: 65˚ 54.706 N
36˚ 22.567 W

Outcrops down the valley to the north of previous station. Large fine-grained amphibolite, no garnet, cut by pegmatite and quartz veins. Rusty staining on quartz vein and small sulphides inside (Figure 81). Contains rafts of amphibolite with all amphibole replaced by biotite. Pegmatite is almost flat lying and fingering around fragments of amphibolite.

• Sample: **567017** - vein with sulphide

Station: 14vivh116
Coord: 65˚ 54.858 N
36˚ 22.583 W

Float (2 x 3 m) of beautiful pink pegmatite with K-spar crystals up to 1.5 m in length containing graphic intergrowth with quartz (Figure 82). Also contains quartz, white plag and minor biotite. Not in outcrop at station, but can see the outcrop a little further up the hill to the east of station. Very good cleavage in the crystals and easy to tell plagioclase and quartz apart, as well as K-spar and plagioclase. Ideal location for mineral ID. The pegmatite is markedly different from the other pegmatites seen today.

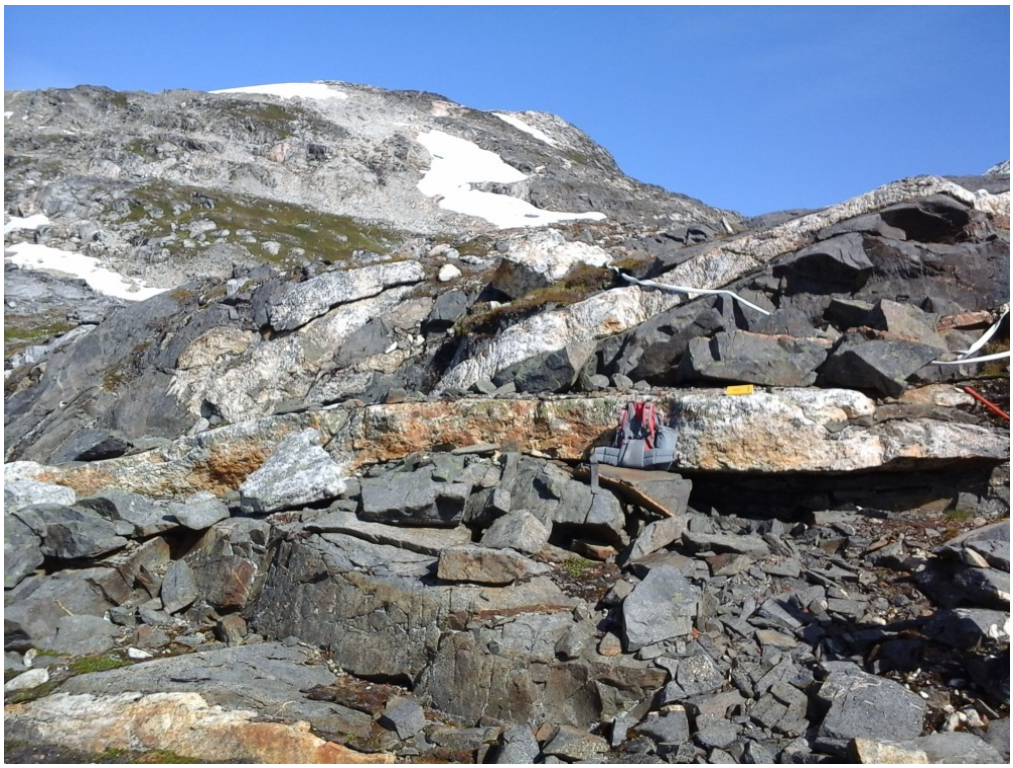

Figure 81. *Flat-lying pegmatite with rusty weathering and sulphides inside. Sample collected.*

Boulder field in between stations 14vivh115 and 14vivh116 has abundant float of gneiss with amphibolite boudins and folding: very nice textures!

• Sample:**567018** - pegmatite for geochronology

According to the geological map there should be meta-sediments in this area, but none were found and not even any unit that might be interpreted as a meta-sediment with the possible exception of the rusty brown alteration zone: meta-sediments should be removed from the map.

Station: 14vivh117
Coord: 65˚ 54.979 N
36˚ 22.543 W

Outcrop just before second valley to the north of station 14vivh116. Consists of foliated diorite (Figure 83) with plag, amphi, bt and qtz. Very homogeneous rock. Fits nicely in a story of melt compositions from mafic to felsic.

• Sample: **567019** - diorite for geochemistry

Figure 82. *Rock boulder with very coarse grains of orange-pink feldspar, white plagioclase and grey quartz.*

Figure 83. *Foliated diorite.*

Station: 14vivh118
Coord: 65˚ 54.817 N
36˚ 22.534 W

Outcrops of amphibolite back towards village but before crossing the first stream. Black amphibolite with folded and foliated lenses of light minerals (Figure 84) -> starting to develop gneissic banding. Plag, amphi, bt and qtz. In contact with coarse-grained deformed diorite.

• Sample: **567020** - amphibolite for geochemistry

Figure 84. *Outcrop of folded and foliated amphibolite.*

Station: 14vivh119
Coord: 65˚ 53.577 N
36˚ 45.159 W

Dyke on the side of the fjord, 25-30 m wide. Coarse-grained (2 mm sized grains) dolerite dyke with brown weathering. Next to old overgrown ruin.

• Sample: **567021** - dyke sample
• Dyke orientation: 114/80 (ddd) measured on actual contact
146/86 (ddd) measured on actual contact

5.6.2.1 Overview August 3

Geology is a bit more challenging than Tiniteqilaaq in terms of a clear story. Probably the best here is to centre it on magmatic series from mafic to felsic and the processes that allow you to change magmatic compositions. Textures in the rocks are beautiful and there is a good spread of compositions including intermediate ones. The pegmatite with megacrysts of K-spar is also very nice and a great spot for mineral ID, as the minerals have perfect cleavage and other characteristics.

5.6.3 August 4

Visit to ridge north of Kuummiut seen on flight back from camp 5, which has pegmatite dykes cutting mafic/ultramafic material: check for metasomatic interaction. In the afternoon, explored Kuummiut to prepare a geological guide. Overcast in morning, but sunny later in the day.

Station: 14vivh120
Coord: 65˚ 56.698 N
36˚ 59.725 W

Outcrops on ridge in between two glaciers. Very nice sequence, ~200 m in length perpendicular to strike, of amphibolites, gneisses, calc-silicates and rusty weathered schists. All are intruded by aplites and pegmatites with retrogression in enclosing rocks to these. Locally reactions between pegmatite and amphibolite + calc-silicates, former to biotite + green amphibole, latter to massive, randomly oriented green amphibole grains -> right setting for rubies, but none found.

Gneisses contain folded quartz veins, whereas amphibolites have almost no fabric to them. Also raft of gneiss in the amphibolite: mafic melt intruded the felsic gneiss.

There is a variety of rusty brown weathering zones, which reside in different lithologies. Locally minor sulphides in these, but mostly graphite. Some of the graphite occurs together with ~4 cm sized idiomorphic green amphibole crystals with interstitial creamy white mineral: carbonate?

Pegmatites are mostly 5 to 40 cm in width with plag, K-spar, qtz and some with lots of musc. Also aplites and thick sheets that look like granite in the face of the mountain (unable to access these). Most pegmatites contain biotite instead of muscovite.

Calc-silicates vary from massive beige rock with green amphibole veinlets, to pure green amphibolite to float of sugary marble. The float is rounded, so may not be local: interpret cautiously.

Wide variety of amphibolites on the ridge from black amphi-dominated to leucogabbro, to green amphibolite with garnet, to dark garnet-amphibolite. The dark amphibolite has plag-rims on garnet and locally all garnet has been replaced. It also contains laths of plag + qtz pseudomorphing something. There is also a black amphibolite with large, up to ~8 cm long,

irregular brown laths of amphibole? on foliation planes. Brown grains look porphyroblastic. The diversity in amphibolites on such a short section is surprising and markedly different from the general amphibolite occurrences in the area. Suggests a large variety of protoliths on a small scale: Volcanic area with diversity of lithologies as flows/scoria; Repeated intrusion of melts with very different composition, or; Reactions among the units with local modification of compositions by metasomatism? Given that the units look homogeneous within each unit, the third option is unlikely. The presence of calc-silicates suggests some primary protolith variability, but the crosscutting relationship between gneiss and amphibolite also shows that at least some of the amphibolites are later intrusive melts. Makes for a nice detailed geochem + PT project.

About halfway along transect towards the west, there is a retrogressed rock at pegmatite contact with garnet, musc, chl? and qtz. Next to it a layer of very dense layered rock with quartzitic appearance. Density seems wrong for pure quartz, but grain size is too fine to determine mineralogy. Could contain a lot of garnet. Should check what this material is. The layers within it are not continuous and are cut off, giving the rock an almost sedimentary appearance. Could be a meta-sediment unit within the package.

At eastern end of transect and just east of station, there is a granite sheet in the rock face with a pegmatitic layer at its lower contact, which is in contact with a calc-silicate unit. The calc-silicate is massive brown and has a well-developed metasomatic reaction zone to the pegmatite of biotite at contact and green amphibole further inside. The biotite zone also contains a hexagonal beige mineral -> check what this is.

• Samples:
- **567022** - gneiss for geochron + geochem, sampled where amphibolite can be seen intruding it
- **567023** - amphibolite with large brown laths on foliation plane
- **567024** - biotite and green amphibole parts of the reaction zone between pegmatite and calc-silicate at eastern end of transect
- **567025** - brown calc-silicate at contact with pegmatite at E end of transect
- **567026** - graphite bearing schist
- **567027** - biotite-bearing pegmatite for geochron
- **567028** - marble float
- **567029** - graphite bearing schist
- **567030** - garnet - green amphi amphibolite
- **567031** - graphite bearing schist
- **567032** - layered quartzite-like material
- **567033** - amphibolite with plagioclase rims on garnet and pseudomorphic laths of plagioclase + quartz -> figure out what is being replaced
- **567034** - garnet-bearing schist adjacent to quartzite-like material
- **567035** - large sample of layered quartzite-like material

Station: 14vivh121
Coord: 65˚ 51.989 N
37˚ 01.102 W

Outcrops along road cut to the fish factory in Kuummiut. Beautiful gt-sill schist with pink garnets up to 3 cm in diameter (Figure 85) and biotite-defined foliation planes full of sillimanite needles. Sill occurs as nice elongate grains, not fibrolite, so likely from the breakdown of muscovite at second sillimanite-isograd. Great sample for PT.

Within this also parts with large plagioclase grains, but without the garnet and sillimanite. This material looks like a meta-granite or meta-rhyolite with relict, deformed plagioclase phenocrysts. This would suggest a sequence of meta-seds consisting of aluminous, likely sedimentary protoliths, and felsic volcanic material. Or, pre-metamorphic alteration of the felsic intrusive, locally enriching aluminium such that garnet and sillimanite form.

- Sample: **567036** - garnet-sillimanite sample for PT
- Foliation along outcrop (some folding) from W to E along road cut:
  355/65 to N (ddd)
  004/60 to N (ddd)
  025/70 to N (ddd)
  355/80 to N (ddd)

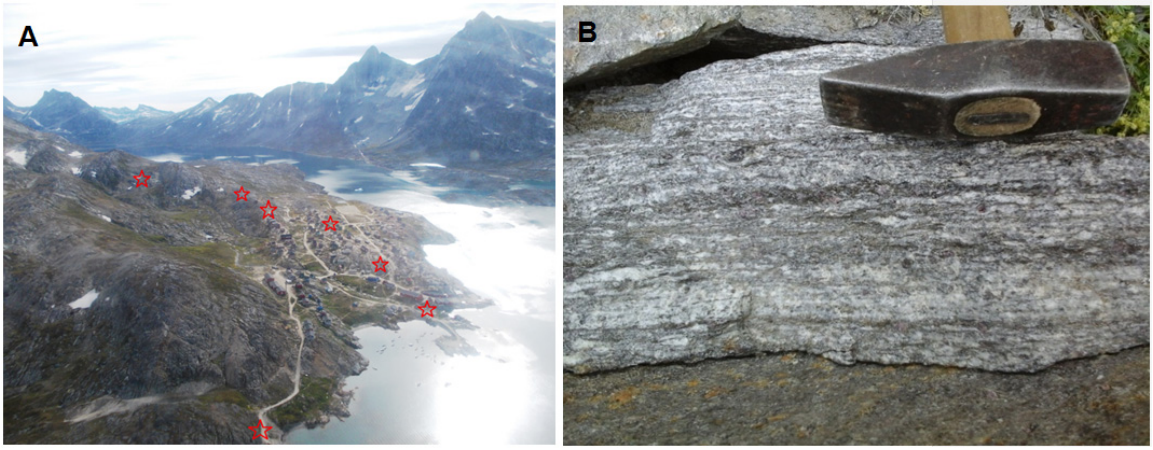

Figure 85. *A) Kuummiut aerial photo. The red stars mark some of the interesting geological features found in Kuummiut. The red star in the bottom of the photo is the gt-sill schist locality shown in Fig. 85B. B) Garnet-sillimanite schist with pink garnets.*

Station: 14vivh122
Coord: 65˚ 51.863 N
37˚ 00.673 W

Outcrops along stream on other side of the harbour in Kuummiut. Same aluminous schists as at previous station with large pink garnets. Within this sequence a sericite-bearing layer with rusty weathering.

- Foliation: 008/65 to N (ddd)

Station: 14vivh123
Coord: 65˚ 51.855 N
36˚ 59.935 W

Outcrops next to soccer field of well-foliated grey gneiss with boudinaged amphibolite of leucogabbroic composition within it (Figure 86). In pressure shadows of pegmatite that crosscuts these units, an earlier foliation is preserved in the leucogabbro.

Figure 86. *Well-foliated grey gneiss with boudinaged amphibolite of leucogabbroic composition.*

Station: 14vivh124
Coord: 65˚ 51.977 N
36˚ 59.745 W

Outcrop on ridge to the west of heliport. Nice shear zone with foliation folding into the shear band (Figure 87). Crosscutting pegmatite is caught up in the shearing and partly boudinaged. The shear zone is anastomosing around lenses of foliated and folded gneiss. Beautiful textures in the rocks here. The pegmatite must predate the shear zone. It is also metamorphosed and contains large grains of blue kyanite.

Figure 87. *Shear zone with foliation folding into the shear band. Crosscutting pegmatite is caught up in the shearing and partly boudinaged.*

Station: 14vivh125
Coord: 65˚ 52.139 N
36˚ 59.533 W

Outcrops at waterfall above Kuummiut. Large lens (~50 m long) of green meta-gabbro with nice plagioclase crystals and gabbroic texture (Figure 88). Locally it develops a blackwall metasomatic reaction zone against its host gneisses and later pegmatites with development of 5 cm long green amphibole crystals. Where it is intruded by pegmatite, it develops a net-veined pegmatite dyke network enclosing fragments of amphibolite. Beautiful texture.

Station: 14vivh126
Coord: 65˚ 53.298 N
36˚ 58.039 W

Rusty zone about 10 m wide, graphite-bearing schist.

• Sample: **569201**

Figure 88. *Green meta-gabbro with nice plagioclase crystals and gabbroic texture.*

Station: 14vivh127
Coord: 65˚ 53.146 N
36˚ 58.242 W

Calc-silicate layer next to rusty zone approx. 0.5 m wide (Figure 89). The layer is following same foliation as the graphite-bearing schist. Looks like marble that has been altered into calc-silicate, and has many different mineral phases.

Layers are next to each other: sericite schist - graphite bearing schist - calc-silicate layer – gneiss.

• Sample: **569202**

Station: 14vivh128
Coord: 65˚ 53.131 N
36˚ 58.286 W

Sericite layer approx. 1.5 m wide next to graphite bearing schist

Figure 89. *Marble approximately 0.5 m wide. Next to a rusty-weathered sericite schist.*

Station: 14vivh129
Coord: 65˚ 53.137 N
36˚ 58.657 W

Garnet-bearing amphibolite retrogressed. The garnets are partly replaced by plagioclase. The zone is about 20 m wide.

• Sample: **569203** - sample for P-T

Station: 14vivh130
Coord: 65˚ 52.916 N
36˚ 59.253 W

Mafic intrusive rock - ultramafic or a gabbro.

• Sample: **569204**

5.6.3.1 Overview August 4

Kuummiut has beautiful rocks exposed in the village and surrounding hills, especially with regards to metamorphic and deformation textures, and metamorphic minerals. There are beautiful garnet-sillimanite schists, where minerals are easy to recognize and for which a reasonable PT constraint can be determined from mineralogy alone; shear zone showing how movement of rocks is recorded with foliation bending into shear zone and boudinaging; interactions between pegmatites and gneiss + mafic lenses. The main focus on this area could be centred on metamorphism and its various impacts on rocks: Mineralogy; Fabric; and Element exchange (metasomatism).

5.6.4 August 5

Geological reconnaissance of Kulusuk by MADP. VIVH travelled to Kulusuk and further on to Iceland.

Station: 14vivh131
Coord: 65˚ 54.582 N
37˚ 11.194 W

View point for Kulusuk above the harbour. The rocks exposed here are a coarse-grained rock with plagioclase + pyroxene + quartz? Could be a pyroxene-bearing diorite? The rock type resembles charnockite. Some coarse-grained pegmatites cut the dioritic rock. The peaks surrounding the town are more resistant to weathering. The geological history of the area with continental collision and mountain building would be obvious to tell here (in the guide).

• Sample: **569205**

Station: 14vivh132
Coord: 65˚ 34.426 N
37˚ 11.150 W

Behind the local school. There are several types of granites here some with lighter colour and other have darker colour, as well as pegmatites cross-cutting the granites.

Station: 14vivh133
Coord: 65˚ 34.234 N
37˚ 11.011 W

The locality is a steep valley about 5 m wide (Figure 90) could be a fault and has a mafic dyke, which is partly eroded away on the surface. The dyke (and valley) can be traced for several hundred meters. The basaltic dyke is fine-grained, and has a chilled margin against the granite.

• Samples: **569206** - light coloured granite
569207 - basaltic dyke

Figure 90. *Steep valley about 5 m wide formed by preferential weathering. Along the valley floor a mafic dyke was found, which can be traced for about 500 m from the valley.*

Station: 14vivh134
Coord: 65˚ 34.202 N
37˚ 11.114 W

Viewpoint over Kulusuk and harbour, where the different rock types are visible from a distance with varying colours.

Station: 14vivh135
Coord: 65˚ 34.472 N
37˚ 10.941 W

Good locality for studying pegmatites with many different directions. The rock type the pegmatites intrude is a brownish coloured gabbro.

• Sample: **569208**

Station: 14vivh136
Coord: 65˚ 34.441 N
37˚ 10.960 W

The dyke is found again here, same dyke as at locality 14vivh133. Can be traced for more than 300 m. The dyke is next to a gabbro.

Station: 14vivh137
Coord: 65˚ 34.484 N
37˚ 10.571W

Very coarse grained pyroxene bearing diorite resembles a charnockite.

Station: 14vivh138
Coord: 65˚ 34.870 N
37˚ 08.536 W

The rock is possible a diorite. The minerals are quartz, amphibole/pyroxene, plagioclase and biotite.

5.6.4.1 Overview August 5

In Kulusuk (not the airport area) most of the rocks are pyroxene-bearing granites (resembling charnockites) with some minor felsic granitic parts in small areas. The appearances of the rocks in Kulusuk are brownish weathering surfaces of the granites possible due to high content of pyroxene in these granites.

In the center of Kulusuk, a dyke of about 3 m wide was found. The dyke can be traced several hundred meters across the settlement.

There are several different types of granites behind the school, and some late stage pegmatites are cross-cutting the granites. The area shows evidence for very high pressures and temperatures during continental collision. The main focus on this area and local geology could be continental collision and mountain building.

5.6.5 August 6

Geological reconnaissance of Tasillaq by MADP.

Station: 14vivh139
Coord: 65˚ 36.883 N
37˚ 38.008 W

Viewpoint over the church in Tasiilaq. Here, the mountain peaks surrounding Tasiilaq can be seen. The mountains have a brownish red appearance but some places have a more reddish colour, possible due to a change in rock type. The typical rocks in the area are diorites, granites and garnet-bearing schists. The rock type in Tasiilaq is fairly similar type, a green to brownish pyroxene-bearing diorite.

There are pegmatites cross cutting the pyroxene-bearing diorites in the area.

Station: 14vivh140
Coord: 65˚ 36.868 N
37˚ 38.040 W

A stone wall can be observed outside the church, a good locality for studying the local rock types in the area. Are all the stones the same rock type? Are some of the rocks different? There seem to be the pyroxene-bearing rock (diorite?), sandstone, basalt, and gneiss. The grain sizes and different mineral content can be discussed here.

Station: 14vivh141
Coord: 65˚ 36.833 N
37˚ 38.095 W

An outcrop of two different rock types can be seen next to the road. The pyroxene-bearing diorite? is crosscut by a alkali-feldspar rich granite.

Station: 14vivh142
Coord: 65˚ 36.690 N
37˚ 39.075 W

The hill above the cemetery in the Blomsterdal. The landscape has clearly been affected by glaciers, eroding the pyroxene-bearing rocks in the town area.

Station: 14vivh143
Coord: 65˚ 36.735 N
37˚ 39.113 W

Finer grained diorite surrounded by coarse-grained granite. The granite is younger than the diorite.

• Sample: **569209**

Station: 14vivh144
Coord: 65˚ 36.808 N
37˚ 39.088 W

Pegmatite with lots of alkali-feldspar, quartz and biotite, crosscuts a pyroxenite.

Station: 14vivh145
Coord: 65˚ 36.806 N
37˚ 38.957 W

View point over Tasiilaq from above the Blomsterdal. Here an alkali-feldspar rich granite is found intermingling with the pyroxene-bearing diorite.

• Sample: **569210**

5.6.5.1 Overview August 6

The hard rock geology in Tasiilaq is very similar to Kulusuk. The rocks are mainly pyroxene-bearing granites with minor amounts of felsic granites. The town is very dusty, which seems to be due to extensive weathering of the rocks. The soils from the pyroxe-bearing granites seem to be good fertilizers for plants in the area.

The church in Tasiilaq has a wall decorated with rocks from the area, which is a good place to look at different rock types in the area. From Blomsterdalen close to the cemetery in Tasiilaq a steep U-shaped valley is seen. Glaciers affect the landscape around Tasiilaq, with the areas with high amounts of coarse-grained pyroxene-bearing granitic rocks are eroded more easily than dioritic rocks which are seen as peaks in the area surrounding the town. The main focus for the area and local geology will be mountain building and glaciation.

Appendix A. List of stations (from aFieldwork)

Station ID	Description	Lat. (N)	Long. (W)	Elev. (m)	Date
14vivh001	Loose boulder of ultramafic with met-asomatic veinlets	65.71746	39.11027	470	17-7-2014
14vivh002	Outcrop next to lake	65.72613	39.14883	448	17-7-2014
14vivh003	Large flat outcrop glacially polished	65.72752	39.15621	496	17-7-2014
14vivh004	Glacially polished flat outcrops	65.72014	39.12181	428	18-7-2014
14vivh005	Orange red weathered gneiss with yellow staining	65.72056	39.13871	437	18-7-2014
14vivh006	Large outcrop on slope towards fjord	65.70041	39.14633	442	18-7-2014
14vivh007	Large polished outcrop of homoge-nous silicic intrusive	65.70225	39.14470	459	18-7-2014
14vivh008	Glacially polished flat outcrop	65.70411	39.14456	468	18-7-2014
14vivh009	Outcrop at contact with granite	65.70715	39.14186	471	18-7-2014
14vivh010	Outcrop of light green rock in foliated basement	65.71225	39.14328	510	18-7-2014
14vivh011	Outcrop of ttg in dry riverbed, 50 x 50 m	65.71587	39.14340	459	18-7-2014
14vivh012	Outcrop on side of dry river valley	65.71705	39.14301	435	18-7-2014
14vivh013	Large flat outcrops next to lake	65.72013	39.13630	413	18-7-2014
14vivh014	Outcrop on small island	65.62101	38.48551	62	19-7-2014
14vivh015	Outcrop of UM lenses on island	65.61996	38.47991	64	19-7-2014
14vivh016	Lenses of coarse-grained amp plag in ttg gneiss	65.75768	39.21618	602	19-7-2014
14vivh017	20 m wide black meta gabbro in ttg gneisses	65.75924	39.21923	592	19-7-2014
14vivh018	Small stream next to camp	65.72073	39.12160	431	20-7-2014
14vivh019	Lens of UM 10 by 8 meters	65.72052	39.12108	429	20-7-2014
14vivh020	Outcrops next to lake and camp	65.61572	38.47384	142	21-7-2014
14vivh021	Outcrop on slope towards fjord	65.61636	38.47081	118	21-7-2014
14vivh022	Outcrops in narrow valley	65.61689	38.46852	98	21-7-2014
14vivh023	Outcrop further down towards fjord	65.61799	38.46698	80	21-7-2014
14vivh024	Outcrop on slope towards fjord	65.61883	38.46813	109	21-7-2014
14vivh025	Highest point on island	65.61967	38.46955	168	21-7-2014
14vivh026	Eastern end of island	65.62130	38.46905	117	21-7-2014
14vivh027	Narrow valley at eastern end of island	65.62112	38.46581	82	21-7-2014
14vivh028	Ridge outcrops of UM	65.61825	38.47233	145	21-7-2014
14vivh029	UM with ruby bearing veinlets	65.62101	38.48551	62	22-7-2014
14vivh030	Second band of UM	65.62083	38.48437	60	22-7-2014
14vivh031	Second band of UM on small island	65.61728	38.46383	59	22-7-2014
14vivh032	Crosscutting dyke	65.61638	38.46203	50	22-7-2014
14vivh033	Wide dyke on mainland	65.63368	38.50723	63	22-7-2014
14vivh034	River outcrop. Boundary between am-phibole gneisses and meta sedi-ments. No discordant contact.	65.59284	38.55557	53	22-7-2014
14vivh035	Outcrop of lowermost UM in western band	65.61952	38.48146	60	23-7-2014
14vivh036	Outcrop on hillside	65.61886	38.47899	60	23-7-2014
14vivh037	UM on top of mountain	65.61800	38.47087	82	23-7-2014
14vivh038	UM in eastern band	65.61988	38.47948	61	23-7-2014
14vivh039	Outcrop close to ice in western limb of diorite	66.12831	38.11032	738	24-7-2014
14vivh040	Outcrop on other side of lake	66.12687	38.10122	705	24-7-2014
14vivh041	Outcrops on hill crest further into dio-rite	66.12043	38.09699	657	24-7-2014
14vivh042	Plug of UM high above everything around it	66.02441	38.27352	856	24-7-2014

Station ID	Description	Lat. (N)	Long. (W)	Elev. (m)	Date
14vivh043	Outcrops of well-foliated gneiss on hill	65.76952	37.77505	420	25-7-2014
14vivh044	Well foliated gneiss E of previous station	65.76873	37.76358	435	25-7-2014
14vivh045	Gneiss outcrops further to the east	65.76831	37.75984	431	25-7-2014
14vivh046	Outcrop next to small river	65.77037	37.75474	426	25-7-2014
14vivh047	Outcrop on hill	65.77623	37.75320	474	25-7-2014
14vivh048	Flat polished outcrop of garnet bearing felsic gneiss with pseudotachelyte	65.77802	37.75167	443	25-7-2014
14vivh049	Outcrops along small stream	65.77902	37.74947	460	25-7-2014
14vivh050	Flat outcrop on saddle	65.77988	37.74614	482	25-7-2014
14vivh051	Outcrops at lake just below camp	65.77264	37.77176	395	26-7-2014
14vivh052	Outcrop to the n of camp	65.77378	37.77183	387	26-7-2014
14vivh053	Outcrops on lake to the N of camp	65.77398	37.76972	401	26-7-2014
14vivh054	Outcrops S of camp next to river	65.77193	37.77304	404	26-7-2014
14vivh055	River south of camp that drains the lake	65.77133	37.77384	404	26-7-2014
14vivh056	Outcrops in and up river valley NW of camp	65.77631	37.77739	496	26-7-2014
14vivh057	Outcrops of well-foliated gneiss on hill	65.77683	37.79032	648	26-7-2014
14vivh058	Stream n of camp flowing into lake	65.77485	37.77110	405	26-7-2014
14vivh059	Vein network just N of camp	65.77320	37.77276	407	26-7-2014
14vivh060	Top of valley on nunatak	66.69868	37.63577	1.286	27-7-2014
14vivh061	Gneisses on flank of valley on nunatak	66.69716	37.63500	1.273	27-7-2014
14vivh062	Slope towards glacier on eastern side of nunatak	66.69455	37.63336	1.234	27-7-2014
14vivh063	Outcrop further down to ice	66.69371	37.63274	1.214	27-7-2014
14vivh064	Moraine from small glacier that came down from AN on bigger glacier	66.67062	36.89991	1.190	27-7-2014
14vivh065	Locality on top of nunatak	66.71367	37.35222	2.026	27-7-2014
14vivh066	Eastern end of nunatak	66.71844	37.24664	2.084	27-7-2014
14vivh067	Outcrops west of camp	66.34962	37.08878	338	28-7-2014
14vivh068	Outcrops further to the west towards next valley	66.34795	37.09818	455	28-7-2014
14vivh069	Further to west	66.34782	37.10045	437	28-7-2014
14vivh070	Hill between two valleys	66.34780	37.10239	446	28-7-2014
14vivh071	Outcrop down towards western valley	66.34843	37.10347	447	28-7-2014
14vivh072	Western valley just east of river	66.34918	37.10688	402	28-7-2014
14vivh073	Outcrops along river in western valley	66.34971	37.10810	427	28-7-2014
14vivh074	Rocks west of river in western valley	66.34998	37.10924	444	28-7-2014
14vivh075	Outcrops on slope west of river in western valley	66.34997	37.11128	452	28-7-2014
14vivh076	Further up the valley to the west	66.34975	37.11295	452	28-7-2014
14vivh077	Saddle in the western valley, west of last station	66.34962	37.11419	462	28-7-2014
14vivh078	West of western valley	66.34642	37.12661	428	28-7-2014
14vivh079	Outcrops just before cliff in west	66.34602	37.14092	473	28-7-2014
14vivh080	Outcrops east of valley of camp	66.35100	37.08084	289	29-7-2014
14vivh081	Outcrops along stream, north of camp	66.35143	37.08556	254	29-7-2014
14vivh082	Float on boulder field north of camp	66.35440	37.08455	364	29-7-2014
14vivh083	Outcrop above scree slope north of camp	66.35624	37.08898	520	29-7-2014
14vivh084	Outcrops just poking through vegetation	66.35689	37.07734	474	29-7-2014
14vivh085	Outcrop on top of hill east of camp	66.35847	37.07259	541	29-7-2014
14vivh086	Outcrops to NW of previous station	66.35989	37.07446	544	29-7-2014
14vivh087	Outcrops on hill W of Sermilik Fjord	65.98086	38.10902	530	30-7-2014
14vivh088	Outcrop on side of lake	65.99787	38.06854	72	30-7-2014
14vivh089	Outcrop next to small lake	65.97213	37.99510	425	30-7-2014

Station ID	Description	Lat. (N)	Long. (W)	Elev. (m)	Date
14vivh090	Outcrops a little further up the hill	65.97301	37.99806	461	30-7-2014
14vivh091	Outcrops on southern side of river	66.16252	37.47505	0	31-7-2014
14vivh092	Outcrops on slope south of river	66.16281	37.49173	136	31-7-2014
14vivh093	Outcrops south of river on m7ddle layer	66.16459	37.50013	96	31-7-2014
14vivh094	End of transect over middle metased layer. In flat outcrops just poking through vegetation	66.16362	37.50031	99	31-7-2014
14vivh095	Outcrops on southernmost metased layer	66.16015	37.52072	117	31-7-2014
14vivh096	Outcrops on ridge behind camp to NE	66.16591	37.48144	107	1-8-2014
14vivh097	Low ridge just north of camp	66.16537	37.49023	90	1-8-2014
14vivh098	Outcrops on coast of Sermilik Fjord	66.16829	37.50279	61	1-8-2014
14vivh099	Ridge just behind camp	66.16498	37.49570	77	1-8-2014
14vivh100	Viewpoint above town in gneisses	65.89255	37.77934	107	2-8-2014
14vivh101	Outcrops in small rock quarry	65.89170	37.77573	96	2-8-2014
14vivh102	Outcrops next to fjord behind waste dump	65.88929	37.76873	61	2-8-2014
14vivh103	Outcrops a little further to the east	65.88849	37.76662	51	2-8-2014
14vivh104	Outcrops in cliff on coast further east along coastal path	65.88829	37.76646	50	2-8-2014
14vivh105	Granite outcrops on point at end of path	65.88736	37.76315	56	2-8-2014
14vivh106	Outcrops further along the fjord of ra-zor-sharp contact between granite and metagabbro	65.88767	37.76120	51	2-8-2014
14vivh107	Outcrop in village just below house	65.88978	37.77781	72	2-8-2014
14vivh108	Outcrops of 2m wide pegmatite with gneiss raft in town	65.88947	37.77948	72	2-8-2014
14vivh109	Outcrops next to the school of rusty weathered material	65.88967	37.78077	57	2-8-2014
14vivh110	Pegmatite with large biotite on way down to harbour just before store	65.88852	37.77879	68	2-8-2014
14vivh111	Outcrops at end of fjord of granite in contact with gabbro	65.75652	37.19374	60	2-8-2014
14vivh112	Outcrops next to fuel depot	65.90848	36.38291	63	3-8-2014
14vivh113	Outcrops along path up the mountain behind cemetery	65.90983	36.37653	124	3-8-2014
14vivh114	Outcrops on top of hill above village	65.91059	36.37746	159	3-8-2014
14vivh115	Outcrops of amphibolite down to-wards valley	65.91177	36.37609	138	3-8-2014
14vivh116	Float of pink very coarse-grained peg-matite on other side of valley	65.91425	36.37640	161	3-8-2014
14vivh117	Outcrop on southern side of next val-ley	65.91605	36.37617	184	3-8-2014
14vivh118	Outcrop back to south	65.91355	36.37553	143	3-8-2014
14vivh119	Dolerite dyke outcrop on side of fjord	65.89323	36.75253	99	3-8-2014
14vivh120	Outcrop on ridge in between glacier	65.94496	36.99541	878	4-8-2014
14vivh121	Outcrops along road cut in Kuummiut	65.86636	37.01849	65	4-8-2014
14vivh122	Outcrops in stream valley on other side of harbour	65.86439	37.01122	54	4-8-2014
14vivh123	Outcrops next to soccer field towards heliport	65.86426	36.99881	73	4-8-2014
14vivh124	Outcrops west of heliport on ridge	65.86628	36.99587	127	4-8-2014
14vivh125	Outcrops just N of waterfall in river above Kuummiut	65.86896	36.99238	159	4-8-2014

Appendix B. Sample details (from aFieldwork)

GEUS no.	Lat. (N)	Long. (W)	Locality ID	Earth material	Rock Name
562701	65.71746	39.11027	2014vivh001	hydrothermal-vein	
562702	65.72613	39.14883	2014vivh002		
562703	65.72752	39.15621	2014vivh003		
562704	65.72056	39.13871	2014vivh005	metamorphic-gneiss (schist>1 cm)	
562705	65.70041	39.14633	2014vivh006	metamorphic-gneiss (schist>1 cm)	
562706	65.70225	39.14470	2014vivh007	plutonic-subalkaline	Hyp alkali feld-spar granite
562707	65.70411	39.14456	2014vivh008	plutonic-subalkaline	diorite <Qtz;<10 Kfs; An <50
562708	65.70715	39.14186	2014vivh009	metamorphic-gneiss (schist>1 cm)	
562709	65.71225	39.14328	2014vivh010	metamorphic-granofels (no schistosity)	
562710	65.71587	39.14340	2014vivh011	metamorphic	
562711	65.71705	39.14301	2014vivh012		
562712	65.71705	39.14301	2014vivh012		
562713	65.72013	39.13630	2014vivh013	plutonic-subalkaline	diorite <Qtz;<10 Kfs; An <50
562715	65.75924	39.21923	2014vivh017	metamorphic	
562714	65.75768	39.21618	2014vivh016		
553300	65.72073	39.12160	2014vivh018		
562717	65.72052	39.12108	2014vivh019		
562718	65.72052	39.12108	2014vivh019	metamorphic-gneiss (schist>1 cm)	
562719	65.72052	39.12108	2014vivh019	hydrothermal-vein	
562720	65.72052	39.12108	2014vivh019	hydrothermal-vein	
562721	65.61572	38.47384	2014vivh020	metamorphic-gneiss (schist>1 cm)	
562722	65.61636	38.47081	2014vivh021	metamorphic-gneiss (schist>1 cm)	
562723	65.61636	38.47081	2014vivh021	metamorphic-specific	amphibolite
562724	65.61799	38.46698	2014vivh023		
562725	65.62112	38.46581	2014vivh027	metamorphic-gneiss (schist>1 cm)	
562730	65.62101	38.48551	2014vivh029		
562731	65.62101	38.48551	2014vivh029		
562727	65.62101	38.48551	2014vivh029	hydrothermal-vein	
562728	65.62101	38.48551	2014vivh029	hydrothermal-vein	
562729	65.62101	38.48551	2014vivh029	hydrothermal-vein	
562732	65.62083	38.48437	2014vivh030		
562733	65.62083	38.48437	2014vivh030	metamorphic-gneiss (schist>1 cm)	
562734	65.61638	38.46203	2014vivh032	metamorphic	
562735	65.63368	38.50723	2014vivh033	metamorphic	
553299	65.59284	38.55557	2014vivh034		
562726	65.62083	38.48437	2014vivh030	hydrothermal-vein	
553298	65.62083	38.48437	2014vivh030		
562741	65.61952	38.48146	2014vivh035		
562736	65.61886	38.47899	2014vivh036	metamorphic	
562737	65.61800	38.47087	2014vivh037	hydrothermal-vein	
562738	65.61800	38.47087	2014vivh037	dyke-leucocratic dyke	pegmatite

GEUS no.	Lat. (N)	Long. (W)	Locality ID	Earth material	Rock Name
562739	65.61988	38.47948	2014vivh038	hydrothermal-vein	
562740	65.61952	38.48146	2014vivh035	metamorphic-gneiss (schist>1 cm)	
562742	66.12831	38.11032	2014vivh039	metamorphic	
562743	66.12687	38.10122	2014vivh040	metamorphic-gneiss (schist>1 cm)	
562744	66.12687	38.10122	2014vivh040	metamorphic	
562745	66.12043	38.09699	2014vivh041	metamorphic	
562746	66.02441	38.27352	2014vivh042		
562747	65.76952	37.77505	2014vivh043	metamorphic-gneiss (schist>1 cm)	
562748	65.76873	37.76358	2014vivh044	metamorphic-gneiss (schist>1 cm)	
562749	65.76873	37.76358	2014vivh044	metamorphic-gneiss (schist>1 cm)	
562750	65.76831	37.75983	2014vivh045	metamorphic-gneiss (schist>1 cm)	
562751	65.77802	37.75167	2014vivh048	fault rock-cohesive	
562753	65.77902	37.74947	2014vivh049	metamorphic-gneiss (schist>1 cm)	
562752	65.77988	37.74614	2014vivh050	fault rock-cohesive	
562756	65.77264	37.77176	2014vivh051		
562755	65.77264	37.77176	2014vivh051	metamorphic	
562754	65.77264	37.77176	2014vivh051	hydrothermal-vein	
562757	65.77378	37.77182	2014vivh052	metamorphic	
562758	65.77398	37.76971	2014vivh053	metamorphic-gneiss (schist>1 cm)	
562759	65.77378	37.77182	2014vivh052	dyke-leucocratic dyke	pegmatite
562760	65.77193	37.77304	2014vivh054	metamorphic-schist (schist< 1 cm)	
553297	65.77133	37.77384	2014vivh055		
562761	65.77631	37.77739	2014vivh056	metamorphic	
553296	65.77485	37.77109	2014vivh058		
562762	65.77320	37.77276	2014vivh059	hydrothermal-vein	quartz
562763	66.69868	37.63577	2014vivh060	metamorphic-schist (schist< 1 cm)	
562765	66.69455	37.63336	2014vivh062	metamorphic-gneiss (schist>1 cm)	
562764	66.69455	37.63336	2014vivh062		
562766	66.69371	37.63274	2014vivh063	metamorphic-gneiss (schist>1 cm)	
562771	66.71843	37.24664	2014vivh066	metamorphic-schist (schist< 1 cm)	
562767	66.67062	36.89991	2014vivh064	metamorphic	
562768	66.67062	36.89991	2014vivh064	metamorphic-gneiss (schist>1 cm)	
562769	66.67062	36.89991	2014vivh064	metamorphic-gneiss (schist>1 cm)	
562770	66.71367	37.35222	2014vivh065	metamorphic-gneiss (schist>1 cm)	
562772	66.34962	37.08878	2014vivh067	metamorphic-schist (schist< 1 cm)	
562773	66.34795	37.09818	2014vivh068	metamorphic-specific	amphibolite
562774	66.34780	37.10239	2014vivh070	metamorphic-schist (schist< 1 cm)	
562775	66.34843	37.10347	2014vivh071	metamorphic-schist (schist< 1 cm)	
562776	66.34918	37.10688	2014vivh072	metamorphic-specific	amphibolite

GEUS no.	Lat. (N)	Long. (W)	Locality ID	Earth material	Rock Name
562777	66.34971	37.10810	2014vivh073	metamorphic-schist (schist< 1 cm)	
562778	66.34997	37.10924	2014vivh074		
562779	66.34975	37.11295	2014vivh076	metamorphic-schist (schist< 1 cm)	
562781	66.35143	37.08556	2014vivh081	metamorphic-gneiss (schist>1 cm)	
562780	66.35143	37.08556	2014vivh081	metamorphic-schist (schist< 1 cm)	
562782	66.35440	37.08455	2014vivh082	metamorphic	
562783	66.35624	37.08898	2014vivh083	metamorphic	
562784	66.35624	37.08898	2014vivh083	metamorphic-schist (schist< 1 cm)	
562785	66.35847	37.07259	2014vivh085	metamorphic-specific	amphibolite
562786	66.35989	37.07446	2014vivh086	metamorphic-gneiss (schist>1 cm)	
562787	66.35989	37.07446	2014vivh086	metamorphic	
562788	65.98086	38.10902	2014vivh087	metamorphic	
562789	65.99787	38.06854	2014vivh088	metamorphic-specific	eclogite
562790	65.97213	37.99509	2014vivh089	metamorphic-schist (schist< 1 cm)	
562791	65.97213	37.99509	2014vivh089	metamorphic-schist (schist< 1 cm)	
562792	65.97301	37.99806	2014vivh090	metamorphic-schist (schist< 1 cm)	
562796	66.16459	37.50013	2014vivh093	metamorphic-specific	amphibolite
562794	66.16459	37.50013	2014vivh093	metamorphic	
562795	66.16459	37.50013	2014vivh093	metamorphic-specific	calc-silicate rock
562793	66.16459	37.50013	2014vivh093	metamorphic-schist (schist< 1 cm)	
562797	66.16459	37.50013	2014vivh093	hydrothermal-vein	
562798	66.16362	37.50031	2014vivh094	metamorphic-schist (schist< 1 cm)	
562799	66.16591	37.48144	2014vivh096	metamorphic-specific	calc-silicate rock
567002	66.16591	37.48144	2014vivh096	metamorphic-specific	calc-silicate rock
567001	66.16591	37.48144	2014vivh096	metamorphic	
567003	66.16536	37.49023	2014vivh097	metamorphic-schist (schist< 1 cm)	
567004	66.16536	37.49023	2014vivh097	metamorphic-schist (schist< 1 cm)	
567005	66.16827	37.50279	2014vivh098	metamorphic-gneiss (schist>1 cm)	
567006	66.16827	37.50279	2014vivh098	metamorphic	
567007	66.16498	37.49570	2014vivh099	metamorphic-specific	calc-silicate rock
567008	65.89255	37.77933	2014vivh100	metamorphic-gneiss (schist>1 cm)	
567009	65.89169	37.77573	2014vivh101	metamorphic-schist (schist< 1 cm)	
567010	65.88829	37.76646	2014vivh104	metamorphic-gneiss (schist>1 cm)	
567012	65.88767	37.76120	2014vivh106	plutonic-subalkaline	granite >20 Qtz; 65-90 Kfs
567011	65.88767	37.76120	2014vivh106	metamorphic	
567013	65.88947	37.77948	2014vivh108	metamorphic-schist (schist< 1 cm)	
567014	65.75652	37.19374	2014vivh111	plutonic-subalkaline	granite >20 Qtz; 65-90 Kfs
567015	65.90983	36.37653	2014vivh113	metamorphic-specific	amphibolite

GEUS no.	Lat. (N)	Long. (W)	Locality ID	Earth material	Rock Name
567016	65.91059	36.37746	2014vivh114	metamorphic-gneiss (schist>1 cm)	
567017	65.91177	36.37609	2014vivh115	hydrothermal-vein	quartz
567018	65.91425	36.37639	2014vivh116	dyke-leucocratic dyke	pegmatite
567019	65.91605	36.37617	2014vivh117	metamorphic	
567020	65.91355	36.37553	2014vivh118	metamorphic-specific	amphibolite
567021	65.89323	36.75253	2014vivh119	dyke-mafic dyke	dolerite
567027	65.94496	36.99541	2014vivh120	dyke-leucocratic dyke	pegmatite
567025	65.94496	36.99541	2014vivh120	metamorphic-specific	calc-silicate rock
567034	65.94496	36.99541	2014vivh120	metamorphic-schist (schist< 1 cm)	
567026	65.94496	36.99541	2014vivh120	metamorphic-schist (schist< 1 cm)	
567029	65.94496	36.99541	2014vivh120	metamorphic-schist (schist< 1 cm)	
567031	65.94496	36.99541	2014vivh120	metamorphic-schist (schist< 1 cm)	
567022	65.94496	36.99541	2014vivh120	metamorphic-gneiss (schist>1 cm)	
567033	65.94496	36.99541	2014vivh120	metamorphic-specific	amphibolite
567023	65.94496	36.99541	2014vivh120	metamorphic-specific	amphibolite
567024	65.94496	36.99541	2014vivh120	metamorphic-specific	calc-silicate rock
567028	65.94496	36.99541	2014vivh120	metamorphic	
567030	65.94496	36.99541	2014vivh120	metamorphic-schist (schist< 1 cm)	
567032	65.94496	36.99541	2014vivh120	metamorphic-gneiss (schist>1 cm)	
567035	65.94496	36.99541	2014vivh120	metamorphic-gneiss (schist>1 cm)	
567036	65.86636	37.01849	2014vivh121	metamorphic-schist (schist< 1 cm)	
569201	65.88837	36.96722	2014vivh126	metamorphic-schist (schist< 1 cm)	
569202	65.88577	36.97074	2014vivh127	metamorphic-schist (schist< 1 cm)	
569203	65.88537	36.97790	2014vivh129	metamorphic-schist (schist< 1 cm)	
569204	65.88225	36.98762	2014vivh130	Plutonic-mafic	
569205	65.57584	37.18642	2014vivh131	Plutonic-granite	
569206	65.57056	37.18350	2014vivh133	Plutonic-granite	
569207	65.57056	37.18350	2014vivh133	Dyke-mafic	
569208	65.57463	37.18240	2014vivh135	Plutonic-granite	
569209	65.36735	37.39113	2014vivh143	Plutonic-diorite	
569210	65.36806	37.38957	2014vivh145	Plutonic-granite	

Appendix C. Structure details (from aFieldwork)

All measurements are reported as Dip – Dip direction (DDD).

Station	Structure class & type		Azimuth	Dip	Notes
14vivh006	planar	foliation	340	48	Main foliation of ttg
14vivh020	planar	foliation	36	54	
14vivh024	planar	foliation	24	76	
14vivh032	planar	dyke, sill	90	90	Approx. orientation
14vivh033	planar	dyke, sill	128	90	
14vivh043	planar	foliation	1	82	Dip to N
14vivh050	planar	fault	162	90	General orientation because pseudotachelyte is braided
14vivh048	planar	fault	132	90	General orientation because pseudotachelyte is braided
14vivh050	planar	foliation	18	90	Dip varies to N and S around vertical
14vivh054	planar	foliation	174	74	
14vivh056	planar	foliation	344	86	
14vivh057	planar	foliation	180	80	Foliation varies around vertical
14vivh061	planar	foliation	318	65	Undulating foliation
14vivh067	planar	foliation	305	78	
14vivh068	planar	foliation	270	70	Foliation in garnet amphibolite. Very consistent
14vivh072	planar	foliation	290	76	
14vivh073	planar	shear zone	103	88	Foliation in core of shear zone
14vivh084	planar	foliation	99	86	
14vivh084	planar	foliation	312	80	Strike bends around at outcrop towards N
14vivh085	planar	foliation	93	70	
14vivh091	planar	foliation	192	85	
14vivh092	planar	foliation	170	57	Dips to S
14vivh093	planar	foliation	182	90	
14vivh094	planar	foliation	355	85	To N
14vivh095	planar	dyke, sill	90	72	
14vivh096	planar	foliation	15	70	To N
14vivh096	planar	foliation	94	16	Section through anticline and syncline from north to south. Sect1
14vivh096	planar	foliation	148	20	Sect2
14vivh096	planar	foliation	173	25	Sect3
14vivh096	planar	foliation	2	40	Sect4
14vivh096	planar	foliation	48	27	Sect5
14vivh096	planar	foliation	4	63	Sect6
14vivh096	planar	foliation	4	80	Sect7
14vivh097	planar	foliation	182	80	To S
14vivh098	planar	foliation	6	80	To S
14vivh114	planar	foliation	312	70	To N
14vivh119	planar	dyke, sill	114	80	Actual contact, varies along contact
14vivh119	planar	dyke, sill	146	86	Actual contact, varies along contact
14vivh121	planar	foliation	355	65	To N
14vivh121	planar	foliation	4	60	To N. Measured a little further to E
14vivh122	planar	foliation	8	65	

Appendix D. Photo details (from aFieldwork)

Station	Camera ID		Tablet photo ID	Description
14vivh001	123	124		Overview photo of boulder
14vivh001	125	127		Close up view with ruby at center of image
14vivh002			vivh-Loc-2-No-1.jpg	Overview picture with brown metasomatic zone
14vivh002			vivh-Loc-2-No-2.jpg	Larger overview showing magnetite in diorite
14vivh008			vivh-Loc-8-No-1.jpg	Overview picture looking south from station. Coarse-grained diorite in forefront, fine-grained darker diorite on other side of stream cut by granite
14vivh010			vivh-Loc-10-No-1.jpg	Overview
14vivh012			vivh-Loc-12-No-1.jpg	Overview of outcrop
14vivh013			vivh-Loc-13-No-1.jpg	Over view of 3 units
14vivh013			vivh-Loc-13-No-2.jpg	Rafts in granitoid
14vivh013			vivh-Loc-13-No-3.jpg	Two types of rafts in granitoid
14vivh014			vivh-Loc-14-No-1.jpg	Overview picture
14vivh015			vivh-Loc-15-No-1.jpg	Gt bearking UM
14vivh016			vivh-Loc-16-No-1.jpg	
14vivh016			vivh-Loc-16-No-2.jpg	
14vivh017			vivh-Loc-17-No-1.jpg	Overview of outcrop
14vivh004			vivh-Loc-4-No-1.jpg	Foliated part of granitoid with sheared rafts
14vivh004			vivh-Loc-4-No-2.jpg	Foliated part of granitoid with sheared rafts
14vivh004	229	230		Shear band between diorite and UM with de-formation concentrated in rafts
14vivh004	228	228		Pegmatite vein intersected by granitoid
14vivh004	226	227		Mingling in diorite cut by granitoid
14vivh004	225	225		Mingling in diorite,
14vivh004	222	224		Coarse-grained diorite melts around rafts mingling with finegrained diorite. No partial melting of rafts but coarse-grained diorite clings to rafts
14vivh019			vivh-Loc-19-No-1.jpg	veinlet without plag
14vivh019			vivh-Loc-19-No-2.jpg	veinlet with plag
14vivh020			vivh-Loc-20-No-1.jpg	Overview pic
14vivh020			vivh-Loc-20-No-2.jpg	Overview with melts
14vivh020			vivh-Loc-20-No-3.jpg	Detail with folded melt and dark amphibole around it. Melt and restite?
14vivh021			vivh-Loc-21-No-1.jpg	Intrusive contact
14vivh021	246	246		Overview of aluminous unit
14vivh021			vivh-Loc-21-No-3.jpg	Detailed view of garnrt bearing unit
14vivh022	247	247		Contact with amphibolite
14vivh022	248	248		Large green xtals in metasomatised pegma-tite
14vivh023			vivh-Loc-23-No-1.jpg	Staining on amphibolite
14vivh023	252	252		view out towards small island with two UMs. Peninsula in foreground
14vivh025			vivh-Loc-25-No-1.jpg	Overview picture of outcrop with isoclinal folding
14vivh027			vivh-Loc-27-No-1.jpg	view of quartzite with pinkish layers
14vivh028			vivh-Loc-28-No-1.jpg	view towards small island along UM band
14vivh030	255	264		Overview and detailed photos of UM
14vivh029	265	266		view of UMs back to our island
14vivh029	270	271		Pale green gneisses enclosing UM
14vivh029	267	269		Well foliated pale green gneiss
14vivh029	272	273		Overview of veinlet
14vivh031	274	274		Amphibolite with melt veinlets

Station	Camera ID		Tablet photo ID	Description
14vivh037			vivh-Loc-37-No-1.jpg	Pegmatite dyke in UM with metasomatic rims
14vivh037			vivh-Loc-37-No-2.jpg	Ruby bearing veinlet
14vivh039			vivh-Loc-39-No-1.jpg	Overview of meta diorite
14vivh039			vivh-Loc-39-No-2.jpg	Raft of meta diorite in ttg gneiss
14vivh040			vivh-Loc-40-No-1.jpg	Rusty brown weathered gt kya gneiss
14vivh043			vivh-Loc-43-No-1.jpg	Overview of outcrop
14vivh044			vivh-Loc-44-No-1.jpg	Brecciated amphibole garnet lens
14vivh044			vivh-Loc-44-No-2.jpg	Brecciated amphibole garnet lens
14vivh044			vivh-Loc-44-No-3.jpg	Dyke cutting gneiss and bring cut by pegmatite
14vivh046			vivh-Loc-46-No-1.jpg	Garnet veinlet in meta diorite
14vivh048	324	324		Pre metamorphic mafic dyke
14vivh048	325	334		Pseudotachelyte with harmers marking offset in 333 and 334
14vivh049			vivh-Loc-49-No-1.jpg	Overview of lens
14vivh050	338	338		Overview picture of outcrop
14vivh051			vivh-Loc-51-No-1.jpg	Overview of leucogabbro
14vivh052			vivh-Loc-52-No-1.jpg	Overview of outcrop
14vivh052			vivh-Loc-52-No-2.jpg	Late pegmatite cutting the breccia
14vivh052			vivh-Loc-52-No-3.jpg	Gabbro lens in granitoid both cut by light gray dyke
14vivh053			vivh-Loc-53-No-1.jpg	Overview of outcrop
14vivh053			vivh-Loc-53-No-2.jpg	Shear bands
14vivh054			vivh-Loc-54-No-1.jpg	Shear bands around leucogabbro lenses
14vivh054			vivh-Loc-54-No-2.jpg	Qtz veins in shear bands
14vivh057			vivh-Loc-57-No-1.jpg	Overview picture of outcrop
14vivh058			vivh-Loc-58-No-1.jpg	Picture of stream at sample location
14vivh058			vivh-Loc-58-No-2.jpg	view upstream
14vivh059			vivh-Loc-59-No-1.jpg	Overview of outcrop
14vivh062			vivh-Loc-62-No-1.jpg	Overview of outcrop
14vivh062			vivh-Loc-62-No-2.jpg	Detailed view of gneiss
14vivh062			vivh-Loc-62-No-3.jpg	Amphibolite
14vivh063			vivh-Loc-63-No-1.jpg	Massive sillimanite a little further down the slope
14vivh064			vivh-Loc-64-No-1.jpg	Anorthosite in outcrop
14vivh066			vivh-Loc-66-No-1.jpg	Sample of kyanite schist
14vivh066			vivh-Loc-66-No-2.jpg	Sample of kyanite schist
14vivh066			vivh-Loc-66-No-3.jpg	Sillimanite in pegmatite that crosscuts the kyanite schist
14vivh068			vivh-Loc-68-No-1.jpg	view up the mountain along strike to N
14vivh070			vivh-Loc-70-No-1.jpg	Folded calc-silicate in amphibolite
14vivh071			vivh-Loc-71-No-1.jpg	Pseudomorphs in garnet amphibolite
14vivh073			vivh-Loc-73-No-1.jpg	Overview of silicified amphibolite
14vivh073			vivh-Loc-73-No-2.jpg	Shear zone in silicified amphibolite with NS strike
14vivh077			vivh-Loc-77-No-1.jpg	Overview of outcrop
14vivh078			vivh-Loc-78-No-1.jpg	Sillimanite nodules in mica schist
14vivh081			vivh-Loc-81-No-1.jpg	Overview of outcrop with carb schist at bottom and amphibolite in middle. Felsic garnet bearing schist at top.
14vivh082			vivh-Loc-82-No-1.jpg	Picture of float
14vivh082			vivh-Loc-82-No-2.jpg	Structure in the carbonate float
14vivh083			vivh-Loc-83-No-1.jpg	Overview of outcrop
14vivh083			vivh-Loc-83-No-2.jpg	view to the south
14vivh083			vivh-Loc-83-No-3.jpg	view to marble towards north
14vivh083			vivh-Loc-83-No-4.jpg	view of the marble to the NW
14vivh083			vivh-Loc-83-No-5.jpg	Marble in package at top of ridge
14vivh089			vivh-Loc-89-No-1.jpg	Overview of outcrop
14vivh090			vivh-Loc-90-No-1.jpg	Overview of outcrop

Station	Camera ID		Tablet photo ID	Description
14vivh093			vivh-Loc-93-No-1.jpg	Overview of marble
14vivh093			vivh-Loc-93-No-2.jpg	Overview of calc-silicate
14vivh093			vivh-Loc-93-No-3.jpg	view of calc-silicate band looking east onto middle metased layer from valley west of it
14vivh096			vivh-Loc-96-No-1.jpg	Picture of calc-silicate band
14vivh096			vivh-Loc-96-No-2.jpg	Overview of calc-silicate band further to the east along strike
14vivh098			vivh-Loc-98-No-1.jpg	Mylonite with boudinaged pegmatite
14vivh098			vivh-Loc-98-No-2.jpg	Detail of boudinaged pegmatite
14vivh100			vivh-Loc-100-No-1.jpg	Overview of outcrop
14vivh100			vivh-Loc-100-No-2.jpg	Nice boudin train of amphibolite
14vivh101			vivh-Loc-101-No-1.jpg	Sericitised schist
14vivh101			vivh-Loc-101-No-2.jpg	Pegmatite cutting gabbro and gneiss
14vivh102			vivh-Loc-102-No-1.jpg	Overview of outcrop
14vivh102			vivh-Loc-102-No-2.jpg	Garnet layer in meta gabbro
14vivh104			vivh-Loc-104-No-1.jpg	Overview of outcrop
14vivh105			vivh-Loc-105-No-1.jpg	Raft of meta gabbro in granite
14vivh105			vivh-Loc-105-No-2.jpg	Raft of gneiss in granite
14vivh106			vivh-Loc-106-No-1.jpg	Overview of outcrop
14vivh106			vivh-Loc-106-No-2.jpg	Frontal view of contact
14vivh107			vivh-Loc-107-No-1.jpg	Overview of outcrop
14vivh108			vivh-Loc-108-No-1.jpg	Overview of outcrop with large feldspar crystals
14vivh108			vivh-Loc-108-No-2.jpg	Wide main pegmatite offset by approx. 15 cm by small, later pegmatite
14vivh109			vivh-Loc-109-No-1.jpg	Graphite in rock
14vivh110			vivh-Loc-110-No-1.jpg	Overview of outcrop
14vivh112			vivh-Loc-112-No-1.jpg	Sharp contact between garnet free and garnet bearing metagabbro
14vivh112			vivh-Loc-112-No-2.jpg	Gneiss folding around the metagabbro lens with some development of foliation in the metagabbro
14vivh113			vivh-Loc-113-No-1.jpg	Metasomatic reaction rim on pegmatite
14vivh113			vivh-Loc-113-No-2.jpg	Metasomatic biotite nests in amphibolite
14vivh114			vivh-Loc-114-No-1.jpg	Boudins of leucogabbro in gneiss
14vivh115			vivh-Loc-115-No-1.jpg	Overview of outcrop
14vivh116			vivh-Loc-116-No-1.jpg	Graphic intergrowth of kspar and quartz
14vivh116			vivh-Loc-116-No-2.jpg	Overview of outcrop
14vivh117			vivh-Loc-117-No-1.jpg	Overview of outcrop
14vivh118			vivh-Loc-118-No-1.jpg	Rock texture
14vivh121			vivh-Loc-121-No-1.jpg	Overview of outcrop
14vivh123			vivh-Loc-123-No-1.jpg	Amphibolite boudins in gneiss
14vivh123			vivh-Loc-123-No-2.jpg	Earlier foliation in pressure shadow
14vivh124			vivh-Loc-124-No-1.jpg	Overview of outcrop