Qaanaaq 2001: mineral exploration reconnaissance in North-West Greenland

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Project *Qaanaaq 2001*, involving one season's field work, was set up to investigate the mineral occurrences and potential of North-West Greenland between Olrik Fjord and Kap Alexander (77°10´N – 78°10´N; Fig. 1). Organised by the Geological Survey of Denmark and Greenland (GEUS) and the Bureau of Minerals and Petroleum (BMP), Government of Greenland, the project is mainly funded by the latter and has the overall goal of attracting the interest of the mining industry to the region.

The investigated region – herein referred to as the Qaanaaq region – comprises 4300 km^2 of ice-free land centred on Qaanaaq, the administrative capital of Qaanaap (Thule) municipality. Much of the region is characterised by a 500–800 m high plateau capped by local ice caps and intersected by fjords and glaciers. High dissected terrain occurs in Northumberland Ø and in the hinterland of Prudhoe Land where nunataks are common along the margin of the Inland Ice.

The field work covered three main topics: (1) systematic drainage sampling, (2) reconnaissance mineral exploration, and (3) geological mapping. It was carried out between 22 July and 30 August by the authors assisted by two young men from Qaanaaq (Thomassen 2001). A chartered 75-foot vessel, M/S *Kissavik,* served as a base, working from 12 anchorages (Fig. 2). Two rubber dinghies enabled access to coastal localities and a helicopter was available for a 14-day period. The work was initiated in the north where the winter sea ice breaks up first, then continued in Inglefield Bredning to reach the outer islands and Olrik Fjord at the end of August. This ensured that reasonable ice conditions were encountered in all areas, apart from innermost Inglefield Bredning, north of Josephine Peary Ø, where thick calf ice rendered navigation impossible. Sixty percent of the field period was seriously hampered by bad weather, with seven days completely lost. Regional coverage was therefore not as thorough as planned.

Geological setting and map status

The Qaanaaq region is underlain by two bedrock provinces: a high-grade Archaean–Palaeoproterozoic crystalline shield overlain by the unmetamorphosed Mesoproterozoic sediments and volcanics of the intracratonic Thule Basin. The profound unconformity between these units is well preserved. The Thule Basin straddles the northern extremity of Baffin Bay, and the western outcrops are in coastal Ellesmere Island, Canada (Fig. 1). In Greenland, exposures of the Thule Basin crop out on islands and the outer coastal areas, bordered on the east by the crystalline shield.

The Qaanaaq region has not been systematically mapped at a consistent scale. The western part where the Thule Basin is exposed has been mapped at 1:100 000; the area at the head of Inglefield Bredning, composed entirely of the crystalline shield, has been depicted at 1:200 000 (Dawes 1988). The only detailed mapping undertaken was of the Smithson Bjerge (Nutman 1984). The Survey's 1:500 000 geological map sheet (Thule, sheet 5; Dawes 1991) has a northern border at 78°N; the northernmost part of the project region around Kap Alexander is featured in Dawes (1997) and Dawes *et al.* (2000).

Much of the Survey's mapping work for the Thule 1:500 000 map sheet (1971–1980) was based on shoreline investigations with only limited helicopter traverses inland. The helicopter support during *Qaanaaq 2001* was reserved for geochemical sampling and mineral reconnaissance, but enabled some inland areas to be visited for the first time leading to new geological observations and revision of some boundaries.

Geological results

Geological results given here are mainly those having significance for mineral potential. Where not otherwise stated, rock unit names are those used on the Survey's 1:500 000 geological map sheet (Dawes 1991).

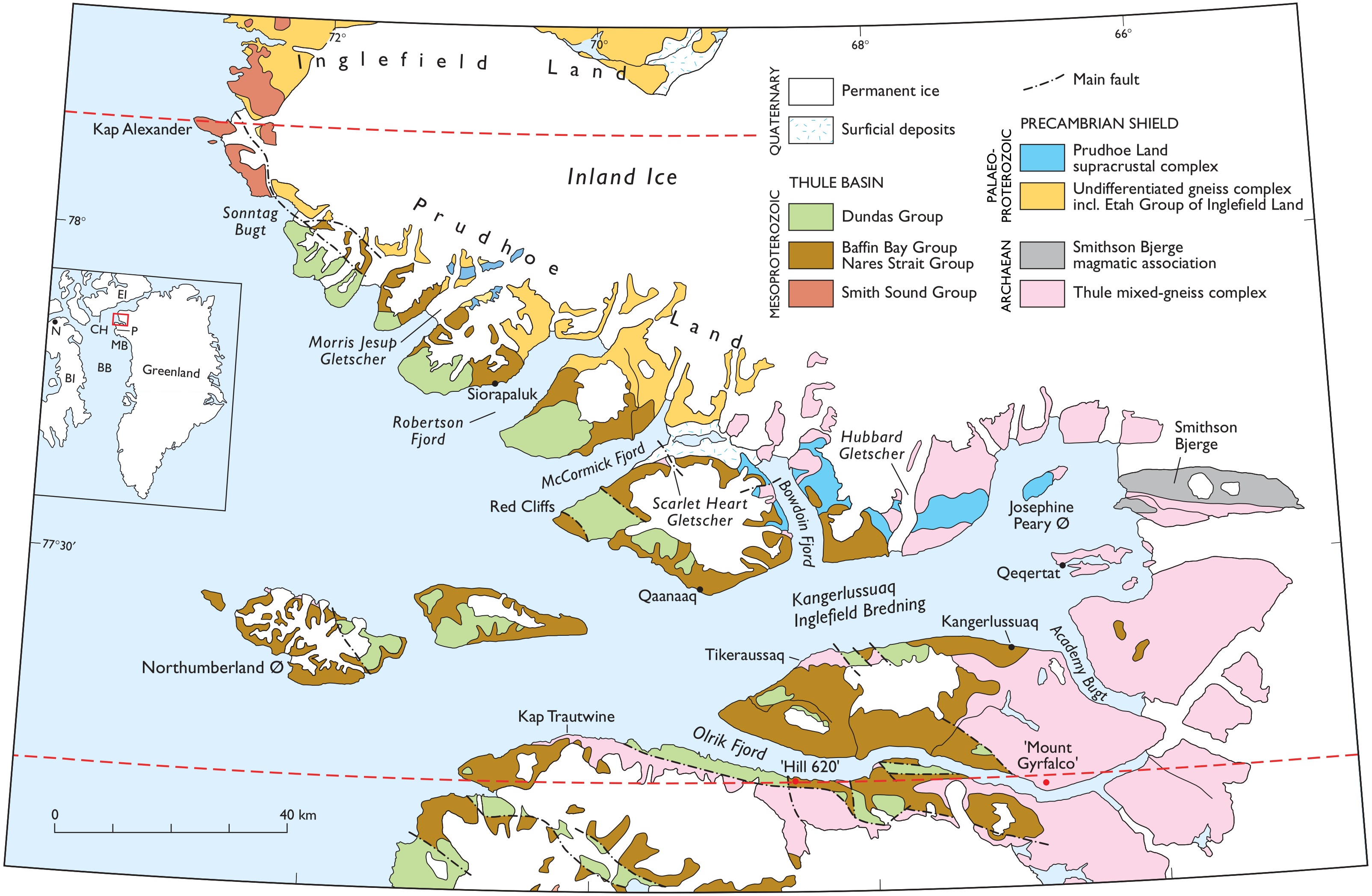

Fig. 1. Geological map of the Qaanaaq region with place names used in the text; project limits of *Qaanaaq 2001* are shown by **red dashed lines**. Basic sills, that in some areas of the Dundas Group form large outcrops, are not shown. Only faults affecting disposition of groups of the Thule Supergroup are depicted. **Black dots** are settlements; **red dots** other localities. Inset map: **BB**, Baffin Bay; **BI**, Baffin Island; **CH**, Clarence Head; **EL**, Ellesmere Island; **MB,** Melville Bugt; **N**, Nanisivik; **P**, Pituffik (Thule Air Base). **Red frame**, location of Qaanaaq region. Compiled from Dawes (1991) and Dawes *et al.* (2000) with modifications from *Qaanaaq 2001*.

Precambrian shield

Thule mixed-gneiss complex. This is an Archaean complex of highly deformed amphibolite- to granulite-facies gneisses of variable lithology and derivation, with genetically related granitic rocks. The 2001 work confirmed the intricate association of paragneisses and orthogneisses and it is clear that some intermixed packages can only be unravelled by future detailed mapping. Of note are widespread light coloured garnet-bearing quartzitic layers interleaved with gneisses. At the head of Olrik Fjord, these rock associations contain a rusty unit of banded iron-formation (BIF), e.g. north-east of 'Mount Gyrfalco' (see later under *Mineralisation*). Several amphibolite bodies were found to grade into ultramafic rocks and new occurrences of ultramafic bodies were discovered, the largest being a boudin (*c*. 500 × 150 m) within orthogneiss at the head of Academy Bugt.

Prudhoe Land supracrustal complex. These supracrustal rocks, of supposed Palaeoproterozoic age, comprise a thick succession of pelitic, semi-pelitic and quartzitic rocks with some mafic units (amphibolite and pyribolite). The supracrustal complex has conspicuous rusty weathering, and is considered to be a cover sequence to the Thule mixed-gneiss complex (Fig. 3). Both units are interleaved by large-scale isoclinal folds. New outcrops of supracrustal rocks were noted around Bowdoin Fjord and in Robertson Fjord, and units of marble, not hitherto known in the succession, were discovered at Bowdoin Fjord and Morris Jesup Gletscher. This strengthens our view that the supracrustal rocks are a correlative of the Etah Group of Inglefield land in which marble units are common.

Fig. 2. The basic logistics of *Qaanaaq 2001* with typical weather: M/S *Kissavik* and rubber dinghies with overcast, low cloud and rain. View is across Olrik Fjord in late August.

Thule Basin

The Thule Supergroup is a thick, multicoloured, mainly shallow water sedimentary succession with one main interval of volcanic rocks. Basic sills are common at several levels. Five groups are recognised (Dawes 1997), all but one of which (Narssârssuk Group) crop out in the Qaanaaq region (Fig. 1). The Smith Sound Group, present north of Sonntag Bugt, represents the northern basin margin equivalent of the Nares Strait Group and the overlying Baffin Bay Group.

Access to inland exposures in 2001 resulted in some adjustments to group/formation distribution on existing maps. One revision concerns the distribution of the Nares Strait Group with its volcanic component of hypabyssal, effusive and pyroclastic rocks and associated red beds – the Cape Combermere Formation (Dawes 1997). Breccias of the formation have proved to be mineralised. The Nares Strait Group was deemed

Fig. 3. Basement–cover relationship. Rusty-weathering pelitic and quartzitic rocks with amphibolites of the Palaeoproterozoic Prudhoe Land supracrustal complex overlying darker gneisses of the Archaean Thule mixed-gneiss complex. The pelitic schists, rich in graphite and pyrite, generate several Landsat anomalies. North side of Inglefield Bredning, west of Josephine Peary Ø, with main summit 770 m above sea level.

absent at Tikeraussaq where a postulated fault block was considered to be draped by the younger Baffin Bay Group. In 2001, a greenish basaltic unit, at least 20 m thick and in places veined and brecciated, was located within a red bed section directly overlying the crystalline shield: this succession is now referred to the Nares Strait Group. Similar basaltic rocks are also present at Bowdoin Fjord, and in 2001 were also identified farther to the east at Hubbard Gletscher. In North-West Greenland, the Cape Combermere Formation has its maximum thickness on Northumberland Ø (*c.* 200 m); it thins eastwards towards the basin margin, petering out somewhere between Hubbard Gletscher and Kangerlussuaq.

Structure

Compared to the gneisses and supracrustal rocks of the Precambrian shield, the Thule Supergroup is little disturbed; the main structures are fault blocks, grabens and large-scale flexures, as well as some local folds associated with faults. Prominent faults vary from NW–SE-trending, e.g. the fault blocks of Prudhoe Land, to ESE–WNW-trending as in the Olrik Fjord graben in which the Dundas Group is downthrown against the shield (Fig. 1). In 2001, new faults of both trends were located. Of these, a steep fault at Scarlet Heart Gletscher (Fig. 1) has appreciable downthrow, juxtaposing the Baffin Bay Group against gneisses of the shield.

Remote sensing study: a prospecting tool

An integral part of the *Qaanaaq 2001* project was a pre-season remote sensing study of the Qaanaaq region aimed at delineating areas of potential economic interest. This study was based on four images of Landsat 7 ETM data recorded during the season of minimum snow cover. The aim was to pin-point localities with mineralisation potential by means of mapping minerals that carry iron oxides (rust zones) and hydroxyl ions (argillic alteration).

Two different techniques were used for the processing of the data: (1) standard band ratios (Crippen 1989) and (2) feature-oriented Principal Component Analysis (PCA, also called the Crosta technique after its originator: Crosta & McMoore 1989). Anomalies were registered, where an anomaly is defined as a pixel where both processing techniques gave a digital number (DN) above 253, corresponding to 0.0008% of the data, in both the iron oxide and the alteration images. Using this criterion, 28 anomalies were registered: two in the Thule mixed-gneiss complex, eleven in the Prudhoe Land supracrustal complex, four in the Baffin Bay Group and eleven in the Dundas Group. For field use the image data were reproduced as paper copies of Crosta maps.

A rough distinction between the major lithological units was apparent in the image data with the Dundas Group showing up as iron oxide stained. Unfortunately, this meant that small erosional windows or isolated exposures of the Dundas Group were registered as anomalies that proved of little interest from a prospecting viewpoint. Previously known zones of alteration and rust colouring were all represented by anomalies in the image data and most of these were visited; e.g. the rusty supracrustal rocks north of Inglefield Bredning (Fig. 3). However, it became apparent that the statistical criteria selected had too high a cutoff value, as several exploration targets encountered during the season were visible in the image data but *not* registered as being abnormal. It transpires that a very small reduction of the selected DN cutoff value from 253 to 252 would have resulted in 306 anomalies. All areas of alteration and/or rust coloration observed in the field were also registered in the processed Landsat data.

Geochemical survey

The geochemical survey carried out in 2001 forms part of the reconnaissance-scale geochemical mapping of Greenland (Steenfelt 1993, 2001). The stream sediment sampling was undertaken by a two-man team using dinghy or helicopter. Prior to the field work preferred sample locations were marked on aerial photographs, the aim being to obtain an even distribution in first or second order streams with drainage basins not larger than 10 km^2.

At each location representative stream sediment material from 3 to 15 different sites along *c.* 50 m of the stream course was combined to a bulk sample of *c.* 500 g and placed in a paper bag. The total gamma-radiation from rock exposures or predominant boulders was measured using a scintillometer. A duplicate sample set of stream sediment material, collected at *c.* 5% of the localities, had the purpose of estimating the degree of local variation. Suitable streams were lacking in some of the chosen sampling sites, e.g. along glaciers and on nunataks with low relief. In such cases, scree fines or soil from patterned ground were sampled instead of stream sediment.

The sample bags were provisionally dried onboard the ship, and subsequently packed and shipped to Copenhagen where the sediments were dried, sieved and split. The fine fractions (< 0.1 mm) were analysed at Activation Laboratories Ltd, Canada, the 0.1 to 1 mm fractions were archived while fractions above 1 mm were discarded. Major elements were determined by X-ray fluorescence spectrometry using fused samples; trace elements were determined by a combination of instrumental neutron activation analysis (INAA) and inductively coupled plasma emission spectrometry (ICP-ES).

Results

A total of 343 stream sediment samples from 331 locations were analysed. Summary results are shown in Table 1 for 37 trace elements together with lower detection limits for the analytical methods. In cases where the same trace element has been determined by both INAA and ICP-ES the most reliable data are presented. Complete evaluation of the chemical data has yet to be undertaken, and here only some features of interest to mineral exploration are presented.

High concentrations of one or more elements in a sample may reflect mineralisation, or the presence of rock units with unusual chemistry. Figure 4 shows all sample locations together with locations with high concentrations of Au and the base metals Cu, Ni, Pb and Zn. The highest concentrations, i.e. anomalies, are defined here as those above the 98th percentile of the frequency distribution for an element.

Gold anomalies are scattered, with no clusters suggesting mineralisation of any particular stratigraphical unit or tectonic structure. However, the three anomalies occurring in the Thule Supergroup, i.e. from Northumberland Ø, the snout of Hubbard Gletscher and the south coast of Inglefield Bredning, are tentatively related to occurrences of volcanic rocks of the Nares Strait Group (Cape Combermere Formation). The remaining two anomalies are sited on shield lithologies.

The base metal anomalies are all associated with shield lithologies. Two conspicuous clusters are within the Thule mixed-gneiss complex. The combination of high Zn, Cu and Ni is usually attributable to mafic volcanic rocks (now amphibolite); the data therefore suggest that such rocks are part of the mixed-gneiss complex both east of the snout of Hubbard Gletscher (see Fig. 6) and in southern Smithson Bjerge. The two Pb-anomalies east of Hubbard Gletscher are in streams draining the Prudhoe Land supracrustal complex. These samples also have very high concentrations of Th and rare earth elements (REE). The highest values of Th and REE are over 10 times higher than the median values, and all anomalous samples are from streams within the Prudhoe Land supracrustal complex. Metasedimentary units enriched in heavy minerals such as monazite and garnet are probably the source of these anomalies.

The anomalous values of Zn and Pb are not so much higher than the median values, that the scattered

Table 1. Summary of chemical analyses of the < 0.1 mm grain size fraction of 343 stream sediment samples from the Qaanaaq region

Element	Method	l.l.d.	Maximum	Median	98th perc.
Au (ppb)	INAA	2	55	< 2	8
As	INAA	0.5	48	2	9
Ba	INAA	50	5400	690	1400
Br	INAA	0.5	197	3	72
Co	INAA	1	56	20	43
Cr	INAA	2	350	108	280
Cs	INAA	1	9	< 1	7
Hf	INAA	1	85	16	56
Rb	INAA	15	240	84	197
Sb	INAA	0.1	1	< 0.1	1
Sc	INAA	0.1	42	16	32
Ta	INAA	0.5	6	< 0.5	4
Th	INAA	0.2	240	17	113
U	INAA	0.5	18	3	14
W	INAA	1	19	< 1	4
La	INAA	0.5	661	53	343
Ce	INAA	3	1200	110	657
Nd	INAA	5	470	46	245
Sm	INAA	0.1	63	8	33
Eu	INAA	0.2	5	2	4
Tb	INAA	0.5	5	< 0.5	2
Yb	INAA	0.2	9	3	6
Lu	INAA	0.05	1	< 0.05	1
Ag	ICP-ES	0.3	3	1	3
Cd	ICP-ES	0.3	2	< 0.3	1
Cu	ICP-ES	1	151	33	115
Mn	ICP-ES	1	5099	656	1510
Mo	ICP-ES	1	15	2	7
Ni	ICP-ES	1	245	35	138
Pb	ICP-ES	1	77	19	47
Zn	ICP-ES	1	225	67	194
Be	ICP-ES	1	3.3	1.4	2.7
Bi	ICP-ES	2	3.7	< 2	2.5
Sr	ICP-ES	2	578	187	463
V	ICP-ES	2	269	109	212
Y	ICP-ES	1	69	23	47
S (%)	ICP-ES	0.01	0.80	0.03	0.21

All elements in ppm, except Au (ppb) and S (%).
Analyses by Activation Laboratories Ltd, Ontario, Canada.
ICP-ES: inductively coupled plasma emission spectrometry.
INAA: instrumental neutron activation analysis.
l.l.d.: lower limit of detection.
perc.: percentile of the frequency distribution.

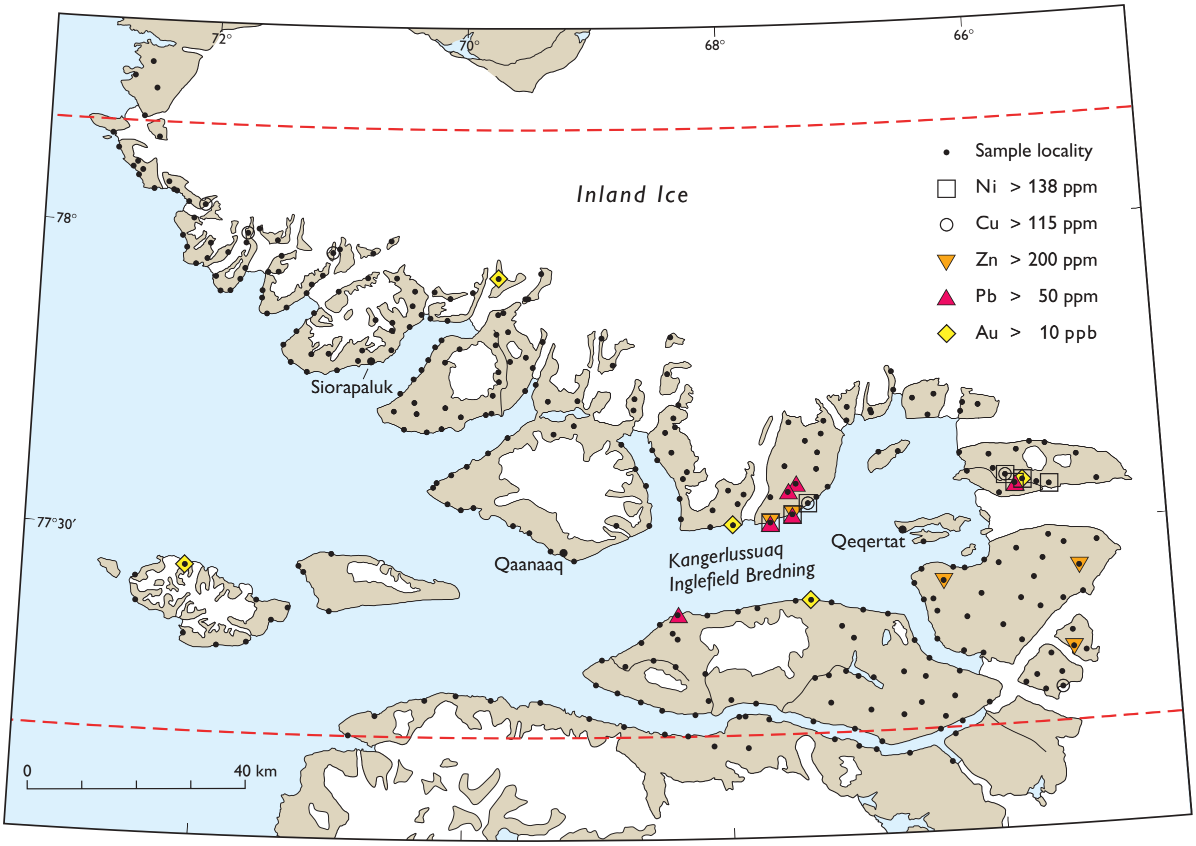

Fig. 4. Map of the Qaanaaq region showing anomalous concentrations of gold, copper, lead, zinc and nickel based on stream sediment samples. For location and place names, see Fig. 1. **Red dashed lines** demarcate the project area.

occurrences outside the clusters are considered indicative of mineralisation. Three Cu anomalies are associated with the Undifferentiated gneiss complex, but again the concentrations are not sufficiently high as to suggest significant mineralisation.

Mineral exploration

Limited mineral exploration has previously been carried out in the Qaanaaq region. In 1969 Greenarctic Consortium discovered malachite-stained sandstone at a locality known as 'Hill 620' in Olrik Fjord (Greenarctic 1971). In 1975 and 1977 the Geological Survey of Greenland (GGU) investigated selected mineral occurrences found during regional mapping (Cooke 1978), and in 1978 BIF was recorded at Smithson Bjerge by Nutman (1984). Nunaoil A/S explored the Qaanaaq region in 1994 and 1995, and reported scattered malachite in the Thule Supergroup as well as pyrite in a variety of settings (Gowen & Sheppard 1994; Gowen & Kelly 1996). Several mineralised rock samples from the Qaanaaq region collected by Greenlandic residents have been submitted to the Greenland mineral hunt programme, *Ujarassiorit* (Dunnells 1995).

During the 2001 field work a systematic visual inspection for signs of mineralisation was attempted along all the accessible coasts of the Qaanaaq region. The work was carried out partly as shoreline prospecting – observations from a rubber dinghy sailing slowly along the coast, combined with onshore investigations of promising localities – and partly as traverses of lateral and terminal moraines of active glaciers looking for mineralised blocks. This work was supplemented by limited helicopter-supported checks of inland localities. In addition to this reconnaissance work, special attention was paid to anomalies detected on Landsat images, known mineral indications, *Ujarassiorit* localities, and promising lithologies and structures. Since previous work had concentrated on the Thule Super-

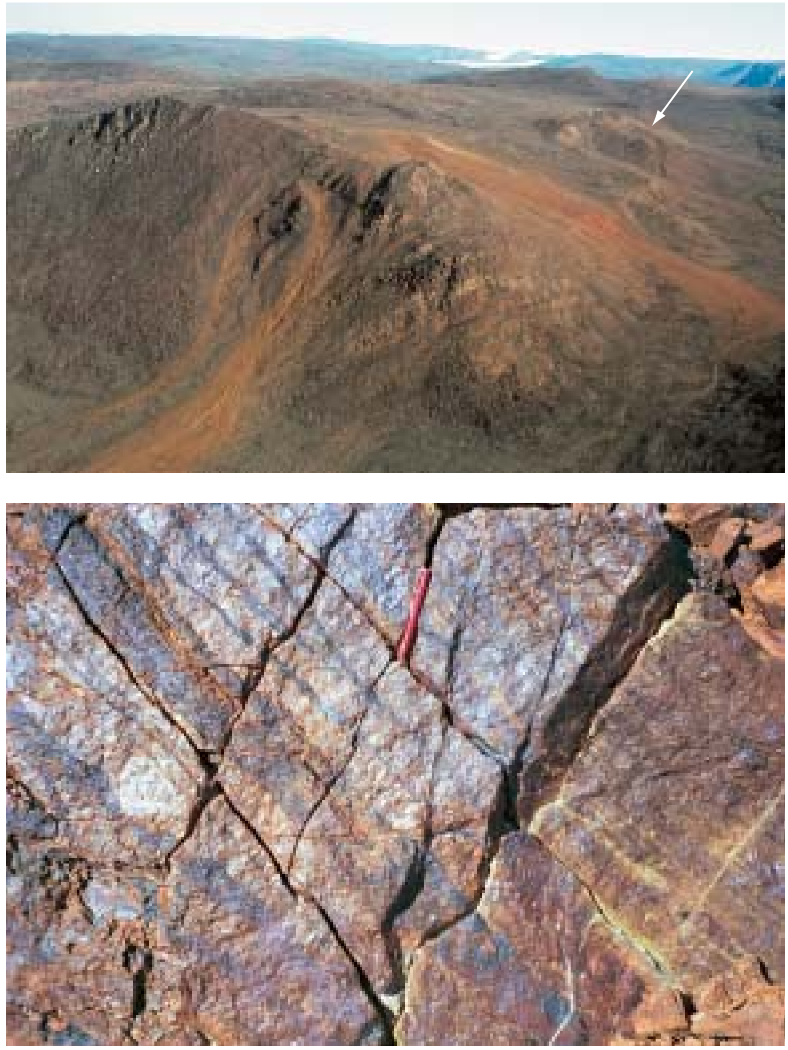

Fig. 5. New iron-formation locality in the Thule mixed-gneiss complex, north-east of 'Mount Gyrfalco', Olrik Fjord. **Above**: general view eastwards of tightly folded, rusty gneisses: **arrow** marks an isoclinal fold hinge. The regional plateau surface in the distance is 500–800 m high. The cliff with the rusty scree in the left foreground is about 400 m high. **Below**: detail of banded iron-formation above with the magnet pen 12 cm long.

group, our emphasis during *Qaanaaq 2001* was on the various lithologies of the Precambrian shield.

A total of 152 mineralised rock samples were collected, mainly loose blocks from moraines, stream beds and screes. All have been analysed by Activation Laboratories Ltd, Canada, for a suite of elements including precious and base metals, and 40 of the samples have also been assayed for gold, platinum and palladium. The main results are summarised in Table 2 and commented on below.

Thule mixed-gneiss complex

Magnetite, often in the form of iron-formation, is common in paragneiss blocks wherever the Thule mixed-gneiss complex crops out. Many of these blocks are BIF consisting of mm- to cm-scale interbedded magnetite, silicates and quartz rocks, while others are near massive magnetite-silicate rocks without any obvious macrostructure. A new occurrence was found north-east of 'Mount Gyrfalco' (Fig. 5), associated with a rust zone registered as a Landsat anomaly, and consisting of a *c*. 20 m thick unit with a strike length of approximately 500 m. It comprises cm-scale interbedded magnetite, quartz, pyroxene and garnet with minor iron sulphides. Chip samples over 6.5 m returned 30.5% Fe, 2.1% Mn, 0.8% S and 8 ppb Au.

Ferruginous quartzite akin to silicate facies BIF occurs on Smithson Bjerge (Nutman 1984). Blocks of comparable quartz-garnet(-pyroxene) rocks with disseminated pyrrhotite, magnetite and traces of chalcopyrite were encountered at several localities in the eastern part of

Table 2. Summary of selected elements for mineralised rock samples from the Qaanaaq region

Geological unit	Samples	Au ppb	Cu ppm	Pb ppm	Zn ppm	Ni ppm	Ti%	Fe%	S%
Quartz veins and basic dykes	6	< 2–5	11–1081	< 3–13	3–104	4–63	0.02–3.06	1.2–10.5	0.03–3.40
Dundas Group	10	< 2–5	12–426	< 3–157	3–20986	3–48	0.02–0.49	2.0–9.4	0.07–4.46
		< 2	57	12	76	26	0.13	5.5	1.82
Baffin Bay Group	10	< 2–7	7–15247	< 3–15	4–47	1–46	0.01–0.39	0.2–3.0	0.03–2.20
		< 2	251	10	6	5	0.05	1.1	0.15
Nares Strait Group	6	< 2	30–10167	< 3–12	22–60	44–119	0.22–0.46	4.3–10.6	0.01–0.18
		< 2	920	5	33	65	0.38	4.6	0.01
Prudhoe Land supracrustal complex	14	< 2–11	8–886	< 3–135	< 1–637	< 1–581	< 0.01–3.12	0.4–21.7	0.04–18.21
		< 2	40	13	31	26	0.09	6.3	3.17
Undifferentiated gneiss complex	25	< 2–76	15–1901	< 3–171	37–1769	7–3582	0.06–1.82	1.8–15.5	0.12–6.05
		< 2	354	11	98	90	0.43	8.8	1.43
Thule mixed-gneiss complex	81	< 2–83	8–1748	< 3–45	22–793	4–3282	0.01–1.72	1.8–35.6	0.01–10.15
		< 2	123	< 3	93	50	0.24	14.8	1.11

Numbers are ranges and medians.
Analyses by Activation Laboratories Ltd, Ontario, Canada.
Analytical methods: Inductively coupled plasma emission spectrometry: Cu, Pb, Zn, Ni, Ti, S.
Instrumental neutron activation analysis: Au, Fe.

the region, but returned only slightly enhanced gold and copper values (max. 83 ppb Au and 931 ppm Cu).

Faint malachite staining, caused by oxidation of minor disseminated pyrite and chalcopyrite, was observed over a distance of 3–4 km in steep coastal cliffs of banded gneisses east of the snout of Hubbard Gletscher; this is also marked by a multi-element anomaly in the stream sediment samples (Fig. 6). Rock samples were collected at one locality, but these returned no significant metal values. Faint malachite coatings caused by minor disseminated pyrite and chalcopyrite were also observed on amphibolitic and ultramafic lenses and pods in the gneisses; samples returned up to 31 ppb Au, 8 ppb Pt, 19 ppb Pd, 1748 ppm Cu and 1298 ppm Ni.

Undifferentiated gneiss complex

A number of moraine blocks derived from this unit (see Fig. 1) contain disseminated iron sulphides, graphite and traces of chalcopyrite. Some samples are slightly enriched in gold and base metals (Table 2).

Prudhoe Land supracrustal complex

This unit is characterised by conspicuous red and yellow rust zones in sulphidic semi-pelitic schist (Gowen & Sheppard 1994), and these correspond to concentrations of Landsat anomalies (Fig. 3). Checks east of Bowdoin Fjord revealed units of highly graphitic and pyritic schist several tens of metres thick with intense argillic alteration; remobilisation of pyrite into veinlets in quartz-rich pinch-and-swell layers is interpreted as due to a hydrothermal overprint. Analyses of chip and grab samples show no significant concentrations of economic metals (Table 2).

Nares Strait Group

Blocks of malachite-stained volcanic breccia on Northumberland Ø were reported by Gowen & Sheppard (1994), and almost certainly derive from the Cape Combermere Formation. This mineralisation was found to consist of specks of malachite-covellite-chalcocite and hematite in moraine boulders collected below the Kiatak fault, a major NW–SE-trending dislocation (Fig. 1) juxtaposing the Dundas and Nares Strait

Fig. 6. Mixed orthogneisses and paragneisses, east of the snout of Hubbard Gletscher. The pale units are garnet-rich quartzites and granitic sheets. Sporadic malachite staining occurs for 3–4 km along these *c*. 600 m high cliffs and the coast constitutes a multi-element geochemical anomaly.

Groups (Dawes 1997). Samples returned up to 1.0% Cu, 11 ppm Ag and 0.9% Ba. Malachite staining has also been reported from the basal clastics of the Nares Strait Group on Northumberland Ø (Jackson 1986) as well as in the Cape Combermere Formation at Clarence Head, Ellesmere Island (Frisch & Christie 1982).

Baffin Bay Group

Faint malachite staining on pale sandstones was observed at several localities in the Qaanaaq Formation of the Baffin Bay Group. This is caused by oxidation of flecks and disseminations of minor pyrite and chalcopyrite. The highest copper concentrations were encountered at Red Cliffs and 'Hill 620'. At Red Cliffs dm-thick layers of interbedded pale sandstone and black shales occur in a small outcrop. In addition to faint malachite staining, interstitial chalcopyrite and minor pyrite were found in a composite sample which returned 1.5% Cu and 0.8% Ba. 'Hill 620' comprises an isolated, 100 × 100 m showing adjacent to an E–W-striking fault and covered by cm–dm-sized blocks of malachite-sprinkled white sandstone. The only primary copper mineral seen under the microscope is chalcopyrite as few μ sized disseminated grains. A composite sample returned 0.4% Cu and 5 ppm Ag.

Dundas Group

The Dundas Group on Northumberland Ø shows various signs of mineralisation. As noted by Dawes (1997), stratiform pyrite is common in sandy shales, but no signs of base metal concentrations were found associated with this mineralisation in 2001. In a sequence of interbedded shale and stromatolitic limestone, minor sphalerite was observed at the base of a limestone unit (Fig. 7). A composite sample returned 2.1% Zn and 0.01% Pb. Also worthy of note is the observation by Marcos Zentilli (personal communication 2002) in the same area of minor galena-barite mineralisation at a basic sill – shale contact.

Fig. 7. Interbedded dark shales and stromatolitic carbonate beds, Dundas Group, north-eastern Northumberland Ø. The base of the carbonate bed (at the notebook) contains zinc mineralisation.

Structures

The pyrite mineralisation along the syn- to post-depositional southern boundary fault of the Olrik Fjord graben noted by Gowen & Sheppard (1994) was checked at one locality, but no gold or base metals occur in the samples collected.

Concluding remarks

Observations during *Qaanaaq 2001* of magnetite-rich rocks in blocks and outcrops in the Thule mixed-gneiss complex may be interpreted as the northward extension of the Archaean magnetite province that stretches for 350 km along the coast of Melville Bugt and into the Pituffik (Thule Air Base) area (Dawes 1976, 1991; Dawes & Frisch 1981). This Greenland iron province is a prime candidate for correlation with the Algoma-type iron deposits of the Mary River Group of northern Baffin Island (Jackson 2000). In addition to iron, BIF provinces have a potential for gold, so much so that in many regions of the world BIF is used as an exploration guide for gold (Kerswill 1996).

The banded gneisses east of the snout of Hubbard Gletscher with their malachite staining and multi-element geochemical anomaly have a base metal potential. These gneisses, as well as those in the anomalous area of southern Smithson Bjerge, warrant further attention.

No convincing signs of economic mineral concentrations were found in the hydrothermally overprinted pyrite-rich graphitic schists of the Prudhoe Land supracrustal complex, but this unit needs closer scrutiny to verify whether it has gold and base metal potential. The stream sediment geochemistry suggests the presence of metasedimentary units with concentrations of REE-rich minerals.

An interesting result of the Landsat study is the presence of rust zones in the Prudhoe Land supracrustal complex and their paucity in other shield lithologies. In Inglefield Land to the north, rust zones caused by iron sulphides and graphite are concentrated in supracrustal rocks of the Etah Group and derived paragneisses (Dawes *et al.* 2000; Thomassen *et al.* 2000). This supports our view that the Prudhoe Land supracrustal complex is a correlative of the Etah Group.

The copper mineralisation in the Cape Combermere Formation of the Nares Strait Group resembles a 'volcanic redbed copper' deposit type (Kirkham 1996), possibly associated with the NW–SE-trending Kiatak fault crossing Northumberland Ø. The geochemical results for this volcanic formation also indicate a gold potential, and the formation and the faults dissecting it warrant further exploration. The disseminated copper mineralisation in sandstones of the Qaanaaq Formation of the Baffin Bay Group is probably of diagenetic origin, perhaps controlled by local faults. It constitutes a low-priority exploration target.

The carbonates of the Dundas Group with their zinc mineralisation, albeit of modest size, show a potential for carbonate-hosted lead-zinc deposits, and in this respect it is worth noting that extensive outcrops of the group occur south of the Qaanaaq region. Also of relevance is the fact that commercial lead-zinc concentrations exist in carbonate rocks of comparable age at Nanisivik in the coeval Borden Basin of Baffin Island, Canada (Olson 1984).

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