



Gold mineralisation and gold potential in South Greenland



No. 1 - March 2002

Gold mineralisation and gold potential in South Greenland



More than 25 years of geological mapping and exploration in South Greenland have demonstrated the existence of geological environments, where gold mineralisations have developed and potentials for viable gold deposits exist. During this period a number of private companies have been engaged in exploration activities, including field investigations and diamond drillings. The Geological Survey has provided systematic geological and geochemical mapping, as well as airborne geophysical surveys including radiometry, magnetometry and EM measurements. A number of geological map sheets in scale 1:100 000 and 1:500 000 are issued. Stream sediment geochemistry analyses have been used to compile a comprehensive geochemical atlas, and geophysical maps are available in varying scales depending on locality. The Survey (GEUS) has issued a CD-ROM including much of the available data in geo-referenced formats.

Geological setting

South Greenland is dominated by the Palaeoproterozoic Ketilidian Orogen (1900–1750 Ma), which covers the southern tip of Greenland. The middle Proterozoic Gardar province includes pronounced intrusive complexes (1300–1120 Ma) in the central part of the area. The environments for gold deposition can be grouped into several different geological scenarios:

- Archaean foreland composed of high-grade gneisses serving as a basement to Palaeoproterozoic volcano-sedimentary successions
- Archaean border zone affected by Ketilidian orogenesis
- A magmatic arc represented by the 30,000 km², calc-alkaline Julianehåb Batholith and segments of volcano-sedimentary sequences interrelated in
- The Psammite Zone south of the batholith composed of metasediments and locally volcanic rocks that are deformed and sometimes migmatized and

- The Pelite zone located most southerly and composed of turbiditic sedimentary rocks, which are highly deformed and migmatized. The supracrustal successions are intruded by a rapakivi suite between 1755–1732 Ma.

Gold and pathfinder elements

The gold potential of South Greenland is indicated in the geochemical mapping by the distribution of high values for gold (Au) and pathfinder elements like arsenic (As) and antimony (Sb) in the fine fractions (<0,1 mm) of stream sediments. Using this information together with gold anomalies in bedrock and in heavy mineral concentrates of stream sediments, the presently recognised potential for gold mineralisations are focussed to specific regions and smaller areas.

The most prospective areas are around the Sermiligaarsuk Fjord, at the southern margin of the Julianehåb Batholith domain, and within large parts of the Psammite Zone.

Gold occurs in various settings and localities:

- Archaean Tartoq Group greenstone Sermiligaarsuk
- Palaeoproterozoic Border Zone Arsur and Kobberminebugt
- Julianehåb Batholith Qoorormiut, Niaqornaarsuk, Igutsaat
- At the border between Julianehåb batholith and Psammite Zone Kangerluluk and Sorte Nunatak
- Psammite Zone Nalunaq, Lake 410, Ippatit and Kutseq

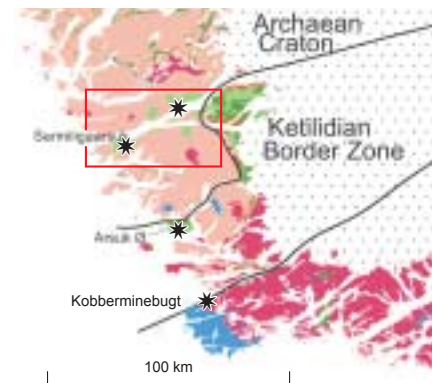
A visit to these localities will reveal a variety of environments and mineral occurrences. They are briefly described here with emphasis on the geological setting and including some important analytical results.

Sermiligaarsuk

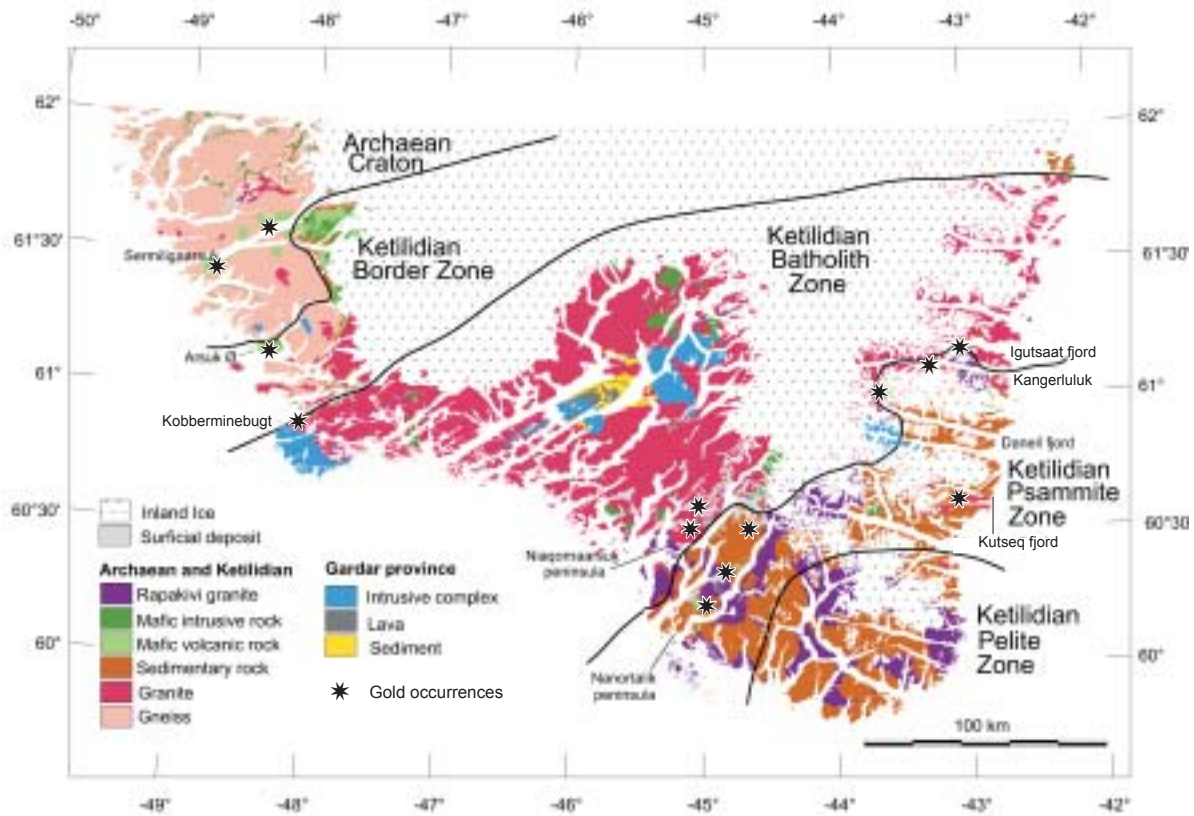
In the Sermiligaarsuk, the Tartoq Group greenstone belt overlies Archaean gneiss. The basement gneiss has ages ranging from 2980–3500 Ma and Taartoq supracrustals are assumed to be late Archaean, deposited between 2500 and 3000 Ma, and older than the unconformably superimposed Palaeoproterozoic Ketilidian sediments and volcanics (several km thick). The Tartoq Group greenstone belt is exposed in several sub-areas along the Sermiligaarsuk Fjord.

Gold formation is confined to linear belts and carbonate-rich zones. The carbonate-rich zones are composed of several individual, 4–10 m wide units of carbonate schists, where gold occurs in two principal forms within the carbonate succession:

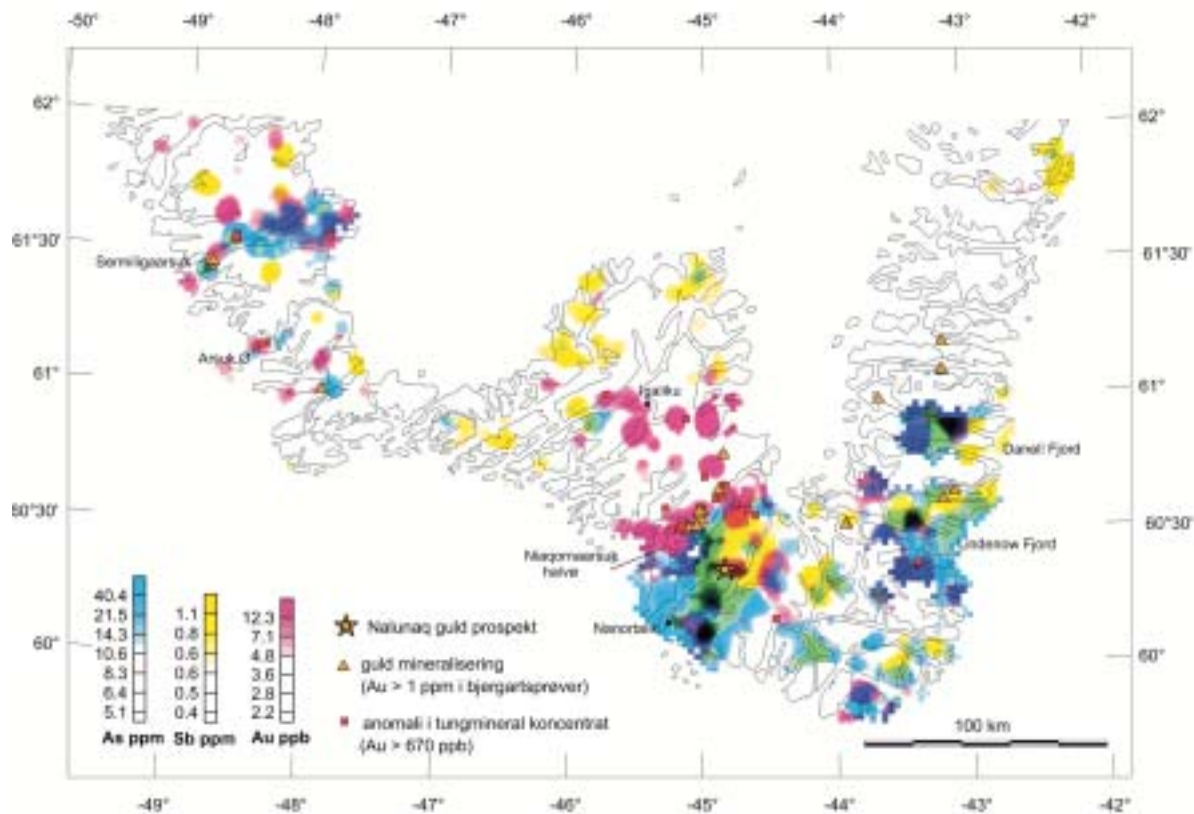
- 1) In disseminated pyrite in quartz-ankerite lenses (up to 2 m by 10 m) and in pyrite accumulations associated with massive arsenopyrite aggregates. In the quartz association gold occurs as discrete inclusions in pyrite. Other sulphides include arsenopyrite, chalcopyrite, tennantite, and chalcocite. The highest grade recorded for gold is 50 g/t, but typical values are 5–8 g/t.
- 2) In association with massive and banded pyrite–arsenopyrite aggregates in meta-chert grading into highly disseminated arsenopyrite – quartz (recrystallised)



Geological map around Sermiligaarsuk in South Greenland.



Geological map of South Greenland.



Gold potential of South Greenland indicated by distribution of gold, arsenic and antimony in stream sediments.

chert) masses, which are up to 1 m by 30 m along strike. The average grade of gold is 8–15 g/t. Gold occurs as tiny inclusions, mainly in pyrite.

Gold is thought to have been introduced into the Taartoq greenstones during the formation of stratiform exhalites with massive-sulphide and chert. Regional metamorphism resulted in recrystallization and segregation of the chert into compact quartz bodies and residual massive-sulphide. Subsequent episodes of shearing and intensive carbonate alteration along the shear zones, lead to the liberation and accumulation of gold.

The gold occurrences in the Taartoq supracrustals are assumed to be deposited between 2500–3000 Ma, and are so far the only Archaean gold mineralisation in South Greenland. An extensive exploration activity has been carried out in the area including several diamond drillings and geophysical surveying.

Arsuk Ø

Arsuk Ø is located within the Border Zone of the Ketilidian mobile belt. On this island there are exposed supracrustal successions of volcanics and metasediments. Bands of mafic metavolcanics, up to 300 m thick, are intercalated within the metasediments. This mixed sequence of volcanics and sediments is overlain by more than 3000 m of pillow lavas, volcanic breccias, agglomerates, tuffs and massive mafic lava flows.

A number of small mineralisations are located on Arsuik Ø. Contents of gold, zinc and copper are generally low; two settings are usually recognized:

- 1) rusty chert horizons in the pillow lava sequence and
- 2) quartz veins in the pillow lava sequence.

Samples show up to 300 ppb gold. The copper content reaches close to 2000 ppm in rusty metabasic rocks and Zn contents up to nearly 900 ppm are recorded in tuff within disseminated sulphides.



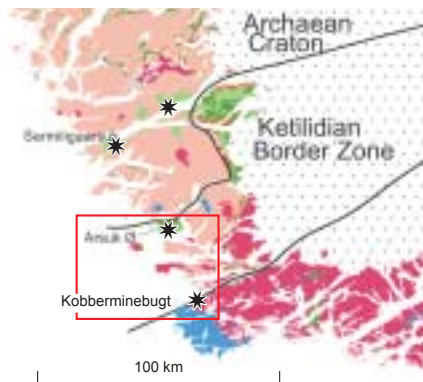
A view at the Taartoq Group greenstones (dark) with intercalations of meta-chert layers (light), hosting gold occurrences, eastern part of Sermiligaarsuk. Persons for scale.



Close-up of solid pyrite-arsenopyrite layer partly malachite stained, eastern Sermiligaarsuk. Hammer head is 10 cm.



View of basic metavolcanics at Blaalershavn, eastern Arsuik Ø.



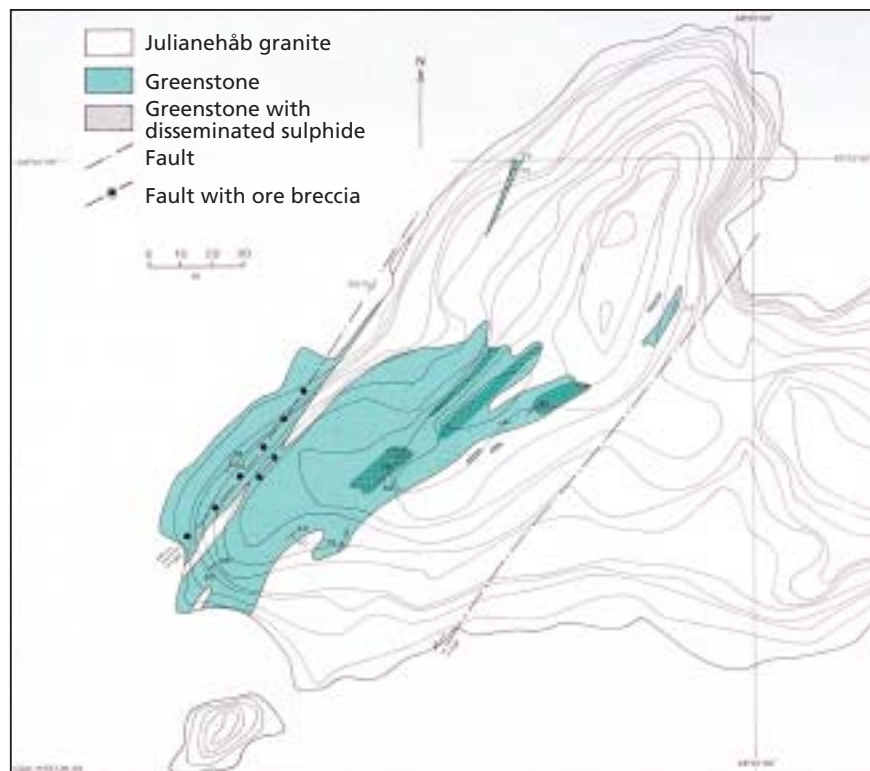
Geological map around Arsuk Ø and Koberminebugt in South Greenland.

Koberminebugt

The copper-gold occurrence is hosted by metavolcanic lithologies of the Ilordleq Group, composed of tuffaceous/rhyolitic lithologies and greenschists. Faults and shear zones are locally mineralised with bornite and chalcocite. A major Cu-mineralisation has been located in a fault zone, which is co-planar with the lithological interfaces in the host rocks and separates mylonitic felsitic schist in the footwall from amphibolite schist in the hanging wall. The fault zone is c.130 cm wide, but the sulphide rich layer only makes up some 32 cm of this at places. The bornite-chalcocite lenses have accessory ilmenite, magnetite, chalcopyrite and electrum. The ore is suggested to be of hydrothermal origin. Chalcopyrite and locally bornite is disseminated in the greenstones hosting the ore, in the area from Josva Mine eastwards to Rinks Havn, with up to 5 vol.% of sulphides.

The average copper content in the ore vein is 3.5%, but percentages of c. 5% are noted in limited parts in upper levels. The ore contains up to 1.5 ppm gold and consistently high silver content up to 250 ppm.

This ore body was actually mined 1904–1915. Total production from the Josva Mine did not exceed 90 tons of copper extracted from 2200 tons of ore with small additional amounts of gold (0.5 kg



Detailed geological map around Josva Mine, showing location of the mineralisation.

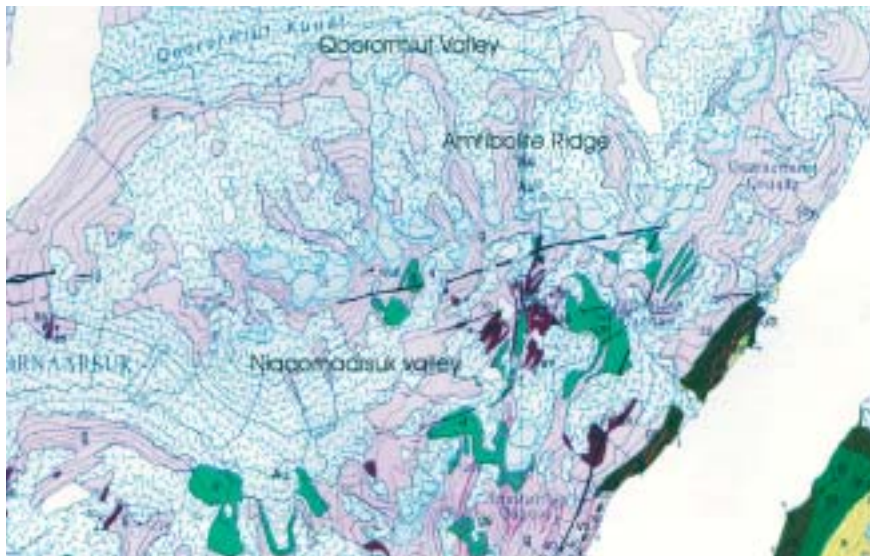


Close-up of the Josva Mine copper vein with solid bornite. Knife for scale.

and silver (50 kg). The size of the remaining ore body at Josva Mine is estimated to be 2000–3000 tons of ore containing 30–40 tons of copper. The potential of the disseminated ore in the vicinity has not been calculated.

Qoorormiut

The gold occurrence in the Qoorormiut Valley is associated with quartz veins in amphibolite dykes hosted in granite of the Julianeåb Batholith. A number of genera-



Geological map of the Qoorormiut-Niaqornaarsuk area.

mation of the mineralisation is 200–400°C at a pressure between 0.5 and 1.5 kbar.

The gold concentration varies significantly in this type of mesothermal gold mineralisation and reaches 380 ppm in narrow silicified shear zones. Chip samples from preliminary exploration activities resulted in assay results between 114 ppm and 147 ppm gold. Later re-sampling by GEUS, however, could not reproduce higher values than 14 ppm gold.

Niaqornaarsuk

The gold mineralisation in the Niaqornaarsuk valley is related to quartz veins, meta-basic rocks, hydrothermally altered granite and aplite within the Julianehåb Batholith. Two different types of mineralisation are present:

- 1. gold and sulphide bearing veins
- 2. molybdenite-quartz veins

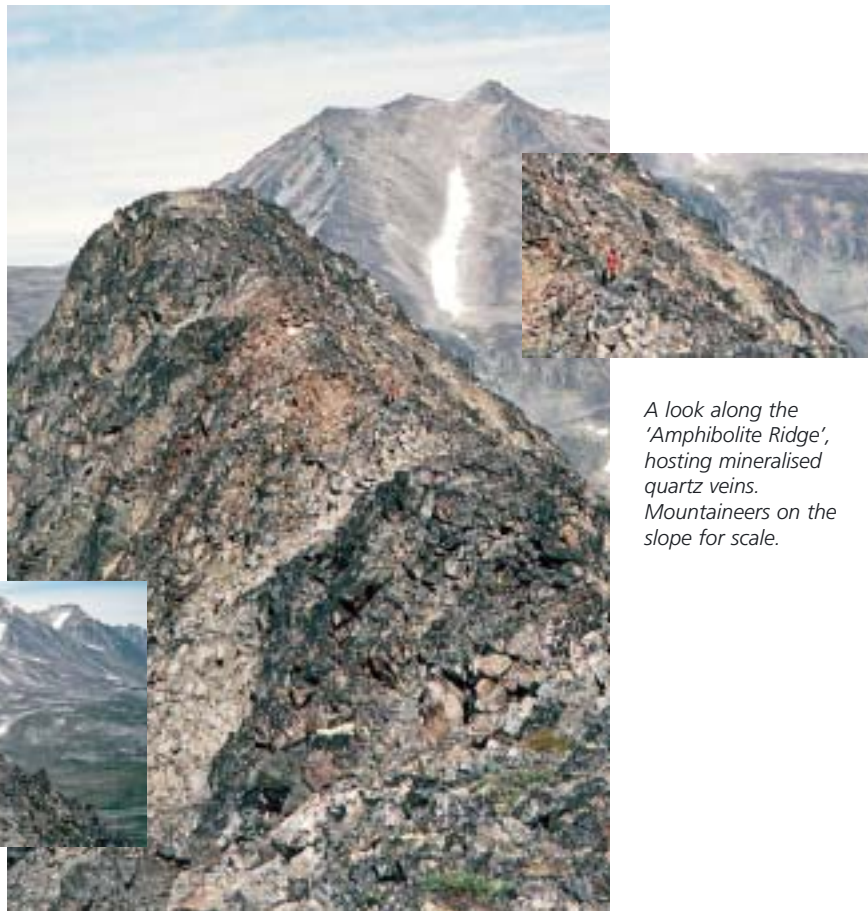
The molybdenite-quartz veins (2) do not carry significant gold (<100 ppb). The gold-mineralisation (1) within the hydrothermal alteration halo contains

tions of quartz veins, more or less deformed, can be identified. The quartz veins all strike NE-E with a steep westerly dip. They are 0.5–5 m wide, rarely up to 10 m, and discontinuous, but can be followed up to 200 m along strike. The latest un-deformed quartz veins are associated

with a gold-sulphide mineralisation. Several stages of mineralisation are identified including pyrite, arsenopyrite, gold, electrum, galena-vikingite, chalcopyrite and spahlerite. Fluid inclusion studies show that the gold is precipitated from the CO₂-CH₄ fluids. The temperature for-

The smelting plant at the Josva Mine, 1911.





A look along the 'Amphibolite Ridge', hosting mineralised quartz veins. Mountaineers on the slope for scale.



traces of Fe-sulphides (sulphidation) and locally arsenopyrite containing 50–200 ppb gold. Up to 3400 ppb gold has been found in rusty and altered diorite-gabbro in the lower Niaqornaarsuk valley.

The structural fabric is compatible with the regional sinistral shear zone move-

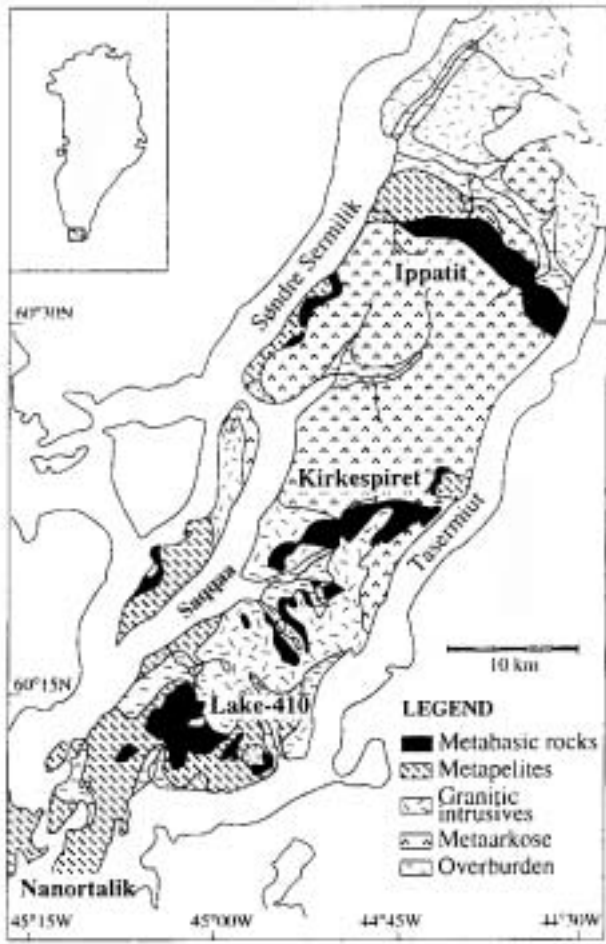
ment with a NNE-trend and controls the location of gold mineralisation on Niaqornaarsuk peninsula. The gold mineralisation is located near the roof of the Julianehåb Batholith and is characteristic by the element association Au-Bi-(As-Mo-W).

Ippatit and Lake 410

The Ippatit and Lake 410 occurrences are hosted in Ketilidian amphibolites, which are interpreted to represent a suite of pyroclastic rocks, lavas, pillow lavas, and dolerites. Associated meta-sediments in



Granodiorite, hydrothermally altered, Niaqornaarsuk.



Geological map of the Nanortalik peninsula.

the area include stratiform, rusty sulphide- and graphite-rich horizons. The amphibolites host quartz veins with minor sulphides. The quartz veins are often associated with calc-silicate alterations.

The gold content is low; a rusty section of bedded chert and graphitic schist shows 20–120 ppb Au and 500–2000 ppm As, and quartz veins in meta-pelites return up to 830 ppb Au.

The host rock is considered to be part of the same sheet of meta-volcanic rocks, which also hosts the Nalunaq gold prospect at Kirkespiret (see map above). Within the central Nanortalik peninsula, the amphibolite sheet has been disrupted

and partly engulfed by late granite diapirs, dated to app. 1805 Ma. The gold mineralised horizons at both Nalunaq and Lake

410 are located close to the roof of the granite batholith.

The gold is concentrated in quartz-veined amphibolite. The quartz veins are sub-concordant and contain minor sulphides, mainly arsenopyrite and chalcopyrite. At both localities the gold contents are found to be low, ranging from 20–830 ppb associated with As in the range 500–3000 ppm.

Nalunaq

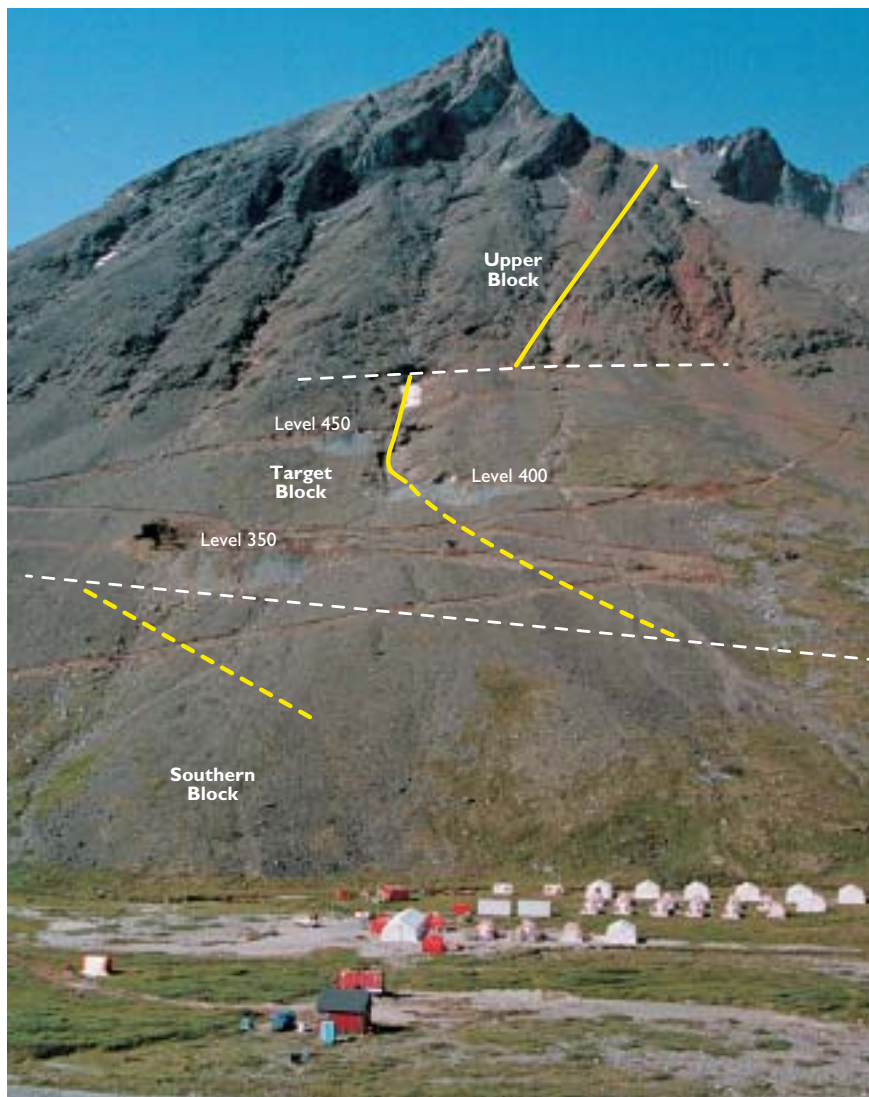
The Nalunaq gold deposit is hosted in meta-pelites and meta-basic rocks of Ketilidian age (1850–1800 Ma). The supracrustal successions are intruded by post-kinematic biotite granites and subsequently by anorogenic rapakivi granites around 1750 Ma. The host rocks represent a thrust sheet overlying molasse-type sediments deposited in a marginal basin in the Ketilidian orogen.

Two major gold-bearing veins occur along a NE-striking ductile thrust zone dipping 40° to 55°SE. The gold mineralisation is epigenetic and resides in quartz-veins and in calc-silicate altered shears sub-parallel to the foliation. The 'Main Vein' of Nalunaq has so far been estimated to be 1700 m long and 0.1 to 2 m wide.

The gold is genetically related to metaliferous fluids associated with the emplacement of late intrusive stages of the



Visible gold in Nalunaq quartz veins.



The Nalunaq Mountain with the so-called 'Main Vein' as a yellow line. The mining camp is located at the valley floor.

Julianehåb Batholith granites (1800–1770 Ma) followed by local remobilisation. Preliminary interpretation of the fluid inclusion data suggests precipitation of gold at 525–575°C and about 2.5 kbar. Measured and indicated resources are 292,000 ounces of gold with an average grade of 25 g/t. As inferred resources 718,000 ounces of gold are considered ore averaging 19 g/t Au. The Nalunaq deposit is expected to go into production during 2003.

Kutseq

In the area around Kutseq fjord on the southeast coast of Greenland, mineralised amphibolite rocks are intercalated within a sequence of psammite and semi-pelittite gneiss. An arsenic-gold association is hosted in shear zones and in dykes in the amphibolites. The mineralised shear zones vary from abundant small horizons 10–20 cm thick and 10–12 m long, to large shear structures up to 12 m across and 500–600 m long.

Gold is found within occurrences of sulpho-arsenides and arsenides. Up to a

few vol.% of disseminated pyrrhotite and arsenopyrite occur within the shear zones. The element contents vary significantly with gold concentrations up to 38.5 ppm and arsenic concentrations up to 6%. Slightly discordant felsic dykes (10–40 cm) carry pyrrhotite and arsenopyrite. As-content reaches 1.7% and gold is up to 200 ppb.

In the As-Au association, arsenopyrite geothermometry suggests precipitation temperatures for arsenopyrite-löllingite-pyrrhotite and gold at 440–560°C. Gold is introduced during an early stage of the formation and was partly re-mobilised during cataclastic shear movements. It is suggested that the As-Au association represents an epigenetic mesothermal, lode type of gold mineralisation with genetic relations to the gold mineralisation in the Nanortalik region (see above).

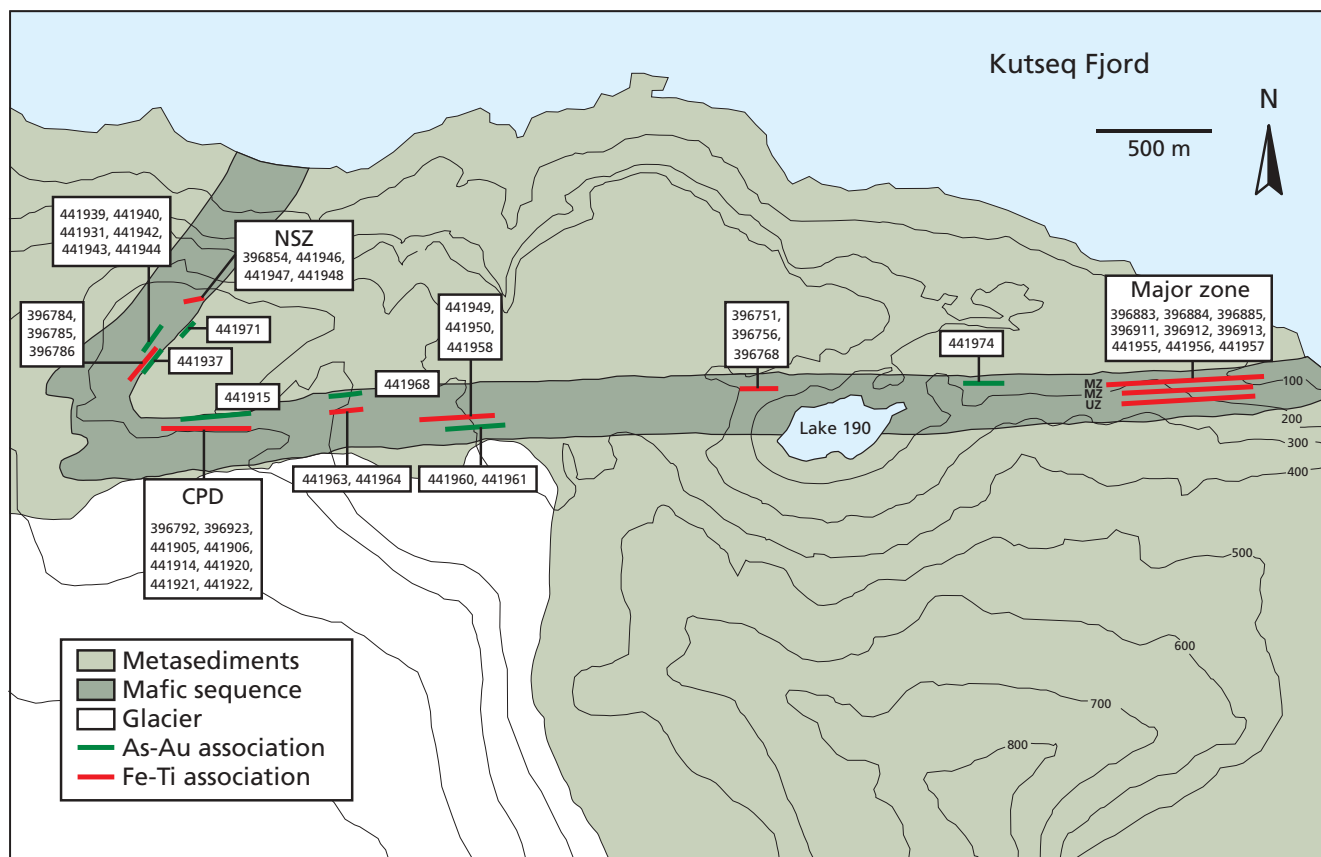
Kangerluluk

A gold-bearing sulphide mineralisation is hosted by a 200–300 m thick mafic volcano-sedimentary supracrustal sequence exposed over an area of app. 4 km². The supracrustals rest unconformably on granites and granodiorites of the Julianehåb Batholith. The following lithofacies: conglomerate-sandstone, pyroclastics, mafic volcanics, and a volumetrically subordinate "peperitic" lithofacies represent the succession. The sequence has been subjected to lower amphibolite facies metamorphism, but sedimentary and volcanic structures are well preserved. At the locality 'Sorte Nunatak' east of Kangerluluk a similar type of mineralisation has been observed.

Alteration and mineralisation

Syn-volcanic alteration: The volcanic rocks were subjected to extensive, pervasive, syn-depositional hydrothermal alteration and seawater interaction. The matrix between pillows is dominated by epidote and is very CaO rich (24–30 wt%) but shows no significant gold or copper accumulation.

Early, post-volcanic alteration: Early post-volcanic alteration mineral paragenese-



Geological map of the Kutseq area, South-East Greenland.

ses within large faults or shear zones cutting the supracrustal package.

The ore minerals related to a quartz association are dominated by pyrrhotite and pyrite (up to a few vol.%). Locally massive pyrrhotite occurs at the contacts between sediments and more massive quartz veins. Up to 40 cm wide silicified alteration halos with very high gold concentrations are associated with the quartz veins. A grab sample from such a halo contains 118 ppm gold.

Pyrite, chalcopyrite and microscopic visible gold occur in association with faults are typical ore minerals in an epidote association. Chip samples returned up to 3.3 ppm Au and 1.6% Cu over half metre intervals.

Late, post-volcanic alteration: Late alteration is characterised by bleaching and metamorphic garnet overgrowth as well as vein-related copper-gold mineralisation and brittle deformation with associated carbonate veining and silicification.

Only the copper association returned gold in samples with up to 6.2 ppm Au and 1.8 wt% Cu.

Igutsaat

A major, 5–8 m thick rusty aplite sill striking E–W, is exposed in mafic rocks surrounded by gneiss on the south side of Igutsait Fjord. The aplite contains 1–2 vol.% of pyrite in disseminated form and also as veinlets. The aplite yields up to 1.4 ppm Au. The mineralisation is comparable to a similar appearance on the SW coast of Greenland within the Batholith Zone (Niaqornaarsuk).

Pb-isotopes and gold emplacement

Pb-isotope studies of different mineral occurrences in South Greenland indicate two stages of gold emplacement. The first stage is related to the regional deformation and metamorphism (1792–1785 Ma),

during which sediment-hosted gold was epigenetically concentrated into shear zones and veins.

The second stage seems related to late hydrothermal activity. The source of Pb is possibly a mixture of juvenile Pb from the Julianehåb Batholith with some contributions from the host rocks around 1780 Ma.

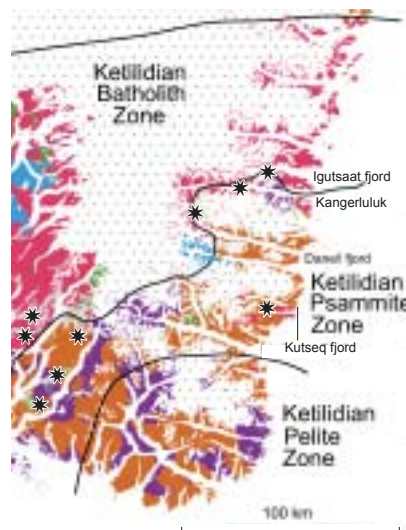
The source indications for Pb in these gold occurrences are a c. 2000 Ma old reservoir, which probably is a mafic source, because of the gold-copper association and the lack of galena. It is concluded that the initial gold mineralisation was genetically related to metalliferous fluids associated with the emplacement of late stages of the Julianehåb Batholith (1800–1770 Ma) followed by local remobilisation.

Gold potential in the Palaeoproterozoic

The gold occurrences in the Ketilidian Orogen are classified as 'Intrusion-related



Basic volcanic rocks with pillow-structures, Kangerluluk.



Geological map of SE Greenland.

Gold Systems'. The gold occurrences are found both within the Julianehåb Batholith and outside as proximal deposits.

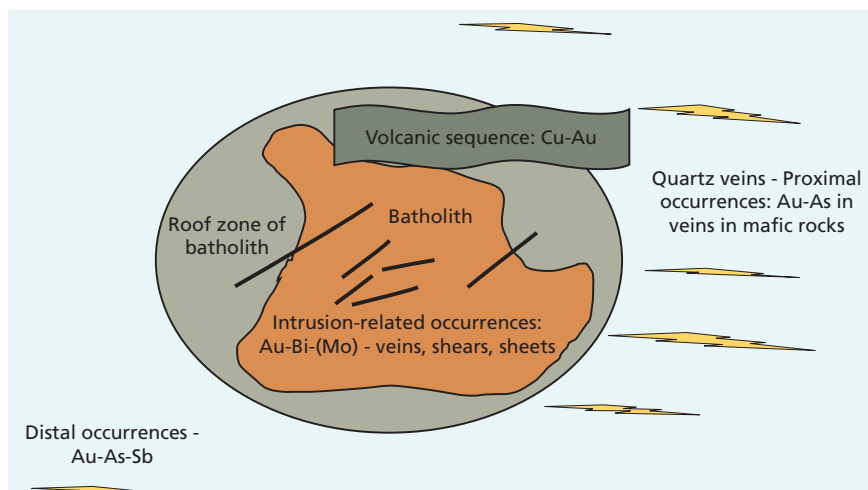
Within the batholith, gold is associated to veins, shears, and sheets in a Au-Bi-W-(Mo) type of mineralisation with disseminated gold. Capping the batholith a Cu-Au association is found in mafic volcanic rocks. Proximal to the batholith quartz veins are carrying Au-As mineralisation in mafic rocks, presently the most promising (e.g. Nalunaq).

Concluding remarks

Gold mineralised occurrences in South Greenland are demonstrated to be located within two major geological environments, the Archaean and the Palaeoproterozoic. During exploration activity in the 1980s and the 1990s the knowledge about gold-mineralisations has been increased and refined and consequently the potential for locating viable gold deposits in the future has improved. As the result of recent exploration and research, the new mine expected to be in operation soon (2003) at the Nalunaq deposit in the southernmost part of Greenland, may signal the opening of a 'golden' period in South Greenland.



Rusty aplite sill, 5 m wide, near Igutsaat.



Schematic presentation of the ore setting in South Greenland.

Key references

Erfurt, P. 1990: Reconnaissance and exploration for gold and base metals in the area between Arsuk and Neria Fjords, South-West Greenland. Work performed 1971 to 1985: Results and discussion. Open File Series Grønlands Geologiske Undersøgelse 90/10, 30 pp.

Evans, D.M. & King, A.R. 1993: Sediment and shear-hosted gold mineralization of the Tartoq Group supracrustals, southwest Greenland, Precambrian Research 62, 61–82.

Gowen, J., Christiansen, O., Grahl-Madsen, L., Pedersen, J., Petersen, J.S. & Robyn, T.L. 1993: Discovery of the Nalunaq Gold Deposit, Kirkespirdalen, SW Greenland. International Geology Review 35, 1001–1008.

Mosher, G. 1995: Summary of mineral occurrences and mineral exploration potential of South Greenland (Sheet 1 – Geological map of Greenland). Open File Series Grønlands Geologiske Undersøgelse 95/3, 35 pp.

Schjøth, F., Garde, A.A., Jørgensen, M.S., Lind, M., Moberg, E., Nielsen, T.F.D., Rasmussen, T.M., Secher, K., Steenfelt, A., Steendal, H., Thorning, L. & Tukiainen, T. 2000: Mineral resource potential of South Greenland, Danmarks og Grønlands Geologiske Undersøgelse Rapport 2000/57, 36 pp, CD-Rom included.

Secher, K. & Kalvig, P. 1987: Reconnaissance for noble and base metal mineralisation within the Precambrian supracrustal sequences in the Ivigtut-Kobberminebugt region, South-West Greenland. Rapport Grønlands Geologiske Undersøgelse 135, 52–59.

Steenfelt, A. 2001: Geochemical atlas of Greenland – West and South Greenland, Danmarks og Grønlands Geologiske Undersøgelse Rapport 2001/46, 40 pp.

Steenfelt, A., Nielsen, T.F.D. & Stendal, H. 2000: Mineral resource potential of South Greenland: review of new digital sets. Danmarks og Grønlands Geologiske Undersøgelse Rapport 2000/50, 47 pp.

Stendal, H. (ed.) 2000: Exploration in Greenland: discoveries of the 1990s. Transactions of the Institution of Mining and Metallurgy, section B, Applied earth science 109, B1-B66.

Stendal, H., Grahl-Madsen, L., Olsen, H.K., Schönwandt, H.K. & Thomassen, B. 1995: Gold exploration in the early Proterozoic Ketilidian Orogen, South Greenland. Exploration and Mining Geology 4, 307–315.

Front cover photograph:

Gold exploration in Ketilidian rocks, Danell fjord, SE Greenland.



The valley down slope from the Nalunaq deposit. The valley was originally named after the steep mountain (middle-upper part) 'Kirkespiret' ('the church steeple'), 1590 m a.s.l.



GREENLAND RESOURCES A/S

Greenland Resources A/S
Tuapannguit 38
P.O. Box 821
DK-3900 Nuuk
Greenland

Tel: (+299) 32 79 13
Fax.: (+299) 32 79 14
E-mail: gras@greenet.gl
Internet: www.resources.gl



Bureau of Minerals and Petroleum
(BMP)
Government of Greenland
P.O. Box 930
DK-3900 Nuuk
Greenland

Tel: (+299) 34 68 00
Fax.: (+299) 32 43 02
E-mail: bmp@gh.gl
Internet: www.bmp.gl



GEUS

Geological Survey of Denmark
and Greenland (GEUS)
Øster Voldgade 10
DK-1350 Copenhagen K
Denmark

Tel: (+45) 38 14 20 00
Fax.: (+45) 38 14 20 50
E-mail: geus@geus.dk
Internet: www.geus.dk

Authors:

Henrik Stendal & Karsten Secher

Graphic Production:

Carsten Thuesen, GEUS

Editor: Karsten Secher, GEUS

Printed: 31st of July, 2002

Printers: FROM & CO