DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2013/56

Sediment-hosted zinc potential in Greenland

Reporting the mineral ressource assessement workshop 29 November – 1 December 2011

Lars Lund Sørensen, Bo Møller Stensgaard,
Kristine Thrane, Diogo Rosa & Per Kalvig

GEOLOGICAL SURVEY OF DENMARK AND GREENLAND
DANISH MINISTRY OF CLIMATE, ENERGY AND BUILDING

G E U S

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(1 CD-Rom included)

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Executive summary

Quantitative information on mineral resources is required among decision makers from governmental agencies and the private mining sector. In response to this, in 2002, the United States Geological Survey (USGS) initiated the project ’Global Mineral Resource Assessment Project’ (GMRAP), with the primary objective to identify the principal areas in the world with potential for selected undiscovered mineral resources, in the uppermost one kilometre of the crust, using available compiled information and modern quantitative statistical models.

The GMRAP is being conducted on a regional-multinational basis for selected deposit models and commodities, and on a global scale, coordinated by the USGS, by compiling information from the regional assessments. The Greenlandic Bureau of Minerals and Petroleum (BMP) and the Geological Survey of Denmark and Greenland (GEUS) are participants in the GMRAP-project and hosted a GMRAP workshop on sedimentary-hosted copper in 2008 (Stensgaard *et al.* 2011). Subsequently, additional assessment workshops have been undertaken at GEUS and BMP on other commodities and mineral deposit models. These workshops have however not been carried out under the auspices of the official USGS GMRAP program, but have, when possible, utilised the standard rules and methodologies set by the GMRAP program.

The assessment workshop for 2011 was chosen by BMP and GEUS to be focused on the potential for undiscovered sediment-hosted zinc deposits in Greenland. The two mineral deposits that were assessed Sedimentary Exhalative (SEDEX) and Mississippi Valley Zn-Pb-Ag deposit types.

The workshop applied the standardised methodology, defined for the GMRAP assessments involving the ‘Three-Part Form’ assessment approach, including, (i) delineation of tracts of land where the geology is permissive for sediment-hosted zinc deposits to form; (ii) selection of grade and tonnage models appropriate for estimating grades and tonnages of the undiscovered sediment-hosted zinc deposits in each tract; and (iii) estimation of the number of undiscovered sediment-hosted zinc deposits in each tract consistent with the grade and tonnage model.

Based on a discussion and evaluation of all available information and data for defined tracts found to be permissive for sediment-hosted zinc, the individual members of the assessment panel provided bids at different confidence levels on how many deposits of a certain size and a certain grade would be possible to find, under the best possible circumstances. After the individual bids, these were discussed and argued until the assessment panel agreed on a consensus opinion on the numbers of undiscovered sediment-hosted zinc deposits. The consensus bid was then used as inputs to a Monte Carlo simulation computer program (EMINERS developed by the USGS), combining the probability distributions of the estimated number of undiscovered deposits, the grades, and the tonnages of the selected model to obtain the probability distributions for undiscovered metals in each tract.

Sedimentary basin environments constitute approximately 40% of Greenland's ca. 410,000 km^2 ice-free land area, and several of the basins host zinc mineralisations. The workshop considered two deposit types; Sedimentary Exhalative (SEDEX) type and Mississippi Valley type (MVT) that accounts for more than 50% of the world's known zinc reserves. A third type; the Volcanic Massive Sulphide type (VMS), that accounts for around 30% of the world's zinc reserves, were not assessed at the workshop due to lack of time.

In the course of the workshop a total of 23 estimations of undiscovered sediment-hosted zinc deposits in defined tracts were assessed in strict accordance with the guidelines for the 'Three-Part Form' assessment approach. The assessment made it obvious that only very scarce information is available for most of the tracts as many areas only have seen limited to none exploration and investigation campaigns.

The expected number of undiscovered SEDEX and MVT deposits in Greenland was estimated to be 8 and 5 respectively with a statistical simulated estimated total mean of undiscovered zinc resources of 24.8 million tons (Zn metal).

These estimates should be used with great caution and should be regarded as an uncertain statistical estimate that reflects the present level of knowledge and investigations that have been undertaken in the assessed tracts. To a large degree, it also reflects the confidence level of the estimated number of undiscovered zinc deposits within the tracts that have been assessed.

The circumstances that the large majority of assessed tracts lack sufficient information and data for an absolute assessment, should give rise to even more cautions when using the estimated zinc resource value. New information, new discoveries, new investigations etc. within a tract should thus, if possible, be taken into account when evaluating an area, as this could either decrease or increase the estimated value.

The bids on undiscovered zinc deposits made by the assessment panel team at different confidence levels and the increase in numbers from one confidence level to another are perhaps the most important information to consider. Deviations from one level to another reflect the level of knowledge about the various areas and the overall assessment of the potential and prospectivity within the areas. Also, deviations between various team members of the panel, may indicate a different level of knowledge amongst members or a difference in rational behind the bids.

The assessment panel team agreed that the largest potential for large grade-tonnage deposits of the SEDEX zinc type was within (i) the trough sequence within the Franklinian Basin in North Greenland, (ii) the Etah Group of the Inglefield mobile belt in North-West Greenland, (iii) the Rivieradal and Hagen Fjord Groups in the Hekla Sund Basin in eastern North Greenland, and (iv) the Foldvik Creek successions in the Jameson Land Basin in central East Greenland.

The biggest potential for MVT-type zinc deposits was agreed to be within (i) the carbonate shelf-platform of the Franklinian Basin in North Greenland, (ii) the Foldvik Creek succession in the Jameson Land Basin in central East Greenland and (iii) the Mârmorilik Formation of the Karrat Group in West Greenland.

Introduction

Quantitative information about the general locations and amounts of undiscovered mineral resources is important to exploration managers, land-use and environmental planners, economists, and policy makers. On this background USGS initiated GMRAP in 2002, with the primary objective to identify the principal areas, globally, that have potential for selected undiscovered mineral resources, in the uppermost 1 km of the crust.

The GMRAP makes use of available compiled information about geology, geochemistry, geophysics, and previous exploration results in the context of modern quantitative statistical models.

The GMRAP is being conducted on a regional-multinational basis for selected deposit models and commodities, and on a global scale, coordinated by the USGS, by compiling information from the regional assessments.

The BMP and GEUS are participants in the GMRAP-project and hosted a GMRAP workshop on sedimentary-hosted copper in 2008 (Stensgaard *et al.* 2011). Subsequently, additional assessment workshops have been undertaken at GEUS and BMP on other commodities and mineral deposit models. These workshops have not been carried out under the auspices of the official USGS GMRAP program, but have, when possible, utilised the standard rules and methodologies set by the GMRAP program. The assessment workshop for 2011 was chosen by BMP and GEUS to be focused on the potential for undiscovered sediment-hosted zinc deposits in Greenland. The workshop was held from 29 November - 1 December 2011 at GEUS in Copenhagen.

A standardized methodology has been defined for the GMRAP assessments based on a 'Three-Part Form' assessment approach, which, in this case, includes, (i) delineation of tracts of land where the geology is permissive for sediment-hosted zinc deposits to form; (ii) selection of grade and tonnage models appropriate for estimating grades and tonnages of the undiscovered sediment-hosted zinc deposits in each tract; and (iii) estimation of the number of undiscovered sediment-hosted zinc deposits in each tract consistent with the grade and tonnage model.

The assessment panel team for this workshop constituted thirteen geologists from research and government institutions; USGS, BMP, GEUS and private exploration companies, each of whom have knowledge on aspects of Greenlandic geology and/or expertise in sediment-hosted zinc deposits.

The initial tracts with potential of hosting non-discovered sediment-hosted zinc deposits were defined and delineated by an internal GEUS assessment group prior to the workshop. Based on a discussion and evaluation of all available information and data for defined tracts found to be permissive for sediment-hosted zinc, the individual members of the assessment panel provided bids at different confidence levels on how many deposits of a certain size and a certain grade would be possible to find, under the best possible circumstances. After the individual bid rounds, the individual bids were discussed and argued until the assessment panel agreed on a consensus opinion on the numbers of undiscovered sediment-hosted zinc deposits. The consensus bid was then used as input to a Monte Carlo simulation computer program (EMINERS), combining the probability distributions of the estimated number of undiscovered deposits, the grades, and the tonnages of the selected models to obtain the probability distributions for undiscovered metals in each tract.

The purpose with the report is threefold:

- To present the discussions, comments and evaluation that took place at the assessment workshop,
- to present the subsequently quantitative estimations of undiscovered zinc resources in Greenland and finally,
- to provide the reader with a review of the regional geology, exploration history and known prospects, mineral occurrences or related deposit types for the different areas that were determined to be permissive for sediment-hosted zinc deposits.

The reviews are mainly extracted from existing literature. It is the intention that each review and each individual tract assessment can be accessed on its own. The report can be read in its full length or as separate sections. Also, in order to enable the reader to gain an overview of the overall results before turning to the evaluation of the individual assessed permissive tracts, the conclusion is placed in front of the report.

Assessed deposit types

The following sections describe the criteria and characteristics that were used by the assessment panel when tracts were assessed for sediment-hosted zinc.

Deposit models covered

For each tract the assessment panel has dealt with the following types of deposit models and their associated grade and tonnage models:

Sedimentary exhalative deposits (SEDEX):
When a tract was assessed for SEDEX type deposits the following mineral deposit model and associated grade-/tonnage model were used:

- <u>Deposit model:</u> Emsbo, P. 2009: Geologic criteria for the assessment of sedimentary exhalative (SEDEX) Zn-Pb-Ag deposits: U.S. Geological Survey Open-File Report 2009−1209, 21 p.
- <u>Grade-/Tonnage Model:</u> Taylor *et al.* 2009: Compilation of mineral resource data for Mississippi Valley-type and clastic-dominated sediment-hosted lead-zinc deposits: U.S. Geological Survey Open-File Report 2009–1297, 42 p.
- <u>Synonyms:</u> Sediment-hosted Zn-Pb deposits are hosted in a variety of sedimentary rocks and have commonly been classified into skarns, polymetallic replacements, Mississippi Valley Zn-Pb (MVT), Sedimentary-exhalative Zn-Pb (SEDEX), sandstone-hosted Pb, Kipushi, and polymetallic vein types. Some of these types have been further subdivided by various authors.

Carbonate-hosted zinc deposits (alias Mississippi Valley-Type; MVT):
When a tract was assessed for MVT type deposits the following mineral deposit model and associated grade-/tonnage model were used:

- <u>Deposit model:</u> Leach *et al.* 2010: A deposit model for Mississippi Valley-Type lead-zinc ores, chap. A of Mineral deposit models for resource assessment: U.S. Geological Survey Scientific Investigations Report 2010–5070–A, 52 p.
- <u>Grade-/Tonnage Model:</u> Taylor *et al.* 2009: Compilation of mineral resource data for Mississippi Valley-type and clastic-dominated sediment-hosted lead-zinc deposits: U.S. Geological Survey Open-File Report 2009–1297, 42 p.
- <u>Synonyms:</u> Numerous sub-types and alternative classifications applied to MVT include but not limited to: Viburnum Trend-, Alpine-, Silesia-, Irish-, Appalachian-, and Reocin-type. A discussion of these sub-types and classification issues is presented in Leach *et al.* (2005).

An operational classification (see Appendix B) for sediment-hosted zinc-lead according to the observed rocks reported in maps (shale, carbonate and mixed sediments) rather that unobservable detailed characteristic within undiscovered deposits has been suggested by

Singer *et al.* (2009). Although the deposit models by Emsbo (2009) and Leach *et al.* (2010) were used for the assessment, it was found useful also to consider the operational classification scheme in the discussion and the heading for the different tracts partly refers to this scheme and the mineral deposit model. The abbreviations used in the headings for the operational classification is given here below (see also Appendix B):

CAam	**CA**rbonate-hosted **am**agmatic
CAig	**CA**rbonate-hosted and **ig**neous related
CAme	**CA**rbonate-hosted exhibiting high-grade **me**tamorphism
SHam	**SH**ale-hosted amagmatic
SHig	**SH**ale-hosted and **ig**neous related
SHme	**SH**ale-hosted exhibiting high-grade **me**tamorphism
MLam	**M**ixed **L**ithology-hosted **am**agmatic
MLig	**M**ixed **L**ithology-hosted and **ig**neous related
MLme	**M**ixed **L**ithology-hosted exhibiting high-grade **me**tamorphism

<u>Definition:</u>
Carbonate (CA): This category includes rocks of massive carbonate sequences and carbonate-shale intercalations. Singer *et al.* (2009) reports that fifty per cent of these deposits are hosted by dolomite and dolomitic rocks and 50 per cent by limestone. The “dolomite index” increases to 72 per cent in SEDEX and to 62 per cent in MVT deposits. Carbonaceous rocks, mainly interlayered shale, only occur in 8 per cent of these predominantly carbonate-hosted deposits (17 per cent in SEDEX).

Shale (SH): This lithological category includes argillite, mudstone, phyllite, siltstone, and slate, according to terminologies from original descriptions of deposits. Singer *et al.* (2009) reports that forty-seven per cent of deposits of the group are hosted by dolomitic shale and/or shale associated with dolomite in the ore-hosting strata. Carbonaceous (or graphitic) shale is characteristic for 62 per cent of the deposits. A presence of tuff and tuffaceous rocks is noted in 42 per cent of the deposits.

Mixed lithology (ML): According to Singer *et al.* (2009) this category could be considered “questionable” or “problematic” because the group includes highly metamorphosed deposits, such as Broken Hill, where researchers interpreted either sedimentary or volcanic original rock compositions. It is possible that host rocks of such deposits had contained mafic (amphibolite) and felsic (mica schist) volcanics, as well as carbonate rocks (calc-silicate rocks) and clastic rocks (mica schist). The group mostly coincides with the Broken Hill-type (BHT) in popular classifications. BHT really is characterized by complex mixed lithology, including such exotic rocks as garnet quartzite, gahnite quartzite, tourmalinite, and sulphide-bearing iron-formation.

Amagmatic (am): includes deposits without igneous manifestations and signs of contact metamorphism in the deposit area and vicinity. Regional metamorphism of country rocks range from “unmetamorphosed” to pre-greenschist and greenschist facies.

Igneous related (ig): consists of deposits with various igneous intrusions, including sills and numerous dikes, and signs of contact metamorphism of country rocks in the deposit area or in its vicinity, independent of the grade of regional metamorphism. Igneous events that are clearly older than host rock were ignored. Also not counted were ultramafic rocks, basalt sills, and diabase dikes. All polymetallic replacement and skarn deposits are in this category. SEDEX and a few MVT deposits affected by intrusions and contact metamorphism can have similar complicated mineralogical ore compositions that may be difficult to distinguish from skarns and re-placements.

Metamorphic (me): includes deposits exhibiting high-grade metamorphism of amphibolite to amphibolite-to-granulite facies including 20 deposits commonly classed as SEDEX and generally hosted by Proterozoic rocks with single Cambrian rock ages. Aside from carbonate marble beds, the original host-rock lithology cannot be recognized reliably. Mineralogical ore compositions are close to deposits of the previous category (ig) but are not as diverse. Data on this category are scarce.

Characteristics of sediment-hosted zinc deposits

Sediment-hosted Pb-Zn deposits contain the world's greatest lead and zinc resources and dominate world production of these metals. They are a diverse group of ore deposits hosted by a wide variety of carbonate and siliciclastic rocks that have no obvious genetic association with igneous activity. A range of ore-forming processes in a variety of geologic and tectonic environments created these deposits over at least two billion years of Earth history (see Figure 1 & Figure 2). The metals were precipitated by basinal brines in synsedimentary and early diagenetic to low-grade metamorphic environments. The deposits display a broad range of relationships to enclosing host rocks that includes stratiform, strata-bound, and discordant ores (Leach *et. al* 2005).

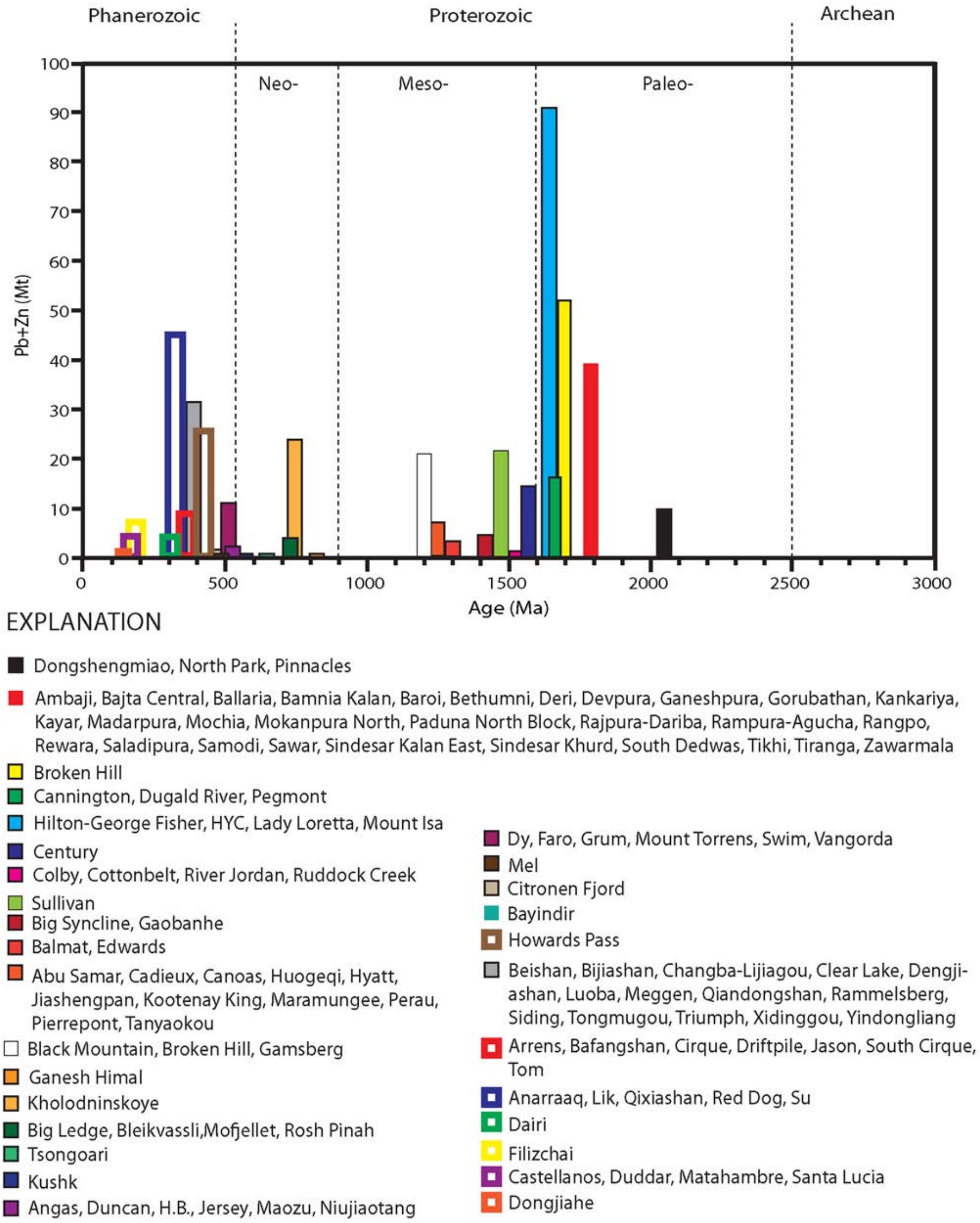


Figure 1. *Clastic-dominated lead-zinc deposits through time. Ages based on direct dating of ore mineralisation or age of host-rock. Explanation list ordered from oldest to youngest deposits. From Taylor et al. (2009).*

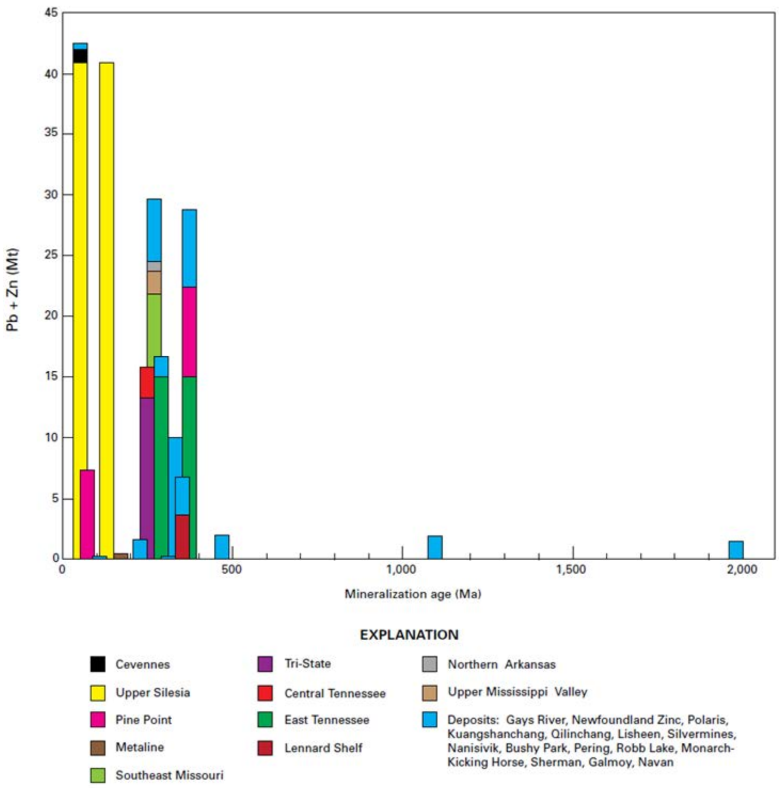


Figure 2. *Secular distribution of Mississippi Valley-type deposits and districts with palaeomagnetic and/or radiometric ages of mineralisation. From Leach et al. (2010).*

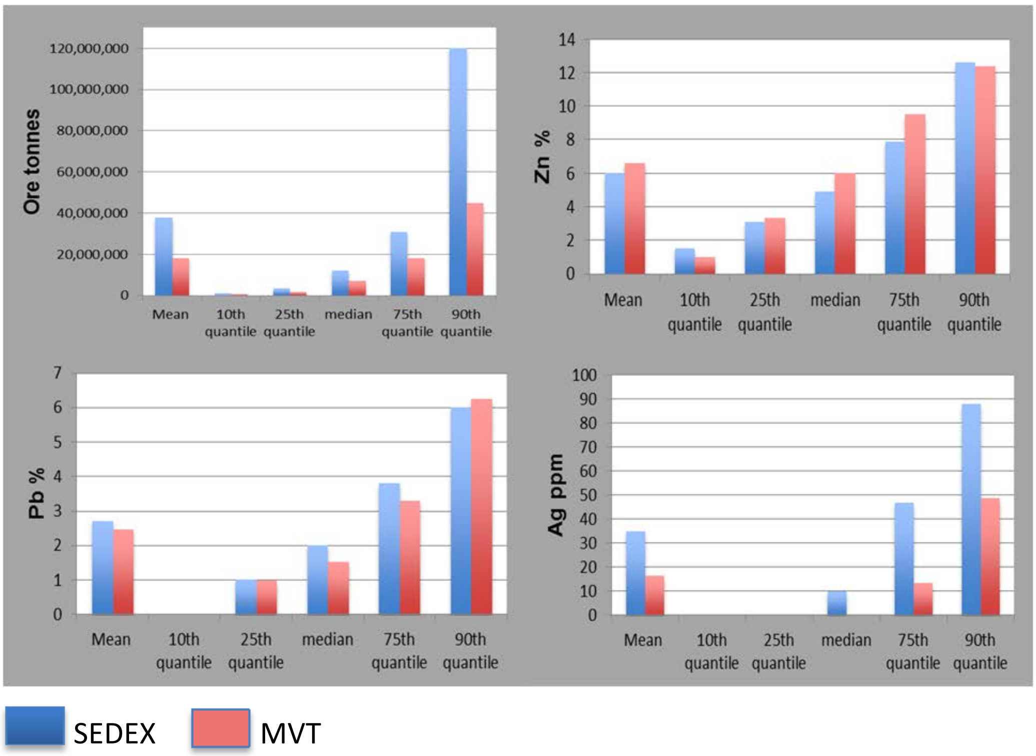


Figure 3. *Distribution of SEDEX vs. MVT on a global scale (million metric tons) and the statistic distribution of Zn, Pb and Ag. From workshop presentation by Emsbo (2011); see Appendix C.*

In general, some global scale features that characterize SEDEX and MVT type zinc deposits are:

SEDEX deposits

SEDEX deposits are finely laminated or bedded sulphide ore deposits, interpreted to have formed by release of ore-bearing hydrothermal fluids into a water reservoir, usually the ocean, resulting in the precipitation of stratiform ore. SEDEX deposits are hosted in rift-generated intracratonic or epicratonic sedimentary basins, often related to a nearby carbonate platform. Deposits occur in carbonaceous shales in basin sag-phase carbonate rock, shale or siltstone facies mosaics that were deposited on thick sequences of rift-fill conglomerates, red beds, sandstones or siltstones and mafic or felsic volcanic rocks (see conceptual model below). SEDEX deposits account for more than 50 per cent of the world's zinc and lead reserves and furnish more than 25 per cent of the world’s production of these two metals. More than 129 deposits of this type have been recognized in sedimentary basins around the world. The statistic distribution of ore tonnes, Zn-, Pb- and Ag-grades for SEDEX are given in Figure 3. A compilation by Sangster & Hillary (2000) show that the largest 65 deposits occur in 25 sedimentary basins, 6 of which contain more than 10 metric tons (Mt) combined Pb+Zn. In order of decreasing endowment these are Mt. Isa–McArthur basins (7 deposits totalling 112 Mt of Zn+Pb metal), Selwyn basin (17 deposits totalling 55 Mt), Brooks Range (3 deposits totalling 40 Mt), Rajasthan (5 deposits totalling 20 Mt), Belt-Purcell (1 deposit totalling 19 Mt), and the Rhenish Basin (2 deposits totalling 11 Mt) (Emsbo 2009). A summary of the overall characteristics of SEDEX models are illustrated in Figure 4.

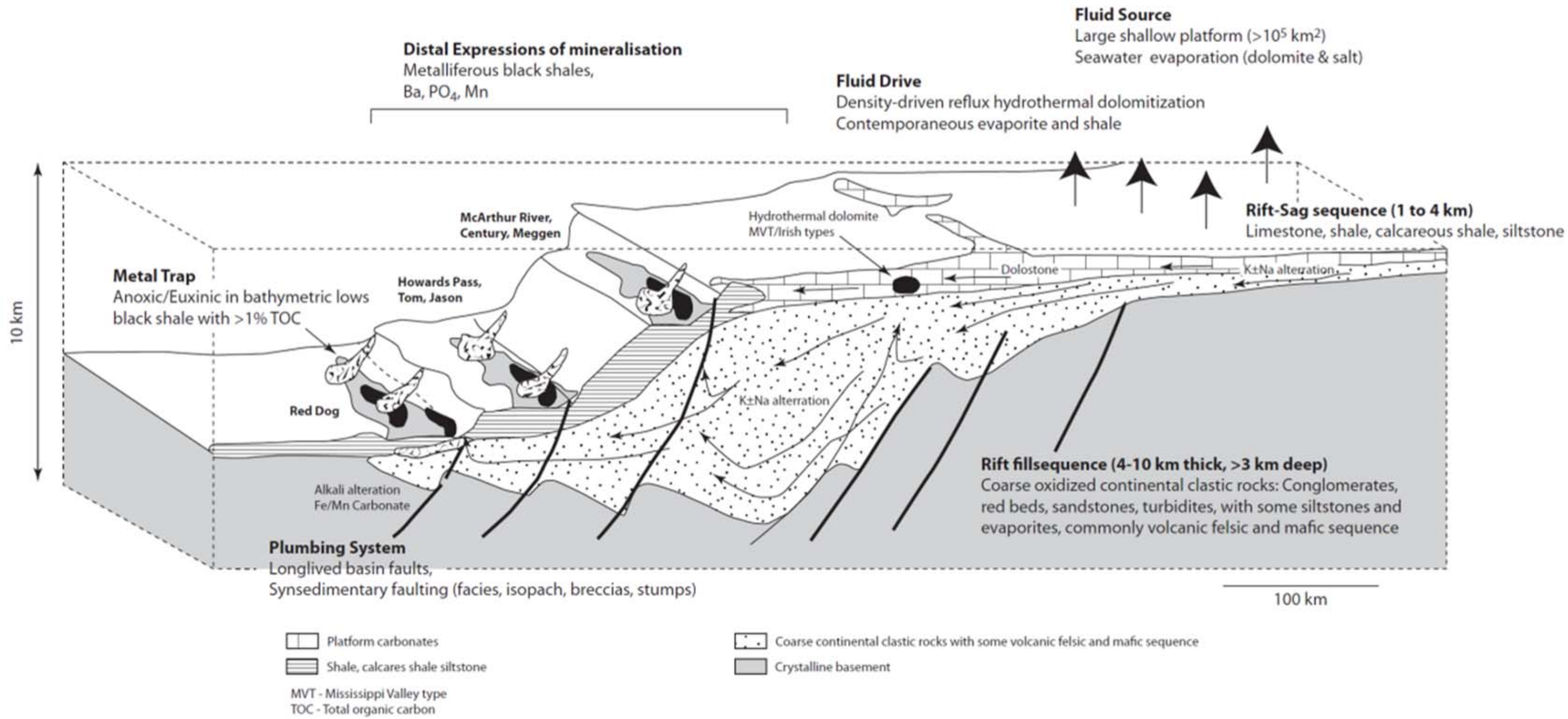


Figure 4. *Conceptual model of the geologic setting and geologic assessment criteria for SEDEX Zn-Pb-Ag deposits. Modified from Emsbo (2009). Grey arrows represent fluid-flow paths inferred from the distribution of altered rocks and an on-going (in 2009) USGS numerical fluid flow-modelling project. The locations of several important SEDEX deposits relative to the shallow-water platform margin are indicated and may reflect the structural architecture of the basin or the maturity of the rift cycle.*

MVT deposits

MVT ore deposits are important and have valuable concentrations of zinc sulphide ore hosted in carbonate (limestone, marl and dolomite) formations. The most important ore controls are faults and fractures, dissolution collapse breccias and lithological transitions. Most MVT deposits are hosted in Phanerozoic rocks and are significantly less common in Proterozoic rocks. MVT ores are located in carbonate platform sequences in passive margin environments and are commonly related to extensional domains landwards of contractional tectonic belts (see Figure 5 for conceptual model). MVT deposits have a median size of 7 Mt and grades of about 7.9 wt. per cent lead (Pb) and zinc (Zn) metal. MVT deposits usually occur in extensive districts consisting of several to hundreds of deposits (Leach *et al*. 2010).

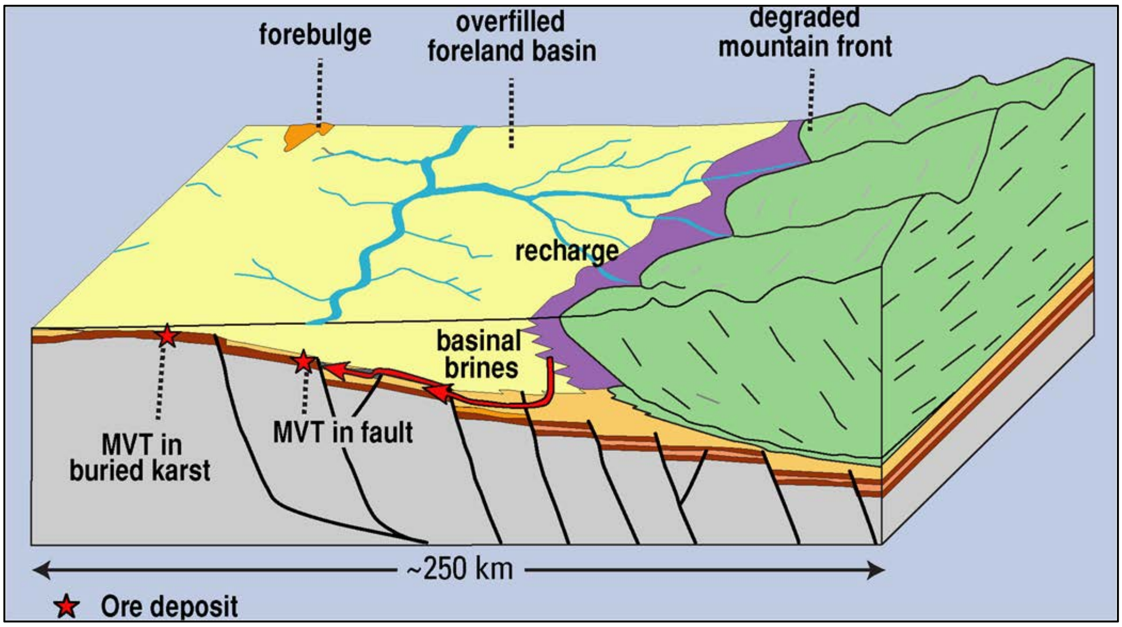


Figure 5. *Conceptual model of the geologic setting and geologic assessment criteria for MVT Zn-Pb-Ag deposits. Red arrows represent fluid-flow paths and red stars represent important sites for deposition of MVT type deposits. From workshop presentation by Emsbo (2011); see Appendix C.*

Sedimentary environments and permissive tracts

SEDEX

According to Emsbo (2009) an area must have the following attributes to be considered permissive/favourable for hosting large SEDEX-type deposits:

- **Intracratonic or epicratonic sedimentary basin:** All SEDEX deposits occur in intracratonic or epicratonic sedimentary basins. Thus an intracratonic or epicratonic sedimentary basin is a prerequisite for this deposit type.

- **Depth to crystalline basement greater than 3 km:** It has been well established that fluid temperatures in excess of 100°C are required to form a SEDEX deposit.

Empirical observations and the current understanding of the thermal regimes of sedimentary basins indicate that at least 3 km of sediment fill is required to achieve these temperatures.

- **Organic-rich black shale or siltstone with greater than 1 per cent C_{org}:** A shale unit with greater than 1 per cent C_{org} is essential for SEDEX-ore formation and must be identified for an area to be permissive.

- **Brine salinity source:** Saline brine (>17 per cent Total Dissolved Salts) is necessary to form a SEDEX deposit. Basin-scale processes are required to produce the volume of brine necessary to form a deposit. Thus, direct geologic evidence for saline brine generation (such as evaporite minerals, breccias indicating salt dissolution or escape, or regional dolomitized platforms sequences) is required. In the rare case where platform margins are obscured or missing owing to erosion or tectonic disruption, palaeolatitude reconstructions can be used to determine if a basin was at a latitude permissive of seawater evaporation during its history.

Emsbo (2009) also describes that many of the defined geologic criteria, though not adequate to limit permissive tracts, directly implicate basin and hydrothermal processes that may influence estimates of number, size, and density of undiscovered deposits within permissive tracts. These can be used to address the tract prospectivity; meaning level of favourability for finding SEDEX deposits. Such criteria are listed below in order of decreasing importance:

- **Already discovered SEDEX deposits or occurrences:** All known SEDEX basins contain multiple deposits in multiple horizons. Thus, the occurrence of SEDEX-ore mineralisation is the strongest indicator of a prospective basin.

- **Coeval evaporative platform and organic-rich basinal sediments:** The analysis of the six most fertile SEDEX-ore-hosting basins reveals that they contain 12 mineralising episodes that correspond with discrete periods of intense evaporation of seawater on the platform and the formation of regional shales anomalously enriched in organic matter. The implication is that these phenomena are related to ore formation and that their coincident occurrence is a strong indicator of SEDEX-ore formation.

- **Large evaporative shallow-water marine epeiric carbonate platform margins**: The empirical and genetic relationships documented here suggest that carbonate platforms are the source of ore brines and provide the fluid drive to form SEDEX deposits. The occurrence of multiple episodes of mineralisation in the six most-fertile SEDEX basins suggests that, once the proper basin architecture is established, SEDEX deposits will form when the basin is exposed to the proper climatic and palaeolatitude conditions for brine generation.

- **Oxidized rift-phase sediments:** Empirical observation, radiogenic isotope studies, and chemical or fluid-flow modelling show that 2-4 km-thick sequences of syn-rift coarse, continental, clastic sediments (conglomerates, red beds, sandstones, turbidites, and subordinate volcanic successions) provided the metals for SEDEX deposits. Oxidized (low C_{org} and high reactive Fe), permeable sequences at depths greater than 3 km are ideal. Mass balance estimates of leachable metal suggest that the volume of these rocks within a given basin may provide an upper limit to the total amount of metal available for ore formation.

- **Evidence of hydrothermal activity:** The large volume of fluids required to form SEDEX deposits leave alteration footprints that can be recognized on the basin scale. This evidence can include extensive dolomitisation of platform carbonate rocks and pervasive alkali-alteration of clastic sediment aquifers. On the local scale, strong mineralogical and chemical alteration along growth faults and alteration and metal halos can be used to vector toward the deposits.

- **Distal signatures of mineralisation:** Regional shales anomalous in C_{org}, metals, and sedimentary Ba, Mn, Fe, and PO_4 deposits are strong indicators of SEDEX deposits.

- **Chemical composition of already discovered mineralisation:** Varying proportions of base metals, baryte, and gold may ultimately reflect the lithology and redox buffering capacity of basin-fill sediments in the metal source regions, which may be a highly useful indicator for deposit formation, metal endowment, and prospectivity of a sedimentary basin.

- **Age of the basin:** The requirement of marine sulfate as a source of reduced sulphur may limit SEDEX deposit formation to Proterozoic and Phanerozoic time. The correspondence of known SEDEX deposits with regional and perhaps global, anoxic events may identify periods of time that are favourable for additional discoveries.

According to Emsbo (2009) the following geologic criteria map favourability within permissive tracts themselves:

- **Basin architecture:** On a regional scale, areas within tens of kilometres of large, long-lived basin-bounding faults that controlled second-order basin features are highly favourable. The close association of synsedimentary faults (recognized by features in the regional to local stratigraphy or basin architecture such as abrupt and truncated facies boundaries in platform-to-slope transition, thick debris flows, intraformational breccias, changes in isopachs, and synsedimentary slump structures) indicates favourable stratigraphic horizons and can be used to vector toward structures that may have been ore-fluid conduits.

- **Geochemical anomalies or zoning:** On a local scale, increasing organic matter and pyrite, and trace element concentrations (and ratios) in reduced sediments can be used as vectors toward areas favourable for ore. Hydrothermal alteration composed of Fe- and Mn-rich carbonate rocks or silicification (or both) allows identification of mineralising faults on a local scale.

- **SEDEX deposits or occurrences:** It is common for multiple SEDEX deposits to be distributed many tens of kilometres along basin-controlling faults. Thus, areas along large fault systems with evidence of mineralisation should be viewed as very favourable for undiscovered deposits.

MVT

According to Leach *et al.* (2010) an area must have the following favourabilities to be considered permissive for hosting MVT-type deposits:

Regional scale favourability:

Neoproterozoic and Phanerozoic platform carbonate sequences located less than ~600 km inboard of Phanerozoic orogenic belts, especially those related to faults and deformation features associated with Pangean and neocontinental supercontinent assembly in Devonian to Early Triassic and Cretaceous to Tertiary time, have the potential for MVT deposition. There is increased favourability in platform carbonate sequences deformed by oblique convergent orogens. Favourability also occurs in Phanerozoic-Neoproterozoic deformed intracratonic basins, with the presence of folds, swells and arches in platform sequences, and with the presence of trace sphalerite and galena in apparently unmineralised rock. There is a low potential on undeformed passive margin carbonate platforms, but it is permissive (Lennard Shelf model). Consideration should be given to the fact that a single MVT deposit is unlikely to be the only one in the region because MVT deposits are the result of large regional occurrences.

Most common favourable factors include:

- Increasing fault density yields increasing favourability.
- Transtensional, wrench, strike-slip, and fore bulge normal faults are most favourable.
- Evidence of evaporative facies in regional carbonates (gypsum and salt casts). Bedded evaporite sequences.
- Presence of karstification (meteoric or hydrothermal).
- Widespread trace and minor occurrences of MVT mineralisation.

Other favourable factors include:

- Presence of regional oxidized basal sandstones.
- Presence of regional aquifers, especially those having a hydrological connection to an orogenic front.
- Presence of reef and barrier facies.
- Presence of regional aquitards (regional fine-grained limestone and shales) with overlying and underlying aquifers.
- Rapid transition of basin sediment to basement contacts (in other words, basement relief) and rapid facies changes (in other words, shale to carbonate transitions, back reef to fore reef facies).
- Presence of regional sparry hydrothermal dolomite.
- Indicators of anomalous regional temperatures unrelated to igneous occurrences.

Geochemical and alteration considerations:
According to Leach *et al.* (2010) most deposits have only limited lithogeochemical halos, but some have regional lithogeochemical zoning. Disseminated pyrite and marcasite may occur as 'blankets' around some deposits. Hydrothermal dolomitization may be present in some regions but only useful as a mineralisation guide in a few districts. Silicification is uncommon. Districts may be characterized by widespread base metal anomalies in stream sediment, soil, and rock-chip sampling. However, use of geochemistry can define or prioritize discrete drill targets.

Surficial zinc anomalies may be useful in exploration; however, care must be taken as not all zinc anomalies are associated with economic mineralisation. For example, shales in the Western Canadian Sedimentary Basin have large background zinc contents that are similar to values associated with orebodies. Anomalous Pb and Zn contents found through soil geochemistry, stream-sediment analysis, and boulder tracing have been successfully used as methods of discovery. The use of "zinc zap" may aid in the discovery of supergene zinc deposits; when this chemical mixture is sprayed, a vibrant scarlet colour forms on secondary Zn-minerals.

Sedimentary environments and permissive tracts
Sedimentary zinc occurrences have been identified in many of the known sedimentary environments in Greenland and many of the areas are anomalous in zinc as depicted on the geochemical plot of stream sediment samples on Figure 6.

In order to undertake the quantitative mineral resource assessment, tracts of land permissive for the occurrence of undiscovered mineral deposits, have been delineated, in accordance with the following rules:

i) All tracts of land where the geology is permissive for the occurrence of the undiscovered mineral deposits are delineated such that the probability of a deposit being outside of a tract is negligible; and

ii) The tracts are subdivided where reasons exist to suspect spatial differences in the density or probability of occurrence of undiscovered deposits within the tracts.

The tract proposals, defined by an internal GEUS assessment group prior to the workshop, served as the basis for the discussions. In the course of the workshop the tract proposals were modified according to the consensus view of the assessment panel, and in some cases, additional tracts were added. All tracts were defined in a GIS environment and digitally accessible data relevant for the assessment was compiled and made available.

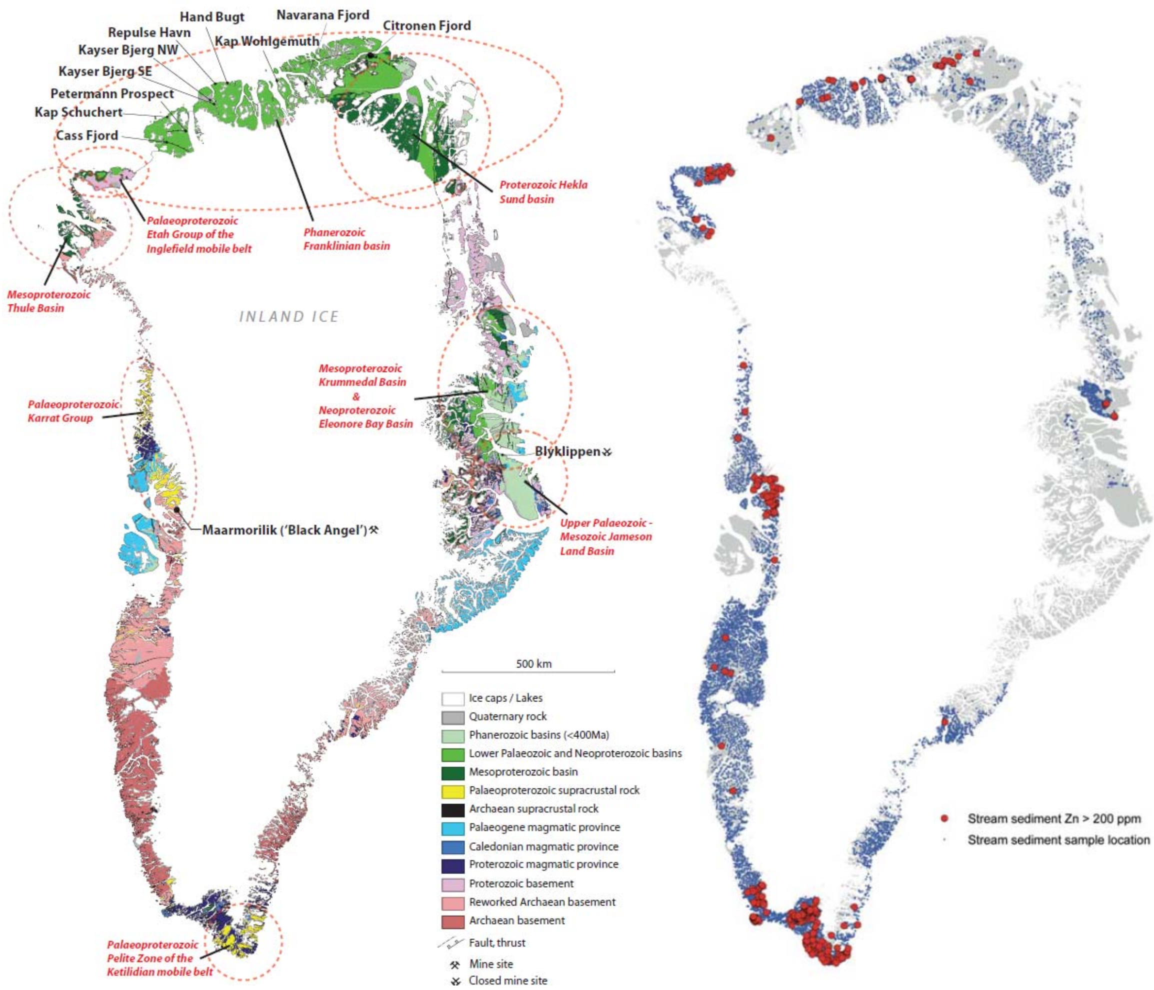


Figure 6. ***(Left)*** *Simplified geological map indicating main lithostratigraphic environments (with red text) and selected known zinc occurrences in Greenland. Distribution of the different sedimentary environments that were assessed during the workshop is also indicated on the map.* ***(Right)*** *Total distribution of stream sediment localities in Greenland and indication of stream sediment localities with zinc values higher than 200 ppm. From workshop presentation by Steenfelt (2011); see Appendix C.*

The tract proposals were based on the following sedimentary environments in Greenland:

i) Palaeoproterozoic Karrat Group in West Greenland;
ii) Mesoproterozoic Thule Basin in North-West Greenland;
iii) Palaeoproterozoic Etah Group of the Inglefield mobile belt in North-West Greenland;
iv) Phanerozoic Franklinian basin in North Greenland;
v) Proterozoic Hekla Sund basin, eastern North Greenland;
vi) Mesoproterozoic Krummedal Basin, Northeast and central East Greenland;
vii) Neoproterozoic Eleonore Bay Basin in Northeast and central East Greenland;
viii) Upper Palaeozoic - Mesozoic Jameson Land Basin, central East Greenland;
ix) Palaeoproterozoic Pelite Zone of the Ketilidian mobile belt in South Greenland.

For distribution of the individual sedimentary environments please refer to Figure 6.

The geology of the individual sedimentary environments and their known zinc deposits are described in more comprehensive details later in this report.

Quantification of resources

For each assessed tract undiscovered resources for the tract were estimated by an Monte Carlo simulation in which the assessment panel's consensus estimate for numbers of undiscovered sediment-hosted zinc, either of the SEDEX (Emsbo 2009) or the MVT (Leach *et al.* 2010) type deposits, is combined with the 'Grade and Tonnage model of the Clastic-dominated sediment-hosted lead-zinc deposits (Taylor *et al.* 2009)'. The Monte Carlo simulation were run using the USGS-developed software EMINERS (Root *et al.* 1991; Duval 2004).

Selected simulation results are reported for each tract. In each simulation contained material in terms of metals (tonnes of Zn and Pb) and tonnages (tonnes of rocks) are estimated at different probabilities together with mean contained material, probability of mean or greater or probability of zero contained material (see e.g. Table 5).

The assessment panel

The following persons were part of the assessement panel:

- Bjørn Thomassen, Avannaa Resources
- Bo Møller Stensgaard, GEUS
- Claus Østergaard, 21st North
- Denis Schlatter, Helvetica Exploration Services GmbH
- Erik Lundstam, Boliden Mineral AB
- Henrik Stendal, BMP
- Kurt Christensen, Angel Mining
- Ole Christiansen, NunaMinerals A/S
- Per Kalvig, GEUS
- Poul Emsbo, USGS
- Stefan Bernstein, Avannaa Resources
- Søren Lund Jensen, Scandinavian Highlands
- Tapani Tukiainen, GEUS

Data sharing in advance of the workshop

Papers describing the assessment process and the initial tract proposals were forwarded to the panel members prior to the workshop, along with a selection of the relevant literature regarding regional and basin/sedimentary geology, mineralisation and zinc deposits in Greenland, as well as key literature on the deposit models covered at the workshop.

Presentations at the workshop

Presentations on the regional geology and sedimentary/basin geology in the selected provinces were given during the workshop by invited speakers along with presentations on mineralisation patterns and known zinc occurrences, prospects or deposits. All presentations are listed in Appendix C and included as PDF files on the CD-ROM accompanying the report.

Permissive tracts assessed

In the course of the workshop a number of permissive tracts favourable for hosting undiscovered SEDEX- and MVT-type deposits have been defined and assessed in accordance with the guidelines provided by the USGS. The distribution of the individual permissive tracts are shown on Figure 7 and listed in Table 1. The background for the tract name abbreviations can be found in Appendix B.

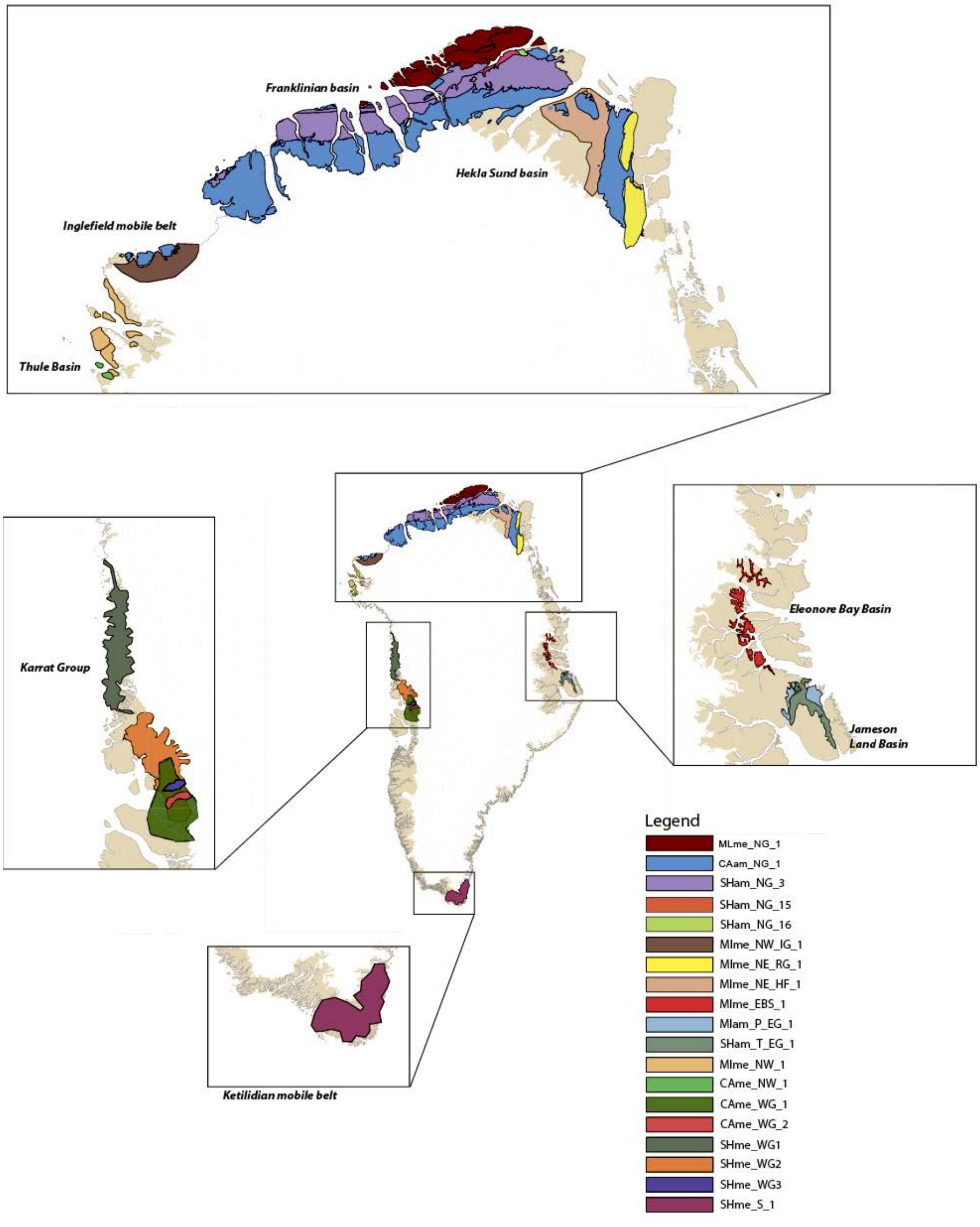


Figure 7. *Map showing the permissive areas (tracts) used for the zinc assessment workshop. More information about the individual tracts can be found in Table 1.*

Table 1. *List of all permissive tracts assessed for undiscovered and discovered sedimentary zinc deposits during the workshop.*

Mineralisation model	Region	Geological setting and age	Tract name	Areal extent Km2	Comments
Sedex	North Greenland	Ordovician, Franklinian Basin, Amundsen Land Group	SHam_NG_15	184	
		Ordovician, Franklinian Basin, Amundsen Land Group	SHam_NG_16	655	
		Silurian, Franklinian Basin, Trough Sequence	SHam_NG_3	30,060	
		Silurian, Franklinian Basin, Trough Sequence (metamorphosed)	MLme_NG_1	12,780	
	West Greenland	Palaeoproterozoic, Karrat Group, Nûkavsak Formation	SHme_WG1	9,606	
		Palaeoproterozoic, Karrat Group, Nûkavsak Formation	SHme_WG2	12,650	
		Palaeoproterozoic, Karrat Group, Nûkavsak Formation	SHme_WG3	606	
	Northwest Greenland	Palaeoproterozoic, Inglefield mobile belt, Etah Group	MLme_NW_IG_1	6,464	
		Meso - Neoproterozoic, Thule Supergroup	MLme_NW_1	4,325	
	Northeast Greenland	Neoproterozoic, Hagen Fjord Group	MLme_NE_HF_1	12,966	
		Neoproterozoic - Rivieradal Group, Half-graben sequence	MLme_NE_RG_1	7,346	
	Central East Greenland	Neoproterozoic, Eleonore Bay Supergroup	MLme_EBS_1	3,069	
		Triassic, Fleming Fjord & Pingodal Formation	SHam_T_EG_1	3,258	
		Upper Permian, Foldvik Creek Group, Ravnefjeld Fm	MLam_P_EG_1	863	
		Upper Permian, Foldvik Creek Group	MLam_P_EG_2	616	Assessed - but no voting
	South Greenland	Palaeoproterozoic, Ketilidian Pelite zone	SHme_S_1	1,065	
MVT	North Greenland	Silurian, Franklinian Basin, Carbonate shelf-platform	CAam_NG_1	51,738	
	Northwest Greenland	Meso - Neoproterozoic, Thule Supergroup	CAme_NW_1	351	
	West Greenland	Karrat Group, Mârmorilik Fm	CAme_WG_1	10,585	
		Karrat Group, Mârmorilik Fm	CAme_WG_2	749	
	Northeast Greenland	Neoproterozoic - Eleonore Bay Supergroup	MLme_EBS_1MVT	3,069	
	Central East Greenland	Upper Permian, Foldvik Creek Group	MLam_P_EG_1M	863	
		Upper Permian, Foldvik Creek Group, Karstryggen	MLam_P_EG_2M	616	

Conclusions

The Greenlandic Bureau of Minerals and Petroleum (BMP) and the Geological Survey of Denmark and Greenland (GEUS) are participants in the 'Global Mineral Resource Assessment Project' (GMRAP), and in this capacity organised its third GMRAP workshop from the 29 November - 1 December 2011 at GEUS in Copenhagen on the assessment of undiscovered sediment-hosted zinc deposits in Greenland.

Sedimentary basin environments constitute approximately 40% of Greenland's 410,000 km^2 ice-free land area, and several of the basins hosts zinc mineralisations. The workshop considered two deposit types; Sedimentary Exhalative (SEDEX) type and Mississippi Valley type (MVT) that accounts for more than 50% of the world's known zinc reserves. A third type; the Volcanic Massive Sulphide type (VMS), that accounts for around 30% of the world's zinc reserves, were not assessed at the workshop due to lack of time.

The assessment panel for this workshop constituted thirteen geologists from research institutions, USGS, BMP, GEUS and private exploration companies, each of whom have knowledge on aspects of Greenlandic geology and/or expertise in sediment-hosted zinc deposits. At the workshop, the individual members of the assessment panel provided estimates on how many deposits of a certain size and a certain grade would be possible to find, under the best possible circumstances. Subsequently, all estimates were used as inputs to a Monte Carlo simulation computer program (EMINERS developed by the USGS), combining the probability distributions of the estimated number of undiscovered deposits, the grades, and the tonnages of the selected model to obtain the probability distributions for undiscovered metals in each tract.

In the course of the workshop a total of 23 estimations of undiscovered sediment-hosted zinc deposits have been assessed in strict accordance with the guidelines provided by the USGS. The assessment made it obvious that only very scarce information is available for most of the tracts, which is mainly because of logistical and economic constraints of undertaking exploration in Greenland.

The estimated total mean of undiscovered zinc resources has been estimated to 24.8 million tons zinc (see Table 2). This value should be used with caution and should be regarded as a statistical estimate that reflects the present level of knowledge and investigations that have been undertaken in the assessed tracts. To a large degree, it also reflects the confidence level of the estimated number of undiscovered zinc deposits within the tracts that have been assessed.

The circumstances that the large majority of assessed tracts lack sufficient information and data for an absolute assessment, should give rise to even more cautions when using the estimated zinc resource value. New information, new discoveries, new investigations etc. within a tract should thus if possible be taken into account when evaluating an area, as this could either decrease or increase the estimated value.

The bids on undiscovered zinc deposits made by the assessment panel at different confidence levels and the increase in numbers from one confidence level to another are perhaps the most important information to consider as it reflects the level of knowledge about the various areas and the overall assessment of the potential and prospectivity within the areas.

The assessment panel agreed that the largest potential for large grade-tonnage deposits of the SEDEX zinc type was within the trough sequences of (i) the trough sequence within the Franklinian Basin in North Greenland, (ii) the Etah Group of the Inglefield mobile belt in North-West Greenland, (iii) the Rivieradal and Hagen Fjord Groups in the Hekla Sund Basin in eastern North Greenland, and (iv) the Foldvik Creek successions in the Jameson Land Basin in central East Greenland.

The biggest potential for MVT-type zinc deposits was agreed to be within (i) the carbonate shelf-platform of the Franklinian Basin in North Greenland, (ii) the Foldvik Creek successions in the Jameson Land Basin in central East Greenland and (iii) the Mârmorilik Formation of the Karrat Group in West Greenland.

A summary of all assessment results for both SEDEX and MVT-type deposits that includes undiscovered deposit estimates, deposit numbers, tract area and deposit density for tracts, are presented in Table 2 on next page.

Table 2. *Summary of assessment results including undiscovered deposit estimates, deposit numbers, tract area and deposit density for tracts.*
** = Tract assessed – but no voting, ** = Ranking according to resource size (1st criteria) and deposit density (2nd criteria).*

Deposit model	Region	Tract name	Tract area	Number of known zinc deposits	Number of unknown zinc deposits	Deposit density	Known zinc resources	Mean estimate of undiscovered zinc resources	Ranking witin specific deposit model
			Km^2				Metric tons	Metric tons	**
SEDEX	North Greenland	SHam_NG_15	184	1	1.30	0.013	5,400,000	3,500,000	2
		SHam_NG_16	655	0	1.10	0.0016	0	2,600,000	3
		SHam_NG_3	30,060	0	2.20	0.000074	0	5,700,000	1
		MLme_NG_1	12,780	0	0.78	0.000061	0	1,900,000	4
		MLme_NE_HF_1	12,966	0	0.41	0.000031	0	990,000	7
		MLme_NE_RG_1	7,346	0	0.44	0.000059	0	1,100,000	6
	North-West Greenland	MLme_NW_IG_1	6,464	0	0.47	0.000072	0	1,200,000	5
		MLme_NW_1	4,325	0	0.17	0.000038	0	380,000	10
	West Greenland	SHme_WG1	9,606	0	0.06	6.20E-06	0	190,000	14
		SHme_WG2	12,650	0	0.11	8.30E-06	0	290,000	11
		SHme_WG3	606	0	0.30	0.0021	0	770,000	9
	East Greenland	MLme_EBS_1	3,069	0	0.14	0.000044	0	280,000	12
		SHam_T_EG_1	3,258	0	0.11	0.000032	0	280,000	13
		MLam_P_EG_1	863	0	0.41	0.00047	0	970,000	8
		MLam_P_EG_2	616	*	*	*	*	*	*
	South Greenland	SHme_S_1	1,065	0	0.06	0.000056	0	150,000	15
MVT	North Greenland	CAam_NG_1	51,738	0	2.80	0.000054	0	2,700,000	1
	North-West Greenland	CAme_NW_1	351	0	0.14	3.80E-04	0	150,000	6
	West Greenland	CAme_WG_1	10,585	0	0.03	2.80E-06	0	27,000	7
		CAme_WG_2	749	1	0.30	0.0017	1,661,000	270,000	4
	East Greenland	MLme_EBS_1MVT	3,069	0	0.17	0.000054	0	150,000	5
		MLam_P_EG_1M	863	0	0.41	0.00047	0	400,000	3
		MLam_P_EG_2M	616	0	0.81	0.0013	0	840,000	2
Total amount of undiscovered zinc resources in Greenland(metric tons): 24,837,000 tons									

Individual assessment of undiscovered sediment-hosted zinc deposits

Ordovician-Silurian Franklinian Basin, North Greenland

Sources of information

The principal sources of information used for the assessment of the tracts of the Franklinian Basin in North Greenland are given in Appendix A.

Regional geology

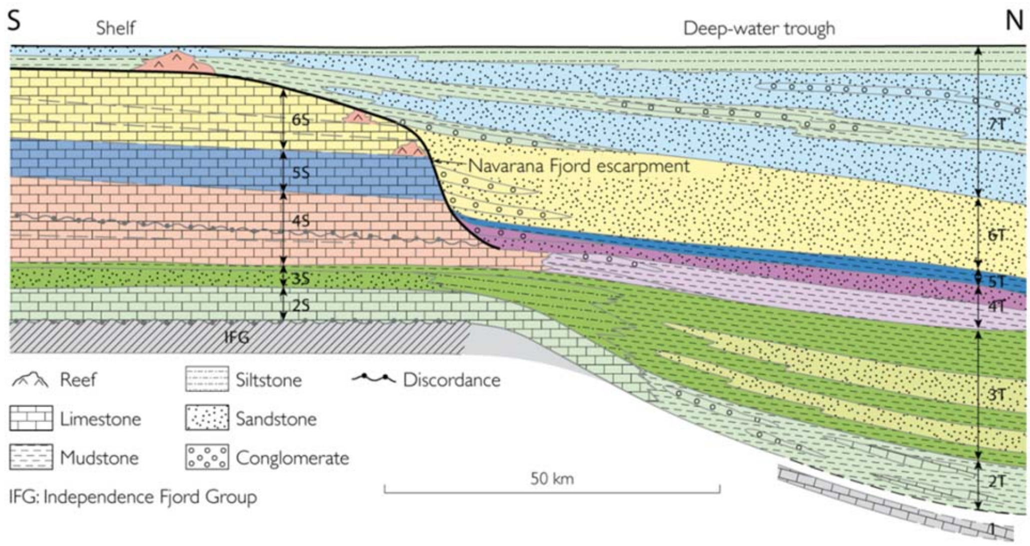
The following text, figures and illustrations are derived from Thrane *et al*. (2011).

The largest sedimentary basin in Greenland, the Palaeozoic Franklinian Basin, extends E-W for more than 2,500 kilometres in northern Greenland and Canada (see Figure 16). Deposition in the Franklinian Basin took place along a passive continental margin and began in the latest Precambrian and continued until at least earliest Devonian.

The sediments were deposited unconformably on Proterozoic sandstones and shales and Archaean crystalline basement rocks. The sedimentary succession is several kilometres thick, and developed into three different sedimentary environments; a southern broad, shallow-water, dominantly carbonate shelf nearest the continent, bordered to the north by a slope with moderate- to deep-water depths environments and an broad outer shelf deep-water trough environment in which a thick flysch succession accumulated. The shelf succession is dominated by carbonates and reaches 4 km in thickness. The shelf-trough sediments are dominated by siliciclastic rocks, including turbiditic siltstones and sandstones, terrigenous mudstones and shales, and have a total thickness of ca 8 km.

The shelf-trough boundary was controlled by deep-seated faults, e.g. the pronounced Navarana Fjord escarpment, which, with time, expanded southwards to new fault lines, with final foundering of the shelf areas in the Silurian. The boundary between the platform and shelf sedimentary regimes fluctuated considerably; in some periods the platform was almost drowned, while in other periods the platform prograded and the platform margin coincided with the shelf-slope break. The evolution of the Franklinian Basin has been divided into seven stages with significant changes in regime linked to southward expansion of the basin margin. Descriptions of the individual stages are included later in this report.

The northern parts of the basin deposits were deformed in Devonian to Carboniferous time during the Ellesmerian orogeny with a resulting development of a thin-skinned fold and thrust zone fold belt in the south. A later deformational event affected the northern-most part of the sequence late in the Cretaceous. For a more comprehensive description of the geological setting of the Franklinian Basin please refer to Peel & Sønderholm (1991).



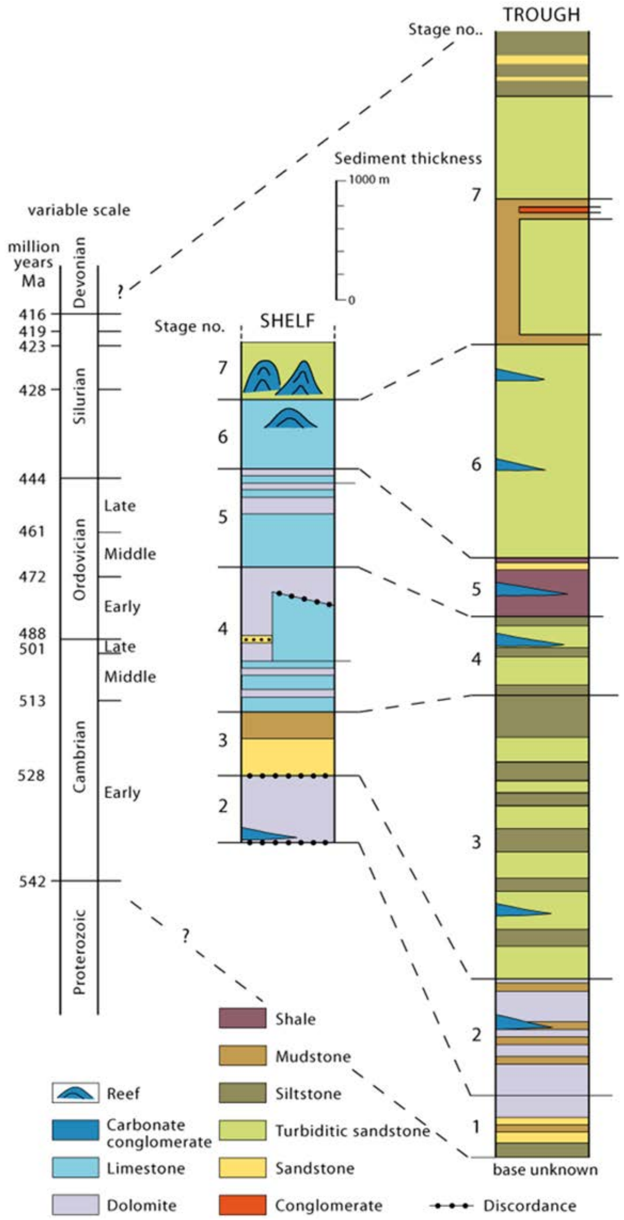


Figure 8. ***(Above)*** *South–north cross-section of the Franklinian Basin showing the transition from shallow-water carbonate shelf to deep-water, sand- and silt-dominated deposits in the trough. The succession is continuous from the earliest Cambrian (542 Ma) to the earliest Devonian (about 410 Ma). The shallow-water sediments of the carbonate shelf pass northwards into a much thicker sequence of clastic, deep-water sediments. The boundary between the shelf and the deep-water trough is a steep escarpment. In the Silurian, deposition of the turbiditic sediments was very rapid, the trough was filled, and turbidites spread out over the shelf areas. The development of the basin can be divided into 7 stages (see left figure); S indicates shelf deposits and T trough deposits. Sediment thickness on the shelf was 3–4 km and in the trough about 8 km.The profile is drawn with a vertical exaggeration. From Henriksen (2008).* ***(Left)*** *Lithostratigraphic division of the Lower Palaeozoic successions in North Greenland. The shelf and slope sequence is a 4 km thick accumulation of carbonate sediments, whereas the deep water sequence comprises dominantly clastic sediments with a composite thickness of up to 8 km. From Henriksen (2008).*

Stage 1: Basin initiation, Late Proterozoic? – Early Cambrian shelf

This stage records the initial subsidence and transgression of the Proterozoic basement in North Greenland.

Skagen Group

The Skagen Group is restricted to scattered outcrops between northeast Peary Land and northern Wulff Land in the northernmost parts of North Greenland. The base is nowhere seen. In its type area at Skagen in northeast Peary Land, it consists of tightly-folded quartzitic sandstones and mudstones conformably overlain by the Paradisfjeld Group. The Skagen Group is restricted to the northernmost parts of North Greenland.

Figure 9. *The lower part of the carbonate platform, from Jørgen Brønlund Fjord, southern part of Peary Land. From Henriksen (2005).*

Stage 2: Early Cambrian platform and incipient trough

At this stage, a clear differentiation into shelf and deep-water sequences is apparent. The shelf is represented by the Portfjeld Formation and the trough sequence by the Paradisfjeld Group (Figure 8)

Portfjeld Formation

The formation is poorly fossiliferous but remains of cyanobacteria indicate a probable Early Cambrian age. In southern Peary Land it is up to 250 m thick, but it thickens to the north and west and reaches 400–700 m in northeast Peary Land and around J. P. Koch Fjord; the thickest developments are close to the platform edge. The formation comprises typically dolomites, silty dolomites and algal-laminated dolomites occasionally with stromatolites. A remarkable mega-breccia unit of the Portfjeld Formation is found around the head of Victoria Fjord. The breccia unit is interpreted as a mass slump of giant rafts of the Portfjeld Formation together with material from underlying sequences.

Paradisfjeld Group

The Paradisfjeld Group comprises at least 1000 m of lime mudstones; at the top it has a series of thick beds of limestone conglomerates. It overlies the Skagen Group and is viewed as the deep-water equivalent of the Portfjeld Formation; the transition zone between the Portfjeld Formation and Paradisfjeld Group is obscured by Ellesmerian thrusts.

Stage 3: Early Cambrian siliciclastic shelf and turbidite trough

This stage is characterised by terrigenous sand and mud deposits on the southern shelf and red and green mudstones on the wide transitional slope e.g. Buen Formation. Coarse siliciclastic turbidites of the Polkorridoren Group were deposited in the northern trough (Figure 8).

Buen Formation

The siliciclastic Buen Formation varies in thickness from 250 to 500 m and is dominated by sandstones in the lower part and mudstones in the upper part. It conformably overlies the Portfjeld Formation but the contact relations outside the type area at Brønlund Fjord suggest a break in sedimentation between the two formations. The Buen Formation can be traced from the western shores of Danmark Fjord in the east to Warming Land in the west. Towards the north it thickens rapidly and passes into the turbiditic Polkorridoren Group. Middle to late Early Cambrian age of the Buen Formation is suggested by fossil assemblages from the middle of the formation. The Buen Formation is interpreted as deposited in a tide and storm dominated shallow marine shelf environment.

Polkorridoren Group

The Polkorridoren Group comprises a sequence of at least 2 km of alternating thick sandstone and mudstone units. The mainly semipelitic and psammitic units are turbiditic developments. They occur as thin bands in the transitional slope sequence, and thicken northwards and dominate the trough succession. In Nansen Land and on adjacent islands, two levels of carbonate conglomerates occur about 600 m above the base of the Polkorridoren Group. These conglomeratic levels are dominated by Portfjeld Formation clasts; the blocks have been interpreted as broken away from the Portfjeld shelf edge to the south. Thus, the edge of the Portfjeld shelf seems to have existed as a positive feature well into Buen times. The uppermost unit of the Polkorridoren Group consists of a sequence of up to 400 m of purple and green mudstones. At the shelf-slope break the mudstone grades into the upper part of the Buen Formation. The Polkorridoren Group is widely exposed throughout Johannes V. Jensen Land and Nansen Land.

Stage 4: Late Early Cambrian – Middle Ordovician shelf and starved Trough

During this stage the shelf area was influenced by; (1) differential subsidence and (2) uplift in eastern North Greenland. In the east, there was a progradational shelf whereas the western areas were characterised by an aggradational shelf with uniform subsidence. In the late Early Ordovician, after the end of uplift in eastern North Greenland, shallow-water aggradational shelf conditions expanded to all of North Greenland, marked by the Wandel Valley Formation of the Ryder Gletscher Group. The trough expanded southward during this stage with deposition of mudstones and turbiditic sandstones of the Vølvedal Group (Figure 8).

Brønlund Fjord and Tavsens Iskappe Groups

During the late Early Cambrian to latest Cambrian the Eastern area was subject to uplift resulting in a strong northward progradation of the carbonate platform and slope facies reflected by the Brønlund Fjord and Tavsens Iskappe Groups. The Brønlund Fjord Group in the type area is up to c. 250 m thick and is dominated by fine-grained limestones and dolomites, with carbonate breccias interpreted as debris flows. Sandstone beds occur in some formations. The Tavsens Iskappe Group is up to 700 m thick, and is a sequence of thin-bedded carbonates with carbonate breccias and sandstones.

Ryder Gletscher Group

In the western part, the deposits of the Cambrian–Ordovician aggradational shelf up to 1100 m thick have been placed in the Ryder Gletscher Group, dominantly comprising carbonates. In the earliest Ordovician these shelf deposits expanded eastwards such that the upper part of the group covered the entire North Greenland shelf. The lower Cambrian part of the Ryder Gletscher Group is up to 470 m thick and consists of burrow mottled dolomites, silty lime mudstones and mud-cracked stromatolitic and cryptalgal dolomites.

Vølvedal Group

The deep-water trough succession of stage 4 is made up of the 600–700 m thick Vølvedal Group. The Vølvedal Group is a sequence of alternating dark mudstones and turbiditic sandstones, which is confined to the Amundsen Land – Frederick E. Hyde Fjord region. The lowest formation consists of dark mudstones and thin-bedded turbidites. The central formation is characterised by greenish chert and cherty mudstones and siltstones, about 50 m thick. Quartzitic turbidites alternating with thin black mudstone beds form the 240 m thick upper formation.

Stage 5: Middle Ordovician – Early Silurian aggradational carbonate platform, starved slope and trough

This stage extends from approximately the Middle Ordovician to Early Silurian. Carbonate deposition continued on the platform in the south, a very thin sequence of siliciclastic sediments accumulated on the slope, and a 350–500 m thick sequence of mainly fine-grained sediments (Amundsen Land Group) were deposited in the trough to the north. The shelf-slope boundary of this stage followed a pronounced east–west trending lineament, the Navarana Fjord escarpment, which can be traced between J. P. Koch Fjord in the east and northern Hall Land in the west (Figure 8 & Figure 10)

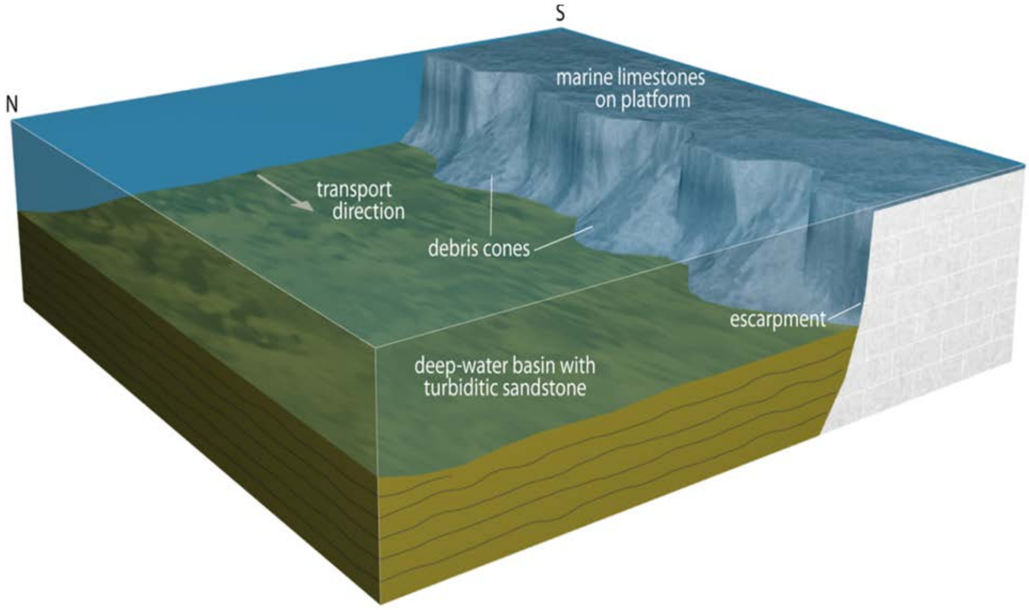


Figure 10. *Model of the carbonate platform to the south, and the deep-water basin to the north, separated by the Navarana Fjord Escarpment. From Henriksen (2005).*

Morris Bugt Group

The platform sequence is represented by the Morris Bugt Group and the basal part of the Washington Land Group in western areas of North Greenland, and by the Børglum River, Turesø and Ymers Gletscher Formations in eastern areas. Throughout the region the total thickness of the platform sequence is constant at about 650 m. The upper part of the shelf sequence reflects a period of pronounced shallowing followed by a deepening of the shelf.

Figure 11. *Exposure at Navarana Fjord. The Carbonate platform to the right, and the deep-water sediments to the left, separated by the Navarana Fjord Escarpment. Profile is 1300 m high. From Henriksen (2005).*

Amundsen Land Group

The slope deposits of this stage are represented by a very restricted starved sequence of cherts and cherty shales, with units of siltstones and mudstones, and totals only 50–100 m in thickness. It is assigned to a formation of the Amundsen Land Group and can be traced as a thin unit along the northern coastal area between J. P. Koch Fjord and northern Nyeboe Land, mainly in anticlinal fold cores. The Amundsen Land Group in its type area represents deposits of the southern part of the deep-water trough. The group is dominated by cherts and mudstones, and includes some thin turbiditic units, as well as conspicuous thick units of carbonate conglomerates derived from the nearby southern carbonate shelf. Three formations with a total thickness of 350–500 m are distinguished. The lowest formation comprises deposits of mud and siliceous ooze. The middle formation made up of sheets of re-deposited Early Ordovician carbonate conglomerate and turbidites is up to c. 200 m thick. The youngest formation includes black cherts and mudstones, siltstones and silty turbidites.

Figure 12. *Cambro-Ordovician platform margin sequence in the foreground and Ordovician shelf sequence clastic rocks in the middle distance. View from the south. Profile height is c. 500 m. From Henriksen et al. (2000).*

Stage 6: Early Silurian ramp and rimmed shelf, and turbidite trough

Trough sedimentation changed abruptly in the early Silurian with the incoming of vast amounts of sandy turbidites of the Peary Land Group (Sydgletscher and Merqujôq Formations), which were derived from the rising Caledonian mountains to the east. At the beginning of stage 6, the shelf-trough boundary still followed the Navarana Fjord escarpment, which extended from north of Hall Land in the west to south of the mouth of Frederick E. Hyde Fjord in the east. Later in this stage, the outer shelf down-flexed due to loading in the trough and turbiditic sediments onlapped the outer platform carbonates. Carbonate deposition continued on the shelf during the general deepening (Figure 8).

Odins Fjord and Djævlekløften Formations

The shelf margin retreated during stage 6 to a new, more southerly position and in Kronprins Christian Land and Peary Land down flexing resulted in a widespread deepening of the platform. The carbonates in the east are assigned to the Odins Fjord Formation, a 200 to 350 m thick sequence characterised by medium to thick-bedded dark limestones and wackestones. Two lime-mudstone members can be distinguished.

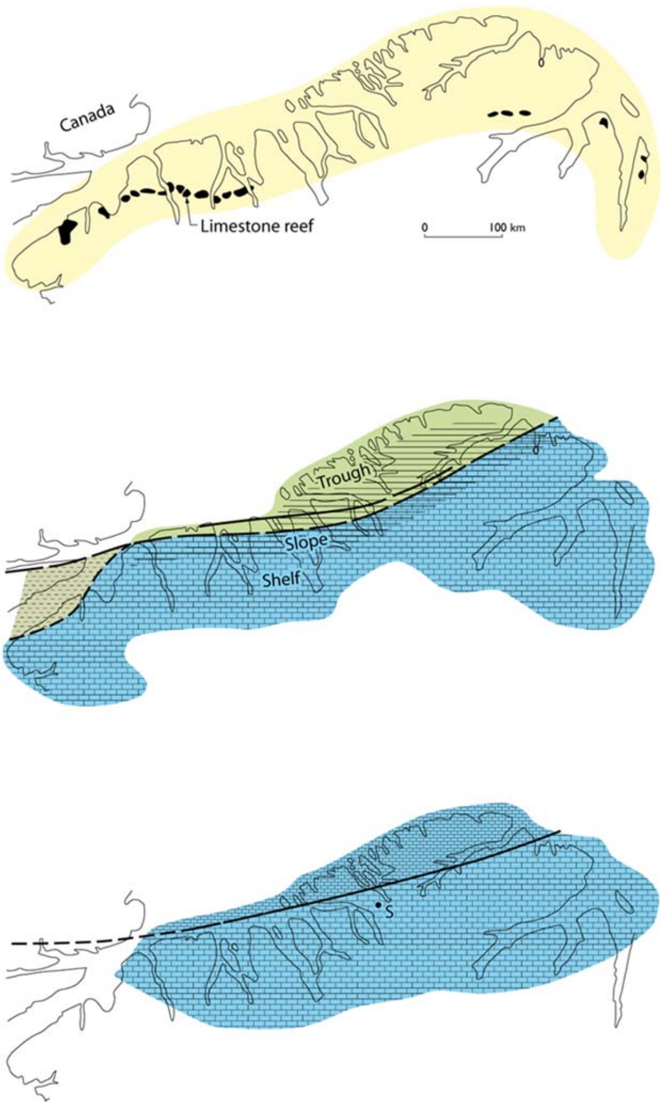


Figure 13. *Simplified evolution of the Franklinian Basin, from the early Cambrian, where the whole area was covered by a carbonate platform (lower picture). Until the Late Ordovician, where the northern half of the platform was flooded and the deep water trough, as well as the Navarana Fjord escarpment was formed. In Late Silurian the trough expanded southwards due to subsidence and most of the platform was drowned and 300 km long limestone reefs were formed. Mudstones were deposited and buried the escarpment. From Henriksen (2005).*

Lower part of the Peary Land Group

In the trough north of the Navarana Fjord escarpment the major longitudinal accumulations of turbidites, mudstones and conglomerates of this stage are assigned to the Merqujôq Formation of the Peary Land Group. The Merqujôq Formation is widely distributed between Frederick E. Hyde Fjord and northern Nyeboe Land, and ranges from 500 m to 2000 m in thickness. In Johannes V. Jensen Land the turbidite succession of the Peary Land Group was initiated with a sandstone sequence (more than 150 m thick) made up of massive up to 30 m thick turbidite beds – the Sydgletscher Formation.

Stage 7: Final drowning of the platform

This stage was marked by a dramatic southward expansion of the trough, turbidites onlapped and buried the Navarana Fjord escarpment and widespread subsidence affected former shelf areas. The shelf areas of stage 6 were inundated by trough mudstones and siltstones forming the middle and upper part of the Peary Land Group. Carbonate deposition was maintained only locally around major mound complexes (Samuelsen Høj and Hauge Bjerge Formations) (Figure 8).

Figure 14. *Silurian Mounds/Reefs growing on top of the carbonate platform. From Henriksen (2005).*

Samuelsen Høj and Hauge Bjerge Formations

The shelf margin retreated southwards during this state to a line trending through southern Hall Land to southern Peary Land and central Kronprins Christian Land, and is marked by a prominent linear belt of large, isolated outer shelf mound complexes, which range in thickness from 200 to 1000 m. The eastern mound complexes are referred to the Samuelsen Høj Formation, whereas those in the west are referred to the Hauge Bjerge Formation. The latter extends for almost 300 km. Mounds are not found between western Peary Land and western Wulff Land, probably due to later erosion.

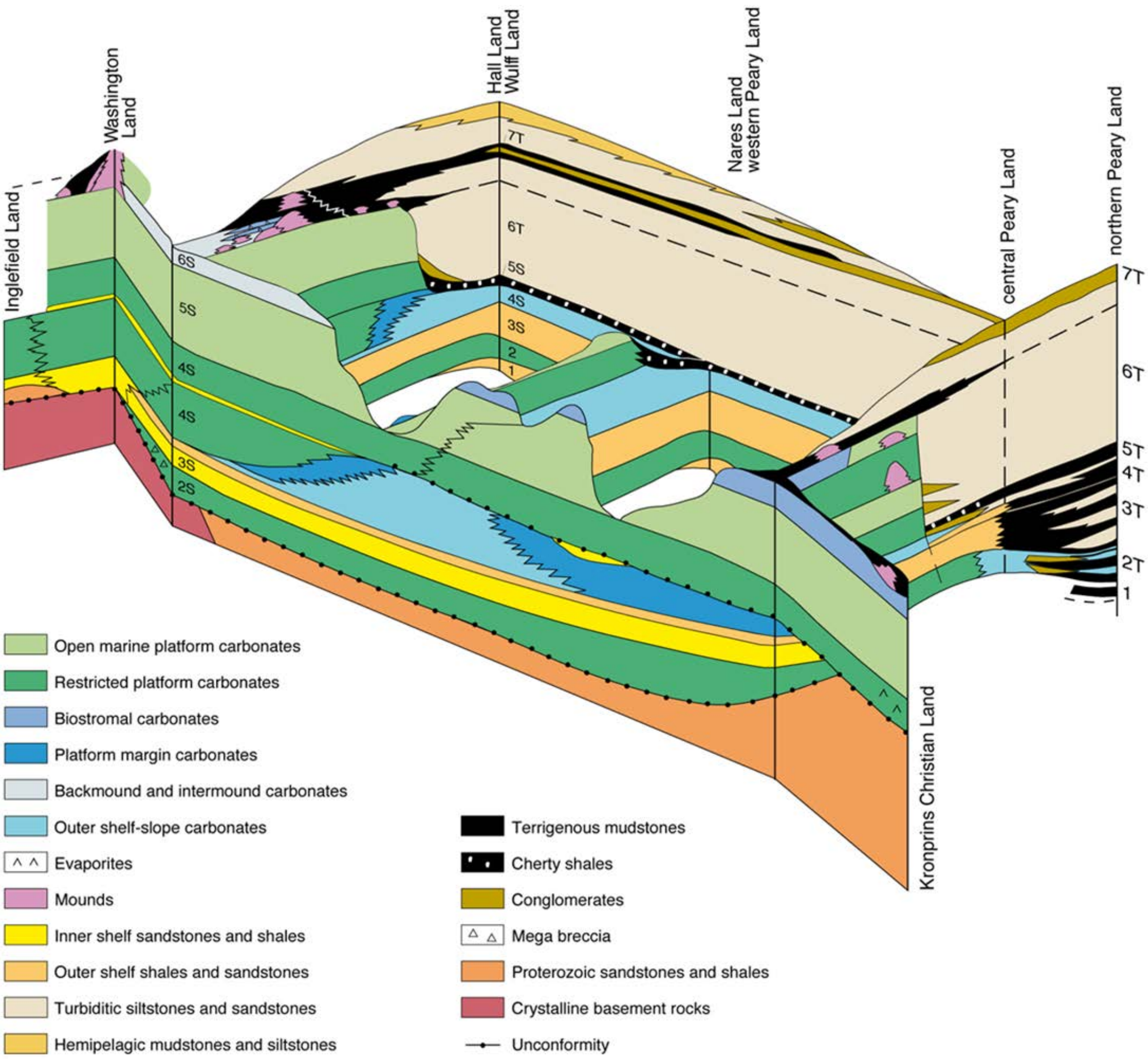


Figure 15. *Block diagram illustrating relationships between shelf, slope and trough sequences in the Lower Palaeozoic Franklinian Basin. The schematic fence diagram covers a region of c. 800 km east-west and c. 200 km north-south. Shelf stages (S) and trough stages (T) are divided into time intervals. 1: Late Proterozoic? – Early Cambrian; 2: Early Cambrian; 3: Early Cambrian; 4: Late Early Cambrian – Middle Ordovician; 5: middle Ordovician – Early Silurian; 6: Early Silurian; 7: later Silurian. From Henriksen et al. (2000).*

Exploration history

The following historical description is derived from van der Stijl & Mosher (1998) and Thrane *et al.* (2011) (see references therein for more details).

Early geological investigations

The early knowledge of the geology of the area around Frederick E. Hyde Fjord is derived from information and samples collected by the Danmark Expedition in 1906–1907, the Danish Peary Land Expedition 1947–1950 and an expedition organized by Lauge Koch in 1953.

The first indication of actual mineralisation in the Frederick E. Hyde Fjord region was reported in 1960 during the first helicopter operation in Peary Land by the U.S. Geological Survey, who noted gossans to the south of Frederick E. Hyde Fjord, referring specifically to Depotbugt (20 km east of Citronen Fjord) where “there are extreme plays of color and every appearance of mineralisation”

In 1969, during the British Joint Services Expedition, a multi-disciplinary, spring–summer skidoo expedition to Johannes V. Jensen Land (northernmost part of Peary Land), the Depotbugt gossan was checked. In addition several gossans on the shore of Frederick E. Hyde Fjord just west of Citronen Fjord was observed (called ‘West gossan area’). One of these was investigated and found to be hosted in a carbonate breccia-conglomerate with sulphide mineralisation associated with intense calcite veining. Other conspicuous limestone breccia-conglomerate beds were noted in cliffs on the western coast of Citronen Fjord.

One recumbently folded unit within dark shales and siltstones and overlain by a thick succession of calcareous sandstones was sampled and subsequently dated from its shelly fauna as early Silurian in age

Regional geological mapping

A decade later the Frederick E. Hyde Fjord region was revisited in the period 1978–1980 during helicopter supported regional systematic mapping by the Geological Survey of Greenland.

The Citronen Fjord area is included on the 1:500 000 Peary Land map sheet and all strata at Citronen Fjord are referred to the Merqujôq Formation (the basal part of the Peary Land Group).

Sulphide mineralisation within limestone conglomerates south of Citronen Fjord is associated with fault splays of the NW–SE-trending Trolle Land Fault Zone. Fracture-filling copper-zinc mineralisation has been noted with quartz-calcite veining; the main mineral assemblage being pyrite, sphalerite, chalcopyrite and traces of galena. The mineralisation is stratabound and it has an epigenetic appearance.

Discovery of massive sulphides

In 1992 Platinova A/S participated in a joint venture program with Nanisivik Mines Ltd. to explore for base metals in the Franklinian Basin, in western North Greenland (Hall Land – Freuchen Land region). The primary focus of this work was an assessment of the deep-water clastic sediments of the Amundsen Land Group, the stratigraphic equivalent of the

Hazen Formation of Arctic Canada. This group occurs in the Nyeboe Land – Freuchen Land region as a narrow east–west striking belt over a distance of about 300 kilometres.

Numerous, minor occurrences of zinc and lead sulphides in various settings were found throughout the belt during helicopter reconnaissance. Although none of these occurrences had apparent economic potential, it was obvious that the Amundsen Land Group is highly prospective and that a similar evaluation of the eastern portion of the belt was warranted. In Peary Land to the east, exposures of Amundsen Land Group sediments are largely confined to the lands bordering Frederick E. Hyde Fjord where there are discontinuous outcrops over a distance of about 125 km.

Thus, after the initial investigations in western North Greenland in 1992, Platinova A/S continued the study into the following year with a prospecting programme in the Frederick E. Hyde Fjord area. Field work was based on the low-cost logistics of skidoo transport using the fjord-ice in spring and early summer as main access through the region. This program began in May and had as one of its primary objectives the investigation of the reported gossans and sulphide occurrences in the Citronen Fjord area that had been observed in 1969 and 1979. Massive, outcropping sulphides were encountered on the first day of exploration at Citronen Fjord in the inland gossan area now termed the Discovery area. The discovery was so promising that a full-scale exploration programme that included drilling was organized and executed the same summer.

The Discovery area is close, but not obviously related, to the fracture-controlled mineralisation sampled by the Geological Survey of Greenland in 1979 and it is about eight kilometres south-east of the outcropping sulphides first observed and sampled in 1969 on the south shore of Frederick E. Hyde Fjord. Exploration work suggests that sulphide mineralisation may be continuous between these two areas outlining a major NW-trending mineralisation zone. The geological, geophysical and drilling work started in 1993 by Platinova A/S continued each year to 1997. In total Platinova completed 143 drill holes totalling 32,400 m.

Since 2007 Ironbark Zinc Limited has extensively explored the Citronen Fjord deposit and to date in excess of 67,000 m of diamond drilling has been completed on the deposit. Ironbark is currently undertaking a feasibility study. The current development plan envisages the process plant being constructed on three barges and towed to site where they will be positioned and joined together on the eastern margin of the Citronen Fjord.

Commercial exploration

Although mineral exploration in the High Arctic has been naturally hampered by its remoteness and climatic conditions, there have been two operative mines in the Canadian Arctic Islands; the Polaris and the Nanisivik mines.

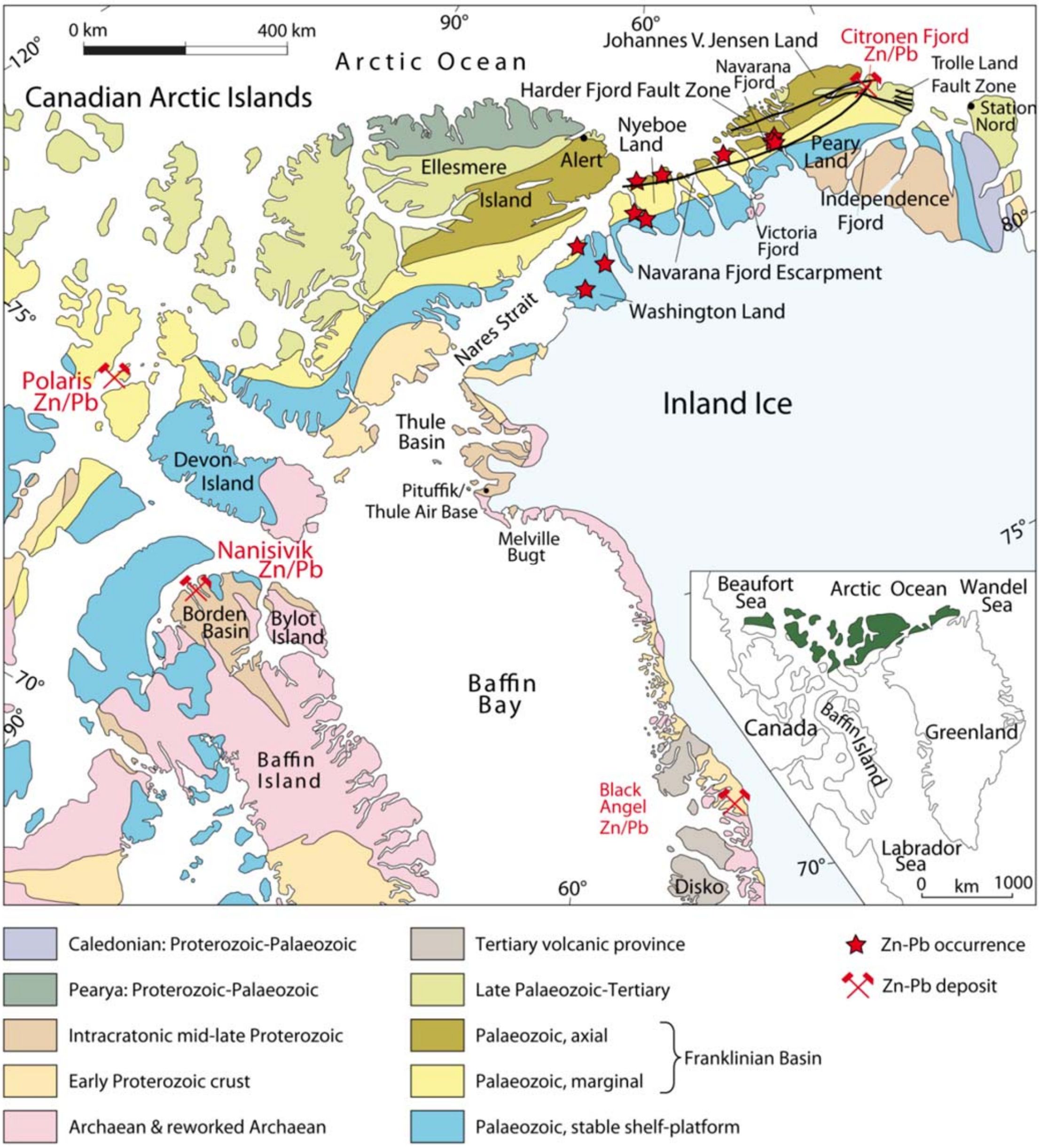


Figure 16. *Map of North Greenland and correlations to North-East Canada. Zn-Pb deposits and occurrences are shown. Modified after van der Stijl & Mosher (1998).*

<u>Polaris</u>

The Polaris mine was in production from 1981 to 2002. It was an underground mine on Little Cornwallis Island in the Arctic Islands in the Canadian territory of Nunavut (Figure 16) and was the most northerly mine in the world at the time. Zinc comprised a little over 12% of the ore mined, while lead accounted for about 3.5%. The Polaris mine produced over 21 million tonnes of lead-zinc ore during the life of the mine, with a market value of over 15 billion dollars.

Polaris is an MVT deposit hosted by carbonates of the Middle to Upper Ordovician Thumb Mountain, which is part of the Cambrian to Devonian Franklinian shelf. The economic ore consists of varying styles of epigenetic mineralisation. Sphalerite and galena occur as replacements, open space fillings, colloform masses and veins as well as disseminations in the host rocks.

Nanisivik
The Nanisivik mine (Figure 16) was in production between 1976 and 2002, located on Baffin Island. It was Canada’s first mine in the Arctic.

Nanisivik is an MVT deposit hosted in grey dolostones of the Society Cliffs Formation. It is a carbonate platform sequence in the middle of the >600 m thick Mesoproterozoic Bylot Supergroup. The supergroup was deposited in the Borden rift basin, a graben that formed within the pre-existing Canadian Shield.

The origin and the age of the sulphide deposit are still not clear. The sulphides are obviously epigenetic, but there are contrary views regarding the nature of the emplacement. The argument revolves around whether the sulphides simply filled pre-existing open caverns or whether the ore fluids themselves were sufficiently corrosive to affect carbonate dissolution during the overall process of sulphide precipitation.

Known prospects, mineral occurrences or related deposit types

North Greenland hosts a number of zinc mineral occurrences and is considered a highly prospective part of Greenland for zinc. The known occurrences represent several types and ages of zinc mineralisation as described in this section. Table 3 lists name and host for the occurrences and Figure 17 shows their location.

In this report, the term “mineral showing” defines observed mineralisations of unknown importance; no data on either the dimensions or the grade is available. The term “mineral prospect” applies to mineral occurrences carrying the potential to host economic deposits; it may/may not have been licensed and drilled by an exploration company – but not yet proven as a mineral resource. The term “deposit” applies to mineral occurrences that have extensively been drilled and a proven mineral resource has been defined e.g. according to the Canadian NI 43-101 standard or the Australian JORC standard.

Table 3. *List of zinc deposits, prospects and showings in North Greenland. Information extracted from the GEUS-BMP mineral occurrence database (GMOM).*

Class	Locality name	Type
Deposit	Citronen Fjord, Peary Land	shale-hosted Zn, Pb
Prospect	Cass Fjord, Washington Land	carbonate-hosted Zn, Pb, Ba
Prospect	Petermann Prospect, Washington Land	carbonate-hosted Zn, Pb, Ag
Showing	Navarana Fjord, Freuchen Land	stratabound Zn, Pb, Ba
Showing	Navarana Fjord, Lauge Koch Land	stratabound Zn, Pb, Ba
Showing	Navarana Fjord, Sulphide zone	calcite vein hosted Zn, Ba
Showing	Navarana Fjord, Baryte zone	calcite vein hosted Ba
Showing	Kap Schuchert, Washington Land	carbonate-hosted Pb, Zn
Showing	Kayser Bjerg SE, Hall Land	carbonate-hosted Zn, Pb
Showing	Kayser Bjerg NW, Hall Land	carbonate-hosted Zn, Pb
Showing	Kap Wohlgemuth, Nares Land	stratabound Zn, Pb, Ba
Showing	Hand Bugt, Nyboe Land	stratabound Zn, Pb, Ba
Showing	Repulse Havn, Nyboe Land	stratabound Zn, Pb, Ba

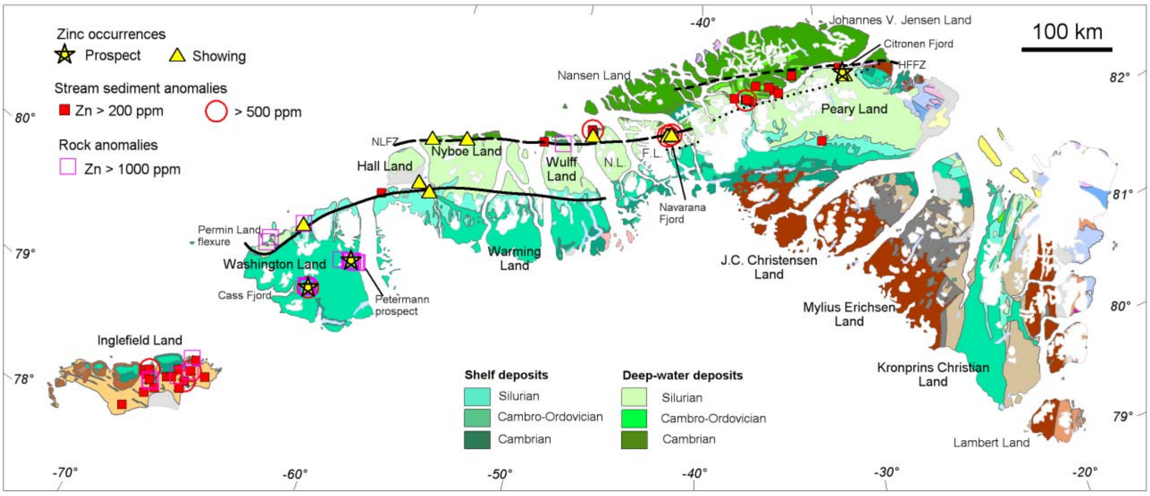


Figure 17. *Distribution of zinc anomalies and occurrences illustrating favourable trends for zinc deposits in North Greenland. Major tectonic lineaments include the Nyboe Land fault zone (NLFZ), the Permin Land flexure, the Navarana fault (dotted lines) and Harder Fjord fault zone (HFFZ). N.L.: Nares Land. F.L.: Freuchen Land. From Thrane et al. (2011).*

Citronen Fjord deposit, Peary Land

Base metal mineralisation at Citronen Fjord is primarily contained within Amundsen Land Group mudstones. Three main stratigraphic horizons of mineralisation have been identified by Platinova (Figure 18). Level 1 Sulphides, which make up the gossans at the Discovery Zone, lies immediately beneath the Hangingwall Debris Flow within the Footwall Shale Unit. Towards the central and lower part of the Footwall Shale Unit is the Level 2 Sulphide horizon, which makes up much of the Beach Zone and is also found at the Esrum Zone. Immediately below the Middle Debris Flow within the Middle Mudstone Unit lies the Level 3 Sulphides which is the most widely spatially distributed horizon. Level 3 Sulphides are found at Discovery, Beach, Esrum and also the Western Gossans. Known sulphide and zinc mineralisation occurs over an area of 12 km in strike (Figure 19).

Three main styles of sulphide mineralisation have been identified at Citronen Fjord: mound-like masses that formed above sea-floor vents; interbedded sulphides that form laminae and beds within the mudstone sequence and were deposited as broad aprons to the sulphide mounds; and cross-cutting, epigenetic mineralisation that is primarily found in the debris flows and probably represents feeder systems for overlying sea-floor vents.

The main sulphides present at Citronen are pyrite, sphalerite and galena. Both sphalerite and galena are generally fine grained. Pyrite dominated sulphide mineralisation takes on a brassy yellow hue and changes in colour to a pale brown and then to a pale pink/red with increasing zinc grade.

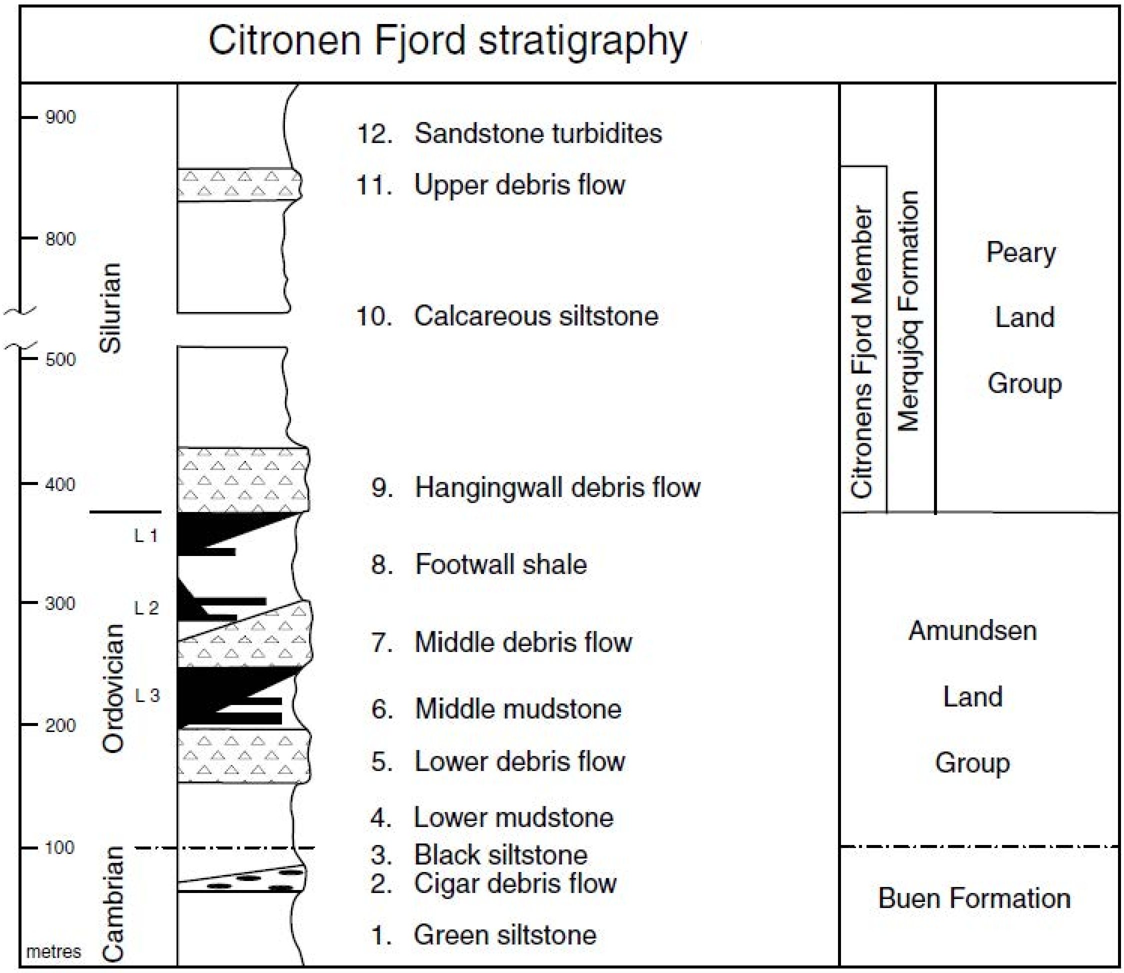


Figure 18. *Generalized stratigraphic section for the Citronen Fjord area showing the twelve informally-named units recognized in this paper, their correlation with the formally defined lithostratigraphy and the three levels of massive sulphide mineralisation (L1, L2 and L3). The geometric characteristics of the sulphide sheets within their respective host rock units are schematically shown by the shape of the black areas. From van der Stijl & Mosher (1998).*

The massive sulphides are generally medium grained and weakly bedded or have little sedimentary structure. They often display distinct dendritic pyrite with voids filled with calcite or dolomite. Zinc grades are generally low, ranging from 1% to 3% Zn. The massive sulphides are interpreted to be vent-proximal pyritic sulphide mounds, with the dendritic textures representing remobilization by pulses of sulphide bearing fluids. The bedded and laminated sulphides contain higher concentrations of sphalerite and galena than the massive sulphides. Bedded sulphides are characteristically planar-laminated and thin-bedded, with individual layers ranging from 1mm to 1m, although most layers are tens of centimetres thickness.

Zinc grades generally range from 1% Zn up to 30% Zn for individual layers.

Within the debris flows matrix fill and replacement type mineralisation occurs, with its distribution strongly controlled by steeply dipping NW striking faults. This style of mineralisation is much coarser grained than bedded and massive sulphides, with very coarse grained sphalerite. It is interpreted to be epigenetic in origin, and may represent feeder zones to the overlying massive and laminated sulphides. The most well drilled and understood of these is called the Discovery “XX” Zone (Figure 19), where mineralisation is controlled by a NW striking fault within the Middle Debris flow. Volumetrically this style of mineralisation is relatively insignificant, constituting less than 1% of the global zinc resource tonnage.

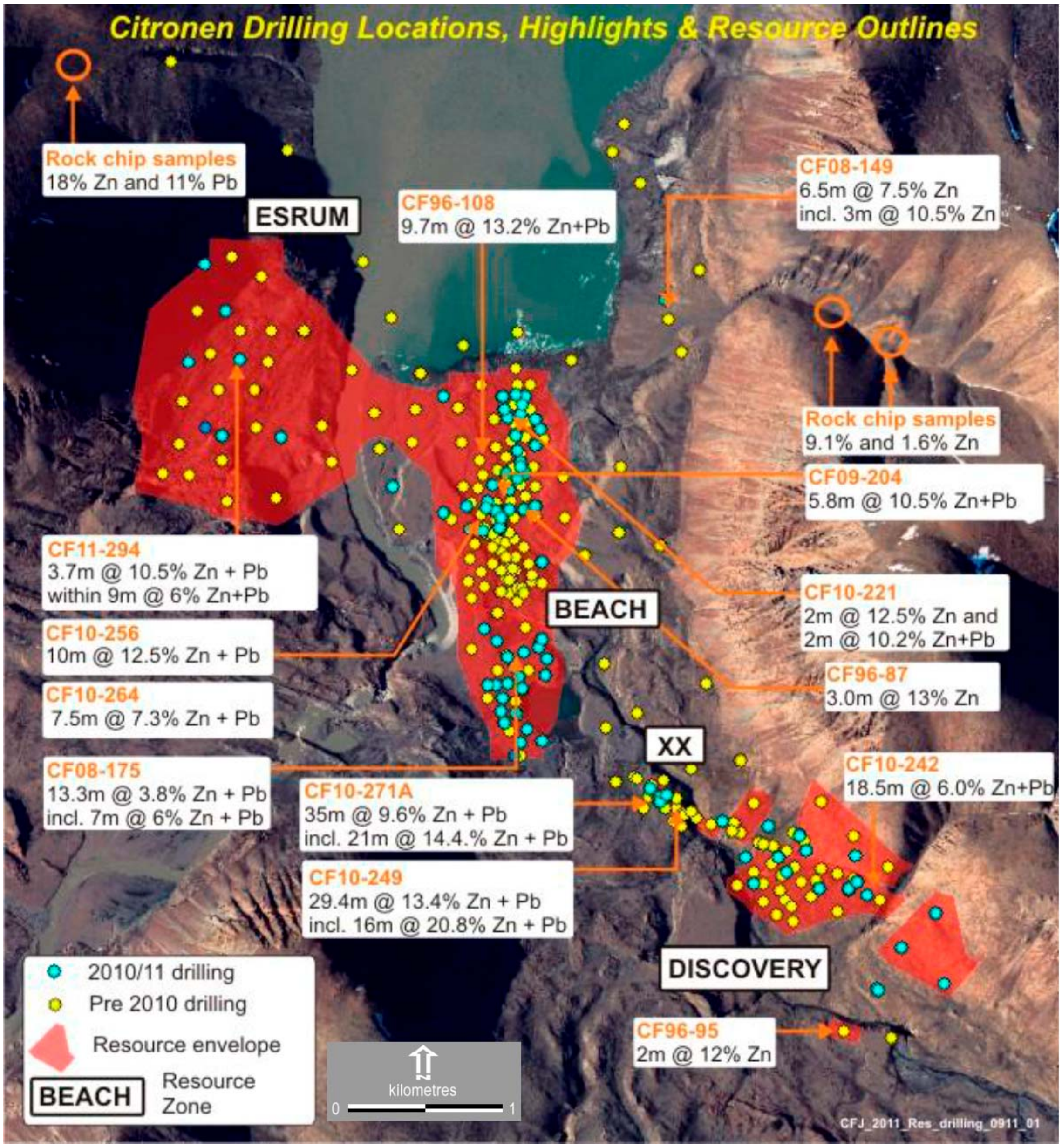


Figure 19. *Satellite view of the Citronen Fjord Zinc deposit, showing prospect areas, drilling sites and reported grades. Sulphide horizons in red. Copyright Ironbark Zinc Limited (2011).*

The January 2012 JORC resource for citronen as reported by the company:

- Global resource of 132 Mt @ 4.5% Zn+Pb (2% Zn cut-off);
- Medium grade resource of 71 Mt @ 5.7% Zn+Pb (3.5% Zn cut-off).

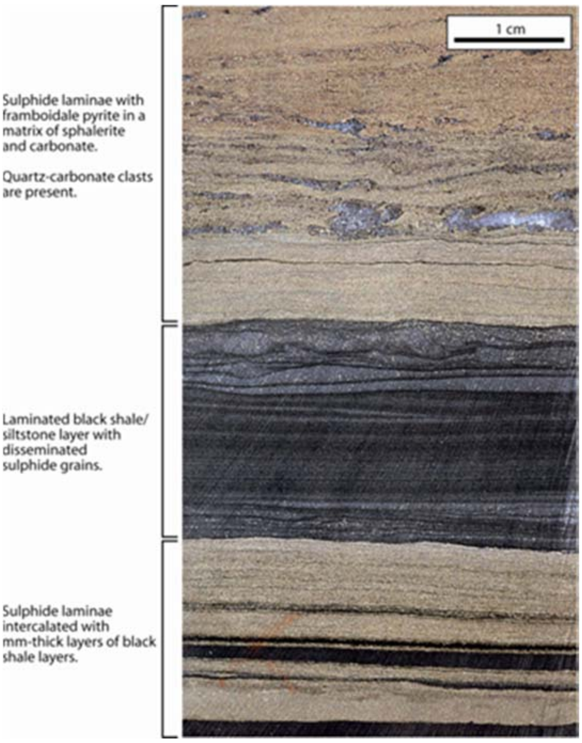


Figure 20. *Fine-grained laminated sulphides in black mudstone. The sulphide laminae consist of framboidal pyrite in a matrix of sphalerite and carbonate. Zn-content is the upper sulphide layer is 25-30% and in the lower layer 1–3%. Platinova drill-core CF-15, 3.6 cm across. From Kragh (1996).*

The zinc-lead deposit is interpreted to be of SEDEX type formed by the precipitation of sulphides from metal-bearing fluids introduced onto the sea floor through underlying fractures.

The precise tectonic control of the fractures is debatable, as is the role of the Navarana Fjord Escarpment assumed to lie immediately to the south of the Citronen Fjord (van der Stijl & Mosher 1998).

Figure 21. *View of the Discovery area seen from the north, showing two of the main gossans with exposures of massive sulphides at the base of the mountain slope immediately east of "Citronen Elv". From van der Stijl & Mosher (1998).*

Navarana Fjord Ba-Zn mineralisation

The Navarana Fjord barium-zinc occurrence is the most important of the showings. It was discovered in Freuchen Land on an east facing cliff facing Navarana Fjord during geochemical mapping in 1984 (Steenfelt 1985; Jakobsen and Steenfelt 1985) and was studied further as reported in Jakobsen & Stendal (1987), Jakobsen (1989a,b) and Jacobsen & Ohmoto (1993). The locality is situated at the Navarana Fjord anticline and hosts two types of mineralisation, syngenetic stratabound baryte-(sphalerite) and epigenetic sphalerite-baryte vein-type.

The most conspicuous mineralisation is the epigenetic vein-type. Massive sphalerite occurs together with baryte and minor galena, chalcocite, chalcopyrite, pyrite, quartz and fluorite in a breccia zone within a 5 to 7 m wide calcite vein hosted by dolomite of the Cambrian Portfjeld formation (Figure 22). The vein has an E-W strike and has been followed westwards over c. 300 m (Jakobsen 1989b). Fractures in the vicinity of the vein are sphalerite mineralised. A chip sample of a mineralised breccia from the opposite side of Navarana Fjord, on Lauge Koch Land, has yielded 2% Zn and 0.2% Pb (von Guttenberg & van der Stijl 1993).

The mineralisation is clearly epigenetic and the vein occupies a fracture zone on the flank of the Navarana Fjord anticline. Several minor E-W trending faults were observed in the surroundings of the vein. The time of the mineralisation is estimated at Devonian to Early Carboniferous, associated with Ellesmerian folding (Jakobsen 1989b).

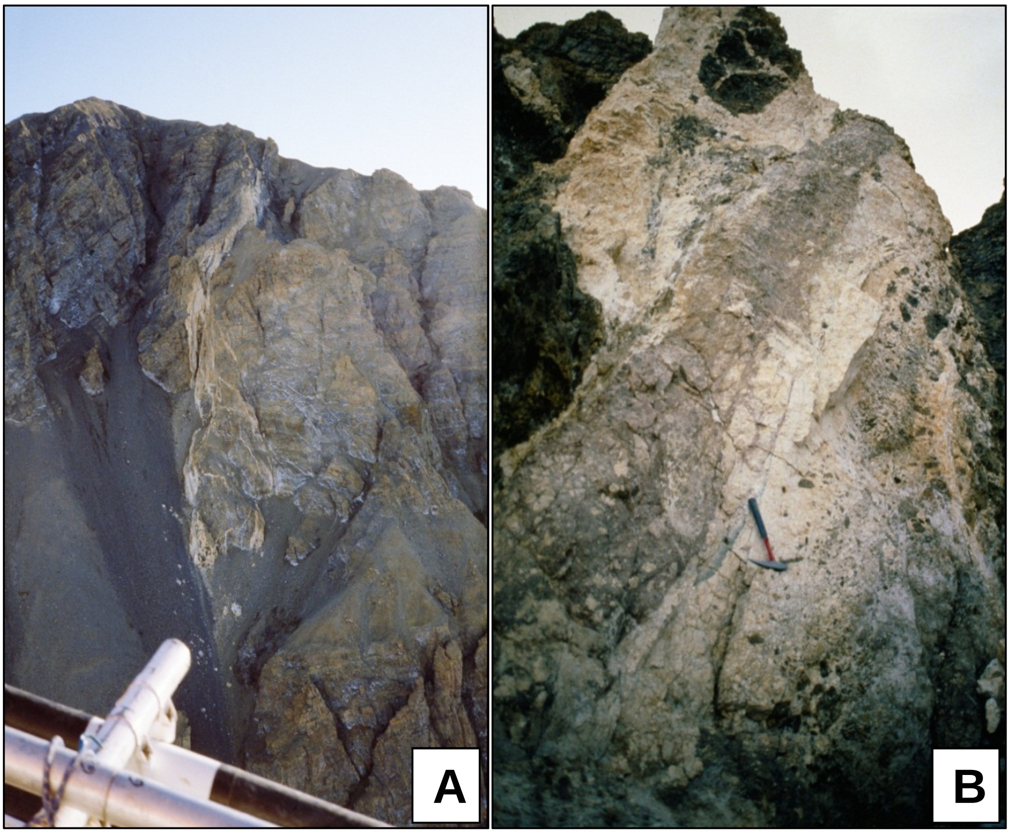


Figure 22. *The Navarana Fjord calcite vein centrally mineralised with baryte and sphalerite. (A) The vein is exposed over 60 m in an east-facing cliff section, (B) and has a central zone of massive grey-brown sphalerite. Photos from workshop presentation by A. Steenfelt (2011); see Appendix C.*

A pronounced rusty-yellow gossan zone that has developed at the surface north of the vein drew attention to the area of mineralisation. The gossan contains large volumes of hydrated iron sulphates (Jakobsen 1989a), that are preserved in the dry arctic climatic conditions.

Several stratabound Ba- and Zn-mineralised layers are present in carbonaceous shale and chert of the Amundsen Land Group sediments. A chert unit of this group has concentrations of up to 6 wt% Ba and black cherts and shales from another layer Ba concentrations of 1 wt%. There is no chemical or mineralogical correlation between Ba and Zn, and they are clearly located in different horizons. According to Jakobsen 1989b, the mineralisation can immediately be classified as an unmetamorphosed equivalent to the Aberfeldy deposit in Scotland on the basis of: (a) deposition in a starved 2^{nd} to 3^{rd} order basin, (b) Ba mineralisation associated with chert units, and (c) the presence of several Ba silicates.

Petermann prospect, Washington Land

Carbonate-hosted zinc-lead-silver mineralisation was discovered in 1997 along 19 km of a fault-controlled valley on Petermann Halvø in Washington Land with the main sites along NW–SE- to NNW–SSE-trending fault lineaments that splay off the main E–W- to ENE–WSW-trending, steeply-inclined fault (see summary and references in Dawes *et al.* 2000 and Dawes 2004). It comprises the ‘Petermann prospect’ of the Platinova / Rio Tinto exploration venture (Jensen 1998; Jensen & Schønwandt 1998; Cope & Beswick 1999; Pirie *et al.* 1999). The Petermann prospect is presently licensed by Avannaa Exploration Ltd.

The mineralisation is situated within the upper part of the lower Ordovician Cape Clay Formation (Dawes *et al.* 2000) and is associated with intense dolomitic alteration zones and strong gravity signatures, being dominated by pyrite, with marcasite, smithsonite and hydrozincite, and with galena and sphalerite. These ore minerals occur as open space infills within massive, burrow-mottled, micritic to stromatolitic dolomitised limestones and lime mudstones. Grab samples have yielded values up to 41% zinc, 0.3% lead and 211 ppm silver (Pirie *et al.* 1999). Drill core from ten holes revealed no economic-grade intersections but impressive local mineralisation, for example, a 23 m thick bed of massive pyrite (Cope & Beswick 1999).

According to Iannelli (2002), the mineralisation can be referred to as a Mississippi Valley-type deposit. Lead isotope data suggest that the source of lead in galena is the Precambrian shield underlying the Franklinian Basin (Dawes *et al.* 2000).

Cass prospect, Washington Land

Zinc-lead-barium mineralisation was discovered near Cass Fjord in Washington Land during the 1999 Platinova / Rio Tinto exploration venture. It comprises several mineralised sites along a 4 km strike length zone adjacent to a major ESE–WNW-trending regional fault (Cope & Beswick 1999; Iannelli 1999, 2002). The mineralisation is hosted in three massive ‘reactive’ limestone levels in the lower half of the upper Cambrian Cass Fjord Formation, with the lowest being the most pervasively dolomitised and most extensively mineralised. The main mineralisation consists of fine-grained, brown amber sphalerite, and medium- to coarse-grained galena and baryte set in a buff to brown ferroan dolomite. Baryte also forms seams and open space infills (Dawes *et al.* 2000). The single 107 m deep drill hole re-

turned an intersection of 8.4% zinc, 0.04% lead and 94 ppm silver over an interval of 1.2 m (Cope & Beswick 1999). The Cass prospect is presently licensed by Ironbark Zinc Ltd.
The mineralisation is considered to be of the MVT-type (Thomassen 2007) showing affinities with an 'Irish-type' model (Dawes 2004 quoting Iannelli 2002).

Kap Schuchert and Kayser Bjerg

The showings at Kap Schuchert and Kayser Bjerg occur in rocks of the shelf deposits are small, but they are evidence of mineralising events in this part of the Franklinian Basin (see references in Dawes 2004). At Kap Schuchert on the north coast of Washington Land, vug fillings of galena and sphalerite (1.47% Zn, 2.03% Pb) occur in Silurian reef carbonates. At eastern Hall Land, sphalerite-pyrite-galena-fluorite-baryte mineralisation (1.9% Zn at locality, Kayser Bjerg SE, 0.4% Pb, 20% Zn at locality, Kayser Bjerg NW) is confined to zones of calcite veining in organic-rich carbonate rocks of the Silurian Washington Land Group. The maximum size of sphalerite-rich lenses observed in calcite veins reaches 1.5x1.0x0.4 m, the maximum strike length of zones with intermittent mineralisation is about 1400 m.

Nyboe Land and Nares Land

Three showings on Nyboe Land and Nares Land are occurrences of epigenetic Zn-Pb-Ba mineralisation. They are hosted in stratabound brecciated dolomitic mudstones like those on either side of Navarana Fjord. The localities are Kap Wohlgemuth in Nares Land, and Hand Bugt and Repulse Havn at the north coast of Nyboe Land, all visited and sampled by Platinova A/S & Nanisivik Mines Ltd. (von Guttenberg *et al.* 1993). They are situated close to the Nyboe Land fault zone, like the two occurrences at Navarana Fjord, and it is assumed that the fault zone provides the pathway for the mineralising fluids. A grab sample from Repulse Havn returned 11% Zn and 2% Pb.

Grade and tonnage model selection

Based on the characteristics of the known mineralisations in the Franklinian Basin, the assessment panel found it justifiable to use the sediment-hosted zinc, both SEDEX and MVT subtype (Taylor *et al.* 2009) as the appropriate grade and tonnage models in the estimation of undiscovered deposits in this region.

Individual tracts assessed during workshop

Figure 23 shows the distribution of tracts being treated by the assessment panel for Ordovician-Silurian hosted SEDEX and MVT-type zinc deposits of the Franklinian Basin in North Greenland during the workshop.

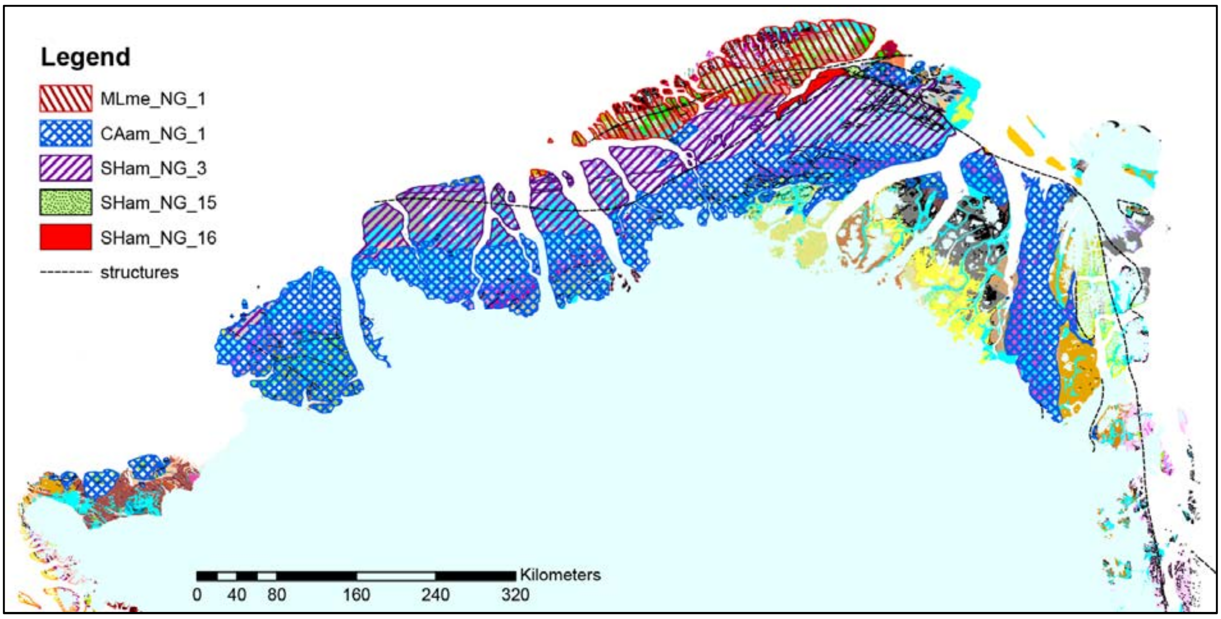


Figure 23. *Tracts for Ordovician-Silurian hosted SEDEX and MVT-type zinc deposits of the Franklinian Basin in North Greenland. The assessed tracts are; SHam_NG_15, SHam_NG_16, SHam_NG_3, MLme_NG_1 & CAam_NG_1. For geological legend see Appendix A.*

Tract SHam_NG_15 – SEDEX zinc type

Location and delineation of the permissive tract

The tract SHam_NG_15 is located at Citronen Fjord, Peary Land in North Greenland and includes the Citronen Fjord Zn-Pb deposit that is contained within the Amundsen Land Group (

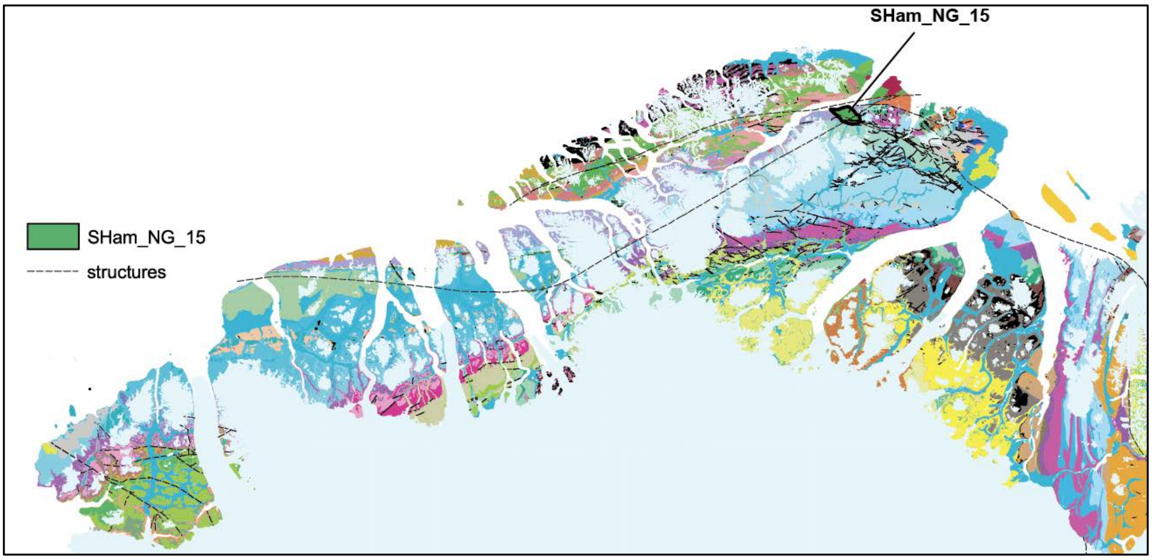


Figure 24). The tract was assessed for SEDEX type deposits. Summary of the estimated undiscovered zinc resources can be found in Table 4.

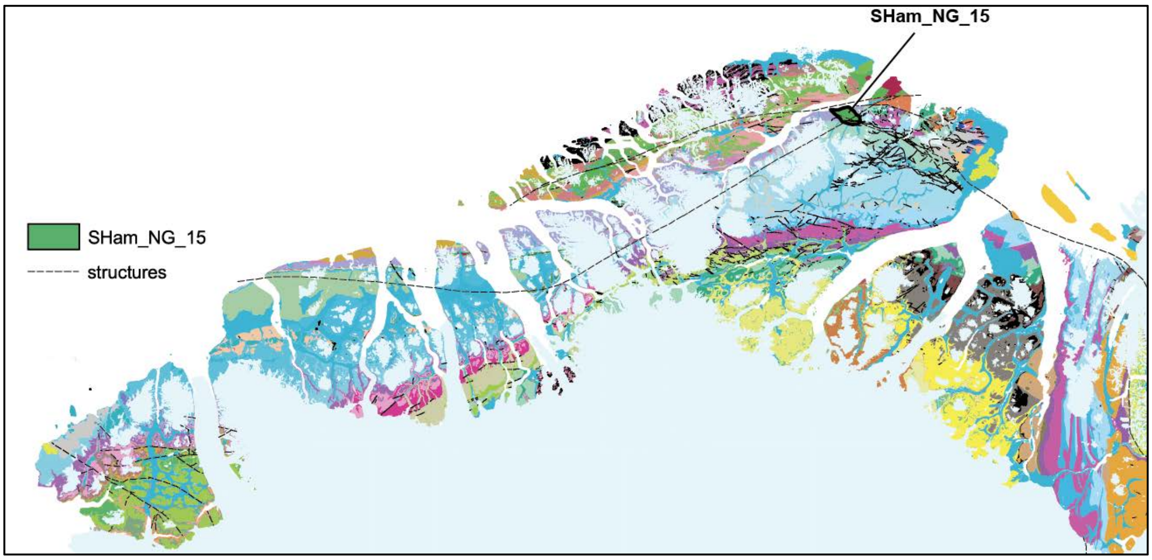


Figure 24. *Sham_NG_15 is located at Citronen Fjord, Peary Land in North Greenland and includes the Citronen Fjord Zn-Pb deposit. For geological legend see Appendix A.*

Table 4. *Summary of selected resource assessment results for the tract SHam_NG_15.*

Assessment depth (km)	Tract area (km^2)	Known zinc resources (metric tons)	Mean estimate of undiscovered zinc resources (metric tons)
1 km	184	5,400,000	3,500,000

Geological criteria and rationale for the estimate

The Citronen Fjord Zn-Pb deposit, located in sediments of the Lower Palaeozoic Franklinian Basin is classified as a SEDEX deposit. Stratiform sulphides are hosted by the Upper Ordovician – Lower Silurian Amundsen Land Group, which comprises black mudstones and chert, interbedded in places with dark grey calcarenitic turbidites and thick carbonate conglomerates of inferred debris flow origin. The Amundsen Land Group was deposited in a sediment-starved trough a few kilometres basinward of the up to 1 km high, E–W trending Navarana Fjord escarpment that formed the outer margin of a wide carbonate platform. Since SEDEX deposits tend to occur in clusters within their host stratigraphy, the area surrounding an identified Citronen Fjord deposit is to be considered as a promising target.

The deposits estimates and the resulting undiscovered resource estimates from the Monte Carlo simulation can be found in Table 5 and Table 6.

Table 5. *Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for SHam_NG_15. [NXX - Estimated number of deposits associated with the xxth percentile, N_{und} – expected number of undiscovered deposits, s – standard deviation, Cv% - coefficient of variance, N_{known} – number of known deposits in the tract that are included in the grade and tonnage model, N_{total} – total of expected number of deposits plus known deposits, area – area of permissive tract in square kilometers, density – deposit density reported as the total number of deposits per km^2. N_{und}, S, and Cv% are calculated using a regression equation (Singer and Menzie 2005)].*

Consensus undiscovered deposit estimate					Summary statistics					Area (km^2)	Deposit density (N/km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}		
1	1	2	3	4	1,3	0,87	65	1	2,3	180	0,013

	Estimated number of undiscovered deposits				
Estimator	**N90**	**N50**	**N10**	**N05**	**N01**
Individual 1	0	1	1	2	3
Individual 2	1	1	1	2	3
Individual 3	1	3	4	4	5
Individual 4	1	1	2	3	4
Individual 5	0	1	1	2	3
Individual 6	1	1	3	5	7
Individual 7	1	2	3	4	5
Individual 8	0	2	2	5	5
Individual 9	1	1	1	2	3
Individual 10	1	2	2	3	3
Individual 11	-	-	-	-	-
Individual 12	-	1	2	2	4
Individual 13	1	2	2	2	3
Consensus	**1**	**1**	**2**	**3**	**4**

Table 6. *Results of Monte Carlo simulations of undiscovered resources in the tract SHam_NG_15. [t = metric tons; Mt; megatonne or million tons]*

Material	Probability of at least the indicated amount						Probability of mean or greater	Probability of zero [none]
	0.95	0.90	0.50	0.10	0.05	Mean		
Zn (t)	0	16,000	740,000	10,000,000	18,000,000	3,500,000	0.23	0.07
Pb (t)	0	0	300,000	4,500,000	8,400,000	1,600,000	0.22	0.12
Rock (t)	0	0	0	0	0	56,000,000	0.10	0.68

Tract SHam_NG_16 – SEDEX zinc type

Location and delineation of the permissive tract

Tract SHam_NG_16 is located along the SW shore of Frederik E. Hydefjord, Peary Land in North Greenland (Figure 25) and contains the Upper Ordovician – Lower Silurian Amundsen Land Group that also hosts the Citronen Fjord Zn-Pb deposit. The tract was assessed for SEDEX type deposits. Summary of the estimated undiscovered zinc resources can be found in Table 7.

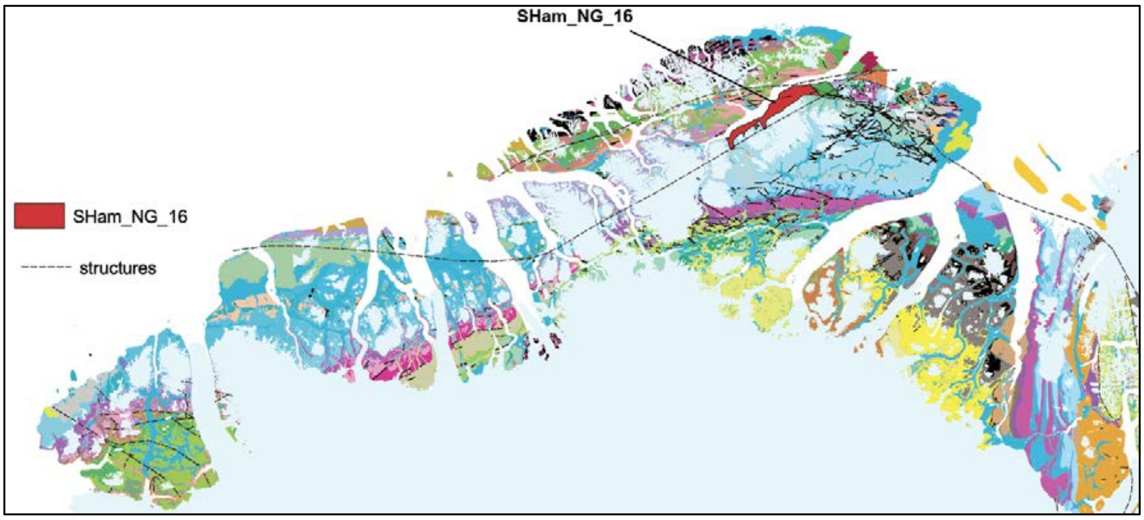


Figure 25. *Sham_NG_16 is located along the SW shore of Frederik E. Hydefjord, Peary Land in North Greenland and contains the Upper Ordovician – Lower Silurian Amundsen Land Group that hosts the Citronen Fjord Zn-Pb deposit. For geological legend see Appendix A.*

Table 7. *Summary of selected resource assessment results for the tract SHam_NG_16.*

Assessment depth (km)	Tract area (km^2)	Known zinc resources (metric tons)	Mean estimate of undiscovered zinc re-sources (metric tons)
1	655	0	2,600,000

Geological criteria and rationale for the estimate

This tract includes the time-equivalent horizon that hosts the Citronen Fjord deposit which, as this deposit attests, is closely associated with favourable synsedimentary faults and second order basins focusing hydrothermal fluids.

The deposits estimates and the resulting undiscovered resource estimates from the Monte Carlo simulation can be found in Table 8 and Table 9.

Table 8. *Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for SHam_NG_16. For further details see text associated with Table 5.*

Consensus undiscovered deposit estimate					Summary statistics					Area (km^2)	Deposit density (N/km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}		
0	1	2	2	4	1,1	1	97	0	1,1	650	0,0016

	Estimated number of undiscovered deposits				
Estimator	**N90**	**N50**	**N10**	**N05**	**N01**
Individual 1	0	1	2	2	3
Individual 2	1	3	3	4	5
Individual 3	0	1	2	2	3
Individual 4	0	1	2	2	3
Individual 5	0	1	2	2	4
Individual 6	0	0	1	1	2
Individual 7	0	1	1	2	3
Individual 8	0	0	1	1	2
Individual 9	0	1	2	3	5
Individual 10	0	1	2	3	5
Individual 11	-	-	-	-	-
Individual 12	0	0	1	2	2
Individual 13	0	0	1	1	2
Consensus	**0**	**1**	**2**	**2**	**4**

Table 9. *Results of Monte Carlo simulations of undiscovered resources in the tract SHam_NG_16. [t = metric tons; Mt; megatonne or million tons]*

Material	Probability of at least the indicated amount						Probability of mean or greater	Probability of zero [none]
	0.95	0.90	0.50	0.10	0.05	Mean		
Zn (t)	0	0	300,000	7,400,000	14,000,000	2,600,000	0.20	0.31
Pb (t)	0	0	100,000	3,100,000	6,000,000	1,100,000	0.21	0.34
Rock (t)	0	0	0	0	0	41,000,000	0.08	0.76

Tract SHam_NG_3 – SEDEX zinc type

Location and delineation of the permissive tract

Tract Sham_NG_3 is covering the through sequence of the Franklinian Basin and stretches from Independence Fjord in the east to Washington Land in the west in North Greenland (Figure 26). The tract was assessed for SEDEX type deposits. Summary of the estimated undiscovered zinc resources can be found in Table 10.

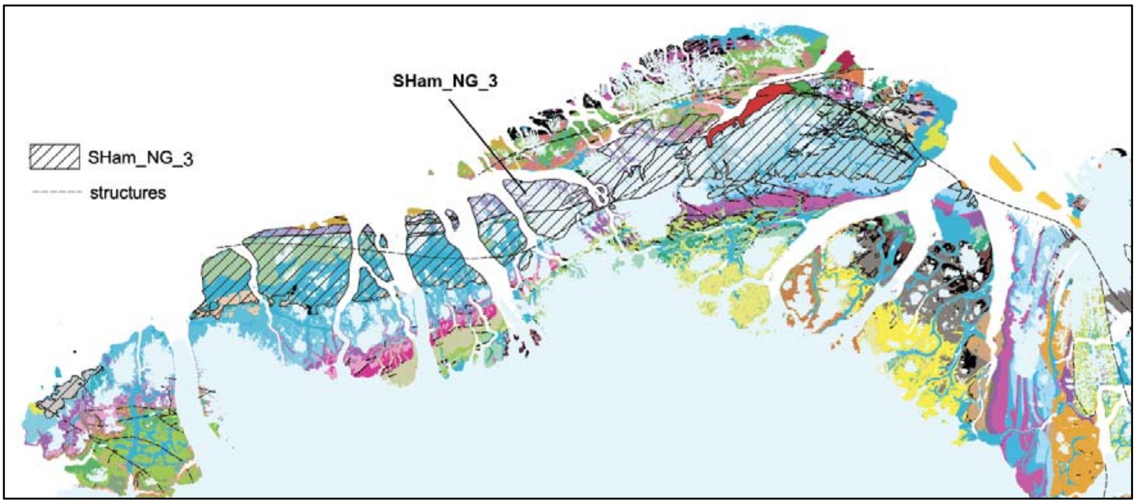


Figure 26. *Sham_NG_3 is covering the through sequence of the Franklinian Basin and stretches from Independence Fjord in the east to Washington Land in the west in North Greenland. For geological legend see Appendix A.*

Table 10. *Summary of selected resource assessment results for the tract SHam_NG_3*

Assessment depth (km)	Tract area (km^2)	Known zinc resources (metric tons)	Mean estimate of undiscovered zinc resources (metric tons)
1 km	30,060	0	5,700,000

Geological criteria and rationale for the estimate

The northern part of this tract, namely in the area of Amudsen Land, includes the time-equivalent horizon that hosts the Citronen Fjord deposit which, as this deposit attests, is closely associated with favourable synsedimentary faults and second order basins focusing hydrothermal fluids in a SEDEX setting. Confirming the prospectivity of this area, there are several significant stream sediment anomalies. Elsewhere, namely towards the west, this tract covers an extensive part of the carbonate platform where MVT deposits, associated with fault zones, karst surfaces, unconformities or Silurian mounds, can be present. Some significant stream sediment anomalies, possibly related to this mineralisation type, are present in this tract, especially along its southern edge, and showings have been identified in southern Hall Land.

The deposits estimates and the resulting undiscovered resource estimates from the Monte Carlo simulation can be found in Table 11 and Table 12.

Table 11. *Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for SHam_NG_3. For further details see text associated with Table 5.*

Consensus undiscovered deposit estimate					Summary statistics					Area (km^2)	Deposit density (N/km^2)
N90	**N50**	**N10**	**N05**	**N01**	N_{und}	**s**	**Cv%**	N_{known}	N_{total}		
1	2	3	5	10	2,2	1,8	82	0	2,2	30,060	0,000074

	Estimated number of undiscovered deposits				
Estimator	**N90**	**N50**	**N10**	**N05**	**N01**
Individual 1	0	2	3	5	10
Individual 2	0	3	5	8	10
Individual 3	1	2	3	5	10
Individual 4	0	1	2	2	5
Individual 5	1	2	3	4	8
Individual 6	1	2	3	4	6
Individual 7	2	3	4	8	10
Individual 8	0	2	2	5	10
Individual 9	1	2	5	10	15
Individual 10	1	2	5	6	18
Individual 11	-	-	-	-	-
Individual 12	0	1	2	4	7
Individual 13	0	1	2	2	4
Consensus	**1**	**2**	**3**	**5**	**10**

Table 12. *Results of Monte Carlo simulations of undiscovered resources in the tract SHam_NG_3. [t = metric tons; Mt; megatonne or million tons]*

Material	Probability of at least the indicated amount						Probability of mean or greater	Probability of zero [none]
	0.95	**0.90**	**0.50**	**0.10**	**0.05**	**Mean**		
Zn (Mt)	0	0,042	1,7	16	26	5,7	0.26	0.07
Pb (Mt)	0	0,0054	0,68	7,4	12	2,6	0.25	0.09
Rock (Mt)	0	0	0	0	0	90	0.13	0.57

Tract CAam_NG_1 – MVT zinc type

Location and delineation of the permissive tract

CAam_NG_1 is covering the platform sequence of the Franklinian Basin and stretches from Kronprins Christian Land in the east to Inglefield Land in the west in North Greenland (Figure 27). The tract was assessed for MVT type deposits. Summary of the estimated undiscovered zinc resources can be found in Table 13.

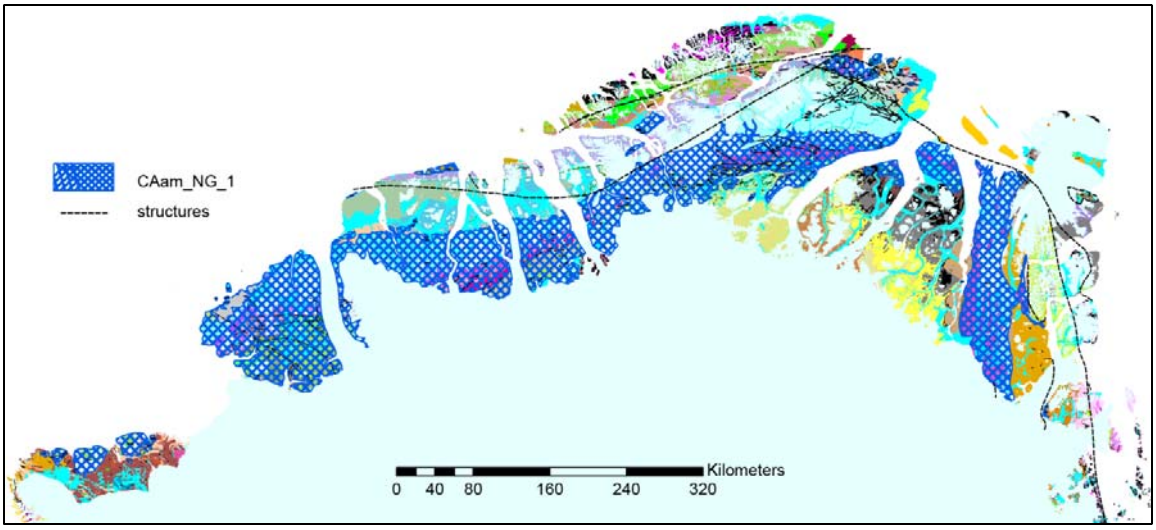


Figure 27. *CAam_NG_1 is covering the platform sequence of the Franklinian Basin and stretches from Kronprins Christian Land in the east to Inglefield Land in the west in North Greenland. For geological legend see Appendix A.*

Table 13. *Summary of selected resource assessment results for the CAam_NG_1 tract.*

Assessment depth (km)	Tract area (km^2)	Known zinc resources (metric tons)	Mean estimate of undiscovered zinc resources (metric tons)
1 km	51,738	0	2,700,000

Geological criteria and rationale for the estimate

This tract covers the southern part of the carbonate platform where MVT deposits, associated with fault zones, karst surfaces, unconformities or Silurian mounds, can be present. Attesting the favourability of this tract, several significant stream sediment anomalies and the Cass Fjord and Peterman prospects have been recognized.

The deposits estimates and the resulting undiscovered resource estimates from the Monte Carlo simulation can be found in Table 14 and Table 15.

Table 14. *Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for CAam_NG_1. For further details see text associated with Table 5.*

Consensus undiscovered deposit estimate					Summary statistics					Area (km^2)	Deposit density (N/km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}		
1	3	4	5	8	2,8	1,7	60	0	2,8	51,740	0,000054

	Estimated number of undiscovered deposits				
Estimator	**N90**	**N50**	**N10**	**N05**	**N01**
Individual 1	2	3	4	5	10
Individual 2	0	4	5	7	10
Individual 3	2	3	4	5	7
Individual 4	1	1	2	3	4
Individual 5	0	1	2	4	6
Individual 6	0	1	2	3	5
Individual 7	2	3	4	5	7
Individual 8	2	2	4	4	10
Individual 9	1	3	6	8	10
Individual 10	0	2	3	5	10
Individual 11	-	-	-	-	-
Individual 12	0	2	4	4	6
Individual 13	0	0	1	2	3
Consensus	**1**	**3**	**4**	**5**	**8**

Table 15. *Results of Monte Carlo simulations of undiscovered resources in the tract CAam_NG_1. [t = metric tons; Mt; megatonne or million tons]*

Material	Probability of at least the indicated amount						Probability of mean or greater	Probability of zero [none]
	0.95	0.90	0.50	0.10	0.05	Mean		
Zn (Mt)	0	0,062	1,4	6,1	9,7	2,7	0.29	0.07
Pb (Mt)	0	0,0097	0,47	2,7	4,4	1,2	0.26	0.08
Rock (Mt)	0	0	0	0	0	61	0.11	0.72

Tract MLme_NG_1 – SEDEX zinc type

Location and delineation of the permissive tract

MLme_NG_1 is covering the metamorphosed part of the through sequence of the Franklinian Basin and stretches from Peary Land in the east to Wulf Land in the west in North Greenland (Figure 28). The tract was assessed for SEDEX type deposits. Summary of the estimated undiscovered zinc resources can be found in Table 16.

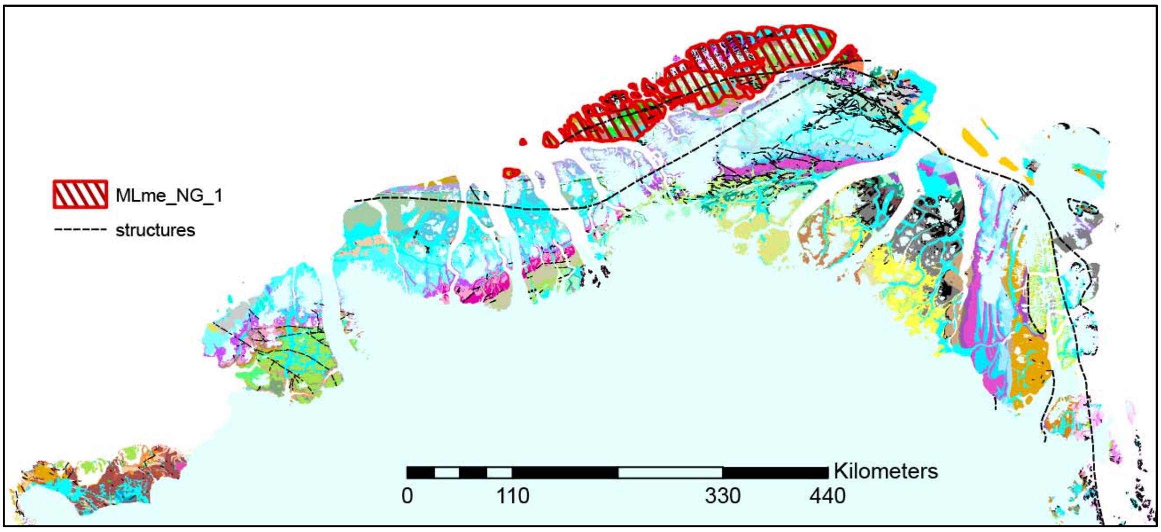


Figure 28. *MLme_NG_1 is covering the metamorphosed part of the through sequence of the Franklinian Basin and stretches from Peary Land in the east to Wulf Land in the west in North Greenland. For geological legend see Appendix A.*

Table 16. *Summary of selected resource assessment results for the MLme_NG_1 tract.*

Assessment depth (km)	Tract area (km^2)	Known zinc resources (metric tons)	Mean estimate of undiscovered zinc resources (metric tons)
1 km	12,780	0	1,900,000

Geological criteria and rationale for the estimate

This tract includes similar rocks as SHam_NG_3 just that these have been slightly metamorphosed and deformed during the Ellesmerian orogeny. Time-equivalent horizon that hosts the Citronen Fjord deposit which, as this deposit attests, is closely associated with favourable synsedimentary faults and second order basins focusing hydrothermal fluids in a SEDEX setting.

The deposits estimates and the resulting undiscovered resource estimates from the Monte Carlo simulation can be found in Table 17 and Table 18.

Table 17. *Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for MLme_NG_1. For further details see text associated with Table 5.*

Consensus undiscovered deposit estimate					Summary statistics					Area (km^2)	Deposit density (N/km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}		
0	0	2	4	5	0,78	1,4	180	0	0,78	12,780	0,000061

	Estimated number of undiscovered deposits				
Estimator	**N90**	**N50**	**N10**	**N05**	**N01**
Individual 1	0	0	2	3	4
Individual 2	0	1	3	4	5
Individual 3	0	0	2	2	3
Individual 4	0	0	1	2	3
Individual 5	0	1	2	3	6
Individual 6	0	0	1	2	3
Individual 7	0	1	2	3	4
Individual 8	0	1	2	2	5
Individual 9	1	2	5	6	7
Individual 10	0	0	3	4	5
Individual 11	-	-	-	-	-
Individual 12	0	0	1	2	3
Individual 13	0	0	0	1	2
Consensus	**0**	**0**	**2**	**4**	**5**

Table 18. *Results of Monte Carlo simulations of undiscovered resources in the tract MLme_NG_1. [t = metric tons; Mt; megatonne or million tons]*

Material	Probability of at least the indicated amount						Probability of mean or greater	Probability of zero [none]
	0.95	0.90	0.50	0.10	0.05	Mean		
Zn (Mt)	0	0	0	5	12	1,9	0.17	0.60
Pb (Mt)	0	0	0	1,8	4,5	0,82	0.16	0.63
Rock (Mt)	0	0	0	0	0	30	0.06	0.84

Meso- to Neoproterozoic Hekla Sund Basin, eastern North Greenland

Sources of information

The principal sources of information used for the assessment of the tracts in the Meso- to Neoproterozoic Hekla Sund Basin for the SEDEX zinc type are given in Appendix A.

Regional Geology

The Meso- to Neoproterozoic sedimentary Hekla Sund Basin in eastern North Greenland includes the post-rift thermal subsidence depositional environment sediments of the Hagen Fjord Group and within the allochthonous Rivieradal Group of the Meso- to Neoproterozoic

The Hagen Fjord Group reaches a maximum thickness of approximately 1,100 m and consists of a succession of sandstones overlain by sandstone-siltstone association and an upper part that is characterised by limestone and dolomites with abundant stromatolites (Fyns Sø Formation). The sediments of the Hagen Fjord Group is deposited on top of an up to 1,350 m thick succession of well-preserved tholeiitic flood basalts of the Proterozoic Zig-Zag Dal Basalt Formation which in turn overlies the more than 2 km thick Independence Fjord Group sandstones that are intruded by numerous mafic sheets and sills of the Midsommersø Dolerite Formation (Figure 29). The sheets and sills have been dated to be 1382±2 Ma (Henriksen et al. 2009).

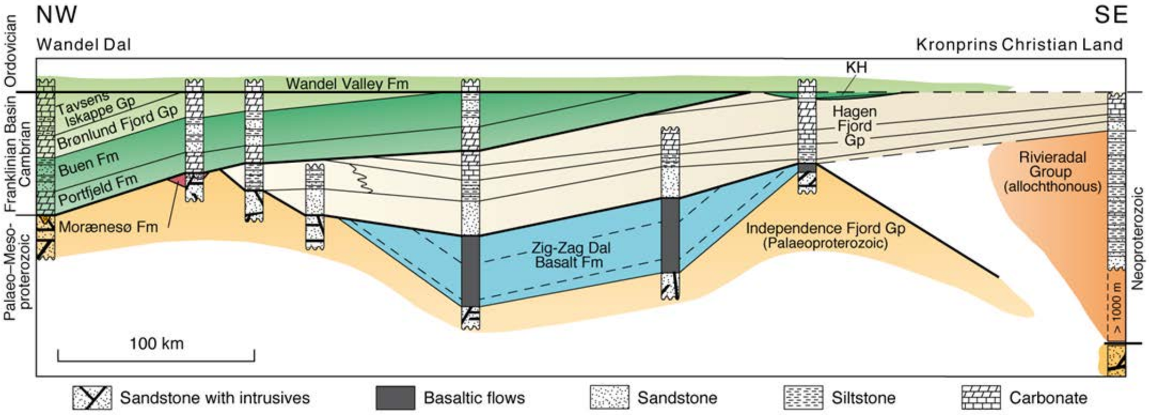


Figure 29. *Schematic cross-section of the Proterozoic–Ordovician Hagen Fjord and Rivieradal Group successions in eastern North Greenland between 82°N and Kronprins Christian Land ~ 80°N. From Henriksen et al. (2009).*

The Rivieradal Group, are confined to the allochthonous, Caledonian, Vandredalen thrust sheet in the Kronprins Christian Land area, and are interpreted as deepmarine deposits equivalent in age to the lower part of the Hagen Fjord Group. This succession is 7,500 to 10,000 m thick and comprises conglomerates, sandstones, turbiditic sandstones and mudstones that accumulated in a major east-facing half-graben basin; the bounding western fault was reactivated as a thrust during the Caledonian orogeny (Henriksen *et al.* 2009).

Exploration history

The following overview is derived from Tukiainen & Lind (2011).

1969-1973:	Greenarctic Consortium, photo geology, regional aeromagnetic survey, gossan check.
1978-80:	The GGU regional mapping campaign included stream sediment sampling for geochemistry and ore microscopy of heavy minerals from the sediment samples
1993:	GGU regional stream sediment sampling and supplementary local sampling.
1994:	GGU regional stream sediment sampling and ground follow up on geochemical anomalies.
1995:	GGU supplementary sampling and reconnaissance.
1998:	AEM Greenland, a combined airborne magnetic and electromagnetic survey covering the eastern part of J.C. Christensen Land
2010:	Avannaa Resources Limited, 2 week field programme.

Known prospects, mineral occurrences or related deposit types

No known sediment-hosted zinc deposits. However, according to Tukiainen & Lind (2011) sandstone hosted stratabound epigenetic lead-zinc mineralisations occur in the upper part of the Campanuladal Formation within the Hagen Fjord group in the eastern part of Campanuladal, eastern North Greenland. For more information about the mineralisation potential please refer to Tukiainen & Lind (2011).

Grade and tonnage model selection

Based on the discussion and the reviews of previous work by various researchers on the mineralisation, the assessment panel found it justified, using the sediment-hosted zinc, SEDEX subtype (Taylor *et al*. 2009) as the appropriated grade and tonnage models in the estimation of undiscovered deposits.

Individual tracts assessed during workshop

Figure 30. *Location of the two tracts; MLme_NE_RG_1 & MLme_NE_HF_1 within the Hekla Sund Basin assessed for undiscovered SEDEX type zinc deposits. For geological legend see Appendix A.*

Tract MLme_NE_HF_1 – SEDEX zinc type

Location and delineation of the permissive tract

The MLme_NE_HF_1 tract is located in the eastern North Greenland between Independence Fjord and Danmark Fjord (Figure 31). The tract was assessed for SEDEX type deposits. Summary of the estimated undiscovered zinc resources can be found in Table 19.

The MLme_NE_HF_1 tract includes the Hagen Fjord Group. The extent of the tract is based on the mapped and interpretated distribution of the Hagen Fjord Group down to an estimated depth of 1 km below surface.

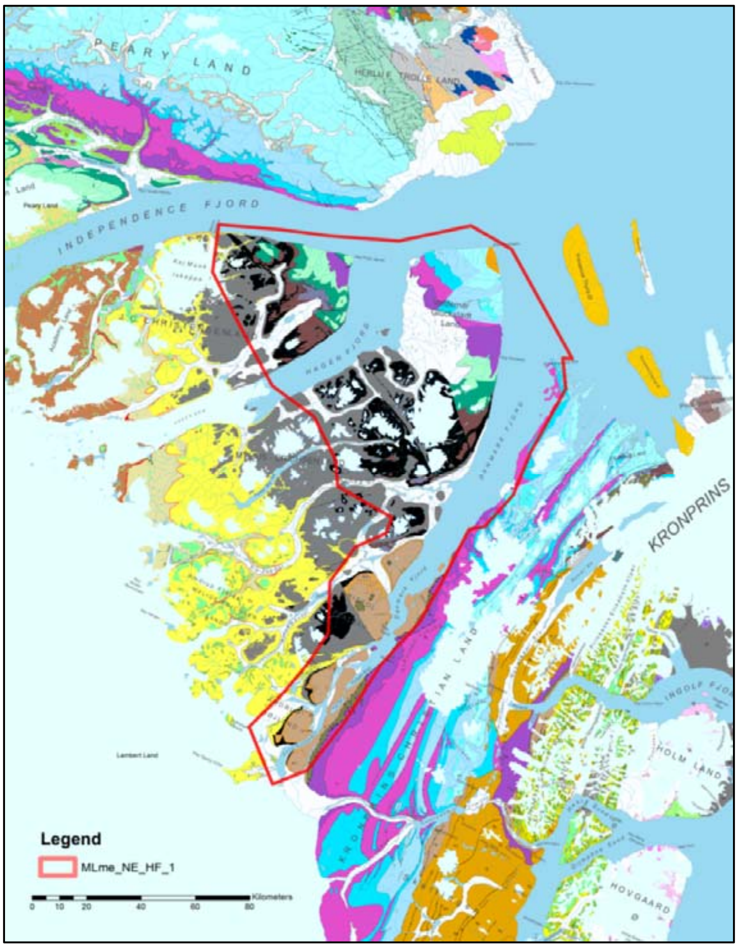


Figure 31. *Distribution of tract MLme_NE_HF_1 assessed for undiscovered SEDEX type zinc deposits. For geological legend see Appendix A.*

Table 19. *Summary of resource assessment results for the tract MLme_NE_HF_1 assessed for SEDEX type zinc deposits.*

Assessment depth (km)	Tract area (km^2)	Known zinc resources (metric tons)	Mean estimate of undiscovered zinc resources (metric tons)
1	12,966	0	990,000

Geologic criteria and rationale for the estimate

The Neoproterozoic sedimentary Hekla Sund Basin in eastern North Greenland was assumed by the assessment panel to hold the right ingredients for SEDEX type deposits. The tracts were defined within the post-rift thermal subsidence depositional environment sediments of the Hagen Fjord Group of the Meso- to Neoproterozoic Hekla Sund Basin. The Hagen Fjord Group consists of a succession of sandstones overlain by sandstone-siltstone association and an upper part that is characterised by limestone and dolomites with abundant stromatolites. The defined tract also outline a very large area were very limited exploration activity have been carried out, so a potential for undiscovered mineralisations is present. The deposits estimates and the resulting undiscovered resource estimates from the Monte Carlo simulation can be found in Table 20 and Table 21.

Table 20. *Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for tract MLme_NE_HF_1. For further details see text associated with Table 5.*

Consensus undiscovered deposit estimate					Summary statistics					Area (km^2)	Deposit density (N/km^2)
N90	**N50**	**N10**	**N05**	**N01**	N_{und}	**s**	**Cv%**	N_{known}	N_{total}		
0	0	1	2	3	0.41	0.82	200	0	0.41	12,970	0.000031

	Estimated number of undiscovered deposits				
Estimator	**N90**	**N50**	**N10**	**N05**	**N01**
Individual 1	0	1	1	2	4
Individual 2	0	0	1	2	3
Individual 3	0	0	1	1	3
Individual 4	0	0	0	0	1
Individual 5	0	0	0	1	1
Individual 6	0	0	1	1	2
Individual 7	0	0	0	2	2
Individual 8	0	0	1	2	4
Individual 9	0	0	1	2	4
Individual 10	0	0	0	2	2
Individual 11	-	-	-	-	-
Individual 12	0	0	0	2	3
Individual 13	0	0	1	1	3
Consensus	**0**	**0**	**1**	**2**	**3**

Table 21. *Results of Monte Carlo simulations of undiscovered resources for tract MLme_NE_HF_1. [t=metric tons; Mt; megatonne or million tons]*

Material	Probability of at least the indicated amount						Probability of mean or greater	Probability of zero [none]
	0.95	**0.90**	**0.50**	**0.10**	**0.05**	**Mean**		
Zn (Mt)	0	0	0	1,8	5,2	0,99	0.14	0.70
Pb (Mt)	0	0	0	0,75	2,2	0,48	0.12	0.71
Rock (Mt)	0	0	0	0	0	16,000,000	0.04	0.91

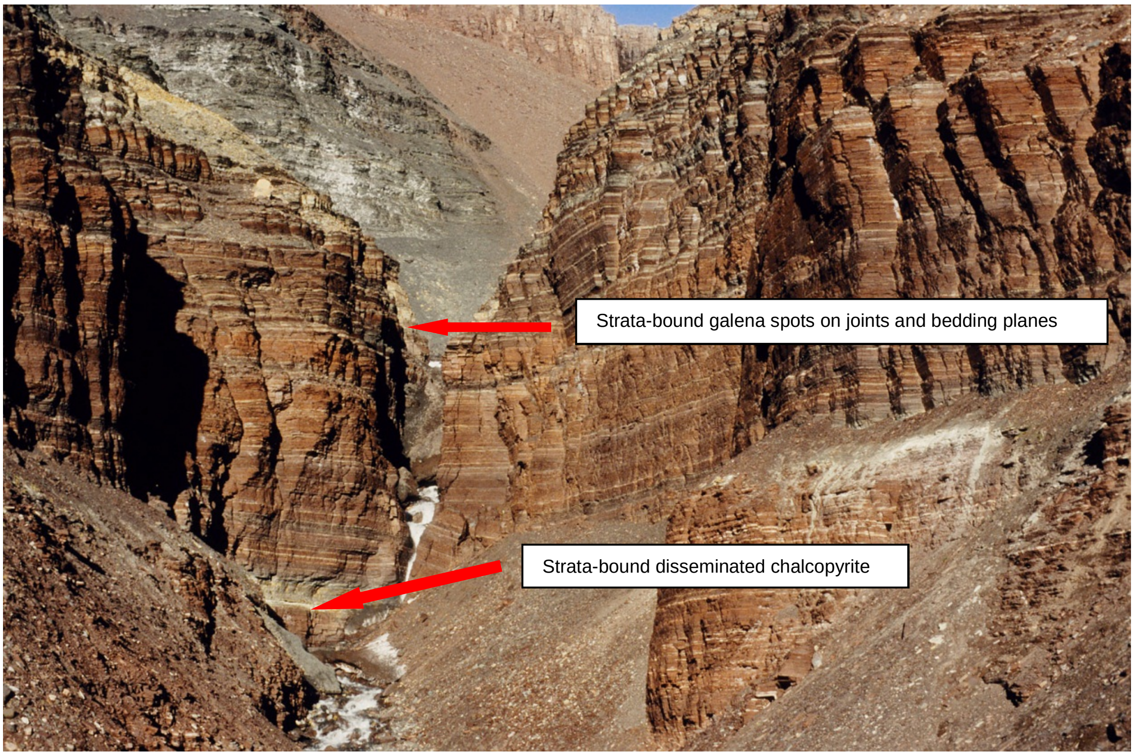


Figure 32. *Typical sequence of sandstones and silty shales of the Campanuladal Formation with strata-bound Cu- and Pb mineralisation indicated on the photo. The locality is located at the eastern side of Campanuladal. From Tukiainen & Lind (2011).*

Tract MLme_NE_RG_1 – SEDEX zinc type

Location and delineation of the permissive tract

The tract MLme_NE_RG_1 is located in the eastern North Greenland between Nioghalvfjerdsfjorden and Kronprins Kristian Land (Figure 33). The tract was assessed for SEDEX type deposits. Summary of the estimated undiscovered zinc resources can be found in Table 22.

The MLme_NE_RG_1 tract includes the Rivieradal Group. The extent of the tract is based on the mapped and interpretated distribution of the Rivieradal Group down to an estimated depth of 1 km below surface.

Figure 33. *Distribution of tract MLme_NE_RG_1 assessed for undiscovered SEDEX type zinc deposits. For geological legend see Appendix A.*

Table 22. *Summary of resource assessment results for the tract MLme_NE_RG_1 assessed for SEDEX type zinc deposits.*

Assessment depth (km)	Tract area (km^2)	Known zinc resources (metric tons)	Mean estimate of undiscovered zinc resources (metric tons)
1	7,346	0	1,100,000

Geologic criteria and rationale for the estimate

The Rivieradal Group succession is 7,500 to 10,000 m thick and comprises conglomerates, sandstones, turbiditic sandstones and mudstones that accumulated in a major east-facing half-graben basin; the bounding western fault was reactivated as a thrust during the Caledonian orogeny. The thickness of the basin and tectonic history favours the potential for formation of SEDEX deposits. In addition the defined tracts outline a very large area were very limited exploration activity have been carried out, so a potential for undiscovered mineralisations is present.

The deposits estimates and the resulting undiscovered resource estimates from the Monte Carlo simulation can be found in Table 23 and Table 24.

Table 23. *Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for tract MLme_NE_RG_1. For further details see text associated with Table 5.*

Consensus undiscovered deposit estimate					Summary statistics					Area (km^2)	Deposit density (N/km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}		
0	0	1	2	4	0.44	0.94	220	0	0.44	7,350	0.000059

	Estimated number of undiscovered deposits				
Estimator	**N90**	**N50**	**N10**	**N05**	**N01**
Individual 1	0	1	1	2	4
Individual 2	0	0	1	2	4
Individual 3	0	0	0	1	2
Individual 4	0	0	0	1	2
Individual 5	0	0	1	2	2
Individual 6	0	0	2	2	3
Individual 7	0	0	1	2	3
Individual 8	0	1	2	5	10
Individual 9	0	0	2	4	6
Individual 10	0	0	0	0	5
Individual 11	-	-	-	-	-
Individual 12	0	0	2	2	4
Individual 13	0	0	1	1	2
Consensus	**0**	**0**	**1**	**2**	**4**

Table 24. *Results of Monte Carlo simulations of undiscovered resources for tract MLme_NE_RG_1. [t=metric tons; Mt; megatonne or million tons]*

Material	Probability of at least the indicated amount						Probability of mean or greater	Probability of zero [none]
	0.95	0.9	0.5	0.1	0.05	Mean		
Zn (t)	0	0	0	1,900,000	5,900,000	1,100,000	0.13	0.70
Pb (t)	0	0	0	850,000	2,800,000	510,000	0.13	0.72
Rock (t)	0	0	0	0	0	17,000,000	0.05	0.90

Figure 34. *Syn-rift, deep-water thin-bedded, mud-rich sequence of the Riveradal group. From workshop presentation by Ineson (2011); see Appendix C.*

Palaeoproterozoic Inglefield mobile belt, North-West Greenland

Sources of information

The principal sources of information used for the assessment of the tracts within the Inglefield mobile belt in North-West Greenland are given in Appendix A.

Regional geology

The Inglefield mobile belt is situated in Inglefield Land in the North-Western part of Greenland (Figure 35). The basement consists of Palaeoproterozoic juvenile para- and ortho - gneisses; i.e. high-grade supracrustal and granitoid rocks. The supracrustal rocks, called the Etah Group, are believed to be the oldest rocks in the area and consist of garnet-rich paragneiss, calc-silicate gneiss, marble-dominated units, amphibolite, ultramafic rock and quartzite. The supracrustal sequence is intruded by the Etah meta-igneous complex, which is composed of intermediate to felsic metaigneous rocks, metagabbros and orthogneisses.

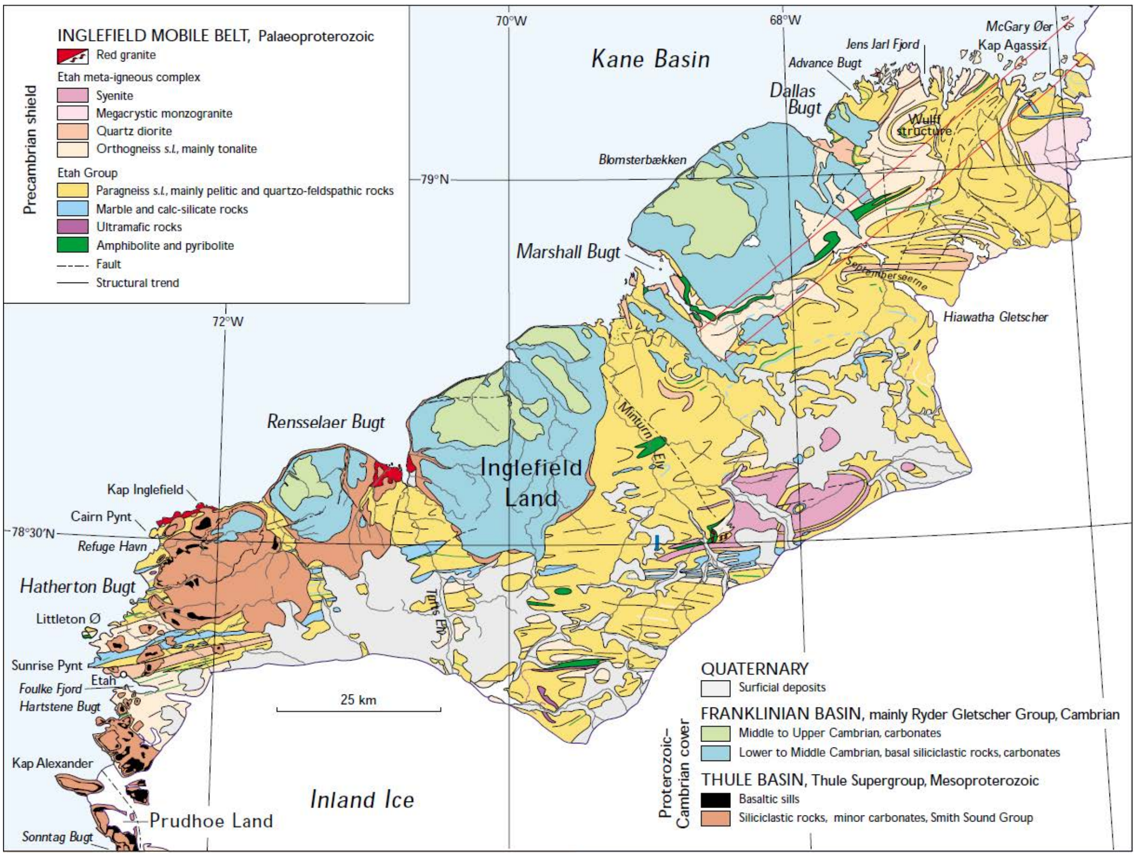


Figure 35. *Geological map of Inglefield Land and northern Prudhoe Land (southern area) from Dawes et al. (2004). The two red lines delimit the 'North Inglefield Land gold belt' described by Thomassen et al. (2000).*

The Etah Group and the Etah meta-igneous complex were metamorphosed at 1920 Ma under low-pressure to medium-pressure granulite facies conditions, coinciding with at least three phases of deformation. The Mesoproterozoic Thule Supergroup (Dawes 1997) and the Cambrian deposits of the Franklinian Basin overlie the Palaeoproterozoic sequence. The Inglefield Mobile Belt is interpreted as a Palaeoproterozoic arc, formed by convergence of two Archaean crustal blocks. The rock sequences of the Inglefield Mobile Belt can be correlated across northern Baffin Bay into Canada, without offset across the Nares Strait.

For a more comprehensive description of the geology of the Inglefield mobile belt please refer to Dawes (2004).

Exploration history

Only a few exploration campaigns have been conducted in this region:

- 1969-1973 Greenartic Consortium and Internationalt Mineselskab A/S
    - Early reco.-type prospecting; widespread gossans; focuses on carbonate supracrustal rocks similar to Black Angel.
- 1991 & 1995 RTZ Mining and Exploration
- 1995 NunaOil A/S
- 1994-1996 GEUS
    - Geological reconnnaissance and regional stream sediment geochemical sampling.
    - GIS compilation.
    - AEM 1994 Survey, electromagnetic and magnetic airborne geophysical survey.
- 1999 GEUS
    - Kane Basin Project – geological mapping and investigations (1:500.000 map).
- 2010 – present NunaMinerals A/S.
    - Gravity and aeromag; Cu-Au targets.

Known prospects, mineral occurrences or related deposit types

There are no known zinc deposits in Inglefield Land.

According to Thomassen *et al.* (2000), several types of occurrences occur and they can be classified on the basis of their host rocks into four types (Figure 36): (1) Paragneiss-hosted mineralisation (localities 3, 5, 6, 8, 11-14 and 18), (2) Skarn-hosted mineralisation (localities 16, 17 and 19), (3) Orthogneiss-hosted mineralisation (localities 15 and 20), and (4) Mafic-ultramafic-hosted/associated mineralisation (localities 1, 2, 4, 9, 10, 12 and 16).

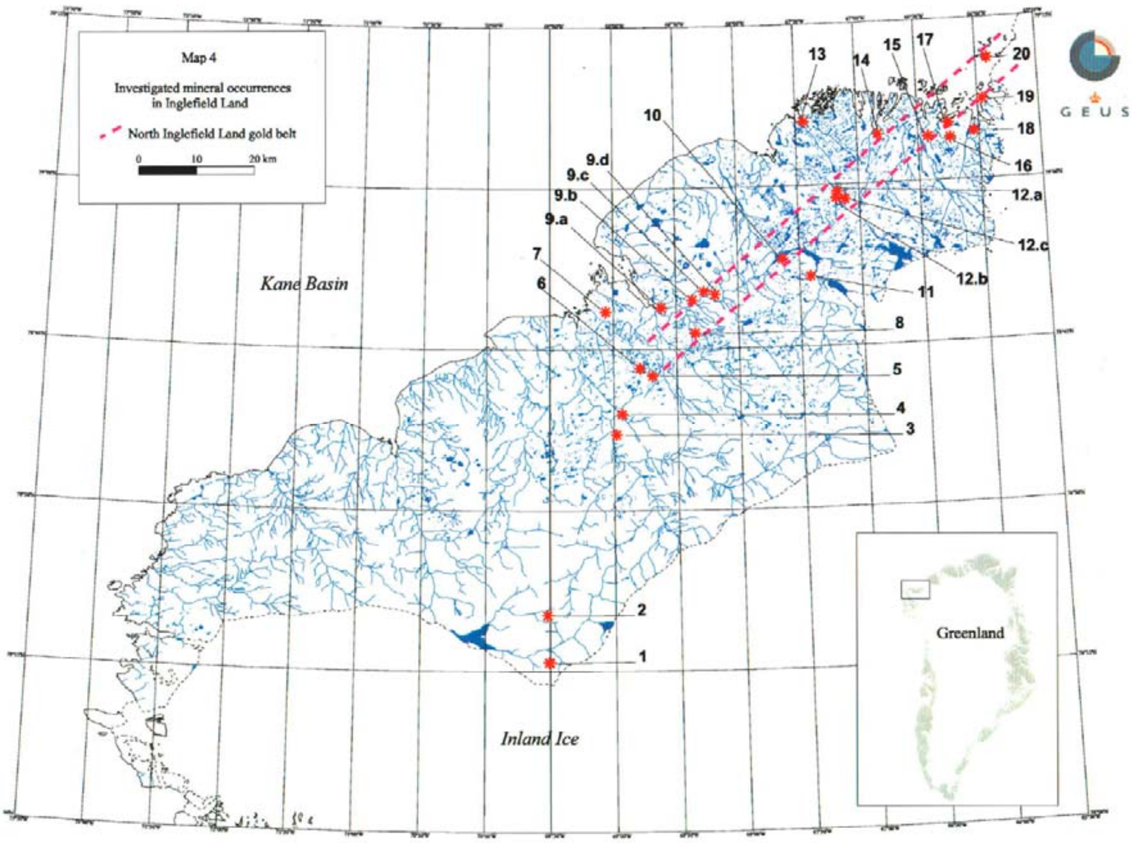


Figure 36. *Map of investigated mineral occurrences as part of the 1999 Kane Basin investigations. Numbers refers to the different mineralisation types mentioned above and described further below. For more details please refer to Thomassen et al. (2000).*

Paragneiss-hosted mineralisation (nine localities)

The garnet-sillimanite paragneisses host widespread bands containing disseminated and semi-massive iron sulphides associated with graphite, the oxidation of which has resulted in rust zones up to 5 km long and 200 m wide. Ore minerals are pyrrhotite, minor pyrite and traces of chalcopyrite. Mineralised samples returned up to 1.4 ppm Au, 0.27% Cu and 0.15% Zn. These sulphide bands are possibly the result of high-temperature, potassium-rich fluids that were channelled along sub parallel shear or mylonite zones, with the sulphides being precipitated in and replacing the matrix of the detorrned rocks.

Skarn-hosted mineralisation (three localities)

At the best investigated locality chalcopyrite-bornite-pyrrhotite-magnetite mineralisation with up to 0.6 ppm Au and 0.91% Cu is associated with a mafic-layered complex intruded into calc-silicate rocks.

Orthogneiss-hosted mineralisation (two localities)

This type of mineralisation, which had not previously been reported from Inglefield Land, was not investigated in any detail. A single grab sample with disseminated copper sulphides returned 12.5 ppm Au, 35 ppm Ag and 1.28% Cu.

Mafic-ultramafic-hosted/associated mineralisation (five localities)
An amphibolite belt, which can be traced discontinuously for over 50 km, exhibits magmatic sulphide mineralisation in conformable layers several metres thick. Sulphides are pyrrhotite with minor pyrite and chalcopyrite, mostly occurring as immiscible droplets or intercumulus. Metal values up to 6.9 ppm Au, 233 ppb Pd, 0.38% Cu, 0.16% Zn and 2.53% Mn have been recorded. Associated shear zone-controlled quartz-rich veins with minor sulphides, probably resulting from the remobilisation of magmatic sulphides, returned up to 0.3 ppm Au and 0.83% Cu.

Gold is typically associated with copper, and the distribution of gold values shows a characteristic pattern: all samples with > 0.2 ppm Au stem from six localities in northern Inglefield Land, of which five are distributed along a 70 x 4 km NE-striking belt that coincides with an aeromagnetic lineament interpreted as a deep-seated geological structure. The correspondence of samples anomalous in gold and the magnetic feature defines a 'North Inglefield Land gold belt'.

Grade and tonnage model selection

Based on the characteristics of the known mineralisations in the Inglefield mobile belt, the assessment panel found it justifiable to use the sediment-hosted zinc, SEDEX - subtype (Taylor *et al.* 2009) as the appropriate grade and tonnage models in the estimation of undiscovered deposits in this region.

Individual tracts assessed during workshop

Figure 37 show the distribution of tracts being treated by the assessment panel for Palaeoproterozoic hosted SEDEX type zinc deposits of the Inglefield mobile belt, North-West Greenland during the workshop.

Tract MLme_NW_IG_1 – SEDEX zinc type

Location and delineation of the permissive tract

The MLme_NW_IG_1 tract includes the Etah group down to an estimated depth of 1 km below surface. The extent of the tract is based on the mapped and interpretated distribution of the Etah group. The tract was assessed for SEDEX type deposits. Summary of the estimated undiscovered zinc resources can be found in Table 25.

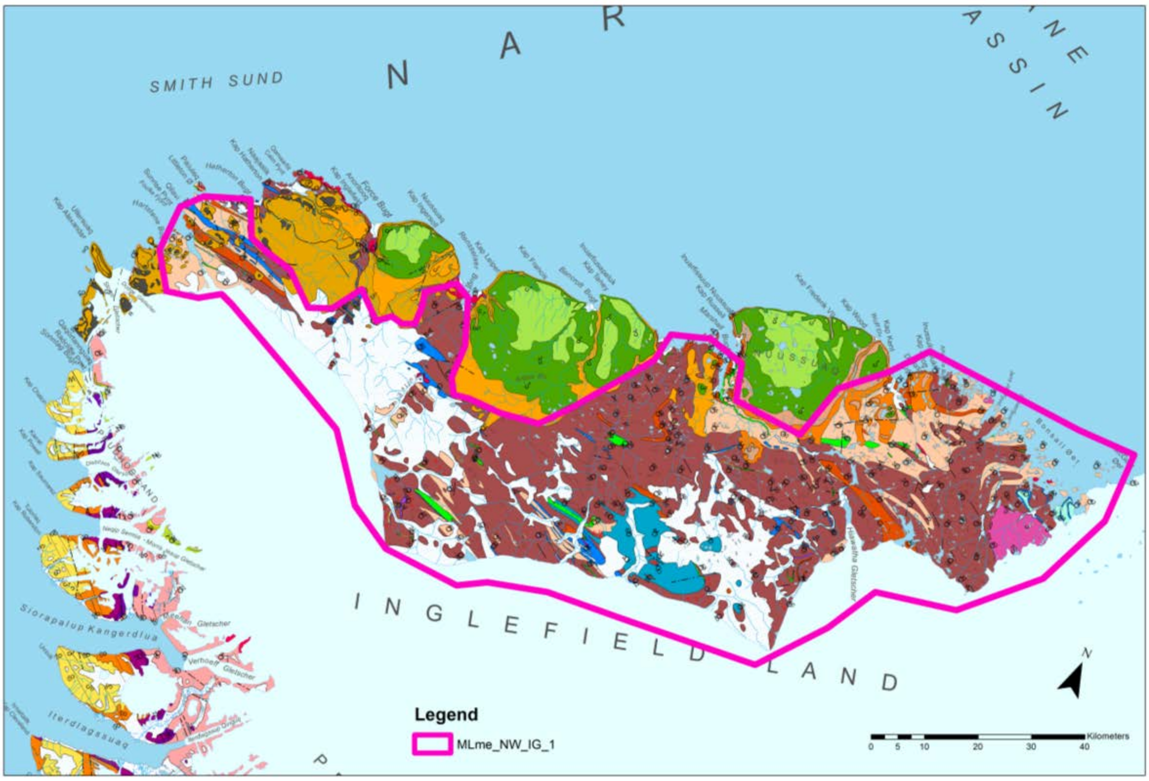


Figure 37. *Extent of the Palaeoproterozoic tract MLme_NW_IG_1 favourable for hosting SEDEX-type zinc deposits in the Inglefield mobile belt in Inglefield Land, North-West Greenland. For geological legend see appendix A.*

Table 25. *Summary of selected resource assessment results for the tract MLme_NW_IG_1.*

Assessment depth (km)	Tract area (km^2)	Known zinc resources (metric tons)	Mean estimate of undiscovered zinc resources (metric tons)
1 km	6,464	0	1,200,000

Geological criteria and rationale for the estimate

The MLme_NW_IG_1 tract includes the Etah Group down to an estimated depth of 1 km below surface as the rocks belonging to this Group were judged to be the most likely host of zinc mineralisations within the Inglefield Land mobile belt. The extent of the tract is based on the mapped and interpretated distribution of the Etah group.

The deposits estimates and the resulting undiscovered resource estimates from the Monte Carlo simulation can be found in Table 26 and Table 27.

Table 26. *Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for MLme_NW_IG_1. For further details see text associated with Table 5.*

Consensus undiscovered deposit estimate					Summary statistics					Area (km^2)	Deposit density (N/km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}		
0	0	1	2	5	0.47	1.1	230	0	0.47	6,460	0.000072

	Estimated number of undiscovered deposits				
Estimator	**N90**	**N50**	**N10**	**N05**	**N01**
Individual 1	1	2	3	4	5
Individual 2	0	0	1	3	5
Individual 3	0	0	0	1	2
Individual 4	0	0	0	1	5
Individual 5	0	0	0	0	1
Individual 6	0	0	1	1	2
Individual 7	0	0	1	2	3
Individual 8	0	1	2	4	8
Individual 9	0	0	2	3	5
Individual 10	0	0	1	2	5
Individual 11	-	-	-	-	-
Individual 12	0	0	2	2	3
Individual 13	0	0	0	1	1
Consensus	**0**	**0**	**1**	**2**	**5**

Table 27. *Results of Monte Carlo simulations of undiscovered resources in the tract MLme_NW_IG_1. [t = metric tons; Mt; megatonne or million tons]*

Material	Probability of at least the indicated amount						Probability of mean or greater	Probability of zero [none]
	0.95	0.90	0.50	0.10	0.05	Mean		
Zn (t)	0	0	0	2,500,000	6,700,000	1,200,000	0.14	0.69
Pb (t)	0	0	0	930,000	2,900,000	530,000	0.13	0.71
Rock (t)	0	0	0	0	0	19,000,000	0.05	0.89

Meso- to Neoproterozoic Thule Basin, North-West Greenland

Sources of information

The principal sources of information used for the assessment of the tracts in the Meso- to Neoproterozoic Thule Basin for the sedimentary zinc type are given in Appendix A

Regional Geology

The following descriptions and maps (Figure 38 & Figure 39) are derived from Dawes (2006) and Thomassen *et al.* (2002).

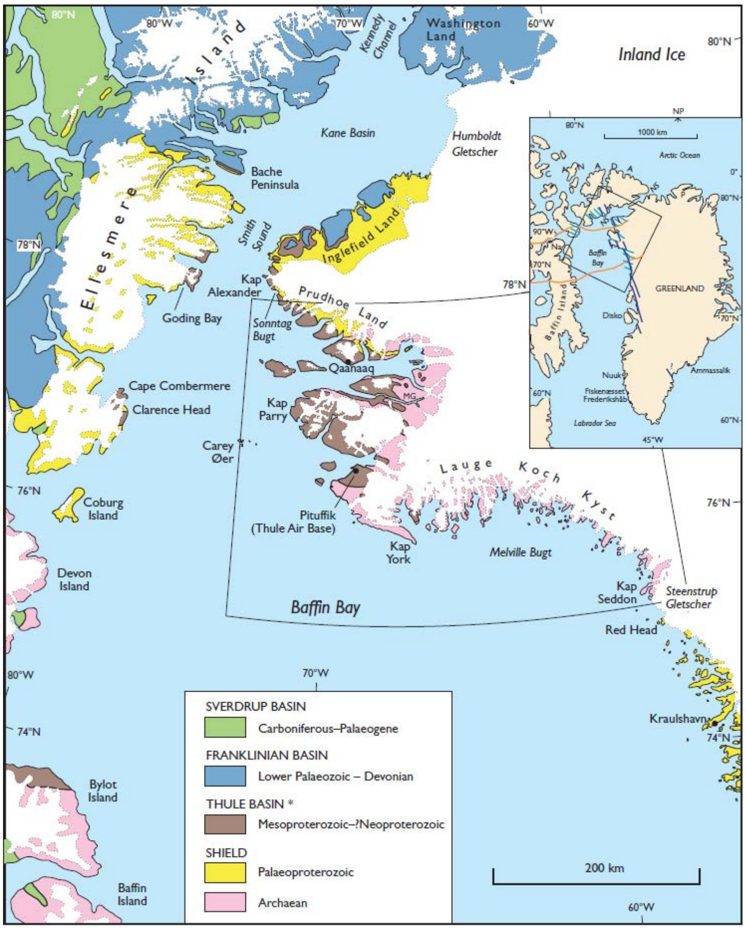


Figure 38. *Simplified geological map of southern Nares Strait with an outine of the Thule map sheet (black frame) and an inset map showing some regional features. Asterisk qualifying Thule Basin in the legend signifies that the outcrop on Bylot Island, Canada, is part of the coeval Borden Basin. Inset map: orange lines, Neoarchaean Committee Fold Belt embracing the Mary River – Lauge Koch Kyst magnetite province; dark blue lines, Palaeoproterozoic Melville Bugt dyke swarm; pale blue lines, Neoproterozoic Thule dyke swarm. Blank areas are ice. Nares Strait (NS) is the seaway joining Baffin Bay and the Arctic Ocean. K, Kronprins Christian Land; MG, 'Mount Gyrfalco'; Na, Nanisivik; NP, North Pole; P, Peary Land. Modified from Dawes (2006).*

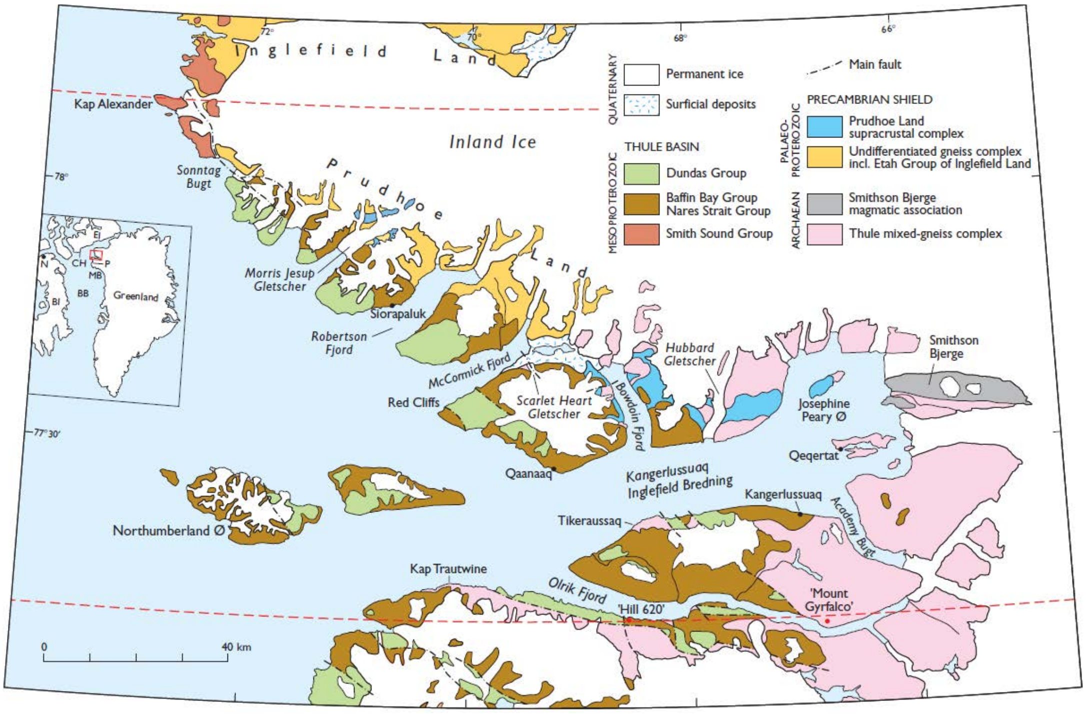


Figure 39. *Geological map of the Qaanaaq region. The "Qaanaaq 2001 project area (see Thomassen et. al. 2002)" are shown by red dashed lines. Basic sills, that in some areas of the Dundas Group form large outcrops, are not shown. Only faults affecting disposition of groups of the Thule Supergroup are 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). Compiled from Dawes (1991) and Dawes et al. (2000) with modifications from Qaanaaq 2001 project. Modified from Thomassen et al. (2002).*

The Proterozoic intracratonic sedimentary-volcanic Thule Basin with total area of approximately 6,000 km^2 and an exposed area of ca. 2,000 km^2 comprises the Thule Supergroup, and is continuous from Greenland to Canada (Figure 38; Dawes 1997). The six kilometre thick Supergroup contains 5 lithostratigraphic groups, Smith Sound Group; Nares Strait Group; Baffin Bay Group; Dundas Group; and Narssarssuk Group (Figure 39). The amount of continental to lacustrine and shallow marine red bed siliciclastics sandstone and shales within the formations is large.

The Thule Basin is an intracratonic fracture basin with block faulting and basin sagging formed in a divergent plate region. The outcrop pattern of Thule strata is thus strongly controlled by faults, mainly WNW–ESE- to NW–SE-trending, that split the region into tilted blocks of varying stature. These fault blocks make up the 'Thule half-graben system' (Figure 40). Six major half-grabens dominate, each with the same fundamental structure: on the north-eastern side, the shield is overlain by a normal, south-westerly dipping section that is bounded in the south-west by a steeply inclined master fault that juxtaposes the upper Thule Supergroup against the shield of the adjoining block (Dawes 1997). Movements along the bounding faults are measurable in kilometres, with the greatest displacements commonly in the west, i.e. in the deepest part of the Thule Basin.

Within the half-grabens, smaller fault blocks occur, including both graben and horst structures, and these represent small to moderate displacements, which repeat stratal levels within the same formation or group, as well as larger displacements affecting the map outcrop pattern. Five of the six half-grabens contain successions that top in the Dundas Group; the Pituffik half-graben preserves the Narssârssuk Group. The Thule half-graben system is schematically shown in Figure 40.

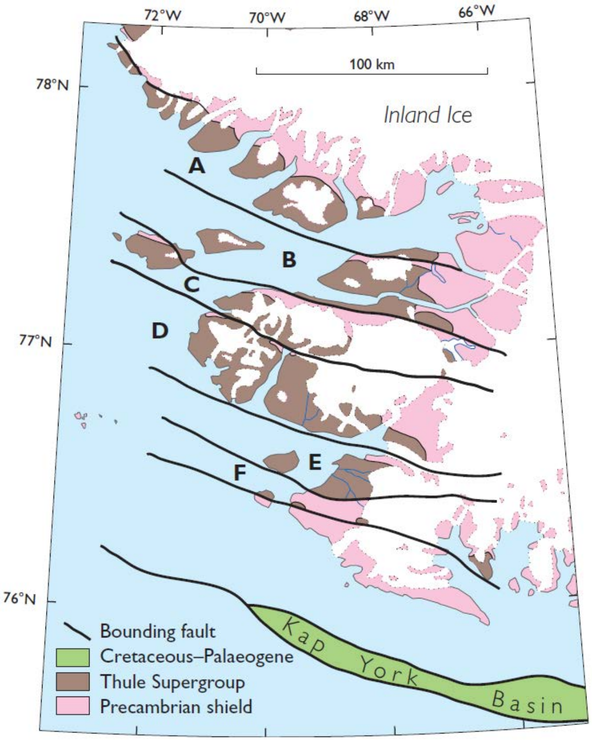


Figure 40. *The Thule half-graben system composed of six half-grabens each with its bounding fault on the southern side along which Thule Supergroup is down-dropped against the shield. Intragraben faults are not shown. From north to south: A, Prudhoe half-graben/ Murchison Fault; B, Olrik half-graben/Itilleq Fault; C, Itillersuaq half-graben/Granville Fault; D, Moriusaq half-graben/Moltke Fault; E, Pituffik half-graben/Narssarssuk Fault; F, Qeqertarsuaq half-graben/Magnetit-bugt Fault. From Dawes (2006).*

The base of the basin is defined by an unconformity with underlying peneplaned shield rocks. The basin is defined by an unmetamorphosed sedimentary-volcanic succession - The Thule Supergroup, comprising five lithostratigraphic groups; the Smith Sound Group, the Nares Strait Group, the Baffin Bay Group, the Dundas Group and the Narssârssuk Group (Figure 41; Dawes 1997).

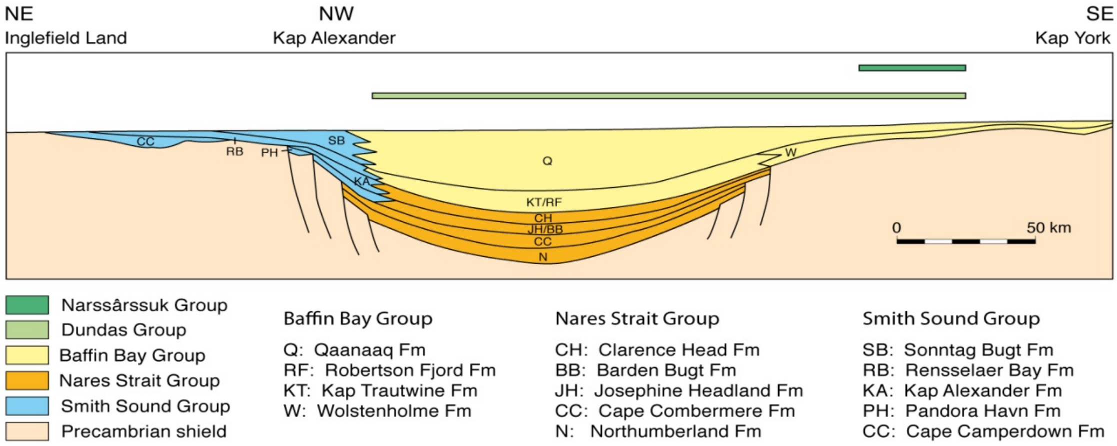


Figure 41. *Schematic cross-section of the lower Thule Supergroup. Figure from workshop presentation by Dawes (2011); see Appendix C.*

Dundas Group

Microfossils suggest a Late Mesoproterozoic and/or early Neoproterozoic age. The group encompasses thick basinal clastic strata with a wide distribution from northern Prudhoe Land to the head of Olrik Fjord and south to Wolstenholme Ø. Regionally, it conformably overlies the Baffin Bay Group along a gradational boundary but locally, as in the Olrik Fjord area, Dundas strata overlap nonconformably fault blocks of the Baffin Bay Group.

The upper limit of the group is unknown and its position in the map legend below the Narssârssuk Group is based on lithological and structural inferences suggesting an older age (see under Narssârssuk Group).

The group forms the uppermost strata in five of the six half-grabens that dissect the Thule Basin and the strata are characteristically downdropped against the shield on the northeastern side of regional NW–SE and WNW–ESE-trending faults (Figure 40).

The group has a somewhat monotonous lithology without regional markers and correlation of sections is not obvious. It is estimated to be at least 2 km, possibly as much as 3 km thick. The three formations recognised – the Steensby Land, Kap Powell and Olrik Fjord Formations are based on lateral lithological facies and are essentially geographically defined. The first two formations conformably overlie the Qaanaaq Formation of the Baffin Bay Group; the Olrik Fjord Formation is only recognised in a downfaulted block and its stratal limits are unknown. However, this formation may well represent the youngest strata as its position in the map legend implies (see below under Narssârssuk Group).

The Steensby Land and Kap Powell Formations (Dundas Group, undivided)

This map unit covers the majority of exposures shown on the map sheet comprising the Kap Powell and Steensby Land Formations that crop out in two NW–SE-trending belts. In the north within the Prudhoe half-graben, the Kap Powell Formation stretches from Kap Chalon throughout coastal Prudhoe Land to the Inglefield Bredning area, while the Steensby Land Formation, characterised by basic sills, forms a broader belt from Northumberland Ø and Herbert Ø through Steensby Land to the type area around Dundas and to the southernmost exposures on Wolstenholme Ø.

The Dundas Group is composed of sandstone, siltstone and shale with lesser amounts of carbonate (dolomite, limestone, arenaceous dolomite), chert and evaporitic beds. Regionally, the unit shows wide lateral variation in the ratio of sandstone to siltstoneshale. The Kap Powell Formation contains more sandstone than the Steensby Land Formation, which is thin bedded and dominated by black shale in which carbonate beds with stromatolitic reefs occur (Figure 42).

Figure 42. *Interbedded dark shales and stromatolitic carbonate beds of the Dundas Group from Northumberland Ø. The base of the carbonate bed (at the notebook) contains minor sphalerite and a composite sample returned 2% Zn. From Thomassen et al. (2002).*

The common upwards-coarsening units suggest deposition in an overall deltaic to offshore environment. The thick cycles of the Kap Powell Formation might represent progradational delta front sequences, the thinner lower energy cycles with some pyrite development of the Steensby Land Formation possible delta plain deposition.

Olrik Fjord Formation

This formation crops out on the south coast of Olrik Fjord restricted to the central part of the Olrik half-graben. Contacts to other geological units are tectonic and the stratal limits of the formation are unknown. To the south, the strata are juxtaposed against the shield and slivers of Baffin Bay Group along the Itilleq Fault; to the east the formation is faulted against the Baffin Bay Group. Over the main outcrops, stratal dips are gentle, but adjacent to the Itilleq Fault, contortions and drag folding produce steeply dipping sections. The thickness of the unit is estimated to be at least 400 m.

The lithology of the formation is a dark-weathering, thin-bedded, clastic sequence characterised by lithological cycles with multi-coloured shale units that are variously intercalated with laminated siltstone, sandstone, thin carbonate beds and evaporitic beds. An overall deltaic or coastal plain environment is favoured for the Dundas Group but the characteristic features of this formation with redbeds may be indicative of a progradation of the shoreline.

The well-layered, dominantly fine-grained lithologies, resembles in gross character some parts of the Narssârssuk Group and similarity in depositional environment is suggested by siliciclastic redbeds topping cyclic sequences with carbonate rocks.

Narssârssuk Group

Microfossils suggest a Late Mesoproterozoic and/or early Neoproterozoic age. The group is restricted to the Pituffik half-graben on the south-eastern margin of the basin. It composes Saunders Ø and a mainland belt limited to the south by the Narssarssuk Fault.

The relationship to the Dundas Group in the north, which is the nearest unit both geographically and stratigraphically, is hidden by surficial deposits filling Pituffik valley.

Regional structure suggests that the Narssârssuk Group is likely to be all, or in part, younger than the Dundas Group (Steensby Land Formation). The group is limited upwards by the present erosion surface. Similarities to Narssârssuk Group lithologies in the Dundas Group suggest depositional affinity and imply a similar biostratigraphic age. For instance, the uppermost beds of the Steensby Land Formation on Dundas Fjeld contain thin carbonate beds with stromatolites, chert and evaporite, while the Olrik Fjord Formation has multicoloured cycles including red siliciclastic rocks and carbonates. The present consensus is that the Narssârssuk and Dundas Groups are not separated by a substantial age gap or a major unconformity.

The group has an unknown but substantial thickness estimated at between 1.5 and 2.5 km. The strata represent subtidal to supratidal deposition in very shallow water and in a low-energy, arid or semi-arid environment, in conditions perhaps analogous to modern coastal sabkhas.

The group is subdivided into the three formations: the Imilik, Aorfêrneq and Bylot Sund Formations.

Imilik Formation

This formation comprises the lowermost strata of the group. On the mainland the base of section is covered by surficial deposits; on the south side of Saunders Ø it is below sea level.

The succession has a well-layered, colourful appearance, due to alternating clastic redbeds and paler carbonates arranged in lithological cycles (Figure 43). A typical cycle has pale limestone and/or dolomite at the base grading into mixed carbonate-siliciclastic lithologies, in places with chert and evaporite, and finally into red siltstone and sandstone. The cycles are taken to indicate regular fluctuations of shallow, quiet water indicating repeated progradation from intertidal carbonates to supratidal siliciclastics. An 8 m-thick bed of “white, light gray or translucent orange gypsum” occurs in drill core from just south of Pituffik air base. Such thick homogeneous evaporite beds have not been recorded in outcrop.

Figure 43. *Imilik (Ni) and Aorfêrneq (Na) Formations of the Narssârssuk Group. Multicoloured progradational cycles with basal grey carbonates topped by red siltstone–sandstone forms the lower strata (Imilik) overlain by abortive carbonate-dominated cycles lacking redbeds (Aorfêrneq). d2, basic dyke of the Thule dyke swarm, which has caused bleaching in a zone several metres wide. Coast south of Pituffik, Bylot Sund, with cliff height c. 150 m a.s.l. From Dawes (2006).*

Aorfêrneq Formation

This unit composes the middle strata in the mainland succession reaching the coast north of Aafeerneq and it forms the western end of Saunders Ø. In contrast to formations below and above, it is not characterised by redbeds. It gradationally overlies the previous unit within a cyclic sequence in which individual cycles are aborted and lack red siliciclastic tops (Figure 43).

A carbonate-dominated (mainly dolomite) cyclic sequence that in many sections is characterised by evaporite in varying forms, from thin beds, veins and nodules to the matrix of thick breccia beds. Stromatolites and algal mat associations, with certified microbiota, are common in the dolomites indicating deposition on broad tidal flats with the persistence of warm hypersaline conditions. Siliciclastic rocks are restricted on the mainland to very sporadic thin beds, some of which are red, although on Saunders Ø pale sandstone, commonly calcareous, and arenaceous dolomite, come in.

<u>Bylot Sund Formation</u>
This formation represents the youngest strata of the group conformably overlying the previous unit. On the mainland, it crops out north of Narsaarsuk in a broad syncline the southern limb of which is truncated by the Narssarssuk Fault while on Saunders Ø it forms much of the eastern and northern parts of the island.

The map unit has a similar appearance and lithology to the Imilik Formation with siliciclastic redbeds topping cycles. However, generally there is lesser siliciclastic material and dolomite, variably arenaceous, predominates. Some transgressive cycles exist in which multicoloured siliciclastic rocks grade upwards into dolomites that are variably arenaceous.

Exploration history

Limited exploration has been carried out in the Thule region, North-West Greenland. The exploration company Greenarctic Consortium discovered the malachite-stained sandstone Olrik Fjord copper occurrence in 1969 (the ‘Hill 620 showing; Smith & Campbell 1971). During regional mapping, the Geological Survey of Greenland (GGU) investigated selected mineral occurrences in the region. This also led to the discovery of banded iron formation at Smithson Bjerge (Dawes 2006). In 1994 and 1995, the Greenarctic Consortium exploration company explored in the Qaanaaq region and reported scattered malachite staining in the Thule Supergroup. In 2001 field work by the Geological Survey of Denmark and Greenland (GEUS) was directed towards visual inspections of signs of mineral occurrences, and regional sediment sampling was undertaken (Thomassen *et al.* 2002).

Known prospects, mineral occurrences or related deposit types

No known sediment-hosted zinc deposits.

Different types of metallic mineral showings are known from the Canadian side, the majority of which involve lead-zinc, both sediment-hosted stratiform-type and Mississippi Valley-type (MVT; Jackson & Sangster 1987). One fault controlled lead-zinc-silver deposit was mined until recently at Nanisivik. The Nanisivik MVT deposit is within the Uluksan Group dominated by shallow-water stromatolitic dolostones of comparable facies to those of the Narssârssuk Group of the Thule Basin, thus focussing attention on the base-metal potential of this part of the Thule succession.

Although no mineralisation of this type has been recorded in Greenland, a glance at the map shows that much of the anticipated extent of the Narssârssuk Group is covered by surficial deposits, leaving ample scope for the presence of subsurface mineralisation.

Grade and tonnage model selection

Based on the discussion and the reviews of previous work by various researchers on the mineralisation, the assessment panel found it justified, to use both the sediment-hosted zinc, SEDEX and MVT subtype (Taylor *et al*. 2009) as the appropriated grade and tonnage models in the estimation of undiscovered deposits.

Individual tracts assessed during workshop

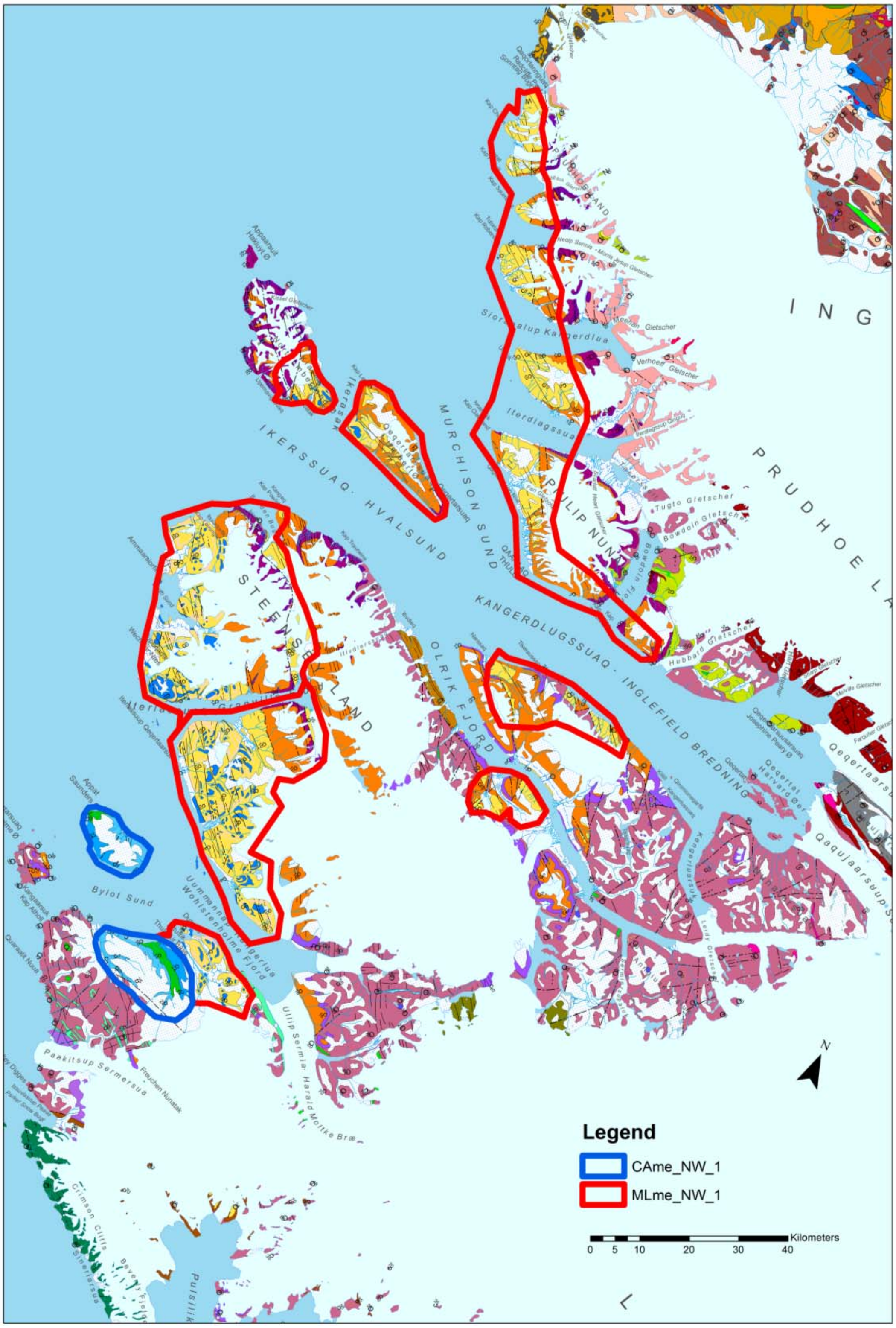


Figure 44. *Tracts for Mesoproterozoic-Neoproterozoic hosted SEDEX and MVT-type zinc deposits within the Thule Basin in North-West Greenland. The assessed tracts are; MLme_NW_1 & CAme_NW_1. For geological legend see Appendix A.*

Tract MLme_NW_1 – SEDEX zinc type

Location and delineation of the permissive tract

The tract MLme_NW_1 is covering areas from Bylot Sund in the south – to Prudhoe Land in the north in North-West Greenland (Figure 45). The tract was assessed for SEDEX type deposits. Summary of the estimated undiscovered zinc resources can be found in Table 28.

The boundaries of the MLme_NW_1 tract are defined by the areal extent of the Dundas Group and Narssârssuk Group to an estimated depth of 1 km below surface. It should be noted, that large parts of the tracts is covered by ice.

Figure 45. *Distribution of tract MLme_NW_1 assessed for undiscovered SEDEX zinc deposit. For geological legend see Appendix A.*

Table 28. *Summary of resource assessment results for the tract MLme_NW_1 assessed for SEDEX type zinc deposits.*

Assessment depth (km)	Tract area (km^2)	Known zinc resources (metric tons)	Mean estimate of undiscovered zinc resources (metric tons)
1 km	4,325	0	380,000

Geological criteria and rationale for the estimate

Dawes (2006) describes bleaching and reduction effects as common in the redbed successions, which indicate, that extensive fluid/brine activity has taken place in the Thule Basin. This is observed at all scales from effects within bedding planes, joints and fissures, to bed scale with development of fish-eye spots and irregular bleach patterns. At a larger scale, purple sandstones tens of meters thick is observed to change into an interfingering network of dark and pale bed, which finally turns into pale, sandstones in which purple colour has been eliminated. Strong reduction patterns have been recorded particularly in the basal strata, both in the marginal and central part of the basin. The unconformity may have acted as an important pathway for the reducing fluids causing the bleaching and reduction. The defined tracts also outline a large area with only limited previous exploration activity, so a potential for undiscovered mineralisations is present.

The deposits estimates and the resulting undiscovered resource estimates from the Monte Carlo simulation can be found in Table 29 and Table 30.

Table 29. *Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for tract MLme_NW_1. For further details see text associated with Table 5.*

Consensus undiscovered deposit estimate					Summary statistics					Area (km^2)	Deposit density (N/km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}		
0	0	0	1	4	0.17	0.69	420	0	0.17	4,330	0.000038

	Estimated number of undiscovered deposits				
Estimator	**N90**	**N50**	**N10**	**N05**	**N01**
Individual 1	0	0	1	1	2
Individual 2	0	0	0	1	4
Individual 3	0	0	0	0	2
Individual 4	0	0	0	1	2
Individual 5	0	0	0	2	2
Individual 6	0	0	0	1	2
Individual 7	0	0	0	2	3
Individual 8	0	0	0	1	4
Individual 9	0	0	0	2	5
Individual 10	0	0	0	1	15
Individual 11	-	-	-	-	-
Individual 12	0	0	0	0	3
Individual 13	0	0	0	0	2
Consensus	**0**	**0**	**0**	**1**	**4**

Table 30. *Results of Monte Carlo simulations of undiscovered resources for tract MLme_NW_1. [t=metric tons; Mt; megatonne or million tons]*

Material	Probability of at least the indicated amount						Probability of mean or greater	Probability of zero [none]
	0.95	0.9	0.5	0.1	0.05	Mean		
Zn (t)	0	0	0	0	630,000	380,000	0.06	0.93
Pb (t)	0	0	0	0	330,000	180,000	0.06	0.93
Rock (t)	0	0	0	0	0	5,800,000	0.02	0.97

Tract Came_NW_1 – MVT zinc type

Location and delineation of the permissive tract

The tract Came_NW_1 is covering areas west and south of Thule Airbase in North-West Greenland (Figure 46). The tract was assessed for MVT type deposits. Summary of the estimated undiscovered zinc resources can be found in Table 31.

The boundaries of the MLme_NW_1 tract are defined by the areal extent of the Dundas Group and Narssârssuk Group to an estimated depth of 1 km below surface. It should be noted, that large parts of the tracts is covered by ice.

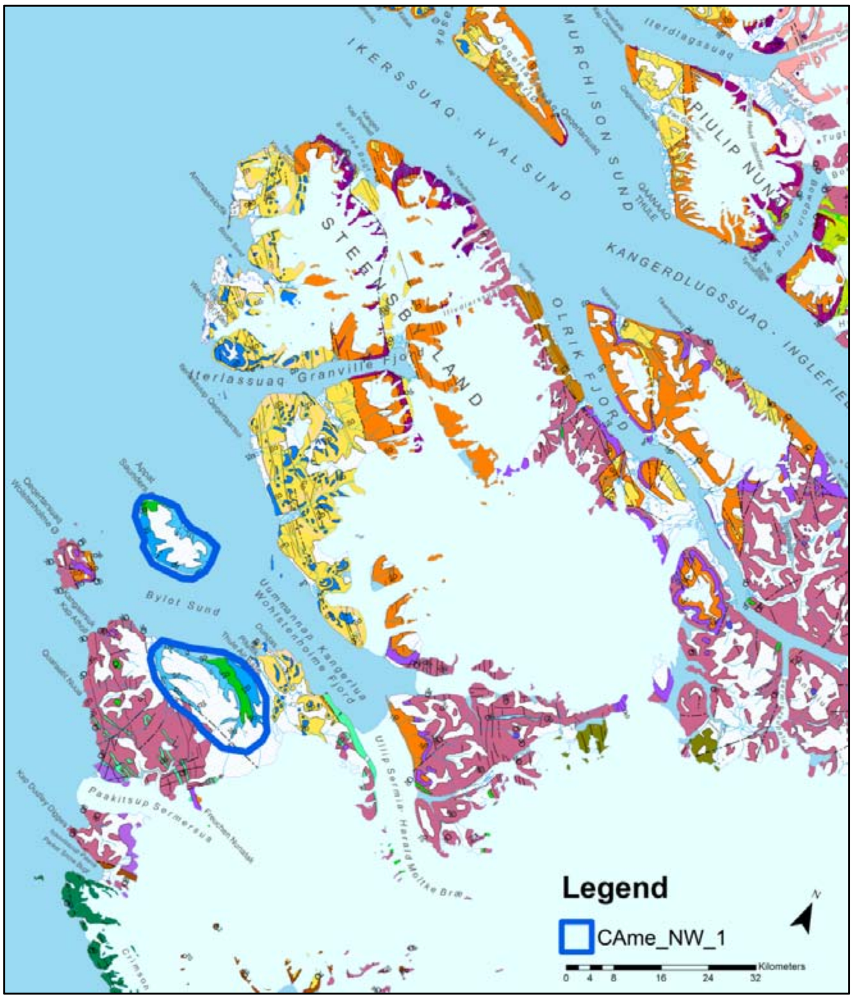


Figure 46. *Location of tract CAme_NW_1 assessed for undiscovered MVT type zinc deposit. For geological legend see Appendix A.*

Table 31. *Summary of resource assessment results for the tract CAme_NW_1 assessed for MVT type zinc deposits.*

Assessment depth (km)	Tract area (km^2)	Known zinc resources (metric tons)	Mean estimate of undiscovered zinc resources (metric tons)
1	351	0	150,000

Geologic criteria and rationale for the estimate

Dawes (2006) describes bleaching (Figure 47) and reduction effects as common in the Thule Basin, which indicate, that extensive fluid/brine activity has taken place in the Thule Basin. This is observed at all scales from effects within bedding planes, joints and fissures, to bed scale with development of fish-eye spots and irregular bleach patterns. At a larger scale, purple sandstones tens of meters thick is observed to change into an interfingering network of dark and pale bed, which finally turns into pale, sandstones in which purple colour has been eliminated. Strong reduction patterns have been recorded particularly in the basal strata, both in the marginal and central part of the basin. The unconformity may have acted as an important pathway for the reducing fluids causing the bleaching and reduction. The carbonate rich formations of the Narssârssuk Group could therefore act as traps for the reducing fluids and thus have led to the formation of MVT-type deposits. The defined tracts also outline a very large area were very limited exploration activity have been carried out, so a potential for undiscovered MVT zinc mineralisations is present. The deposits estimates and the resulting undiscovered resource estimates from the Monte Carlo simulation can be found in Table 32 and Table 33.

Table 32. *Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for tract CAme_NW_1. For further details see text associated with Table 5.*

Consensus undiscovered deposit estimate					Summary statistics					Area (km^2)	Deposit density (N/km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}		
0	0	0	1	3	0.14	0.56	420	0	0.14	350	0.00038

	Estimated number of undiscovered deposits				
Estimator	**N90**	**N50**	**N10**	**N05**	**N01**
Individual 1	0	1	1	1	2
Individual 2	0	0	0	1	2
Individual 3	0	0	1	1	3
Individual 4	0	0	0	0	1
Individual 5	0	0	0	1	1
Individual 6	0	0	0	0	1
Individual 7	0	0	0	1	2
Individual 8	0	0	0	0	3
Individual 9	0	0	0	0	3
Individual 10	0	0	0	0	5
Individual 11	-	-	-	-	-
Individual 12	0	0	0	2	2
Individual 13	0	0	0	0	0
Consensus	**0**	**0**	**0**	**1**	**3**

Table 33. *Results of Monte Carlo simulations of undiscovered resources in the tract CAme_NW_1. [t=metric tons; Mt; megatonne or million tons]*

Material	Probability of at least the indicated amount						Probability of mean or greater	Probability of zero [none]
	0.95	0.9	0.5	0.1	0.05	Mean		
Zn (t)	0	0	0	0	400,000	150,000	0.06	0.93
Pb (t)	0	0	0	0	120,000	59,000	0.06	0.93
Rock (t)	0	0	0	0	0	3,300,000	0.01	0.98

Figure 47. *Typical redbed (siliciclastics) silt- and sandstone of the Narssârssuk Group. From workshop presentation by Dawes (2011); see Appendix C.*

Palaeoproterozoic Karrat Group, West Greenland

Sources of information

The principal sources of information used for the assessment of the tracts in the Palaeoproterozoic Karrat Group in West Greenland are given in Appendix A.

Regional geology

The following text, figures and illustrations is from Thomassen (1992), Thrane *et al.* (2005), Connelly and Thrane (2005) and Connelly *et al.* (2006) (see references therein for more details):

The Palaeoproterozoic supracrustal rocks known as the Karrat Group, extends north–south for a distance of approx. 550 km in West Greenland, covering approximately 10,000 km^2 (Figure 48). The Group rests unconformably on an Archaean gneiss complex and consists of a very thick sedimentary package.

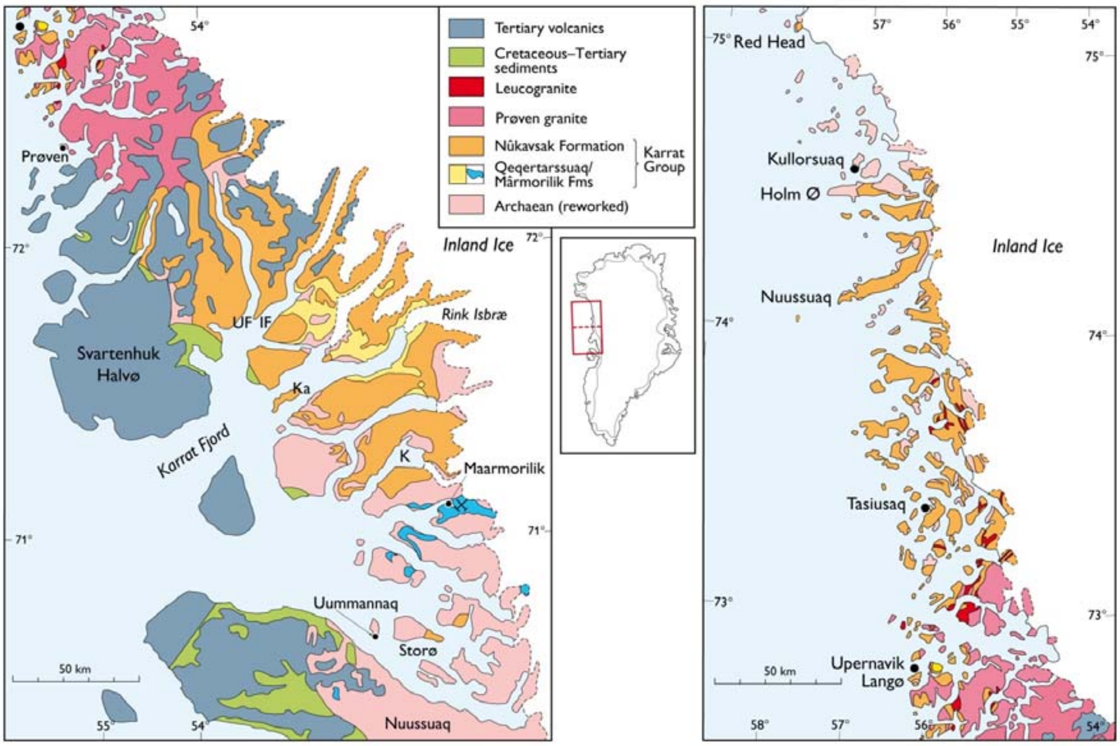


Figure 48. *Map showing the extension of the Karrat Group in West Greenland.*

The Karrat Group is divided into three formations (See Figure 49, Henderson & Pulvertaft 1987). The carbonate dominated Mârmorilik Formation occurs in the southern part of the Umanak district, whereas the mainly siliciclastic Qeqertarssuaq Formation occurs further to the north. The two formations are believed to have been deposited simultaneously in separate sub-basins. The Mârmorilik Formation, which reaches a thickness of 1600 m, consists of calcitic and dolomitic marbles with a thin basal clastic unit, intercalations of pelitic and cherty schists, and locally evaparites (Garde 1978). The Qeqertarssuaq Formation is dominated by impure quartzites with variable amounts of pelitic schists and rare marbles and is up to 3000 m thick. It hosts pods of ultramafic rocks and, at the very top there is a mafic unit of hornblende schist and amphibolite of volcanic origin. The latter is restricted to a sub-basin in the northern Umanak district, where it reaches a maximum thickness of c. 600 m.

The Mârmorilik and Qeqertarssuaq Formations are overlain by a blanket of flysch-type metasediments, the Nûkavsak Formation, that has a minimum structural thickness of 5 km. Graphitic pelites occur near the base of this formation, but otherwise the sequence is wholly dominated by interbedded pelitic and semipelitic rocks, often displaying graded bedding.

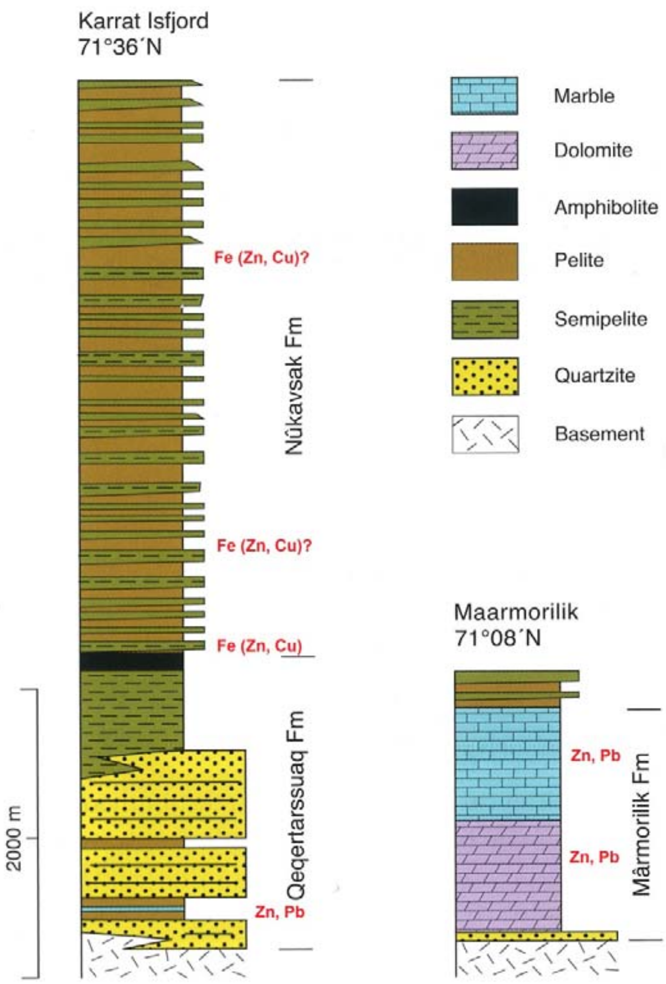


Figure 49. *Schematic Karrat Group section with stratabound mineralisation indicated. Modified from Henriksen et al. (2009).*

These rocks are metamorphosed shales and greywackes. The depositional environment was first a stable shelf setting with rifted sub-basins (Mârmorilik and Qeqertarssuaq Formations); this was terminated by a volcanic episode (Figure 50). After this, the depositional environment changed to a larger, deeper turbidite basin (Nûkavsak Formation). It has been suggested that the Karrat Group was deposited in an epicontinental marginal (back-arc) basin developed in the upper plate above a subduction zone further to the south (Grocott & Pulvertaft 1990) or in a passive margin sequence (Thrane *et al.* 2005).

The Precambrian rocks underwent deformation during the formation of the Palaeoproterozoic Nagssugtoqidian and Rinkian orogens (Connelly *et al.* 2006). The tectonic style is characterised by mantled gneiss domes and gneiss-cored fold nappes north of Maarmorilik, whereas tectonic interleaving of cover and basement rocks is common to the south. However, a number of major low-angle ductile shear zones involving both basement and cover have also been identified in the northern part of the Umanak district. The Rinkian metamorphism occurred under high temperature - low pressure conditions related to lithospheric extension, in an orogenic setting in which several phases of extension and shortening are evident (Grocott & Pulvertaft 1990). The regional metamorphic grade ranges from greenschist to granulite facies, but amphibolite facies rocks are the most widespread.

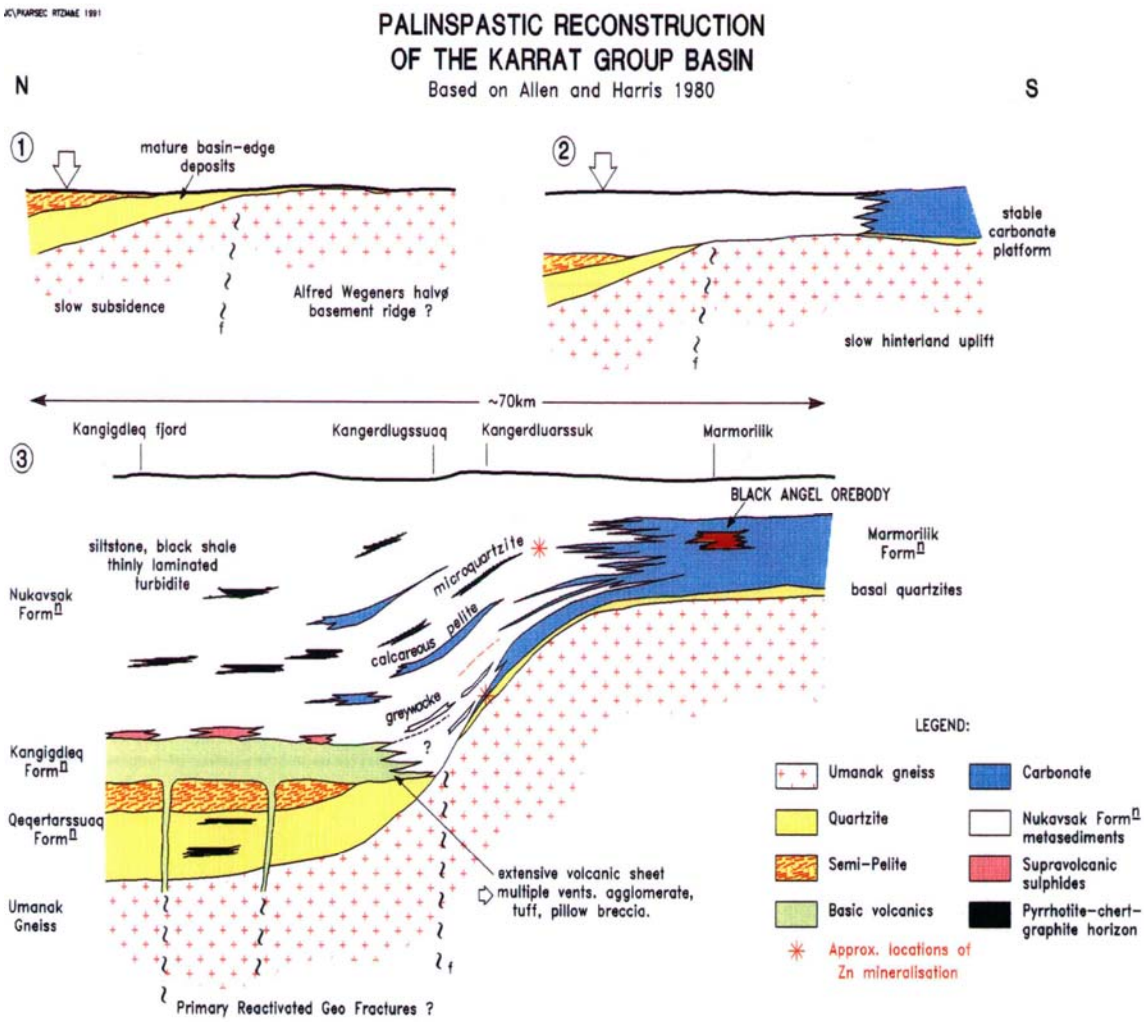


Figure 50. *Schematic palinspastic reconstruction of the Karrat Group basin and associated mineralisation types. From Coppard (1992).*

Exploration history

The Nûkavsak and Qeqertarssuaq Formations

Only a few exploration campaigns have been conducted within the northern most parts of the Nûkavsak and Qeqertarssuaq Formations of the Palaeoproterozoic Karrat Group of West Greenland:

<u>Uummannaq District, north of Maarmorilik</u>

1979–80 Cominco Ltd./Greenex A/S: Regional exploration for Zn, Pb, Cu, Au, Diamonds.

1989–90, 92, 97 GGU/GEUS: Geochemical reconnaissance, Uummannaq district.

1991–92 RTZ Mining and Exploration Ltd.: Find of Kangerluarsuk Zn prospect.

1994 Cominco Ltd.: Exploration for magmatic for Ni-Cu deposits.

2005-present Angel Mining plc.

2007-present Avannaa Resources Ltd.: Exploration for Au, Zn, REE.

<u>Upernavik District</u>

1905–15 Grønlands Minedrift A/S: Exploration for graphite near Upernavik.

1969 Greenarctic Consortium: Brief visit to gossans on Red Head.

1972 Internationalt Mineselskab A/S: Sampling of gossans around Tasiusaq.

1981 Greenex A/S: Reconnaissance for base/noble metals on Red head .

1998 GGU/GEUS: Geochemical reconnaissance, Upernavik district.

Exploration history of the Mârmorilik Formation

Most of the exploration activities within the Mârmorilik Fm. have been conducted in the vicinity of the Black Angel mine area in West Greenland:

1933–40, 1967–72 Marble quarried at Appat and Maarmorilik.

1939 Report of Pb-Zn-mineralised floats at Maarmorilik marble quarry.

1962–64 Mineral exploration involving Cominco Ltd.

1965–1982 Exploration by **Greenex A/S** (owned 62.5% by Cominco Ltd. - from 1986 owned 100% by Boliden Mineral AB):

- 1965-72 Prospect investigations of the Black Angel Pb-Zn ores and regional mineral exploration.
- 1973-90 Mining of the Black Angel Pb-Zn ores.
- 1974-89 Continued exploration in the mine area, including South Lakes and Nunngarut.
- 1975-76 Prospect investigations including drilling at Appat.
- 1975-79 Prospect investigations including drilling at Ukkusissat.
- 1982 Finding of the Nuussuaq Prospect.

1997	Platinova A/S examined the possibilities for re-opening of the mine.
2003-present	Black Angel Mining Ltd.: Investigations in the Maarmorilik area, including drilling at South Lakes.
2008-present	Black Angel Mining A/S holds an exploitation licence over the Black Angel and Nunngarut ore bodies.
2010-2012	Avannaa Exploration Ltd.: Investigation of the Nuussuaq Prospect.

Known prospects, mineral occurrences or related deposit types

The Black Angel

The Black Angel mine took its name from a pelite outcrop that forms a dark angel-like figure on a precipitous cliff face of marble above Affarlikassaa fjord (Figure 53). The mineralised zone actually crops out just above the angel figure about 700 m above fjord level. The 1100-m high Angel Mountain is situated at the margin of the Greenland ice cap at 71°N.

The peninsula across the fjord housed the mining camp, mill and all services and received its name Maarmorilik from a former marble quarry situated there from 1936 (Figure 52, Thomassen 2003). Carbonate-hosted lead-zinc mineralisation is common in the Mârmorilik Formation and in the mine area stratabound sulphide mineralisation occurs at various levels. The main ore bodies are located 600-700 m a.s.l. in the upper part of the sequence, which is dominated by calcite marble. The ore forms flatlying, highly deformed massive lenses up to 30 m thick.

Sulphide samples leading to the discovery of the Black Angel deposit were found in connection with marble quarrying in the 1930s and investigated by Danish geologists in the 1930s and 1940s.

Commercial investigations including diamond drilling were carried out in the 1960s by a syndicate led by Cominco Ltd. of Canada. In 1971 the Danish mining company Greenex A/S (established in 1964 and 62.5% owned by Cominco Ltd. through the subsidiary Vestgron Mines Ltd.) obtained a 25-year exploitation concession.

Financial terms were favourable at that time, with a 45% resource tax of yearly earnings to be paid after recovery of all pre-production costs and capital investments. The investment of c. 333 mill. DKK had been recovered in 1977, after which the company started to pay concession fees.

Underground exploration in 1971–72 indicated a probable ore reserve of 4.1 million tons grading 15.0% Zn, 5.0% Pb and 28 ppm Ag. Based on this and after a hectic construction period of only 15 months, production started in 1973. During the mine's 17-year lifespan, it was possible to more than triple the original minable reserves. In 1985 a major operating loss was incurred, and due to growing financial losses and dwindling ore reserves, Cominco scheduled Black Angel mine for closure in early 1986. Boliden Mineral AB took over Greenex from Cominco in mid-1986. Boliden managed to keep the mine in operation and ensure sufficient mill throughput for profitable operation until mid-1990.

Figure 51. *Map of the Maarmorilik area with orebodies shown in red. Stars in inset map show main prospects of the Black Angel type (MVT). 1 = Kanakip Aufva, 2 = Agpat Island, 3 = Uvkusigssat & 4 = South Lakes Glacier; the red crosses mark the overall location of the Kangerluarsuk Sermia and Alfred Wegner Halvø zinc occurrences.*

The Black Angel deposit comprised ten ore bodies totalling 13.6 million tons grading 12.3% Zn, 4.0% Pb and 29 ppm Ag. Of these 11.2 million tons were extracted in the period 1973–90.

The mining operations ceased when the extractable ore reserves were exhausted, leaving 2.4 million tons of ore tied up in pillars and other areas inaccessible to mining.

The Black Angel Mine deposit is included in tract Came_WG2.

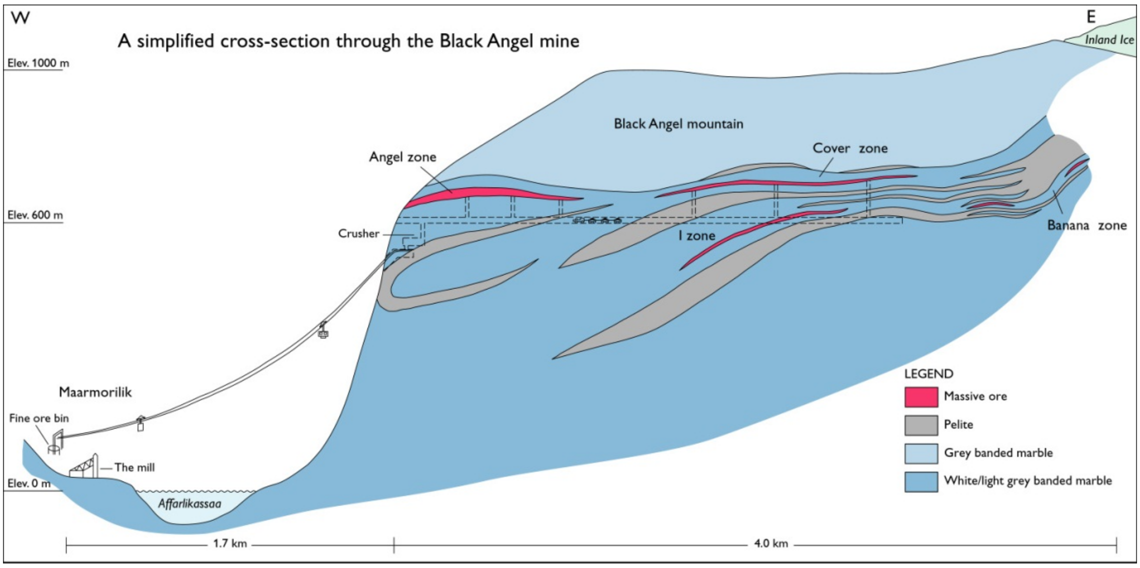


Figure 52. *A simplified cross-section through the Black Angel mine. Not to scale.*

Figure 53. *View from west towards the Angel Mountain and the former cable car installation. Note the entrance (two squared dots) to the mine is situated just below the "left wing" of the dark angel figure.*

South Lakes Glacier prospect

Since 1984, a glacier has retreated several hundred metres and new mineralisation is exposed (Figure 54 + 55). The prospect is currently being investigated by Angel Mining and not much information has been published about the prospect.

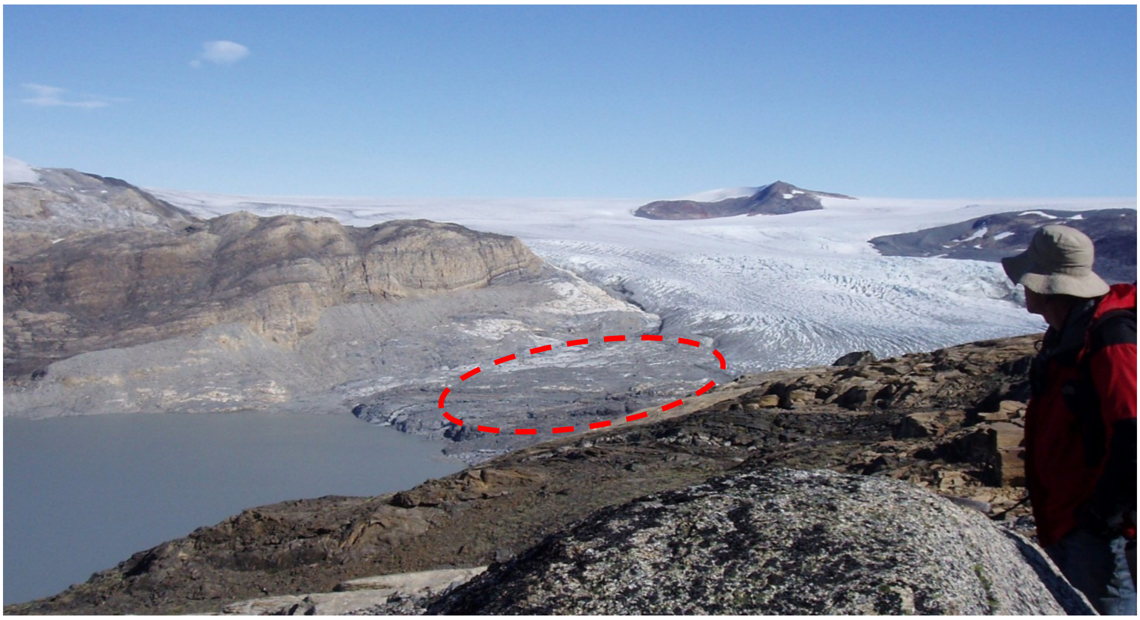


Figure 54. *View from west towards the area (red ellipse) of the retreated glacier and newly exposed massive sulphide. Figure from workshop presentation by Thomassen (2011); see Appendix C.*

Angel Mining has reported that drilling have outlined a continuous, E-W orientated vertical massive sulphide sheet over >700 m along strike. Best intersection in 2006 gave 2.7% Pb and 7.9% Zn over 13.6 m.

The South Lakes Glacier prospect is included in tract Came_WG2.

Figure 55. *Massive sulphide mineralisation exposed on surface within the area of the retreated glacier. Figure from workshop presentation by Thomassen (2011); see Appendix C.*

The Uvkusigssat showing

The following description is derived from the report Della Valle & Sartori (2000).

The Uvkusigssat showing that consists of 16 mineralised occurrences was discovered in the peak 1450 m vertical N cliff in the course of the 1976 exploration program at Maarmorilik exploration concession by Cominco Ltd (Figure 56, 57 & 58).

More detailed prospecting and geological mapping was carried out in 1977. The main showing extends over 210 m with a thick massive sulphide western part and a thinner stratified sulphide eastern part. The massive sulphide (8 m thick over 70 m along strike) grades 9.8% Pb, 27.6% Zn, 68 g/t Ag. The stratified eastern part, 1.4 m thick over 140 m on strike grades 3.3% Pb, 14.1% Zn & 23 g/t Ag.

A drilling program carried out in 1979 to test the Uvkusigssat main showing consisted of 1697 m of core drilling in seven holes plus two holes abandoned in broken ground below the ice. Several drill holes intersected several mineralised horizons with complicated folded structures but failed to prove the extension of a sizable ore body. The drilling target only tested a limited part of the potentially mineralised structure and was based on a stratigraphic and structural model that was perhaps over simplified.

All the showings occur in the Middle Mârmorilik Formation where two main mineralised horizons were identified:

- The lower horizon is situated in the upper part of the calcite-dolomite banded marble and at the base of the overlaying quartzite-pelite bearing marble. This is the case for showing 1 in particular.
- The upper mineralised horizon is located in the top part of the quartzite-pelite bearing marble, normally underlying the white marble. In some cases, this horizon is close to an unconformity defined by a thrust plane

Both mineralised horizons are close to a pelite horizon, which only contains pyrite. No mineralisation has been observed in the dolomite marble (Lower Mârmorilik Formation) and in the white marble (Upper Mârmorilik Formation) on peak 1450 m. This is not the case in the Black Angel area where mineralised horizons are known in the Lower, Middle and Upper Mârmorilik Formation.

Figure 56. *Helicopter view of peak 1450 m. Figure from workshop presentation by Thomassen (2011); see Appendix C.*

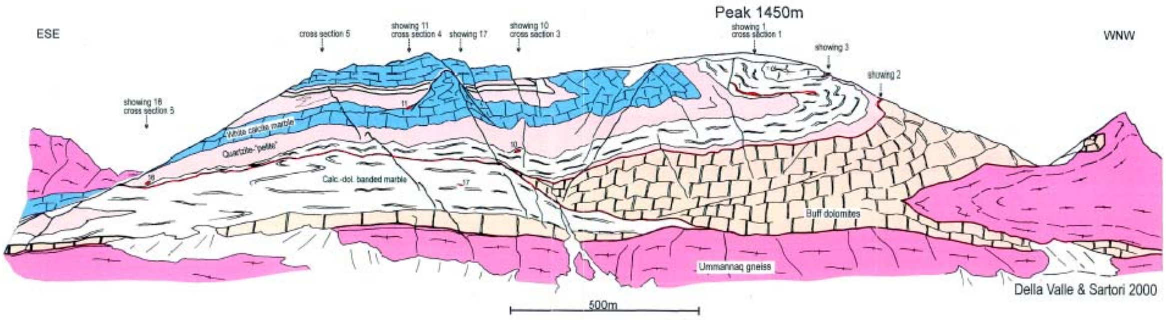


Figure 57. *Panorama sketch of peak 1450 m north face. From Della Valle & Sartori (2000).*

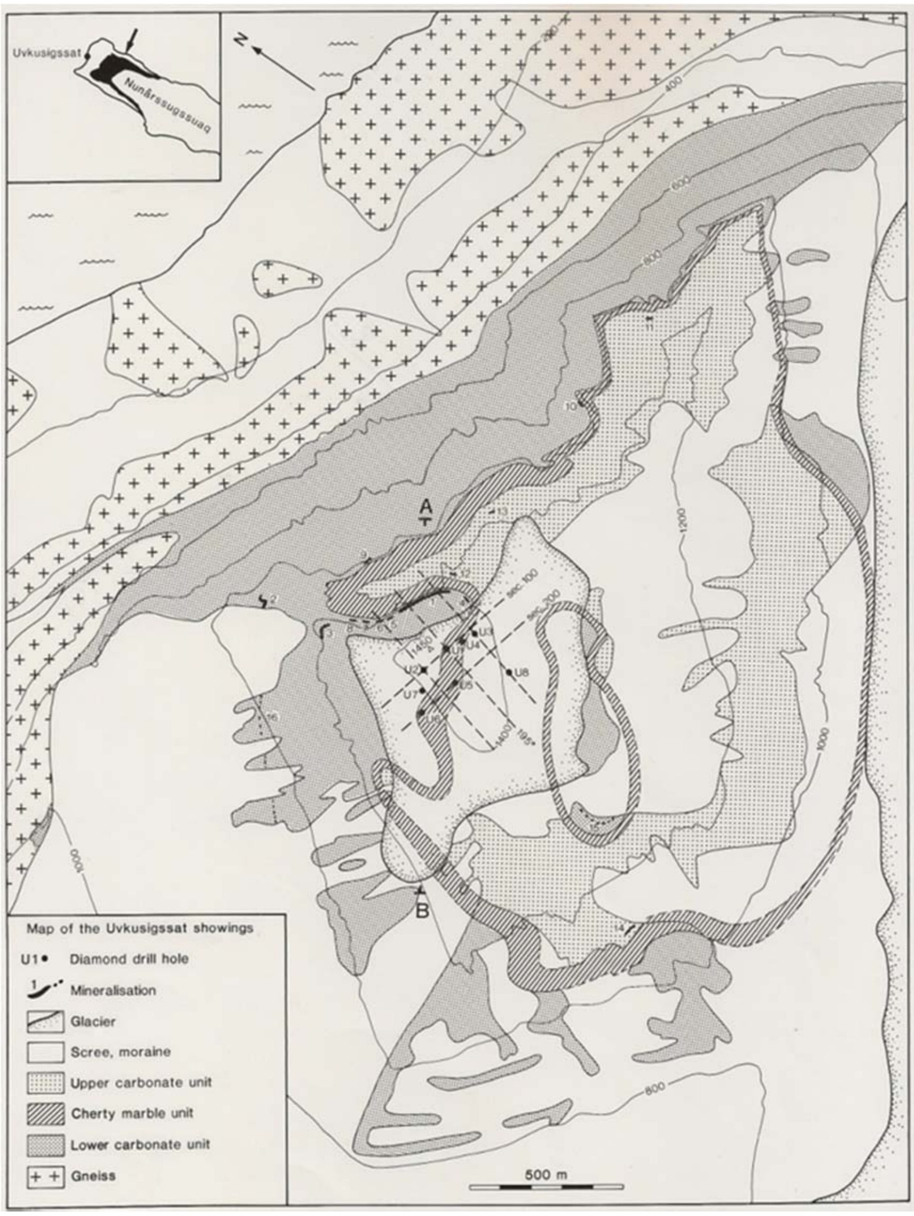


Figure 58. *Detailed geological map of the Uvkusigssat showing with indication of mineralisations and location of drill holes completed during the 1979 field campaign. Figure from workshop presentation by Thomassen (2011); see Appendix C.*

Three types of mineralisation were identified:

- Type 1, bedding plane mineralisation: mainly sphalerite with minor galena and pyrite generally coarse grained disseminated to semi-massive sulphide always in a calcite matrix and with marble fragments.
- Type 2, stratified mineralisation: well bedded stratiform massive to semi-massive sphalerite galena pyrite buckshot texture mineralisation characterized by alternating sulphide marble layers.
- Type 3, massive mineralisation: massive coarse-grained sphalerite galena pyrite buckshot texture mineralisation without any internal bedding structure, with few marble fragments.

In 2000 the Uvkusigssat showing were reinvestigated by New Claymore Resources and the company did detailed geological mapping, structural analysis and a VLF survey. The results from this work were positive and the company concluded that the area could have a potential for hosting massive sulphide remobilised lenses of the Black Angel type and that the mineralisation potential could be in the order of 10 million tons. Due to the global recession New Claymore Resources never returned to the area and the potential still remains untested. The area is currently licensed by Angel Mining PLC.

The Uvkusigssat showing is included in tract Came_WG1.

Appat showing

The following description is derived from King (1993) and from workshop presentation by Thomassen (2011); see Appendix C.

The Appat showing (elevation 1100-1170m) is situated in Middle Maarmorilik Formation calcite-dolomite marbles (Figure 59 & 60) in the eastern part of the Appat Island. It consist of an up to 5 m thick folded layer of massive porphyroclastic sulphides exposed over c. 130 m in the upper part of a cliff face.

58 chip samples collected in 11 sections averaged 0.5% Pb and 32.6% Zn over 3.4 m true width. Drilling of 17 holes totalling 2700 m failed to trace the layer behind the cliff.

The Appat showing is included in tract Came_WG1.

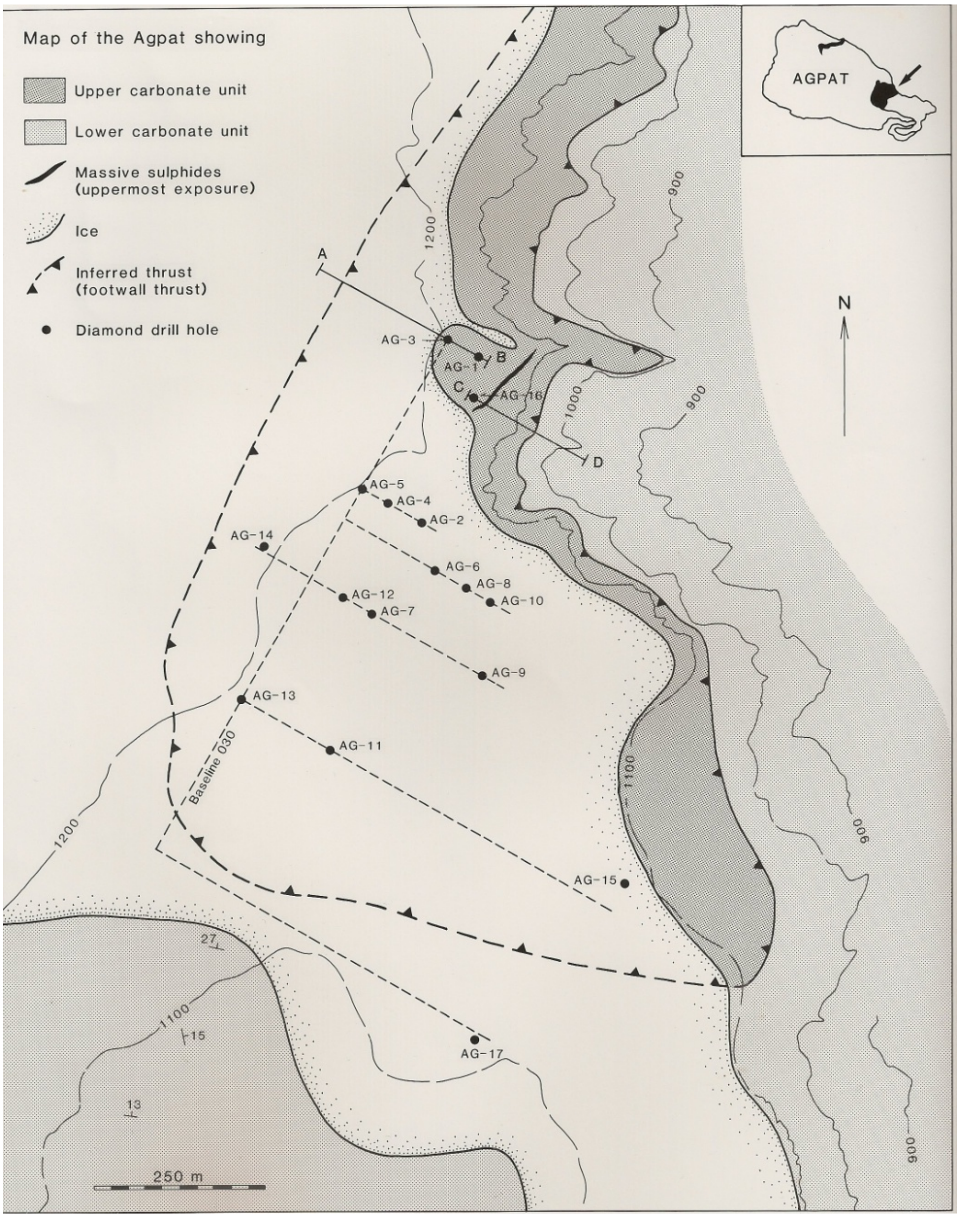


Figure 59. *Detailed geological map of the Appat showing with indication of mineralisations and location of drill holes completed during the 1976 field campaign. Figure from workshop presentation by Thomassen (2011); see Appendix C.*

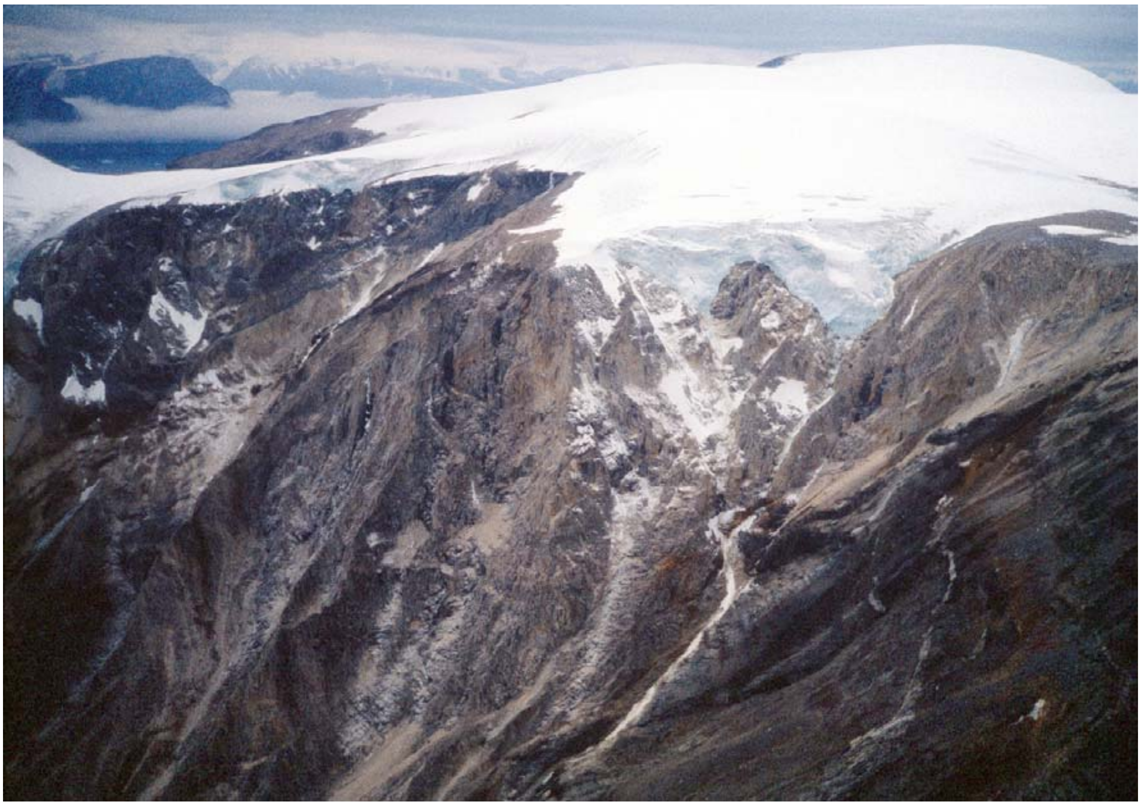


Figure 60. *Helicopter view of the Appat showing. Figure from workshop presentation by Thomassen (2011); see Appendix C.*

Kanakip Aufva occurrence
The following description is from Garde & Thomassen (1990).

The Archaean gneisses of central Nuussuaq host a number of marble occurrences which probably belong to the Lower Proterozoic Mârmorilik Formation. The marble sequence exposed in Kanakip Aufva present important thickness variation from 30 to 50 m in the less deformed area to 350 to 400 m, in the east face of Kanakip Aufva, related to a cascade fold system. True thickness of the marble section is estimated to be up to about 100 to 150 m.The largest marble occurrence is exposed for c. 4 km along strike in a steep, 500-700 m high mountain cliff (Figure 61+ 62). The sequence is capped by Tertiary basalt.

Large scale tectonism has altered the original stratigraphy and low-angle thrusting and intramember isoclinal folding have resulted in the superposition over Mârmorlik Formation of basement gneisses. In Kanakip Aufva this have resulted in an inverted stratigraphy consisting of a lowermost tonalitic pink banded gneiss unit, overlain by the marbles of the Marmorlik Formation, in turn overlain by a dark green dioritic biotite-hornblende gneiss, which is exposed in the core of a large scale recumbent isoclinal fold (Figure 61).

The occurrence of Marmorilik Formation marble on Nuussuaq was mapped by GGU in the 70´ties and investigated by Greenex A/S in 1982. Major lead-zinc showings were discovered following talus slope prospecting with reported average combined values of 15 to 40% Pb-Zn (King 1983).

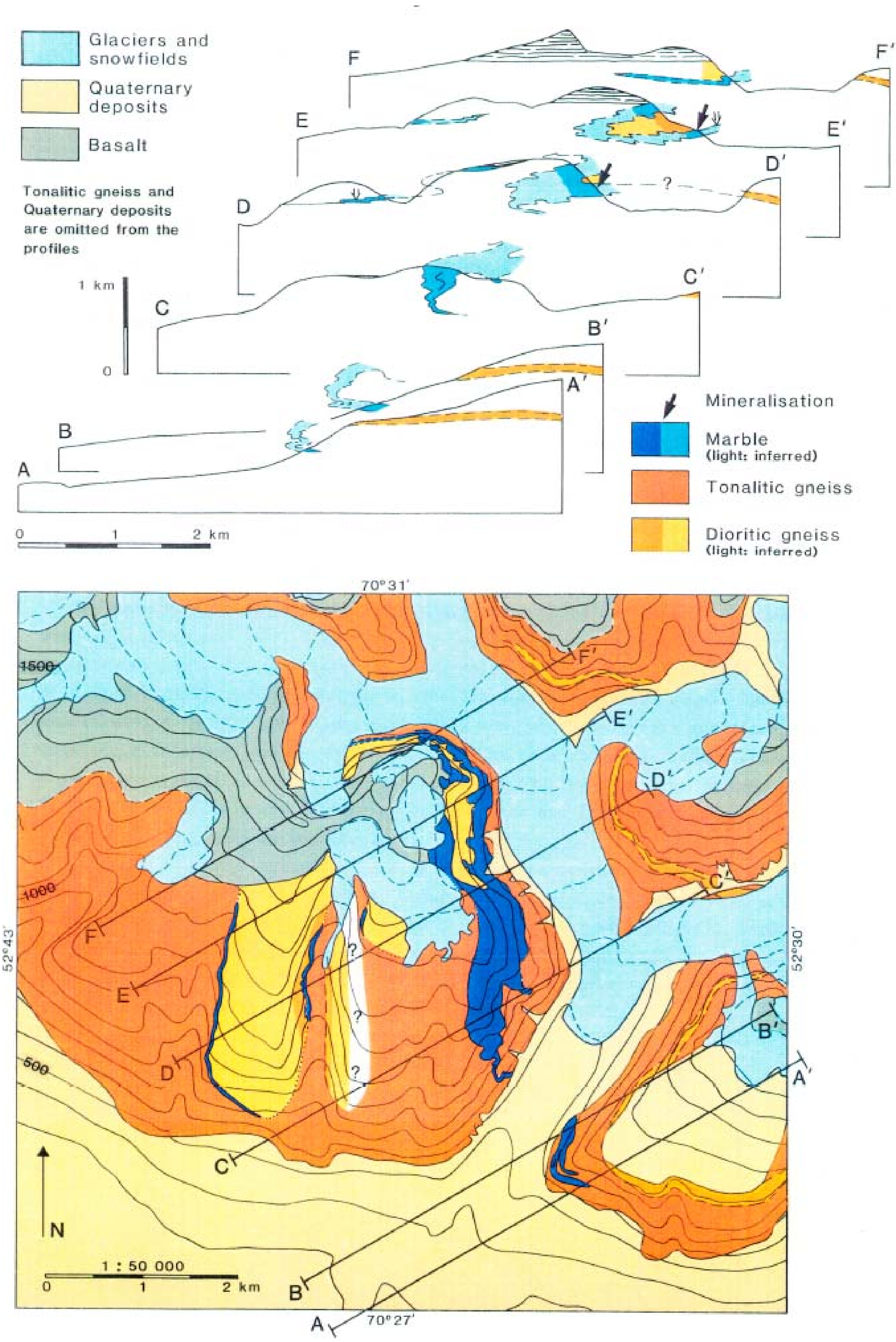


Figure 61. *Geological map of Kanakip aufva, central Nuussuaq. The thicknesses of thin marble layers are 2-3x exaggerated for clarity. The accompanying profiles (horizontal and vertical scales identical) show the authors' interpretation of the marble structure in light blue colour. From Garde & Thomassen (1990).*

Field work carried out by GGU in 1989 suggests that the marble forms a south-west facing recumbent isoclinal fold with a horizontal fold axis trending c. 135°. Horizons of massive sulphides, mainly sphalerite, are known from two localities within this marble occurrence (Figure 62 & Figure 63). The mineralisation resembles the ore of the Black Angel mine situated some 80 km further north-east. A chip sample across a c. 1 m thick sulphide horizon returned 45% Zn and 1% Pb. The structural model presented implied a potential for a significant zinc-lead deposit of the Black Angel type in central Nuussuaq (Garde & Thomassen 1990).

In 1990, Intergeo-Exploration re-evaluated the project but the conclusion was that the tonnage potential of this prospect was limited, based on a standard structural interpretation (Della Valle & Dentan 1991).

Avannaa Resources had an exploration licence covering the Kanakip Aufva occurrence from 2010 - 2012.

Figure 62. *View of the exposed marble sequence on Nuussuaq hosting the Kanakip Aufva occurrence (red arrow indicates position of the mineralisation). Figure from workshop presentation by Thomassen (2011); see Appendix C.*

The Kanakip Aufva occurrence is included in tract Came_WG1.

Figure 63. *Closeup of the Kanakip Aufva occurrence and c. 1 m thick flat laying porphyroclastic horizon of sphalerite with minor pyrite and galena. Figure from workshop presentation by Thomassen (2011); see Appendix C.*

Kangerluarsuk Sermia and Alfred Wegner Halvø zinc occurrences
The two occurrences are described in much detail in Coppard (1992).

The Kangerluarsuk and Alfred Wegner Halvø zinc occurrences are included in tracts SHme_WG3 and Came_WG_1

Grade and tonnage model selection

Based on the characteristics of the known mineralisations in the Karrat Group, the assessment panel found it justifiable to use the sediment-hosted zinc; both SEDEX and MVT subtype (Taylor *et al.* 2009) as the appropriate grade and tonnage model in the estimation of undiscovered deposits.

Individual tracts assessed during workshop

Figure 64 shows the distribution of tracts being treated by the assessment panel for Palaeoproterozoic sediment-hosted zinc deposits within the Karrat Group in West Greenland during the workshop.

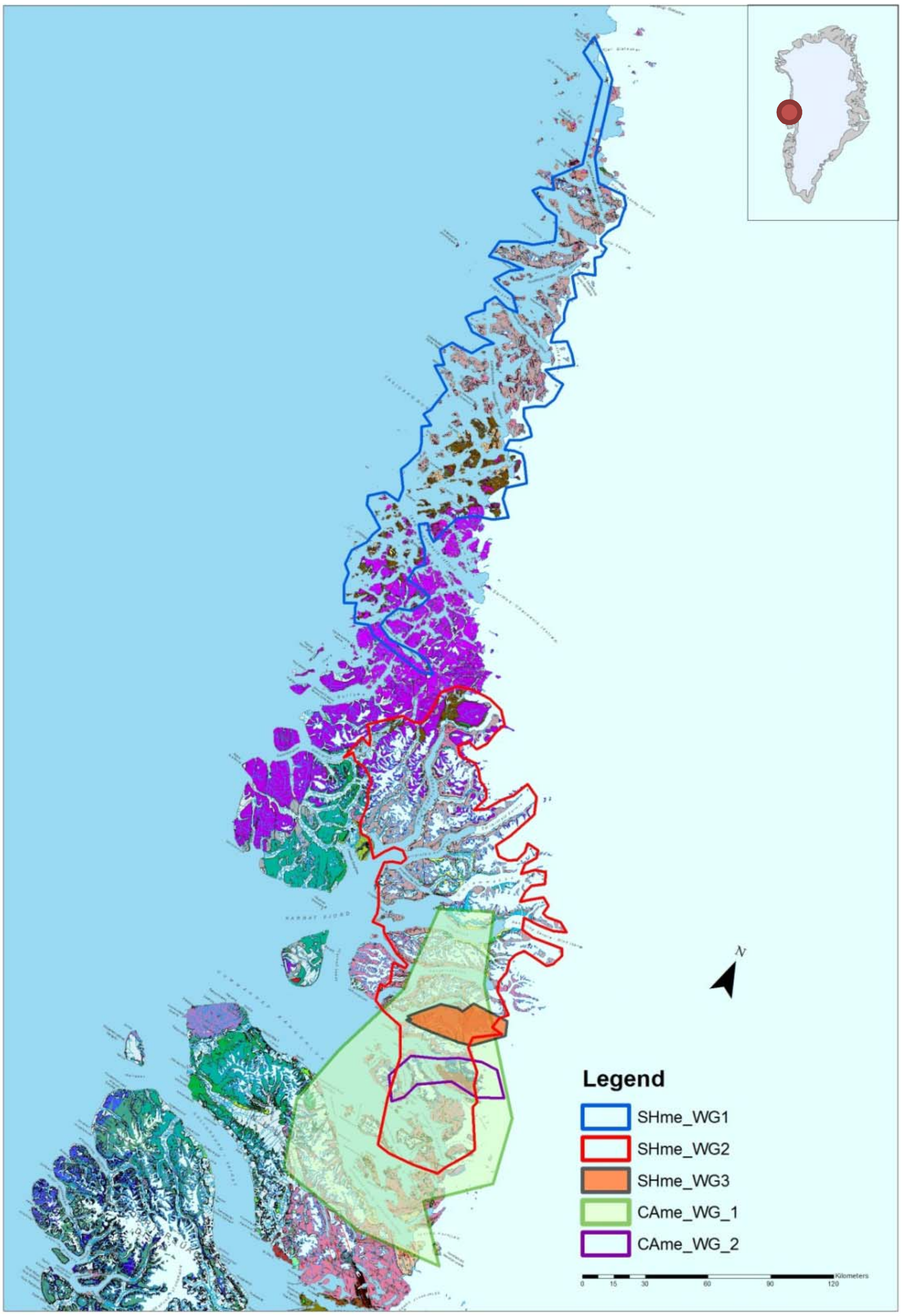


Figure 64. *Tracts for sediment-hosted zinc deposits within the Palaeoproterozoic Karrat Group of West Greenland. The assessed tracts are; SHme_WG1, SHme_WG2, SHme_WG3, CAme_WG_1 & CAme_WG_2. For geological legend see Appendix A.*

Tracts excluded from estimations

The assessment panel decided to exclude the Palaeoproterozoic tract Came_WG_3 (Figure 65), due to lack of data, small thickness of the Karrat Group combined with the view, that the assessment panel did not believe there was a potential for finding undiscovered sediment-hosted zinc deposits within the tract.

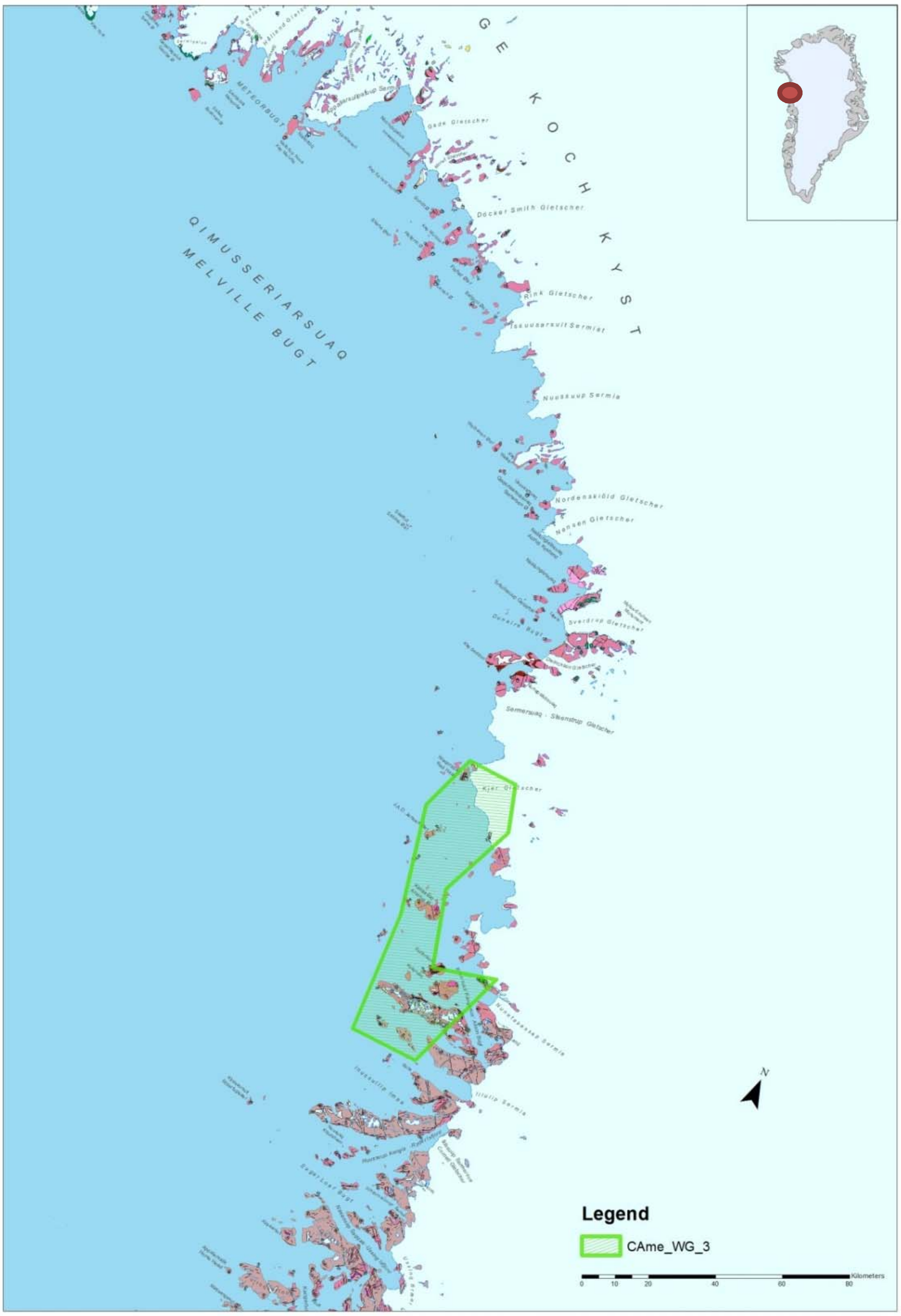


Figure 65. *Location of the excluded tract Came_WG_3 north of Upernavik in West Greenland. For geological legend see Appendix A.*

Tract SHme_WG1 – SEDEX zinc type

Location and delineation of the permissive tract

The Palaeoproterozoic tract SHme_WG1 is located north of Upernavik within the Nûkavsak Formation of the Karrat Group north of the Prøven Igneous Complex in West Greenland (Figure 66). The tract was assessed for SEDEX type deposits. Summary of the estimated undiscovered deposits can be found in Table 33.

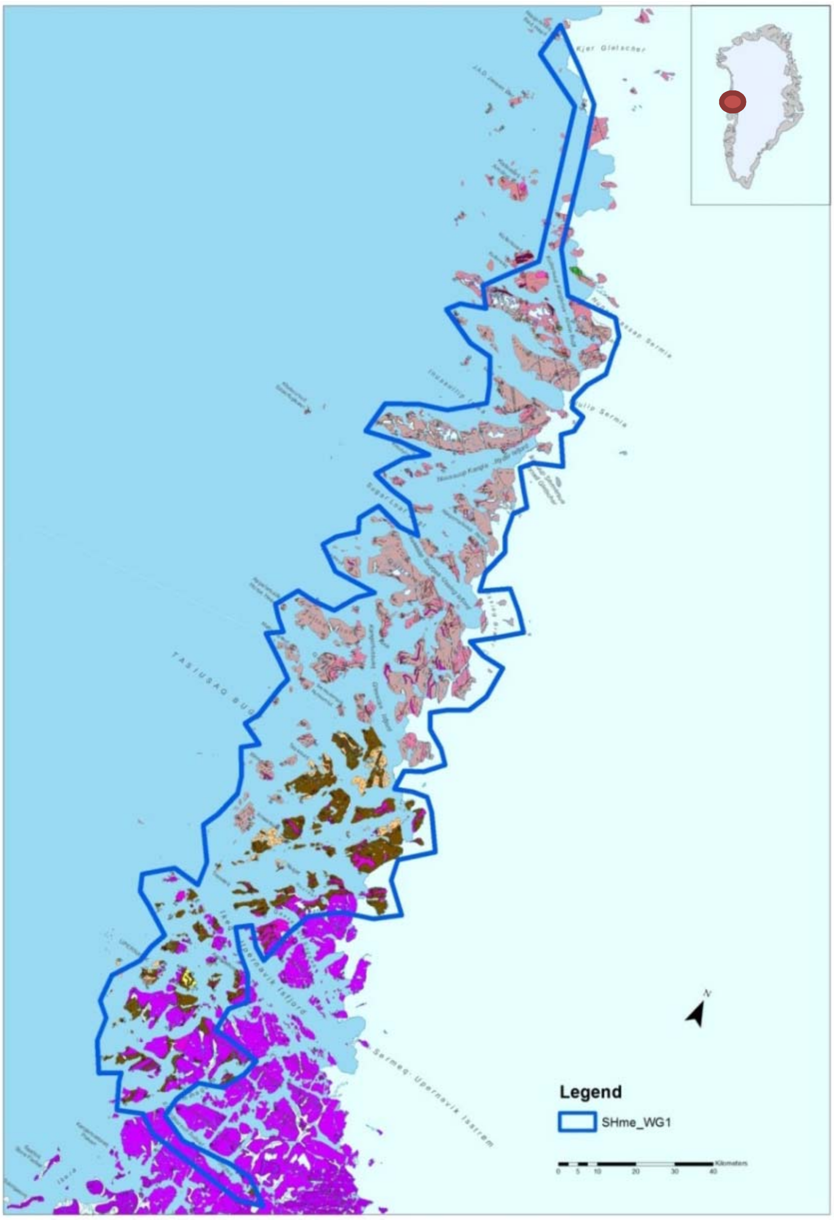


Figure 66. *Location of the tract SHme_WG1 north of Upernavik covering the Nûkavsak Formation of the Karrat Group north of the Prøven Igneous Complex in West Greenland. For geological legend see Appendix A.*

Table 34. *Summary of selected resource assessment results for the tract SHme_WG1.*

Assessment depth (km)	Tract area (km^2)	Known zinc resources (metric tons)	Mean estimate of undiscovered zinc resources (metric tons)
1 km	9,606	0	190,000

Geological criteria and rationale for the estimate

The SHme_WG1 tract includes the Nûkavsak Fm down to an estimated depth of 1 km below surface. The extent of the tract is based on the mapped distribution of the Nûkavsak Fm north of the Prøven Igneous Complex in West Greenland. This formation is believed to be the most likely rock unit to contain metamorphosed shale-hosted zinc (SEDEX) mineralisations.

The deposits estimates and the resulting undiscovered resource estimates from the Monte Carlo simulation can be found in Table 35 and Table 36.

Table 35. *Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for SHme_WG1. For further details see text associated with Table 5.*

Consensus undiscovered deposit estimate					Summary statistics					Area (km^2)	Deposit density (N/km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}		
0	0	0	0	2	0.06	0.37	610	0	0.06	9,610	6.2E-06

	Estimated number of undiscovered deposits				
Estimator	**N90**	**N50**	**N10**	**N05**	**N01**
Individual 1	0	0	0	1	2
Individual 2	0	0	0	1	1
Individual 3	0	0	0	0	1
Individual 4	0	0	0	0	1
Individual 5	0	0	0	0	1
Individual 6	0	0	0	1	2
Individual 7	0	0	0	0	1
Individual 8	0	0	0	1	2
Individual 9	0	0	0	0	2
Individual 10	0	0	1	2	3
Individual 11	0	0	0	0	1
Individual 12	0	0	0	0	0
Individual 13	0	0	0	0	1
Consensus	**0**	**0**	**0**	**0**	**2**

Table 36. *Results of Monte Carlo simulations of undiscovered resources in the Palaeoproterozoic tract SHme_WG1. [t = metric tons; Mt; megatonne or million tons]*

Material	Probability of at least the indicated amount						Probability of mean or greater	Probability of zero [none]
	0.95	0.90	0.50	0.10	0.05	Mean		
Zn (t)	0	0	0	0	0	190,000	0.03	0.96
Pb (t)	0	0	0	0	0	92,000	0.03	0.96
Rock (t)	0	0	0	0	0	3,000,000	0.01	0.98

Tract SHme_WG2 – SEDEX zinc type

Location and delineation of the permissive tract

The Palaeoproterozoic tract SHme_WG2 is located south of Upernavik within the thickest part of the Nûkavsak Formation of the Karrat Group in West Greenland (Figure 67). The tract was assessed for SEDEX type deposits. Summary of the estimated undiscovered zinc resources can be found in Table 37. The extent of the tract is based on the mapped distribution of the Nûkavsak Fm south of the Prøven Igneous Complex. The SHme_WG2 contains the Nûkavsak Fm down to an estimated depth of 1 km below surface.

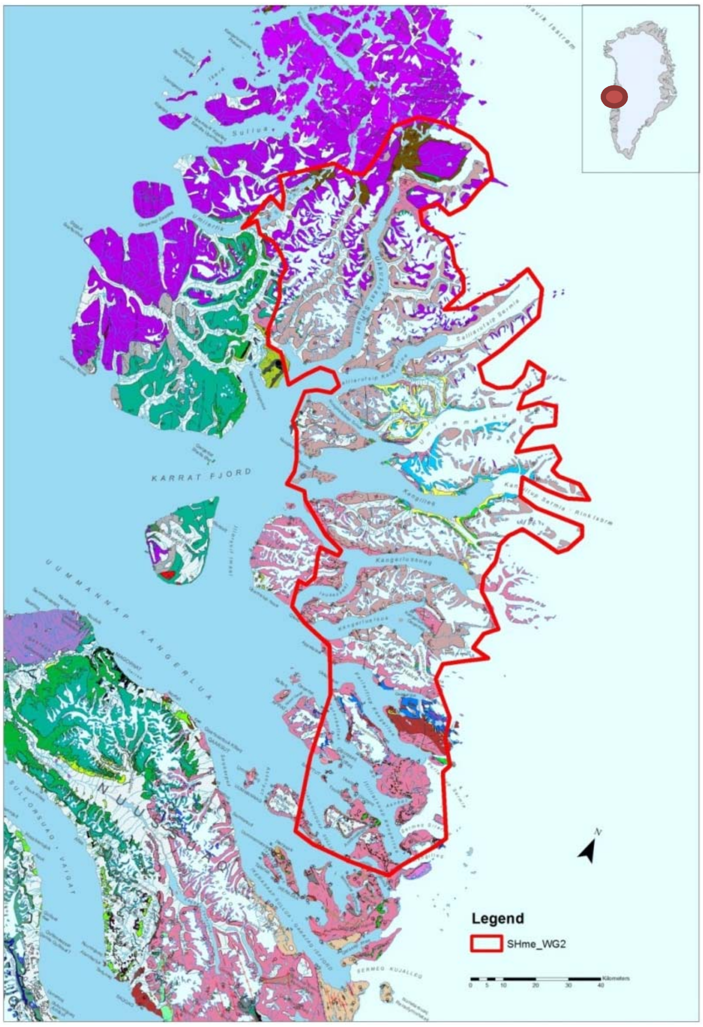


Figure 67. *Location of the tract SHme_WG2 south of Upernavik within the thickest part of the Nûkavsak Formation of the Karrat Group in West Greenland. For geological legend see Appendix A.*

Table 37. *Summary of selected resource assessment results for the tract SHme_WG2.*

Assessment depth (km)	Tract area (km^2)	Known zinc resources (metric tons)	Mean estimate of undiscovered zinc resources (metric tons)
1 km	12,650	0	290,000

Geological criteria and rationale for the estimate

Rusty-weathering horizons containing a few per cent disseminated pyrrhotite are very common in the turbidite sequence of the Nûkavsak Formation, and cherty layers rich in pyrrhotite and graphite, often containing semi-massive pyrrhotite-graphite breccias, are widespread at one or more levels in the formation distinguished between cherty and graphitic sulphide horizons in the Umanak district. The former are best developed southeast of the Íngia area in the lower 500–600 m of the formation. They are multiple bands with prominent thicknesses (5-10 m) and strike extent (5–10 km). The graphitic sulphide horizons are pyrrhotite-rich black shales typically quite thick (2–5 m) and fairly extensive.They show no preference to a particular stratigraphic level or geographical part of the formation. The sulphide minerals are invariably dominated by pyrrhotite with minor pyrite and trace amounts of chalcopyrite and occasionally arsenopyrite. It appears that noble and base metals as well as arsenic and molybdenum are higher here than in the similar mineralisation associated with the metavolcanic rocks of the Qeqertarssuaq Formation. The existence of other types of stratiform mineralisation in the Nûkavsak Formation is indicated by boulders with fine-grained, disseminated arsenopyrite and boulders of tourmalinite in the northern Umanak district. Such mineralisation, easily overlooked, might be quite common in the turbidite sequence. Chip samples with up to 10.8% Zn from the basal part of the formation have been reported from an area c. 25 km NW of Maarmorilik, but no detailed information is available about this mineralisation. The deposits estimates and the resulting undiscovered resource estimates from the Monte Carlo simulation can be found in Table 38 & Table 39. Typical exposures of the Nûkavsak Formation can be seen in Figure 68 & Figure 69.

Table 38. *Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for tract SHme_WG2. For further details see text associated with Table 5.*

Consensus undiscovered deposit estimate					Summary statistics					Area (km^2)	Deposit density (N/km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}		
0	0	0	1	2	0.11	0.44	420	0	0.11	12,650	8.3E-06

	Estimated number of undiscovered deposits				
Estimator	**N90**	**N50**	**N10**	**N05**	**N01**
Individual 1	0	0	0	1	2
Individual 2	0	0	1	1	3
Individual 3	0	0	0	1	1
Individual 4	0	0	0	1	2
Individual 5	0	0	0	1	1
Individual 6	0	0	0	2	3
Individual 7	0	0	0	1	2
Individual 8	0	0	1	2	4
Individual 9	0	0	0	1	2
Individual 10	0	0	1	2	3
Individual 11	0	0	0	1	2
Individual 12	0	0	0	0	1
Individual 13	0	0	0	1	2
Consensus	**0**	**0**	**0**	**1**	**2**

Table 39. *Results of Monte Carlo simulations of undiscovered resources in the Palaeoproterozoic tract SHme_WG2. [t = metric tons; Mt; megatonne or million tons]*

Material	Probability of at least the indicated amount						Probability of mean or greater	Probability of zero [none]
	0.95	0.90	0.50	0.10	0.05	Mean		
Zn (t)	0	0	0	0	320,000	290,000	0.05	0.93
Pb (t)	0	0	0	0	130,000	130,000	0.05	0.93
Rock (t)	0	0	0	0	0	4,200,000	0.02	0.97

Figure 68. *Typical Nûkavsak Formation: interlayered metagreywacke and pelitic schist. Figure from workshop presentation by Thomassen (2011); see Appendix C.*

Figure 69. *Typical Nûkavsak Formation metasediments. Figure from workshop presentation by Thomassen (2011); see Appendix C.*

Tract SHme_WG3 – SEDEX zinc type

Location and delineation of the permissive tract

The Palaeoproterozoic tract SHme_WG3 is located north of the Black Angel Mine at the Karrat Isfjord within the Nûkavsak Formation of the Karrat Group in West Greenland (Figure 70). The tract was assessed for SEDEX type deposits. Summary of the estimated undiscovered zinc resources can be found in Table 40. The SHme_WG3 tract includes the Nûkavsak Fm down to an estimated depth of 1 km below surface. The extent of the tract is based on the delineation of the known zinc occurrences in the Kangerluarsuk Sermia and Alfred Wegner Halvø area as described in Coppard (1992).

Figure 70. *Location of the tract SHme_WG3 north of the Black Angel Mine covering the Nûkavsak Formation of the Karrat Group in West Greenland. For geological legend see Appendix A.*

Table 40. *Summary of selected resource assessment results for the tract SHme_WG3.*

Assessment depth (km)	Tract area (km^2)	Known zinc resources (metric tons)	Mean estimate of undiscovered zinc resources (metric tons)
1 km	606	0	770,000

Geological criteria and rationale for the estimate
Shale-hosted massive base-metal sulphide deposits associated with iron sulphide layers have the potential for economic deposits. Especially, the Nûkavsak Formation has the potential for SEDEX type mineralisation (Thomassen 1992). The widespread pyrrhotite occurrences might be of exhalitic or sedimentary black shale origin. The sulphide-rich layers have enhanced levels of gold, copper, zinc, arsenic and molybdenum indicating a potential for stratiform base metal deposits.

The deposits estimates and the resulting undiscovered resource estimates from the Monte Carlo simulation can be found in Table 41 & Table 42.

Table 41. *Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for SHme_WG3. For further details see text associated with Table 5.*

Consensus undiscovered deposit estimate					Summary statistics					Area (km^2)	Deposit density (N/km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}		
0	0	1	1	1	0.3	0.5	170	1	1.3	610	0.0021

	Estimated number of undiscovered deposits				
Estimator	**N90**	**N50**	**N10**	**N05**	**N01**
Individual 1	0	0	1	1	2
Individual 2	0	0	1	1	2
Individual 3	0	0	1	1	2
Individual 4	0	0	1	2	3
Individual 5	0	0	0	1	1
Individual 6	0	0	0	1	3
Individual 7	0	0	0	0	1
Individual 8	0	1	1	2	2
Individual 9	0	0	0	0	1
Individual 10	0	0	1	2	3
Individual 11	0	1	2	2	2
Individual 12	0	0	0	0	1
Individual 13	0	0	1	1	1
Consensus	**0**	**0**	**1**	**1**	**1**

Table 42. *Results of Monte Carlo simulations of undiscovered resources in the Palaeoproterozoic tract SHme_WG3. [t = metric tons; Mt; megatonne or million tons]*

Material	Probability of at least the indicated amount						Probability of mean or greater	Probability of zero [none]
	0.95	0.90	0.50	0.10	0.05	Mean		
Zn (t)	0	0	0	1,100,000	3,400,000	770,000	0.12	0.70
Pb (t)	0	0	0	480,000	1,600,000	350,000	0.11	0.73
Rock (t)	0	0	0	0	0	12,000,000	0.04	0.93

Tract CAme_WG_1 – MVT zinc type

Location and delineation of the permissive tract
The Palaeoproterozoic tract CAme_WG_1 is located from the northeastern part of the Nuussuaq peninsula to an area north of Karrat Isfjord within the Mârmorilik Formation of the Karrat Group in West Greenland (Figure 71). The tract was assessed for MVT type deposits. Summary of the estimated undiscovered zinc resources can be found in Table 43.

The CAme_WG_1 tract contains the Mârmorilik Fm down to an estimated depth of 1 km below surface. The extent of the tract is based on the interpretated distribution of the Mârmorilik Fm. The tract does not include the Black Angel Mine which is included in tract Came_WG_2.

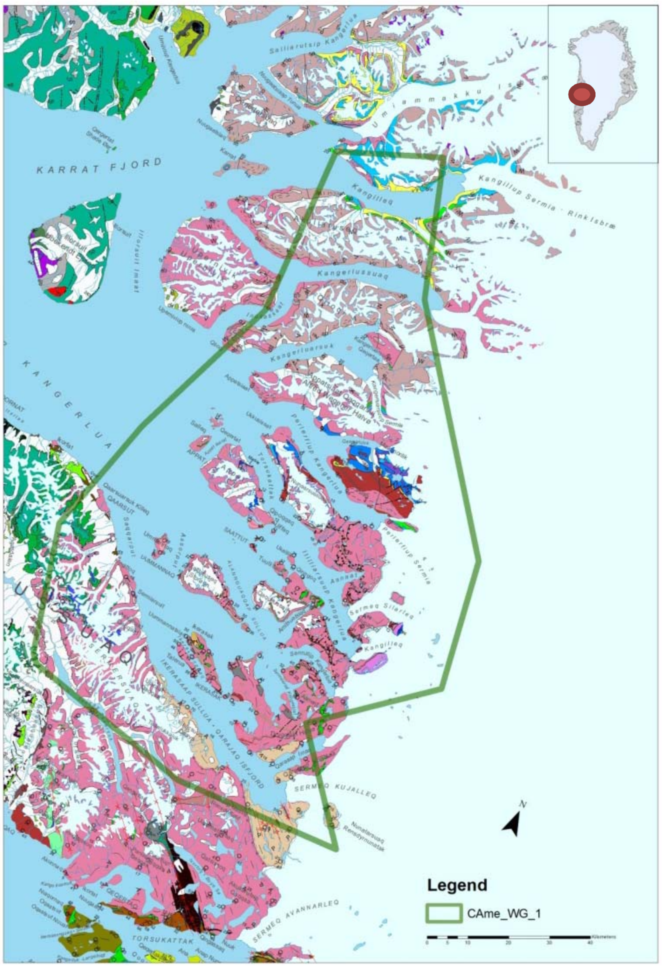


Figure 71. *Location of the tract CAme_WG_1 from the northeastern part of the Nuussuaq peninsula to an area north of Karrat Isfjord within the Mârmorilik Formation of the Karrat Group in West Greenland. For geological legend see Appendix A.*

Table 43. *Summary of selected resource assessment results for the tract CAme_WG_1.*

Assessment depth (km)	Tract area (km^2)	Known zinc resources (metric tons)	Mean estimate of undiscovered zinc resources (metric tons)
1 km	10,585	0	27,000

Geological criteria and rationale for the estimate

The Mârmorilik Formation rests unconformably on an Archaean gneiss complex and is overlain by semipelites of the upper Karrat Group.

The Mârmorilik Formation is part of the Palaeoproterozoic Karrat Group. This Group belongs to the Foxe-Rinkian mobile belt of NE Canada and central West Greenland, which constitutes a component of the Trans-Hudson Orogen of North America. In Greenland, exposures of the Karrat Group are known over a north-south distance of c. 550 km covering some 10,000 km². The Group, that rests unconformably on an Archaean gneiss complex, is intruded by a major 1860 Ma syn-tectonic granite complex and is overlain by Cretaceous-Tertiary sediments and volcanics. The Karrat Group, several kilometres thick, is composed of lower shelf units of carbonates and quartzites, and an upper unit of deepwater turbidites and minor volcanic rocks. The basement and the cover sequence were subjected to several phases of strong folding and thrusting during the Rinkian Mobile Belt and variably affected by regional metamorphism. The Mârmorilik Formation consists of calcitic and dolomitic marbles with a basal quartzitic unit and intercalations of anhydrite-bearing marbles and semipelitic schists. In areas, where the formation has been tectonically thickened to c. 1000 m, three main phases of folding and thrusting have been distinguished, and metamorphism reached upper greenschist facies

The Uvkusigssat showing and Kanakip Aufva occurrence and the Kangerluarsuk Sermia zinc occurrence hosted in the Lower Mârmorilik Formation as described in Coppard 1992 is included in tract Came_WG_1. The deposits estimates and the resulting undiscovered resource estimates from the Monte Carlo simulation can be found in Table 44 & Table 45.

Table 44. *Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for CAme_WG_1. For further details see text associated with Table 5.*

Consensus undiscovered deposit estimate					Summary statistics					Area (km^2)	Deposit density (N/km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}		
0	0	0	0	1	0.03	0.24	810	0	0.03	10,590	2.8E-06

	Estimated number of undiscovered deposits				
Estimator	**N90**	**N50**	**N10**	**N05**	**N01**
Individual 1	0	0	0	0	1
Individual 2	0	0	0	0	1
Individual 3	0	0	0	0	1
Individual 4	0	0	1	2	2
Individual 5	0	0	0	0	1
Individual 6	0	0	0	0	2
Individual 7	0	0	0	0	0
Individual 8	0	0	0	0	2
Individual 9	0	0	0	1	1
Individual 10	0	0	0	1	1
Individual 11	0	0	0	0	0
Individual 12	0	0	0	0	1
Individual 13	0	0	1	1	2
Consensus	**0**	**0**	**0**	**0**	**1**

Table 45. *Results of Monte Carlo simulations of undiscovered resources in the Palaeoproterozoic tract CAme_WG_1. [t = metric tons; Mt; megatonne or million tons]*

Material	Probability of at least the indicated amount						Probability of mean or greater	Probability of zero [none]
	0.95	0.90	0.50	0.10	0.05	Mean		
Zn (t)	0	0	0	0	0	27,000	0.03	0.97
Pb (t)	0	0	0	0	0	10,000	0.03	0.97
Rock (t)	0	0	0	0	0	670,000	0.00	1.00

Tract CAme_WG_2 – MVT zinc type

Location and delineation of the permissive tract

The Palaeoproterozoic tract CAme_WG_2 includes the Black Angel Mine in the Mârmorilik Formation of the Karrat Group in West Greenland (Figure 72). The tract was assessed for MVT type deposits. Summary of the estimated undiscovered zinc resources can be found in Table 45. The CAme_WG_2 tract contains the Mârmorilik Formation down to an estimated depth of 1 km below surface. The extent of the tract is based on the mapped distribution of the Mârmorilik Formation.

Table 46. *Summary of selected resource assessment results for the tract CAme_WG_2.*

Assessment depth (km)	Tract area (km^2)	Known zinc resources (metric tons)	Mean estimate of undiscovered zinc resources (metric tons)
1 km	749	1,661,000	270,000

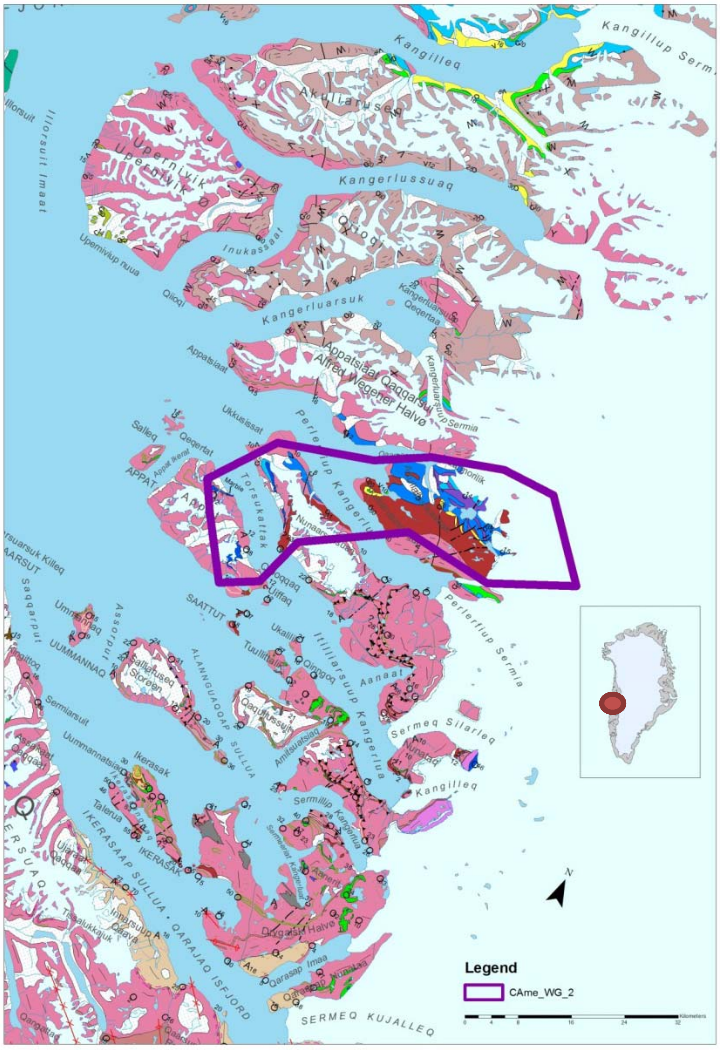


Figure 72. *Location of the tract CAme_WG_2 that includes the Black Angel Mine and surrounding areas within the Mârmorilik Formation of the Karrat Group in West Greenland. For geological legend see Appendix A.*

Geological criteria and rationale for the estimate

The tract includes the Black Angel Mine and associated known mineralisations in the vicinity of the mine and at the South Lakes Glacier prospect. The Black Angel lead-zinc mine is hosted in the Mârmorilik Formation of the Palaeoproterozoic Karrat Group (Garde 1978; Henderson & Pulvertaft 1987). The formation rests unconformably on an Archaean gneiss complex and is overlain by semipelites of the upper Karrat Group. It consists of calcitic and dolomitic marbles with a basal quartzitic unit and intercalations of anhydrite-bearing marbles and semipelitic schists. The main ore bodies are hosted in calcitic marble and dolomite marble. The massive ore consists of pyrite, sphalerite and galena with abundant rotated marble fragments and quartz inclusions. The main accessory ore minerals are pyrrhotite, chalcopyrite, tennantite and arsenopyrite. Cherty horizons and disseminated graphite are quite common in the wall rocks whereas minor fluorite and baryte are restricted to a few of the ore bodies. The deposits estimates and the resulting undiscovered resource estimates from the Monte Carlo simulation can be found in Tables 47 and 48 respectively.

Table 47. *Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for CAme_WG_2. For further details see text associated with Table 5.*

Consensus undiscovered deposit estimate					Summary statistics					Area (km^2)	Deposit density (N/km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}		
0	0	1	1	1	0.3	0.5	170	1	1.3	750	0.0017

	Estimated number of undiscovered deposits				
Estimator	**N90**	**N50**	**N10**	**N05**	**N01**
Individual 1	0	1	1	1	1
Individual 2	0	1	1	3	5
Individual 3	0	1	1	1	1
Individual 4	0	1	1	1	2
Individual 5	0	0	0	1	1
Individual 6	0	0	1	2	3
Individual 7	0	0	0	0	0
Individual 8	0	0	0	0	0
Individual 9	0	0	1	1	1
Individual 10	0	1	2	2	3
Individual 11	0	0	0	0	1
Individual 12	0	0	0	1	1
Individual 13	0	0	0	0	1
Consensus	**0**	**0**	**1**	**1**	**1**

Table 48. *Results of Monte Carlo simulations of undiscovered resources in the Palaeoproterozoic tract CAme_WG_2. t = metric tons; Mt; megatonne or million tons]*

Material	Probability of at least the indicated amount						Probability of mean or greater	Probability of zero [none]
	0.95	0.90	0.50	0.10	0.05	Mean		
Zn (t)	0	0	0	580,000	1,300,000	270,000	0.15	0.71
Pb (t)	0	0	0	190,000	490,000	110,000	0.13	0.72
Rock (t)	0	0	0	0	0	6,100,000	0.02	0.96

Neoproterozoic Eleonore Bay Supergroup, East Greenland

Sources of information

The principal sources of information used for the assessment of the tracts within the Neoproterozoic Eleonore Bay Supergroup in central East Greenland for the SEDEX and MVT-hosted zinc subtypes are given in Appendix A.

Regional Geology

The following description is from Henriksen *et al.* (2009) (see references therein for more details):

The Eleonore Bay Supergroup comprises a more than 14 km thick succession of shallow-water sedimentary rocks which accumulated in a major sedimentary basin exposed between latitudes 71°40´ and 76°N in East and North-East Greenland. Exposures only occur within the present Caledonian fold belt, and in general the sedimentary rocks are moderately deformed and weakly to moderately metamorphose. The nature of the lower contact of the Eleonore Bay Supergroup has been widely debated. The oldest sedimentary rocks are in contact with the Krummedal supracrustal succession, with the contact described in some areas as an extensional detachment, and in other areas as a westward directed thrust. Relationships are complicated by extensive anatexis and the presence of Caledonian granites. Sedimentation is constrained to the interval between c. 900 Ma and c. 665 Ma by the youngest ages on detrital zircons from the lowest levels of the Eleonore Bay Supergroup and the Marinoan (c. 635 Ma) age of the overlying Tillite Group.

The lower part of the Eleonore Bay Supergroup (Figure 73) consists of up to 9000 m of sandstones, siltstones and minor carbonates assigned to the Nathorst Land Group; these were deposited in a shelf environment with facies associations indicating outer to inner shelf environments. The upper part comprises three groups; Lyell Land, Ymer Ø and Andrée Land Groups. Alternating sandstones and silty mudstones of the Lyell Land Group (Figure 73, 74 & 77) reflect deposition in marine shelf environments.

Individual units are 40–600 m thick with a total thickness of 2800 m. The overlying 1100 m thick Ymer Ø Group records two significant phases of shelf progradation. Depositional environments range from siliciclastic basinal and slope deposits through carbonate slope and shelf deposits to inner shelf siliciclastics and evaporites.

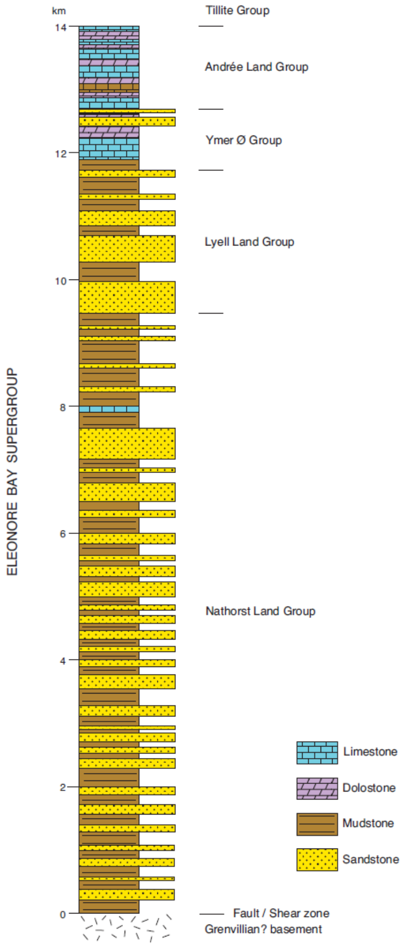


Figure 73. *Schematic composite section of the Neoproterozoic Eleonore Bay Supergroup, central fjord zone (72–74°N), North-East Greenland. From Henriksen et al. (2009).*

Figure 74. *Part of the upper Eleonore Bay Supergroup, west side of Ymer Ø (c. 73°N), North-East Greenland. Succession is approximately 2 km in thickness and includes from left to right: Lyell Land Group (apart from the two lowest formations) and to the right of the black dashed line Ymer Ø Group (the lowest five of seven formations). From Henriksen et al. (2009).*

The latest stage of basin fill is mainly represented by the up to 1200 m thick Andrée Land Group of bedded limestone and dolomites, with 10–30 m thick units of stromatolitic dolomite. Deposition took place in a carbonate ramp system, with a steepened ramp towards the deep sea to the north-east and a sheltered inner lagoon behind an inner shallow-barrier shoal. The uppermost sequence heralding the Marinoan glaciation of the Tillite Group consists of a strongly retrogradational succession indicating drowning of the carbonate platform and deep marine deposition, followed by a short period of carbonate platform progradation.

Exploration history

See Harpøth *et al.* (1986) for a description of the exploration history of central East Greenland and the Neoproterozoic Eleonore Bay Supergroup.

Known prospects, mineral occurrences or related deposit types

There are no known sediment-hosted zinc deposits within the tracts.

However, according to Harpøth *et al.* (1986), geochemical pan-sample anomalies indicate the existence of stratabound barium, lead-zinc occurrences within the Eleonore Bay Supergroup. Zinc anomalies that are not related to known occurrences exist in north Hudson Land, in west Andrée Land, on Ymer Ø, in Forsblad Fjord, in Renland and in Gåseland.

Grade and tonnage model selection

Based on the discussion and the reviews of previous work by various researchers on the mineralisation potential, the assessment panel found it justified, to use the sediment-hosted zinc, SEDEX and MVT subtype (Taylor *et al.* 2009) as the appropriated grade and tonnage models in the estimation of undiscovered deposits.

Individual tracts assessed during workshop

Tract MLme_EBS_1 – SEDEX zinc type

Location and delineation of the permissive tract

The Neoproterozoic tract, MLme_EBS_1 belong to the Eleonore Bay Supergroup, and includes areas in central East to Northeast Greenland from Kong Oscar Fjord in the south (72°N) to Ole Rømer Land in the north (74°N). The tract was assessed for SEDEX type deposits. Summary of the estimated undiscovered zinc resources can be found in Table 49.

The MLme_EBS_1 tract contains the Nathorst Land Group down to an estimated depth of 1 km below surface. The extent of the tract is based on the mapped distribution of the Nathorst Land Group (Figure 75).

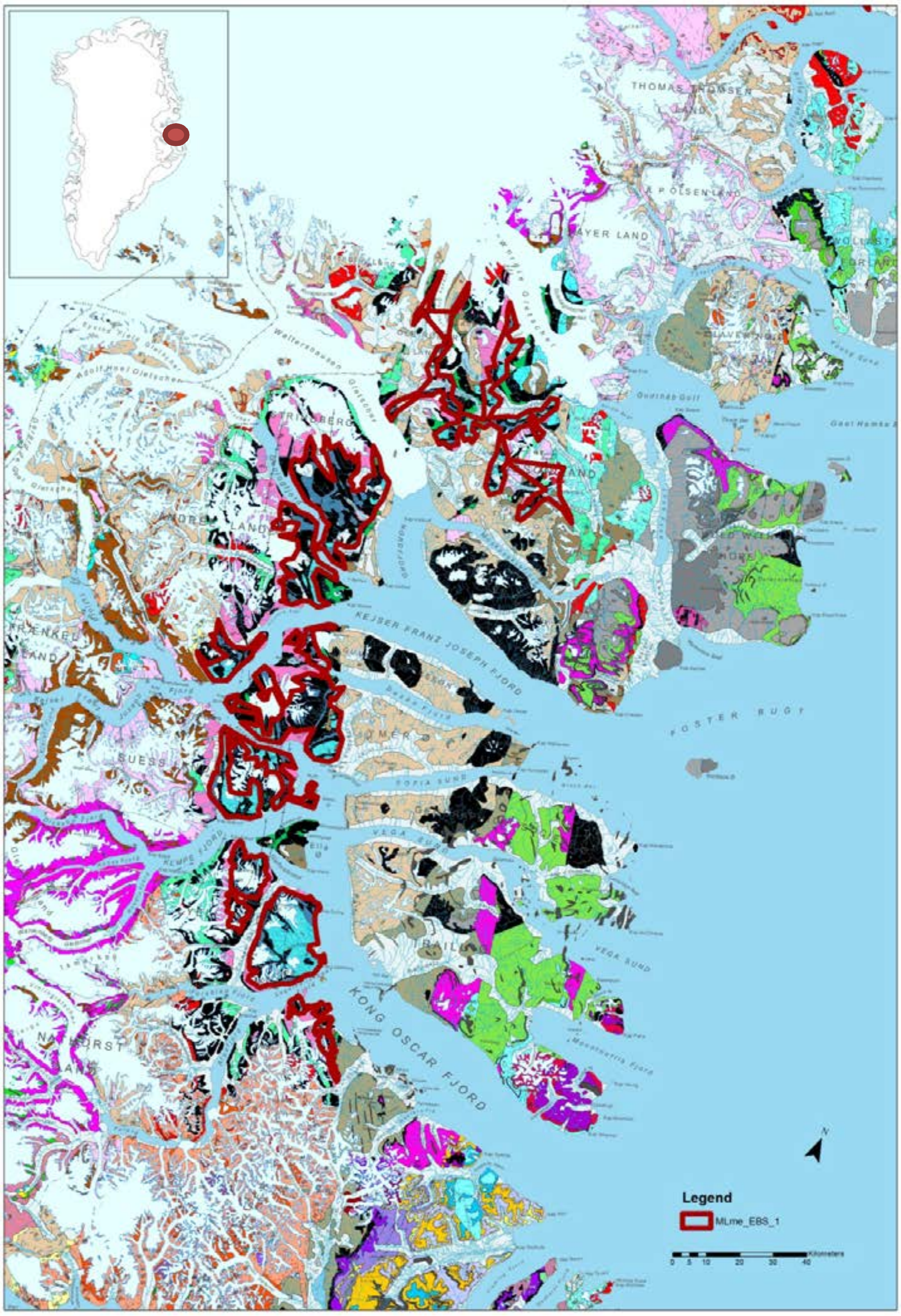


Figure 75. *Distribution of the tract MLme_EBS_1. The tract contains the lower part of the Neoproterozoic Elenore Bay Supergroup assessed for undiscovered SEDEX zinc type deposits. For geological legend see Appendix A.*

Table 49. *Summary of selected resource assessment results for the Neoproterozoic tract MLme_EBS_1*

Assessment depth (km)	Tract area (km^2)	Known zinc resources (metric tons)	Mean estimate of undiscovered zinc resources (metric tons)
1 km	3,069	0	280,000

Geologic criteria and rationale for the estimate

Tract MLme_EBS_1 contains the lower part of the Eleonore Bay Supergroup which consists of up to 9000 m of sandstones, siltstones and minor carbonates assigned to the Nathorst Land Group; these were deposited in a shelf environment with facies associations indicating outer to inner shelf environments.

Based on the discussion and the reviews of previous work by various researchers on the mineralisation, the assessment panel found it justified using the sediment-hosted zinc, SEDEX subtype (Taylor *et al.* 2009) as the appropriated grade and tonnage model in the estimation of undiscovered deposits. The deposits estimates and the resulting undiscovered resource estimates from the Monte Carlo simulation can be found in Tables 50 and 51 respectively.

Table 50. *Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for the tract MLme_EBS_1. For further details see text associated with Table 5.*

Consensus undiscovered deposit estimate					Summary statistics					Area (km^2)	Deposit density (N/km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}		
0	0	0	1	3	0.14	0.56	420	0	0.14	3,070	0.000044

	Estimated number of undiscovered deposits				
Estimator	**N90**	**N50**	**N10**	**N05**	**N01**
Individual 1	0	0	1	2	3
Individual 2	0	0	0	1	2
Individual 3	0	0	0	0	1
Individual 4	0	0	0	0	1
Individual 5	0	0	0	2	2
Individual 6	0	0	0	0	1
Individual 7	0	0	0	2	3
Individual 8	0	0	1	1	3
Individual 9	0	0	1	2	6
Individual 10	0	0	0	0	5
Individual 11	-	-	-	-	-
Individual 12	0	0	1	2	2
Individual 13	0	0	0	0	1
Consensus	**0**	**0**	**0**	**1**	**3**

Table 51. *Results of Monte Carlo simulations of undiscovered resources in the Neoproterozoic tract MLme_EBS_1. [t=metric tons; Mt; megatonne or million tons]*

Material	Probability of at least the indicated amount						Probability of mean or greater	Probability of zero [none]
	0.95	0.9	0.5	0.1	0.05	Mean		
Zn (t)	0	0	0	0	400,000	280,000	0.05	0.93
Pb (t)	0	0	0	0	180,000	140,000	0.05	0.93
Rock (t)	0	0	0	0	0	4,600,000	0.02	0.98

Tract MLme_EBS_1MVT – MVT zinc type

Location and delineation of the permissive tract

The Neoproterozoic tract, MLme_EBS_1MVT delineates the upper part of the Eleonore Bay Supergroup, and includes areas in central East to Northeast Greenland from Kong

Oscar Fjord in the south (72°N) to Ardencaple Fjord in the north (75°N). The tract was assessed for MVT type deposits. Summary of the estimated undiscovered zinc resources can be found in Table 52.

Tract MLme_EBS_1MVT includes the uppermost part of the Neoproterozoic Eleonore Bay Supergroup sedimentary sequence down to an estimated depth of 1 km below surface. The extent of the tract is based on the mapped distribution of the the Ymer Ø Group and the Andrée Land Group (Figure 76).

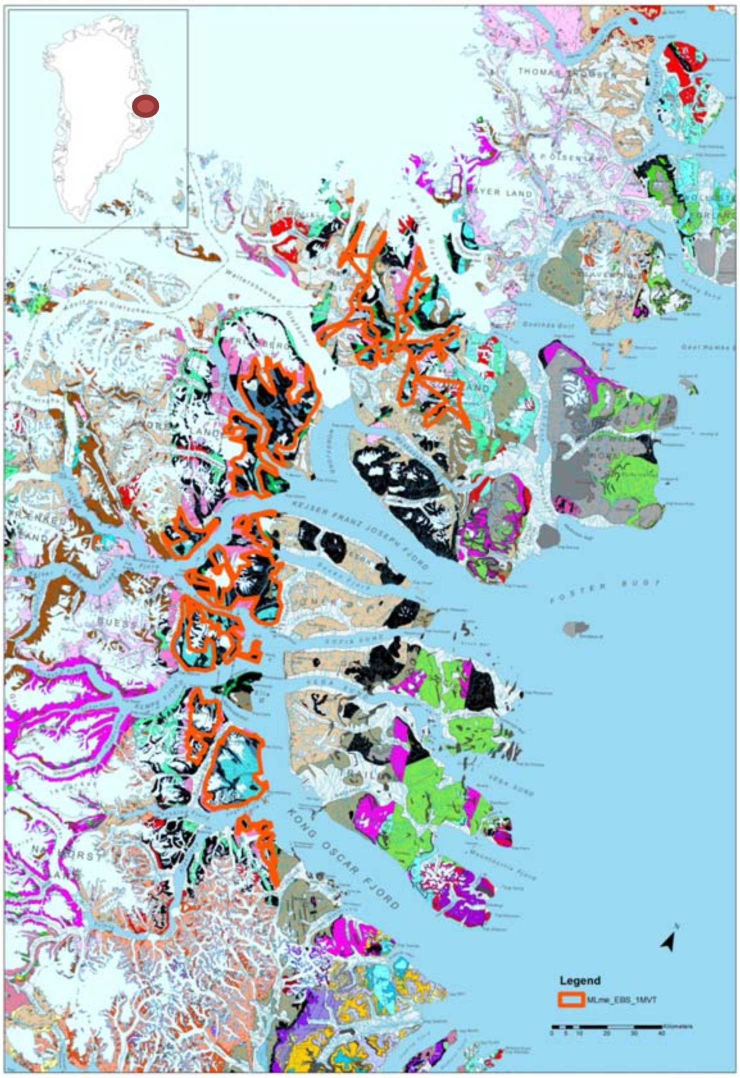


Figure 76. *Distribution of the Neoproterozoic tract MLme_EBS_1MVT. The tract contains the Neoproterozoic Elenore Bay Supergroup assessed for undiscovered MVT zinc type deposits. For geological legend see Appendix A.*

Table 52. *Summary of selected resource assessment results for the Neoproterozoic tract MLme_EBS_1MVT.*

Assessment depth (km)	Tract area (km^2)	Known zinc resources (metric tons)	Mean estimate of undiscovered zinc resources (metric tons)
1 km	3,069	0	150,000

Geologic criteria and rationale for the estimate

Tract MLme_EBS_1MVT includes the uppermost part of the Neoproterozoic EBS sedimentary sequence i.e. the Ymer Ø Group (~1.2 km), and the Andrée Land Group (~1.2 km) which are dominated by platform carbonates with both shallow marine carbonates and deep marine carbonate mud. Based on the discussion and the reviews of previous work by various researchers on the mineralisation, the assessment panel found it justified using the sediment-hosted zinc, MVT subtype (Taylor *et al*. 2009) as the appropriated grade and tonnage model in the estimation of undiscovered deposits. The deposits estimates and the resulting undiscovered resource estimates from the Monte Carlo simulation can be found in Tables 53 and 54 respectively.

Table 53. *Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for the Neoproterozoic tract MLme_EBS_1MVT. For further details see text associated with Table 5.*

Consensus undiscovered deposit estimate					Summary statistics					Area (km^2)	Deposit density (N/km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}		
0	0	0	1	4	0.17	0.69	420	0	0.17	3,070	0.000054

	Estimated number of undiscovered deposits				
Estimator	**N90**	**N50**	**N10**	**N05**	**N01**
Individual 1	0	1	2	3	4
Individual 2	0	0	0	1	2
Individual 3	0	0	1	1	3
Individual 4	0	0	0	0	2
Individual 5	0	0	0	1	1
Individual 6	0	0	0	0	1
Individual 7	0	0	0	1	2
Individual 8	0	0	0	1	2
Individual 9	0	0	1	2	4
Individual 10	0	0	0	0	5
Individual 11	-	-	-	-	-
Individual 12	0	0	2	2	4
Individual 13	0	0	0	1	1
Consensus	**0**	**0**	**0**	**1**	**4**

Table 54. *Results of Monte Carlo simulations of undiscovered resources in the Neoproterozoic tract MLme_EBS_1MVT [t=metric tons; Mt; megatonne or million tons]*

Material	Probability of at least the indicated amount						Probability of mean or greater	Probability of zero [none]
	0.95	0.9	0.5	0.1	0.05	Mean		
Zn (t)	0	0	0	0	470,000	150,000	0.06	0.93
Pb (t)	0	0	0	0	110,000	68,000	0.06	0.93
Rock (t)	0	0	0	0	0	3,700,000	0.01	0.99

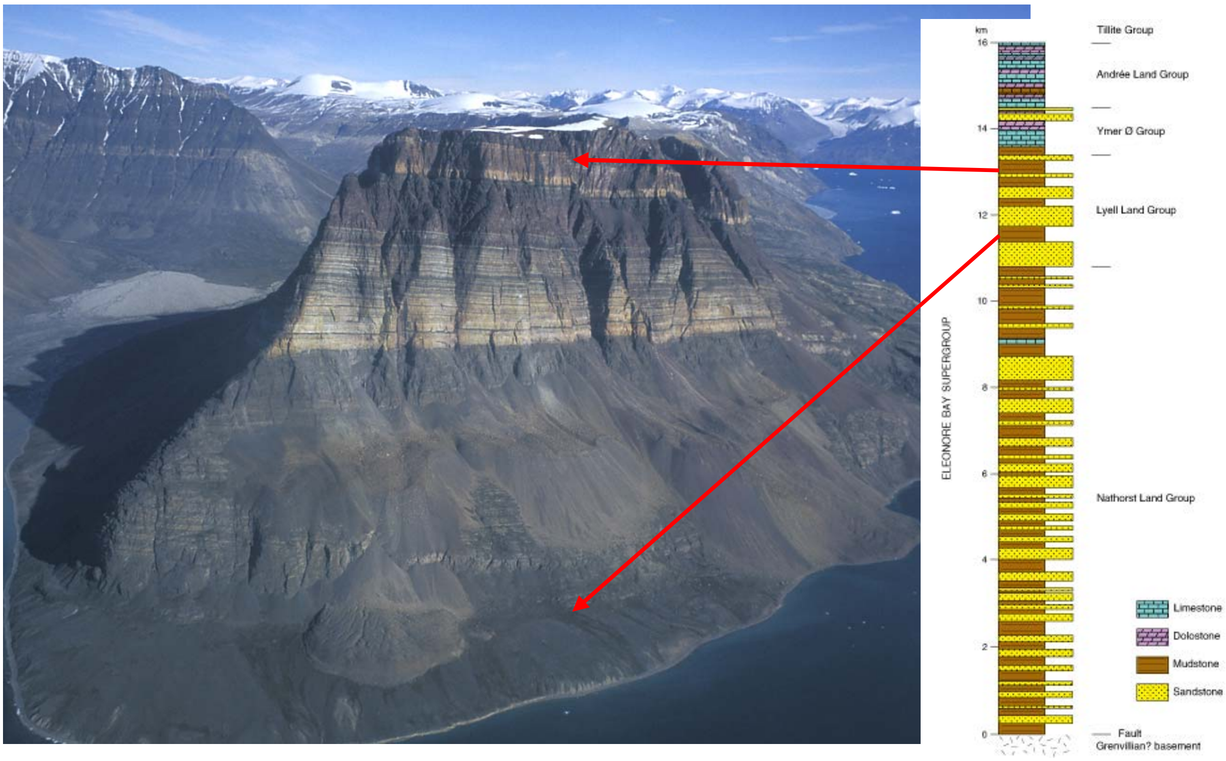


Figure 77. *Aerial view of the the upper Eleonore Bay Supergroup along coastal cliffs of Geologfjord in East Greenland. From Stendal (2009) workshop presentation at the Cu-assesment workshop (Stensgaard et al. 2011).*

Permian and Triassic parts of Jameson Land Basin, central East Greenland

Sources of information

The principal sources of information used for the assessment of the tracts in the Permian and Triassic part of the Jameson Basin in central East Greenland are given Appendix A.

Regional geology

The following description is derived directly from Pedersen 1997 (and references therein):

The Jameson Land basin forms the southern part of the East Greenland depositional basin, a more than 400-km long, N-S-elongated basin situated within the Caledonian mountain chain. Basin formation was initiated in the Middle Devonian due to sinistral wrench faulting and extensional collapse of the Caledonian orogen. Post-Caledonian crustal thinning in the Jameson Land area has been extensive, and seismic investigations have revealed that as much as 17 km of sedimentary rocks intruded by Tertiary dykes and sills lies on a thin (6–8 km) crystalline basement.

The Jameson Land basin is interpreted to be dominated by up to 13 km of Devonian to Lower Permian continental clastic sediments and volcanic rocks. These have been deformed during tectonic events in the Devonian and in mid-Permian times. During the Late Permian, regional sea-level rise, combined with subsidence related to thermal contraction of the crust, led to the establishment of marine conditions in the East Greenland basin. Two major transgressions can be discerned, the first of which resulted in deposition of carbonate platform sediments which were subsequently karstified during subaerial exposure. The second major transgression led to growth of carbonate buildups (Wegener Halvø Formation) on palaeotopographic highs along the basin margins, and deposition of black shales of the Ravnefjeld Formation in the deeper parts of the basin and in inter-reef depressions.

Marine conditions continued into the lowermost Triassic, after which extensive uplift of the basin margins led to rapid deposition of alluvial fan sediments on the basin margin, and flood plain sediments in the basin interior. When uplift of the borderland ceased, the alluvial fans stopped growing and the depositional environment changed into a valley with aeolian sedimentation in the north and west, and gypsiferous playa lake conditions to the east. The whole area later changed into a lake, which was periodically open to the sea. By Late Triassic/Early Jurassic times, the climatic conditions changed from arid to humid. The dominant red sediments characteristic of the Triassic were succeeded by deposition of black, organic-rich mudstones and sheet sandstones in a large wave- and storm-dominated anoxic lake with periodically propagating delta fronts along the margins. During the Early Jurassic, the sea transgressed the southern part of the basin and marine conditions prevailed during the remainder of the Jurassic and Cretaceous.

During the Palaeocene, renewed rifting eventually led to successful seafloor spreading and flood basalt volcanism.

The thick sedimentary package in the Jameson Land basin was during this period overlain by a northwards-thinning series of flood basalts. These were later eroded away during crustal uplift and glaciation in the area, but thick flood basalt units are still exposed south of Jameson Land, and minor occurrences can be found as much as 400 km north of Jameson Land. Seismic investigations have furthermore revealed sills up to 300 m thick to be present in lower parts of the sedimentary sequence in the Jameson Land basin. Later in the Tertiary, a line of intrusive alkaline centres was emplaced along the coast of East Greenland, transecting the northwestern part of the Jameson Land basin where vein-type lead-zinc and barium occurrences as well as a large Climax-type Mo deposit were formed.

Geology and general mineralisation patterns in the Wegener Halvø area

The overall geology of the Wegener Halvø area is characterised by a system of tilted, fault-bounded blocks. The stratigraphy is relatively simple, with the Upper Permian sediments lying unconformably on folded and peneplaned Devonian and locally Lower Permian siliciclastic and volcanic rocks, overlain by a Triassic sequence consisting of shales, sandstones, evaporites, mudstones and minor limestones.

In Upper Permian times, the Wegener Halvø area consisted of a system of north-westward-tilted fault blocks on which carbonates of the Karstryggen and Wegener Halvø formations were laid down. The Karstryggen Formation was deposited in a hypersaline environment during the first transgressive event and was later eroded during subaerial exposure. When the sea transgressed the area again, reef-carbonates belonging to the Wegener Halvø Formation grew preferentially on palaeotopographic highs. In deeper water in the north-western part of the area and in karstic troughs, mud shales of the Ravnefjeld Formation were deposited. The Upper Permian sequence is in most of the area overlain by carbonate-rich sandstones of the Schuchert Dal Formation.

Mineralisations are found in large parts of the stratigraphy in the Wegener Halvø–Devondal area (Figure 78), with a general vertical zonation pattern going from sulphide-bearing quartz veins in the Devonian rocks to stratabound and stratiform sulphide mineralisation in the Upper Permian and Triassic strata.

Stratabound occurrences of copper and barium with minor lead, zinc and fluorite are widespread in the carbonate build-ups of the Wegener Halvø Formation on Wegener Halvø and in Devondal (Harpøth *et al.* 1986). Mineralisation in the Ravnefjeld Formation geographically coincides with these occurrences, but consists mainly of lead and zinc (see Figure 78), with only minor copper (increasing towards the north-west) and no baryte. The richest zones of mineralisation in both the Wegener Halvø and Ravnefjeld Formations are confined to the vicinity of the N–S-orientated Vimmelskaftet lineament (Figure 78 & Pedersen 1997). This lineament can be traced for 12 km and coincides in all localities with narrow shale basins cut down into the underlying carbonates.

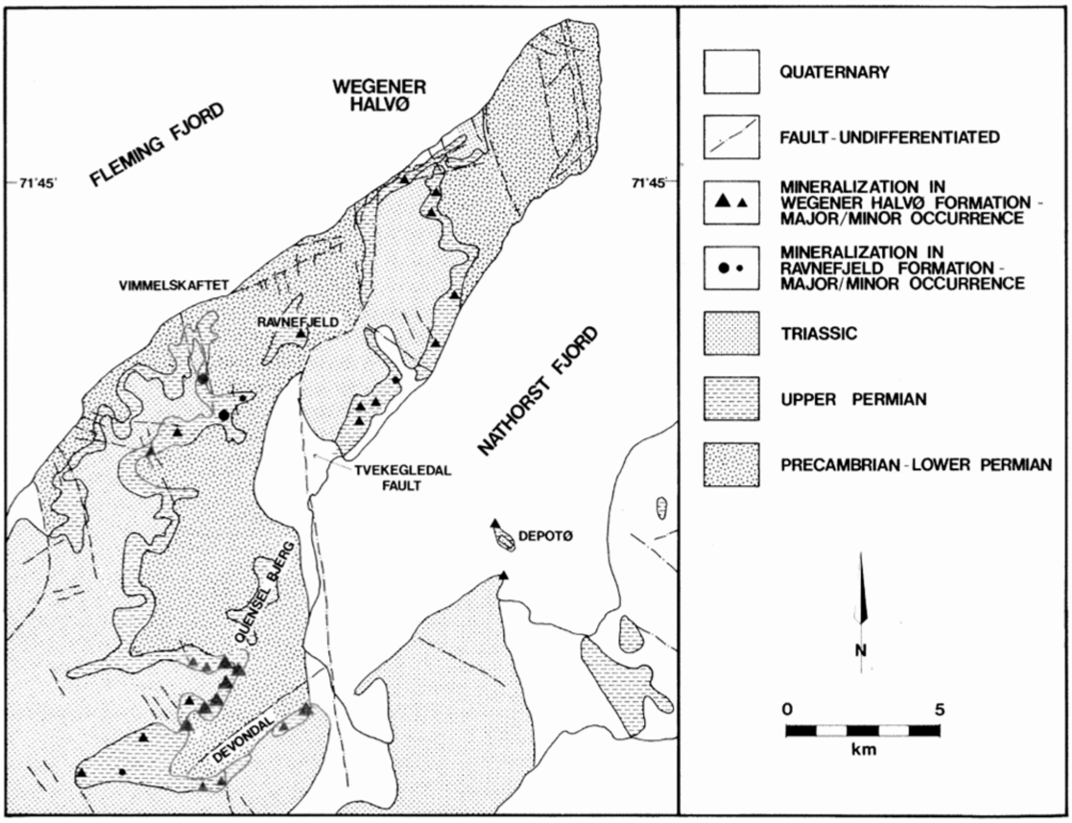


Figure 78. *Simplified geological map of Wegener Halvø with indicated Upper Permian mineralisation. From Harpøth et al. (1986).*

No faulting of Upper Permian rocks has been observed along the lineament, but a ca. 1 m thick Tertiary dyke is intruded along its entire length. Extensive mineralisation in the Ravnefjeld Formation is found in the northern end of the lineament on Lille Ravnefjeld, whereas the Wegener Halvø Formation is strongly mineralised further south on Quensel Bjerg (Figure 78). No mineralisation has been found in the Schuchert Dal Formation.

Minor but widespread occurrences of Cu, Ag, Pb and Zn exist in almost all Triassic formations in the eastern part of the Jameson Land basin, including the Wegener Halvø area. Most of these are interpreted as diagenetic due to occurrences of ore minerals in sandstone cements as well as in desiccation cracks (Harpøth *et al.* 1986).

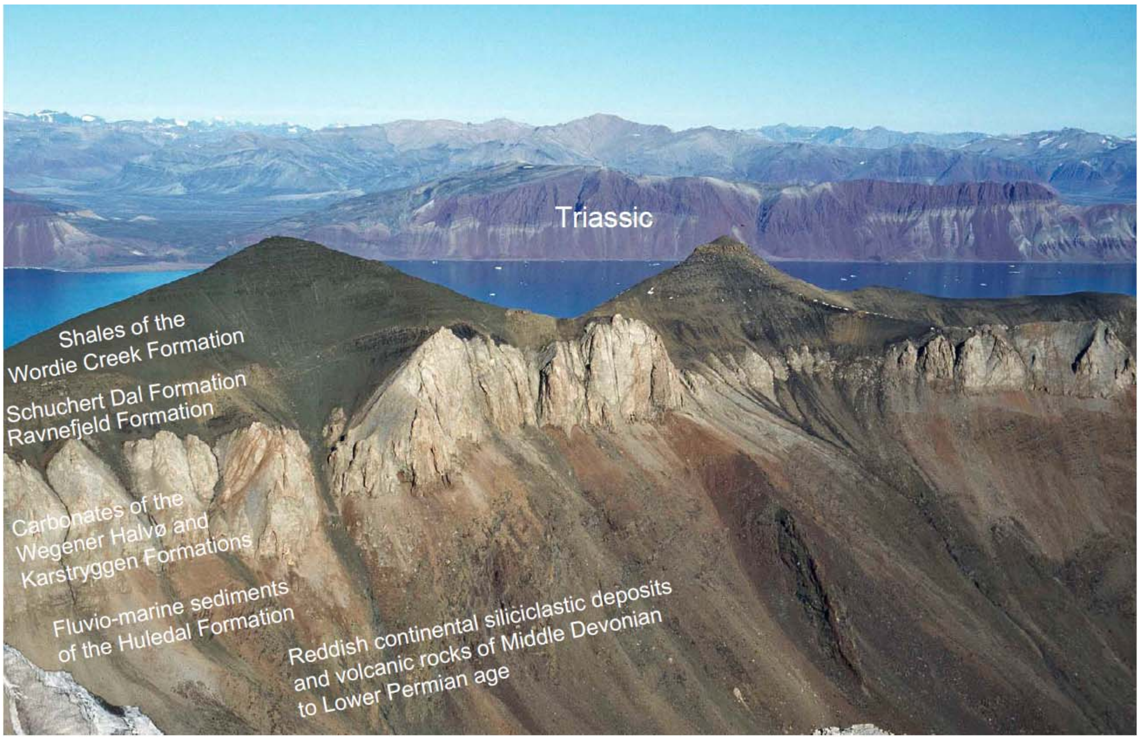


Figure 79. *View of the different Permian formations exposed on Wegner Halvø, East Greenland. Photo from workshop presentation by Nielsen and Pedersen (2011); see Appendix C.*

Ravnefjeld Formation

Exposures of the Ravnefjeld Formation can be found over an area of 80-400 km in East Greenland. The formation consists of calcareous mud shales, which can be divided into two laminated and three bioturbated. The shales interfinger with the time-equivalent carbonate build-ups of the Wegener Halvø Formation (Figure 79). On Wegener Halvø, the shales of the Ravnefjeld Formation are found in two different settings. Basinaltype shale sequences up to 60 m thick are found along the north-western coast of the peninsula, with the laminated facies being 12–20 m thick. In the central part, however, the shales often lie in karstic troughs cut down into the carbonate build-ups of the Karstryggen Formation. The shale sequences in these troughs are of variable thickness and contain abundant carbonate-rich horizons, representing re-sedimented build-up material. Similar horizons are also found in the proximal basinal settings as far as 1 km from the build-ups. The two laminated units in the Ravnefjeld Formation are very rich in organic material (average TOC: 3.8%) and sulphur (average TS: 2.0%), in contrast to the bioturbated units (TOC: 0.5%; TS: 1–2%. The laminated units are interpreted as having been deposited under regional anoxic episodes during maximum flooding at water depths in excess of 125 m. It has been suggested that rapid growth of the fringing carbonate build-ups during times of maximum flooding, together with a stratified water column, created a ‘silled basin’ with restricted water circulation.

The shales have a good potential as oil source rocks and have been compared with the European Kupferschiefer (Harpøth et al. 1986). Stratiform fine-grained mineralisation occurs throughout the Ravnefjeld Formation. The sulphides exhibit colloform textures and replacement of fossils is widespread. The main ore minerals are sphalerite and galena with minor chalcopyrite, pyrite and marcasite. Rare sulphides on joints indicate minor remobilisation.

Channel samples collected southwest of Vimmelskaftet through the lowermost 15 m of the formation average 0.13% Pb, 350 ppm Zn, 200 ppm Cu and up to 30 ppm Ag. In general, the metal content decreases upwards in the sequence. A chip sample over 2,5 m of black shale in Devondal averages 200 ppm Pb, 200 ppm Cu and <500 ppm Zn. Thin, richly mineralised beds are known from several localities, for example south of Vimmelskaftet. Here 1-3 cm beds of biosparite contain c. 10% combined zinc and lead. These beds may grade laterally into barren, silicified horizons. The mineralisation is clearly of syngenetic character.

Wegener Halvø Formation

The Wegener Halvø Formation comprises eight lithofacies of marine limestones representing a transgressive sequence. Mineralisation is mainly associated with up to 150 m thick buildups of massive, bryozoan limestones and their surrounding bedded flank sediments. Downslope from the carbonate buildups, the flank deposits pass gradationally into the black shales of the Ravnefjeld Formation. Mineralisation is scattered over the whole peninsula, but important base-metal concentrations are confined to the Quensel Bjerg – Devondal area to the south. Pronounced silicification and quartz veining is also restricted to the same area, whereas calcite-baryte veining and minor irregular dolomitization occurs all over Wegener Halvø

Exploration history

Nordisk Mineselskab A/S has carried out regional exploration in the region from 70°N to 74°30’N in the period from 1952–1984. Harpøth *et al.*1986 reviews the activities and discoveries made during this period; and the following is from Harpøth *et al*. 1986: ‘The first reports of base-metal mineralisation in the upper part of the Wegener Halvø were made by members of “De Danske Treårsekspeditioner 1931–34”. During a Nordmine reconnaissance in 1968 mineralisation were also found in the Ravnefjeld Formation and the following year a 20 m long trench was blasted and sampled. Later, based on air observations of malachite staining of the limestone of Quensel Bjerg on south Wegener Halvø, a reconnaissance of this area was carried out in 1971–72. Further observations were made here during Nordmine investigations of the Triassic in 1973–76. In 1979 the Upper Permian of the entire Wegener Halvø peninsula was traversed and mapped at scale 1:10 000. Since the Nordisk Mineselskab work, The Ravnefjeld Formation and its sulphide mineralisation has been investigated in two Ph.D. projects (Pedersen 1997; Nielsen 2001) and two mineral exploration companies; Nordic Mining and Avannaa Resources currently have licences covering large parts of the area.

Known prospects, mineral occurrences or related deposit types

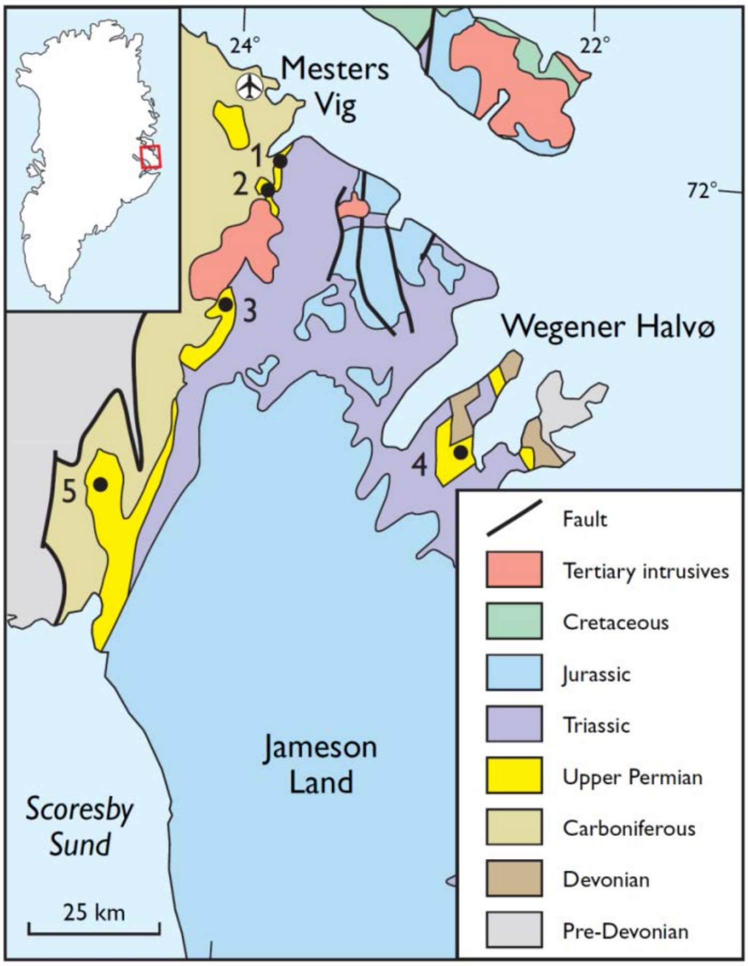


Figure 80. *Map of known upper Permian carbonate-hosted Ba-(Sr)-Pb-Zn-(Cu) mineralisation localities in the Jameson Land Basin, East Greenland. The localities are: 1. Triaskæden, 2. Oksedal, 3. Bredehorn, 4. Ravnefjeld, Devondal + Quensel Bjerg & 5. Karstryggen. From workshop presentation by Thomassen (2011); see Appendix C.*

Upper Permian mineralisations

In the following only the most important mineralisations relevant for the zinc assessment potential is described. For a complete description of all mineralisation localities indicated on Figure 80 please refer to Harpøth *et al.* (1986).

Ravnefjeld

The following is a modified summary of the description of the Ravnefjeld mineralisation given in Nielsen & Pedersen (1998) and Harpøth *et al.* (1986).

Stratiform fine-grained mineralisations of lead, zinc and zinc within the bituminous black shale of the Ravnefjeld Formation at Wegener Halvø and Devondal are found at several locations throughout the formation.

The most significant mineralisation, and the most investigated, is on Wegener Halvø. This mineralisation was originally assumed to be of primary or early diagenetic origin due to similarities with the central European Kupferschiefer. However, later studies have shown that base metal mineralisations in the underlying carbonate reefs of the Wegener Halvø

Formation are Palaeogene. Due to the geographical coincidence between the two mineralisations a common history has been suggested by Nielsen & Pedersen (1998), however, the timing and genesis of the base metal enrichment in the Ravnefjeld Formation on Wegener Halvø is still ambiguous. The Ravnefjeld Formation is up to 60 m thick and is divided into three bioturbated and two laminated units. Along the eastern basin margin, the formation is dominated by bituminous siltstones, which in inter-reef depressions are interlayered with numerous packstone and grainstone layers. More sandy lithologies are found in some areas along the western basin margin.

Figure 81. *Exposure of the black shales hosting the Zn-Pb-Cu mineralisation within the Ravnefjeld formation at Lille Ravnefjeld on Wegner Halvø in East Greenland. Maximum reported values from 7 grab samples are 11.5% Zn, 7.7% Pb, 0.35% Cu. From workshop presentation by Thomassen (2011); see Appendix C.*

At Wegener Halvø, base metal enrichment is widespread, and in an area of almost 50 km^2, ore minerals can be found at nearly all localities (Figure 82 + 83). The base metal enrichment is present in the lowermost few metres of the shale formation only, except for a locality on Lille Ravnefjeld, at Vimmelskaftet, where abundant sphalerite and galena is found over a stratigraphic thickness of 15 m (Figure 81). Base metal sulphides in the mineralised horizons occur as disseminated, anhedral to subhedral grains or aggregates, variable in size from a few hundred microns to several centimetres. Continuous massive sulphide layers (2–3 cm in thickness) are found in the highly mineralised zone around Vimmelskaftet. Maximum reported values within this mineralised zone are: 11.5% Zn, 7.7% Pb, 0.35% Cu (7 mineralised samples).

Sphalerite and galena are by far the most abundant base metal sulphides in the Ravnefjeld Formation with chalcopyrite becoming increasingly important towards the NW. In general, four types of mineralised lithologies are seen: (i) Packstone layers, (ii) Concretionary shale layers (cemented by calcite or quartz, or both), (iii) concretionary shale lenses (cemented by calcite) and (iv) Non-lithified shales.

Scattered base metal sulphides are found throughout the area, e.g. primary sulphides have been found in drill cores from the Schuchert Dal area in the western part of the Jameson Land basin where the shale are thermally immature and no signs of secondary metal enrichment exist. Pyrite is found to be the main sulphide phase in this area.

Figure 82. *Locality with carbonate-hosted Cu, Pb, Zn, Ba mineralisation within the Upper Permian Wegner Halvø Formation on Wegner Halvø, East Greenland. Photo from Thomassen (2009) workshop presentation at the copper assessment workshop in 2009 (Stensgaard et al. 2011).*

Figure 83. *Close-up of the exposed carbonate-hosted Cu, Pb, Zn, Ba mineralisation within the upper Permian Wegner Halvø Formation on Wegner Halvø, East Greenland. Photo from Thomassen (2009) workshop presentation at the copper assessment workshop in 2009 (Stensgaard et al. 2011).*

Quensel Bjerg & Devondal

The following description of the Devondal and Quensel Bjerg mineralisations is from Harpøth *et al. (*1986). At Quensel Bjerg, mineralisation is known from a 2x7 km area (Figure 84+85). The mineralisation is concentrated in a 2-4 m thick quartz-baryte zone at the contact between the limestones and the overlying Schuchert Dal Formation. This zone is associated with feeder-like, nearly vertical baryte veins cutting the limestones along N-S-striking faults and joints. Continuous mineralisation is exposed for a distance of 2 km along the steep north slope of Devondal. A lateral zonation seems to exist with dominance of baryte and copper mineralisation towards the southwest and quartz and lead-zinc mineralisation to the northeast. Tennantite-tetrahedrite, galena and minor chalcopyrite and sphalerite are mainly associated with baryte and only subordinately with quartz. The mineralised zone of Quensel Bjerg is estimated to host c. 10 million tons with 2-4% sulphides and 30-40% baryte.

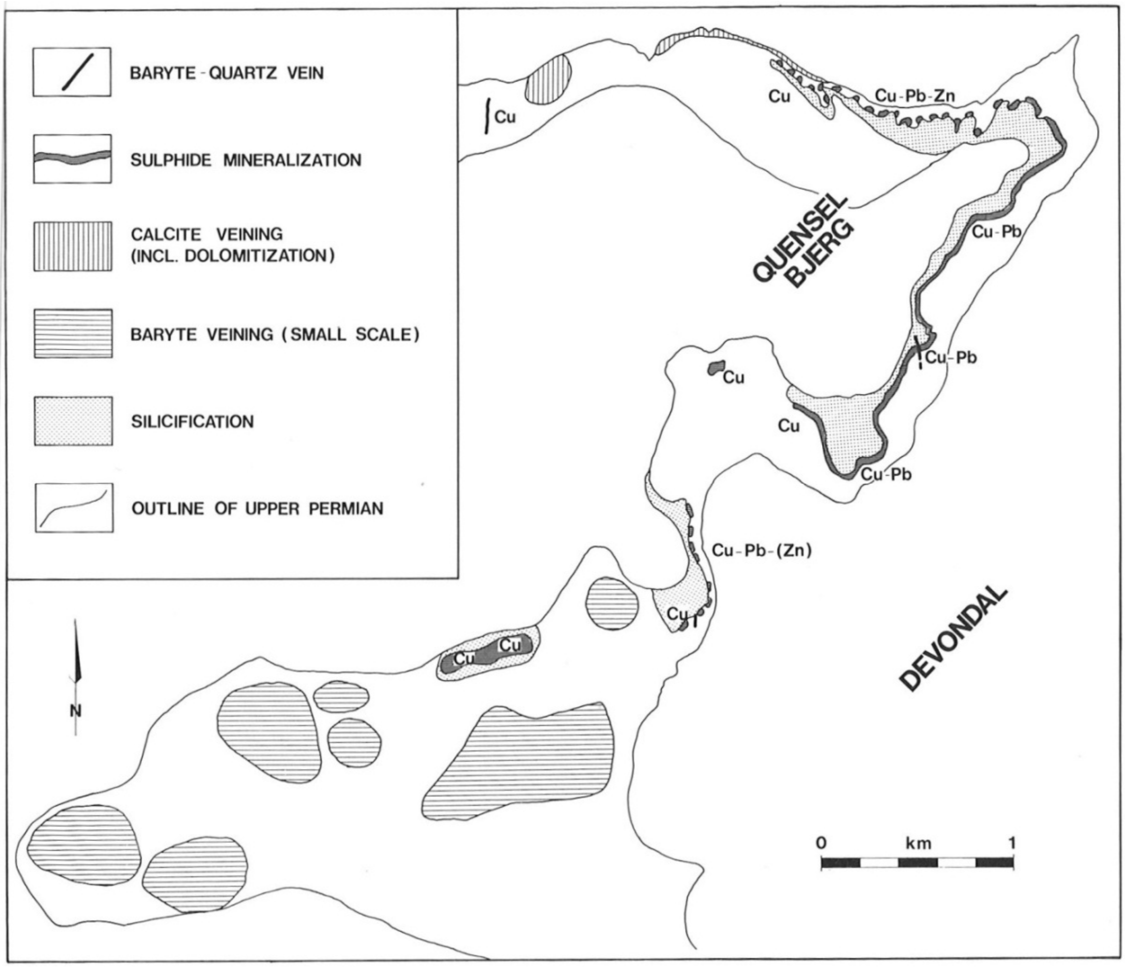


Figure 84. *Geologic setting and alteration pattern of the Upper Permian mineralisation at Quensel Bjerg. From Harpøth et al. (1986).*

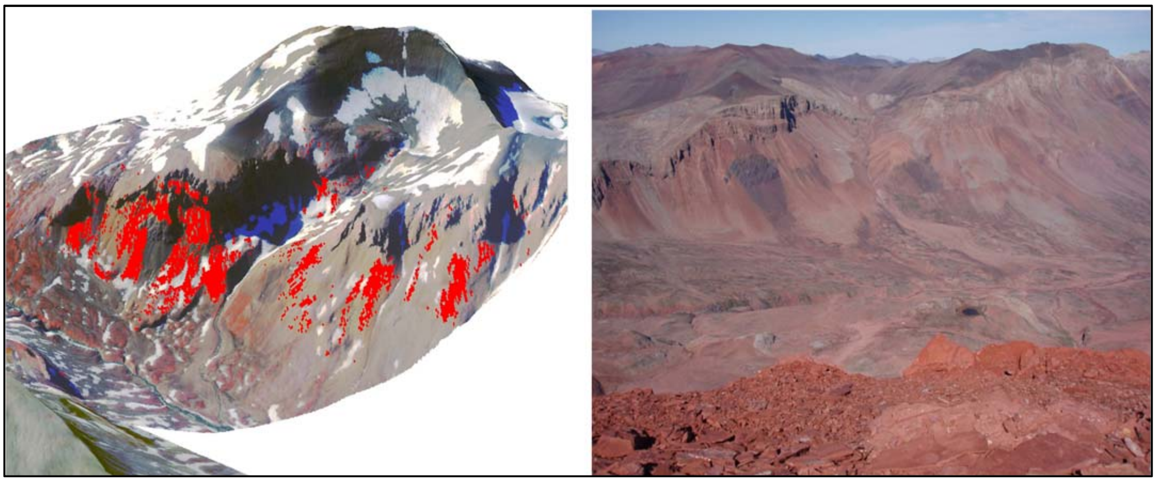


Figure 85. ***Left :*** *The north slope of Devondal showing dolomitic alteration (red) of mineralised Wegener Halvø Formation limestone; based on airborne hyperspectral data.* ***Right:*** *View of the Wegener Halvø Fm. exposed along north the slope of Devondal at Quensel Bjerg, East Greenland. Both images from workshop presentation by Thomassen (2011); see Appendix C.*

On the south side of Devondal mineralisation occurs along the 5 km of Upper Permian outcrops. In general, it is scattered and less pervasive than on Quensel Bjerg. However, the intensity increases going from west towards east. The copper-lead-zinc- silver mineralisation is associated with quartz and baryte veinlets in the uppermost part of the carbonate buildups and surrounding flank sediments. The largest single vein which occurs in the easternmost outcrop is up to 5 m wide and outcrops for 400 m along strike. In addition to abundant rusy quartz it contains scattered sulphides precipitated as open-space fillings. The sulphides are tennantite, chalcopyrite, galena, sphalerite and pyrite. A lateral zonation exists with baryte-copper to the west and a dominance of quartz-copper-lead-zinc to the east. Twenty chip samples from this area covering a 100x500 m area average 0.5% Cu, 0.2% Pb and 0.1% Zn. However, these copper and zinc contents are most likely misleadingly low due to partial weathering out of tennantite and sphalerite.

Karstryggen

The following description is from Harpøth (1982) and Harpøth *et al. (*1986). A strata-bound lead-zinc mineralisation was found at Karstryggen in Schuchert Dal by Nordmine in 1980 during reconnaissance exploration of the Upper Permian. The following year more detailed investigations were performed in the northern part of Karstryggen. The Karstryggen mineralisation is situated close to the Stauning Alper Fault. The Upper Permian of the area comprises a basal fluvio-marine sandy conglomerate unit (Huledal Formation) overlain by a marginal marine carbonate and evaporite unit (Karstryggen Formation) with a more open marine carbonate unit on top (Wegener Halvø Formation) (Figure 87). The Wegener Halvø Formation, which hosts most of the lead-zinc mineralisation, represents a carbonate platform at least 30 km long and up to 10 km wide at Karstryggen.

The carbonate platform, which is dominated by non-reef facies, is divided in to an eastern and a western, more rapidly subsiding, half by an N-S hinge zone. Intra-Permian karsting is reflected as widespread karst breccias in the underlying formation. Lead-zinc mineralisation has been found in both northern and southern Karstryggen.

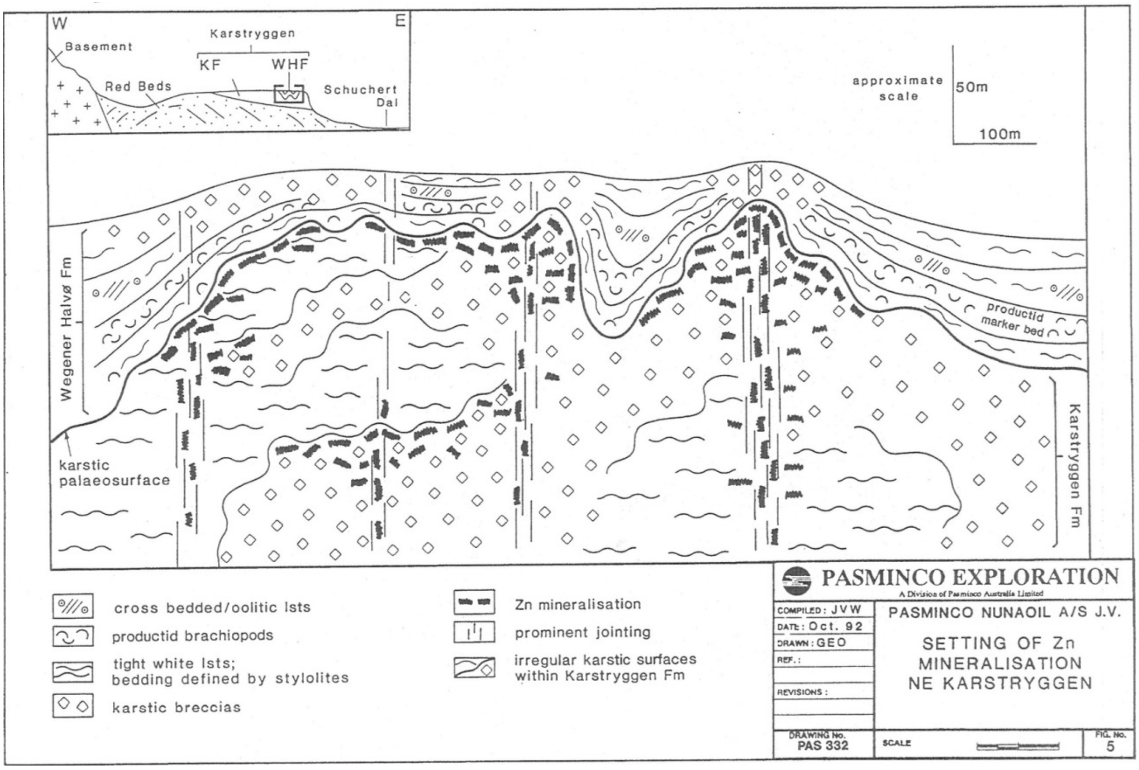


Figure 86. *Pasminco's exploration model for setting of zinc mineralisation at Karstryggen. Best channel sample result from 14 localities: 3.5% Zn over 8 m. From workshop presentation by Thomassen (2011); see Appendix C.*

Figure 87. *Aerial view of the Karstryggen/Wegener Halvø Fms. at Karstryggen in East Greenland. From workshop presentation by Thomassen (2011); see Appendix C.*

In northern Karstryggen strata-bound lead-zinc mineralisation occurs in a 1500x500 m area c. 1 km south of Revdal. Mineralisation occurs throughout all the different carbonate facies of the Wegener Halvø Formation and in the karst breecia sequence of the underlying Karstryggen Formation, and a vertical mineralised section of 40 m has been observed.

However, the estimated average thickness is 20-25 m. Mineralisation occurs partly as galena octahedra dispersed in micritic limestone and partly associated with subvertical joints and fractures striking 20° and 160°.

The latter type contains galena octahedra (up to 0.5 cm), yellowish white sphalerite (hardly macroscopically recognizable) and subordinate pyrite and marcasite in a predominantly calcite gangue with subordinate celestite and fluorite. Analyses of selected samples revealed high contents of lead (max. 10%), zinc (max. 42% - oolitic limestone replaced by whitish sphalerite), cadmium (max. 0.15%) and Ag (max. 150 ppm). A chip sample over 15 m returns 0.15% Pb and 0.26% Zn which confirms the low grade of the mineralisation. A preliminary tonnage estimate indicates several tens of million tons.

In southern Karstryggen, mineralisation occurs on the western bank of the Schuchert river c. 10 km north of Nordostbugt. Lead-zinc mineralisation which occurs in a 50x50 m area and has been observed over a height of 10 m is both lithologically and structurally controlled. The most import control is a set of joints 160°/subvertical (major) and 20°/subvertical (minor). Macroscopically, mm-cm thin veinlets of pyrite, galena, sphalerite, marcasite and minor calcite occur mainly in micritic limestone. Mineralisation is concentrated in the uppermost part of the micritic limestone as well as in limestone breccia below black shale which represents a barrier of permeability (Figure 86). Analyses of selected samples revealed Pb max. 25%, Zn max. 3.5%, and Ag max. 70 ppm. The average grade is estimated to be 1-2% combined lead-zinc. Genetically, both mineralised localities are believed to be associated with the N-S hinge zone in Karstryggen. This zone again is related to the Post-Devonian Main Fault System of the area.

Triassic mineralisations

Base metal mineralisations are found throughout the Triassic stratum in the East Greenland basin (Table 55) although many of these are dominated by copper-lead mineralisations and contain only traces of zinc. The most pronounced zinc mineralisations are found within Gråklint Beds and Kap Seaforth Member both part of the of the Middle Triassic Gipsdalen Formation.

Gråklint Beds

This unit is 5-30 m thick in north-eastern Jameson Land from where it wedges out towards both west and south. The beds are typically cliff-forming and display a variable lithology of grey, calcareous sandstone and limestone with intercalated black limestone and shale. The sediments represent a short marine episode in the continental-lacustrine Middle Triassic sequence. Stratiform mineralisation occurs over a c. 500 km^2 large area between Fleming Fjord and Carlsberg Fjord. Disseminated, fine-grained sulphides are hosted in one or more dm-m thick beds of black shale/limestone and in the uppermost 10-50 cm of underlying grey, calcareous sandstone or limestone. The mineralised horizons are continuous for several hundreds of metres laterally, but metal contents are relatively low – typically 1-2% combined lead-zinc-copper. A synsedimentary-diagenetic origin is presumed.

Table 55. *Triassic lithostratigraphy and mineralisations in the Jameson Land Basin (from Harpøth et al.1986). The stratigraphic level hosting the most pronounced zinc mineralisations are indicated by a red frame. Also, the mineral deposit models applied by the assessment panel are indicated.*

Series	Formation	Member	Beds	Max. thick.	Dominant lithology	Miner-alization	
Upper Triassic	Fleming Fjord	Ørsted Dal	Tait Bjerg	70 m	Light-coloured carbonate rocks and variegated mudstones		
				150 m	Red mudstones and light grey sandstones	*Cu*	
		Malmros Klint		200 m	Red mudstones and fine sandstones	(Cu)	
			Pingel Dal	35 m	Variegated cyclic-bedded sandstones and mudstones	Cu	
		Edderfugledal	Sporfjeld	35 m	Yellowish cyclic-bedded dolomitic sediments		
Middle Triassic	Gipsdalen	Kap Seaforth		160 m	Variegated cyclic-bedded gypsiferous sediments	*Cu, Pb, Zn*	SEDEX
		Solfaldsdal		150 m	Red gypsiferous sandstones		
			Gråklint	30 m	Dark grey limestones and mudstones	*Pb, Zn, Cu*	SEDEX
		Kolledalen		180 m	Yellowish gypsiferous sandstones		
Lower Triassic	Pingo Dal	Klitdal and Paradigmabjerg		>450 m	Pink arkoses and conglomerates	Cu, Ag, Pb, (Zn)	
		Rødstaken		330 m	Dark red sandstones		
	Wordie Creek			500 m	Greenish silty shales and sandstones	(Cu), (Pb), (Zn)	

Cu = major mineralization; *Cu* = minor mineralization; (Cu) = trace of sulphides

Kap Seaforth Member

The member is composed of cyclically-bedded sandstones, mudstones, carbonates and gypsum beds of shallow lake, sabkha and aeolian origin. Mineralisation is restricted to a c. 100 km^2 large sub-basin south of Carlsberg Fjord. The unit is here up to 100 m thick and poorly exposed.

Lead-zinc-mineralised mudstones and dolostones occur at several stratigraphical levels. The black mudstones and dolostones contain disseminated, fine-grained galena, sphalerite and minor pyrite, typically with colloform textures. Although an extremely base-metal-rich sample (50% Cu, 9% Pb and 0.7% Ag) has been found, base-metal contents are generally below one per cent in mineralised layers. A synsedimentary-diagenetic origin is presumed.

Grade and tonnage model selection

Based on the characteristics of the known mineralisations in the Jameson Land Basin, the assessment panel found it justifiable to use the sediment-hosted zinc, both SEDEX and MVT subtype (Taylor *et al.* 2009) as the appropriate grade and tonnage models in the estimation of undiscovered deposits.

Individual tracts assessed during workshop

Figure 88 show the distribution of tracts being treated by the assessment panel for Permian and Triassic sediment-hosted zinc deposits within the Jameson Land Basin in central East Greenland during the workshop.

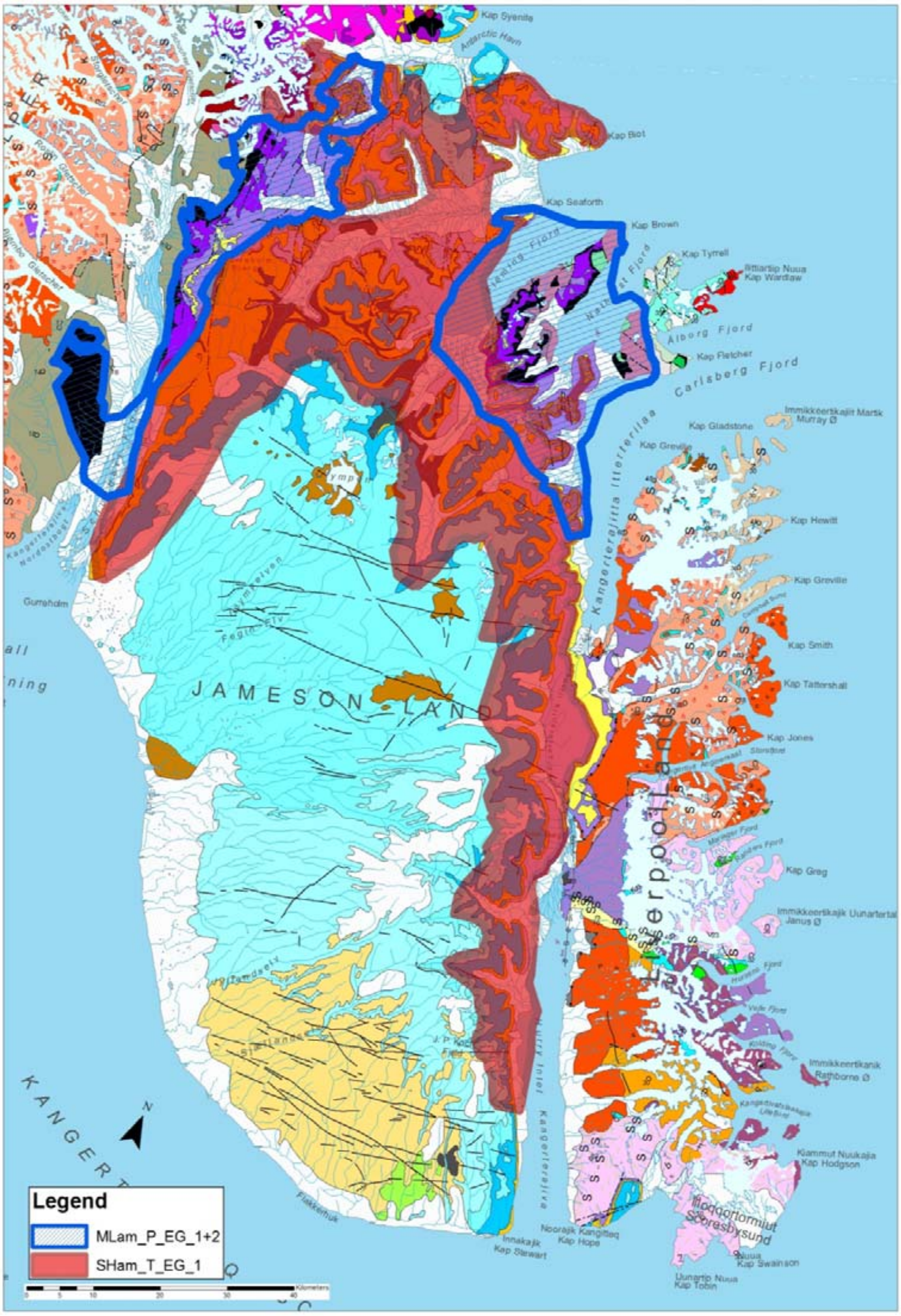


Figure 88. *Tracts for sediment-hosted zinc deposits within the Jameson Land basin, central East Greenland. The tracts are; MLam_P_EG_1, MLam_P_EG_2 & SHam_T_EG_1. For geological legend see Appendix A.*

Tracts excluded from estimations

The assessment panel decided to exclude the Permian tract MLam_P_EG_2, as the panel members did not believe there was potential for finding undiscovered SEDEX zinc deposits within the tract.

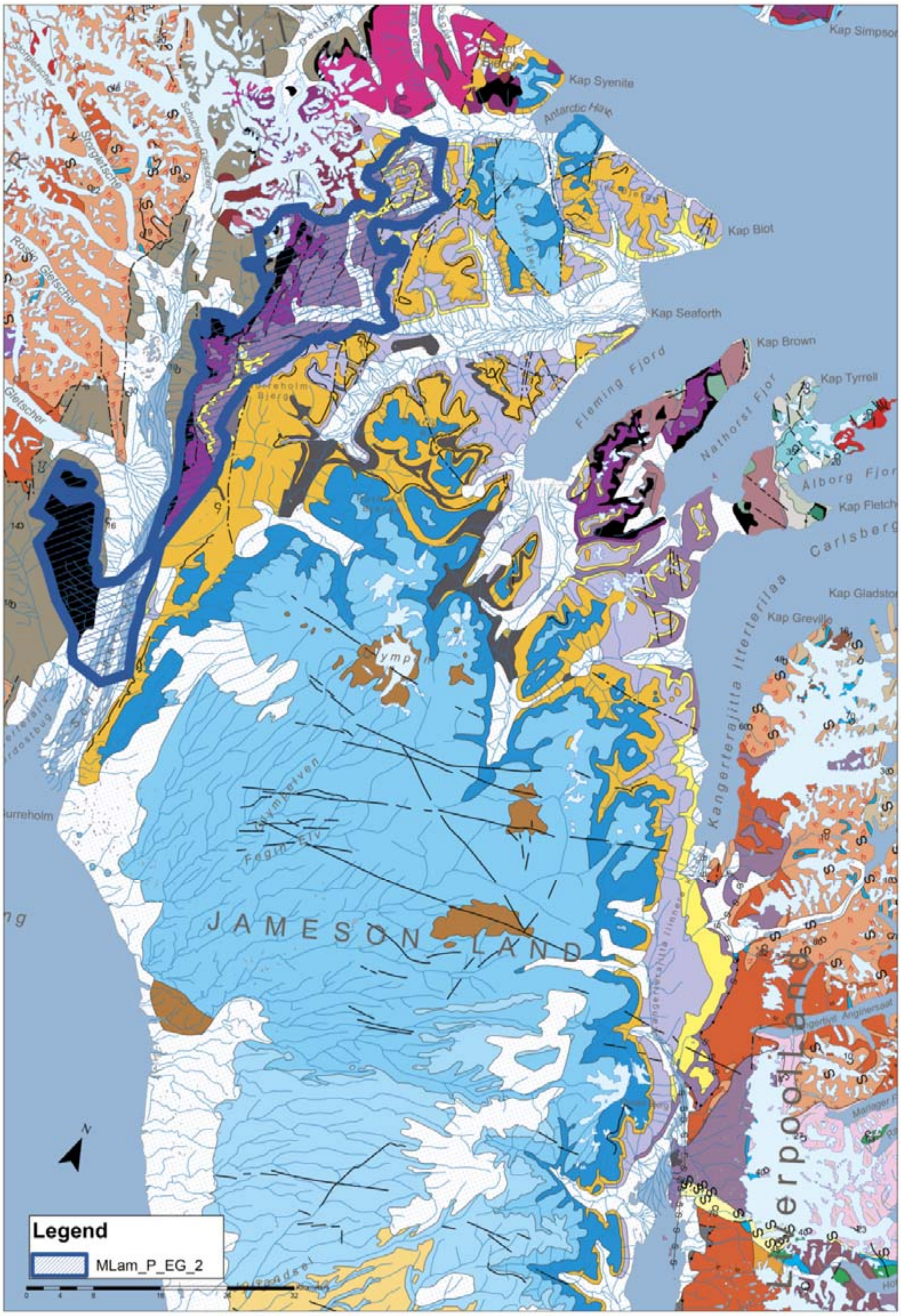


Figure 89. *Location of the excluded tract MLam_P_EG_2 in the NW part of Jameson Land, central East Greenland. For geological legend see Appendix A.*

Tract MLam_P_EG_1 – SEDEX zinc type

Location and delineation of the permissive tract

The Permian tract MLam_P_EG_1 is covering parts of Wegner Halvø in the NE part of the Jameson Land basin (Figure 90). The tract was assessed for SEDEX type deposits. Summary of the estimated undiscovered zinc resources can be found in Table 56.

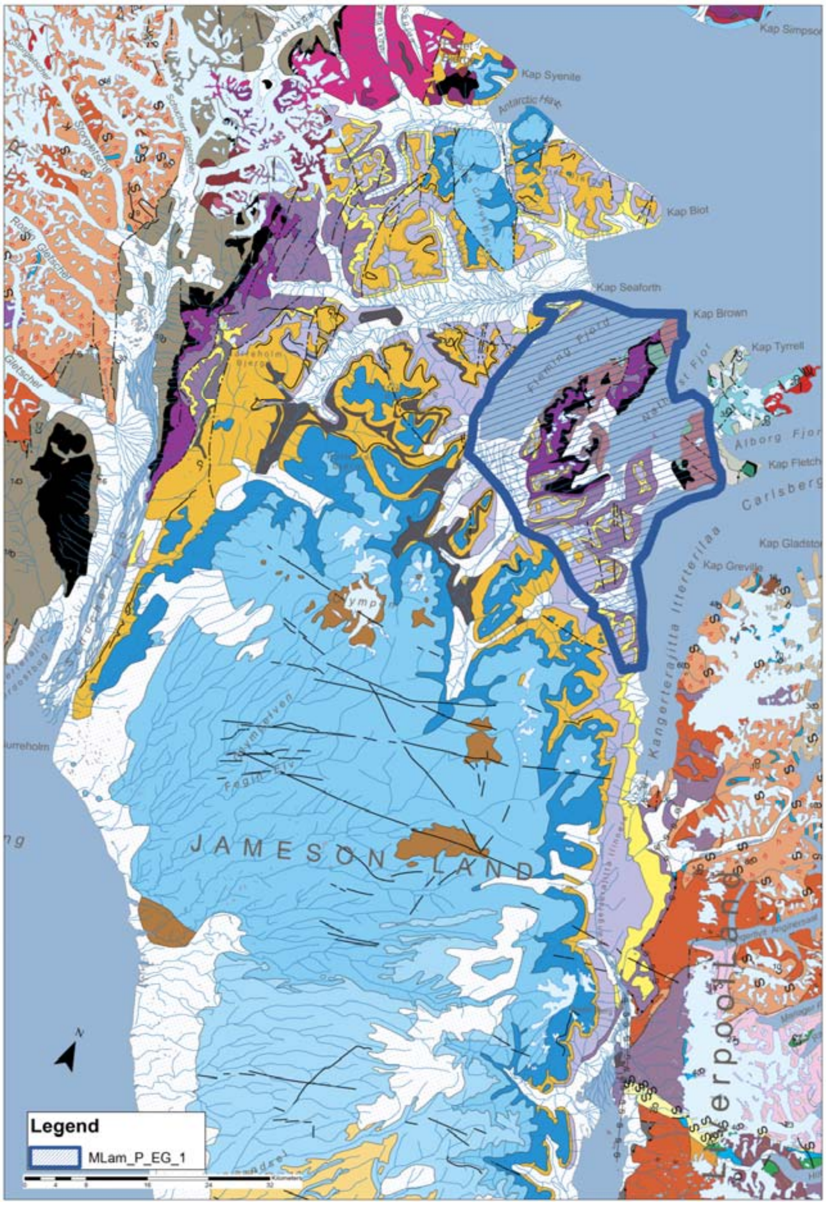


Figure 90. *Location of the MLam_P_EG_1 tract in the NE part of Jameson Land, central East Greenland. For geological legend see Appendix A.*

The MLam_P_EG_1 tract contains the Foldvik Creek Group down to an estimated depth of 1 km below surface. The extent of the tract is based on the mapped distribution of the Foldvik Creek Group, including the Ravnefjeld Formation.

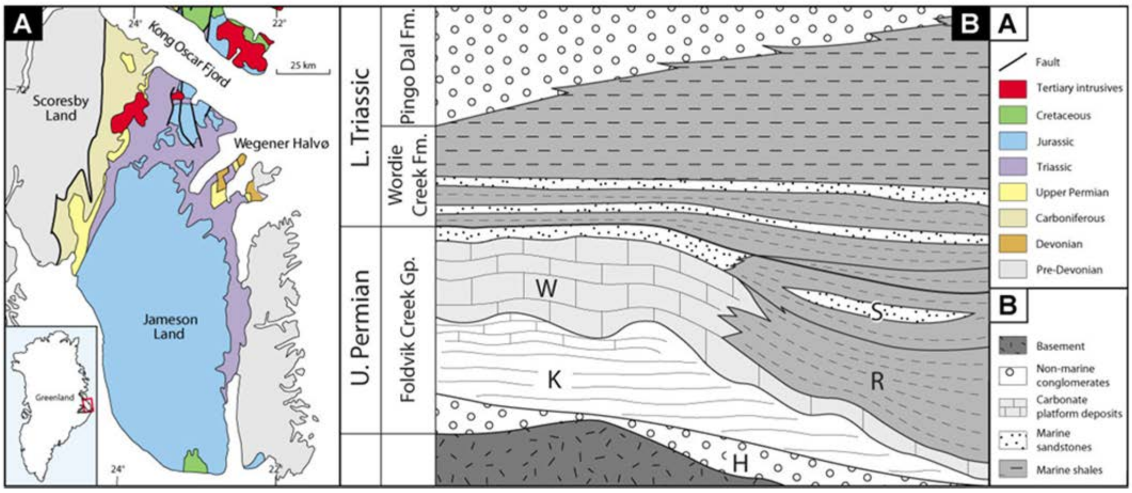


Figure 91. ***A.*** *Simplified geological map of central East Greenland.* ***B.*** *Simplified geological cross section from Upper Permian to Lower Triassic sedimentary succession in Jameson Land Basin. H = Huledal Formation, K = Karstryggen Formation, W = Wegner Halvø Formation, R = Ravnefjeld Formation, S = Schuchert Dal Formation. Figure from workshop presentation by Nielsen and Pedersen (2011); see Appendix C.*

Table 56. *Summary of selected resource assessment results for the tract MLam_P_EG_1.*

Assessment depth (km)	Tract area (km^2)	Known zinc resources (metric tons)	Mean estimate of undiscovered zinc resources (metric tons)
1 km	863	0	970,000

Geological criteria and rationale for the estimate

The Permian tract MLam_P_EG_1 contain the marine Upper Permian Ravnefjeld Formation, which consists of bituminous black shales, deposited in the subsiding East Greenland basin (Figure 91). The shale can be traced throughout the entire East Greenland basin over an N-S distance of more than 400 km, and has been located in offshore mid-Norway drill holes as well. The shales have attracted considerable attention because of their high potential as hydrocarbon source rock (Nielsen & Pedersen 1998). The formation is part of the Upper Permian Foldvik Creek Group, marking the first transgression in the East Greenland basin deposited unconformably on a flat Carboniferous – Lower Permian peneplain (Figure 91).

Stratiform fine-grained base metal mineralisations occur in the black shales of the Upper Permian Ravnefjeld Formation at Wegener Halvø, carrying similarities with the European Kupferschiefer (Figure 92). The known base metal occurrences in the Ravnefjeld Formation are dominated by lead and zinc, and none yield economic zinc grades. Only little exploration has been focused on the Ravnefjeld Formation, and given the lateral extent of the tract (863 km^2) a potential for undiscovered zinc deposits were considered possible. Despite the low grades reported, the assessment panel found it justified to assess the tracts with Upper Permian Ravnefjeld Formation as permissive areas for SEDEX zinc type mineralisation.

The deposits estimates and the resulting undiscovered resource estimates from the Monte Carlo simulation can be found in Tables 57 and 58 respectively.

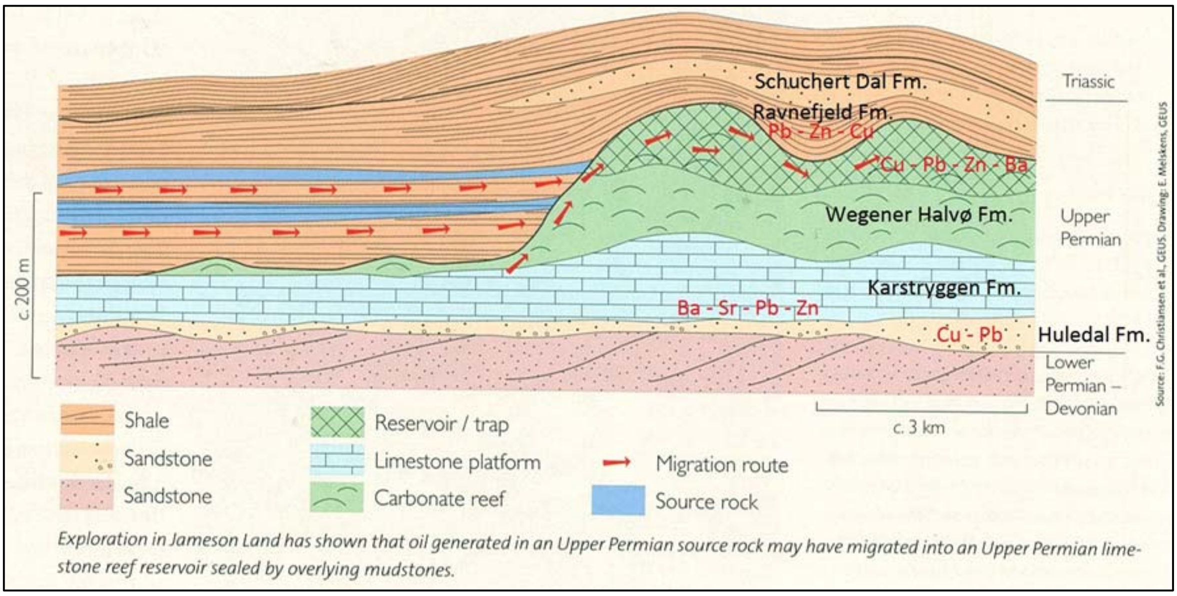


Figure 92. *Upper Permian lithofacies of the Jameson Land Basin indicating migration conduites for oil generated in an upper Permian source rock. The same conduits are believed to been used by mineralising fluids and then deposited in areas with mineralisation indicated. From workshop presentation by Thomassen (2011); see Appendix C.*

Table 57. *Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for MLam_P_EG_1. For further details see text associated with Table 5.*

Consensus undiscovered deposit estimate					Summary statistics					Area (km^2)	Deposit density (N/km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}		
0	0	1	2	3	0.41	0.82	200	0	0.41	860	0.00047

	Estimated number of undiscovered deposits				
Estimator	**N90**	**N50**	**N10**	**N05**	**N01**
Individual 1	0	0	0	1	2
Individual 2	0	0	0	2	3
Individual 3	0	0	1	2	3
Individual 4	0	0	1	2	3
Individual 5	0	0	1	1	3
Individual 6	0	0	1	1	2
Individual 7	0	0	0	1	2
Individual 8	0	0	1	2	3
Individual 9	0	0	1	3	5
Individual 10	0	0	1	1	3
Individual 11	0	0	1	2	3
Individual 12	0	0	1	1	2
Individual 13	0	0	0	1	2
Consensus	**0**	**0**	**1**	**2**	**3**

Table 58. *Results of Monte Carlo simulations of undiscovered resources in the Permian tract MLam_P_EG_1. [t = metric tons; Mt; megatonne or million tons]*

Material	Probability of at least the indicated amount						Probability of mean or greater	Probability of zero [none]
	0.95	0.90	0.50	0.10	0.05	Mean		
Zn (t)	0	0	0	1,800,000	5,500,000	970,000	0.13	0.71
Pb (t)	0	0	0	740,000	2,300,000	490,000	0.13	0.72
Rock (t)	0	0	0	0	0	16,000,000	0.04	0.91

Tract MLam_P_EG_1M – MVT zinc type

Location and delineation of the permissive tract

The Permian tract MLam_P_EG_1M is covering parts of Wegner Halvø in the NE part of the Jameson Land basin (Figure 93). The tract was assessed for MVT type deposits. Summary of the estimated undiscovered zinc resources can be found in Table 59.

The MLam_P_EG_1M tract contains the Foldvik Creek Group down to an estimated depth of 1 km below surface. The extent of the tract is based on the mapped distribution of the Foldvik Creek Group, including the Wegner Halvø Formation.

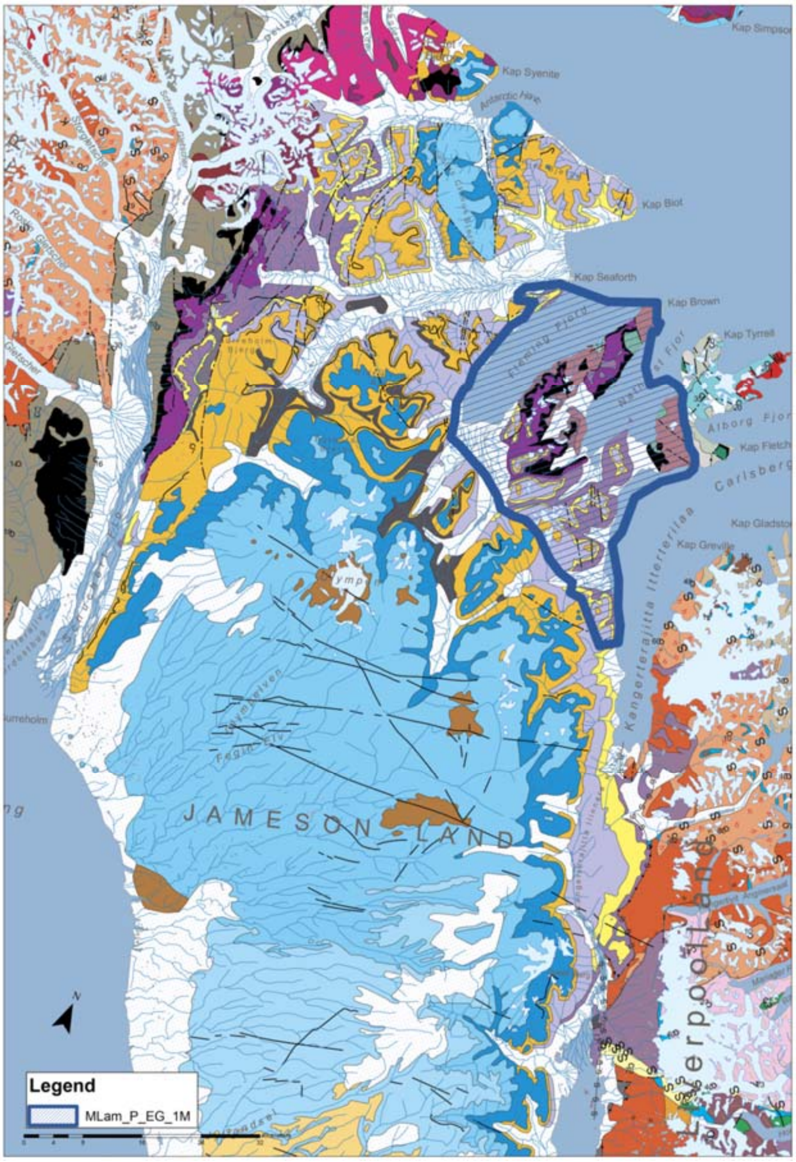


Figure 93. *Location of the MLam_P_EG_1M tract in the NE part of Jameson Land, central East Greenland. For geological legend see Appendix A.*

Table 59. *Summary of selected resource assessment results for the tract MLam_P_EG_1M.*

Assessment depth (km)	Tract area (km^2)	Known zinc resources (metric tons)	Mean estimate of undiscovered zinc resources (metric tons)
1 km	863	0	400,000

Geological criteria and rationale for the estimate

The Permian tract MLam_P_EG_1M contain the marine Upper Permian Wegener Halvø Formation, which is part of the Upper Permian Foldvik Creek Group, marking the first transgression in the East Greenland basin deposited unconformably on a flat Carboniferous – Lower Permian peneplain (Figure 91). The known base metal occurrences in the Wegener Halvø Formation are dominated by lead and zinc, but none yield economic zinc grades. Despite these facts the assessment panel found that the occurrences are evidence for MVT-type mineralisation processes, and that the formation can be considered as being permissive for such mineralisations. Only little exploration has been focused on the Wegener Halvø Formation, and given the lateral extent of the combined tracts (863 km^2) a potential for undiscovered MVT-type zinc deposits were considered possible.

The deposits estimates and the resulting undiscovered resource estimates from the Monte Carlo simulation can be found in Tables 60 and 61 respectively.

Table 60. *Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for MLam_P_EG_1M. For further details see text associated with Table 5.*

Consensus undiscovered deposit estimate					Summary statistics					Area (km^2)	Deposit density (N/km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}		
0	0	1	2	3	0.41	0.82	200	0	0.41	860	0.00047

	Estimated number of undiscovered deposits				
Estimator	**N90**	**N50**	**N10**	**N05**	**N01**
Individual 1	1	1	1	2	3
Individual 2	0	0	1	1	3
Individual 3	0	1	1	2	2
Individual 4	0	0	0	1	2
Individual 5	0	0	0	0	1
Individual 6	0	0	1	1	2
Individual 7	0	0	0	1	2
Individual 8	0	0	1	2	4
Individual 9	0	0	1	3	5
Individual 10	0	0	1	1	1
Individual 11	0	1	2	3	4
Individual 12	0	0	1	2	4
Individual 13	0	0	0	0	1
Consensus	**0**	**0**	**1**	**2**	**3**

Table 61. *Results of Monte Carlo simulations of undiscovered resources in the Permian tract MLam_P_EG_1M. [t = metric tons; Mt; megatonne or million tons]*

Material	Probability of at least the indicated amount						Probability of mean or greater	Probability of zero [none]
	0.95	0.90	0.50	0.10	0.05	Mean		
Zn (t)	0	0	0	980,000	2,000,000	400,000	0.16	0.70
Pb (t)	0	0	0	310,000	770,000	170,000	0.14	0.71
Rock (t)	0	0	0	0	0	9,000,000	0.03	0.95

Tract MLam_P_EG_2M – MVT zinc type

Location and delineation of the permissive tract

The Permian tract MLam_P_EG_2M is located in Schuchert dal in the NW part of the Jameson Land basin and covers the interpretated delineation of the the Foldvik Creek Group including the Karstryggen Fm and the Karstryggen Celestite-Lead-Zinc occurrence (Figure 94). The tract was assessed for MVT type deposits. Summary of the estimated undiscovered zinc resources can be found in Table 62.

The MLam_P_EG_2M tract contains the Foldvik Creek Group down to an estimated depth of 1 km below surface. The extent of the tract is based on the mapped distribution of the Foldvik Creek Group, including the Karstryggen Formation.

Figure 94. *Location of the MLam_P_EG_2M tract in the NW part of Jameson Land, central East Greenland. For geological legend see Appendix A.*

Table 62. *Summary of selected resource assessment results for the tract MLam_P_EG_2M.*

Assessment depth (km)	Tract area (km^2)	Known zinc resources (metric tons)	Mean estimate of undiscovered zinc resources (metric tons)
1 km	616	0	840,000

Geological criteria and rationale for the estimate

The Permian tract MLam_P_EG_2M contains the Foldvik Creek Group including the marine Upper Permian Karstryggen Formation (Figure 91).

The known base metal occurrences in the Karstryggen Formation are dominated by lead, zinc and baryte, and none yield economic zinc grades. Despite these facts the assessment panel found that the occurrences are evidence for potential MVT type mineralisations, and that the formation can be considered as being permissive for such mineralisations. Except for the Karstryggen occurrence, only little exploration has been focused on the Karstryggen Formation, and given the lateral extent of the combined tracts (616 km^2) a potential for undiscovered MVT-type zinc deposits were considered possible.

The deposits estimates and the resulting undiscovered resource estimates from the Monte Carlo simulation can be found in Tables 63 and 64 respectively.

Table 63. *Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for MLam_P_EG_2M. For further details see text associated with Table 5.*

Consensus undiscovered deposit estimate					Summary statistics					Area (km^2)	Deposit density (N/km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}		
0	1	1	2	3	0.81	0.73	90	0	0.81	620	0.0013

	Estimated number of undiscovered deposits				
Estimator	**N90**	**N50**	**N10**	**N05**	**N01**
Individual 1	1	1	1	2	3
Individual 2	0	1	1	1	3
Individual 3	0	1	1	1	2
Individual 4	0	0	0	1	2
Individual 5	0	0	0	0	1
Individual 6	0	0	1	1	2
Individual 7	0	1	1	2	3
Individual 8	0	0	0	1	2
Individual 9	0	1	1	1	2
Individual 10	0	1	1	2	3
Individual 11	0	1	2	3	4
Individual 12	0	1	1	2	3
Individual 13	0	0	0	1	2
Consensus	**0**	**1**	**1**	**2**	**3**

Table 64. *Results of Monte Carlo simulations of undiscovered resources in the Permian tract MLam_P_EG_2M. [t = metric tons; Mt; megatonne or million tons]*

Material	Probability of at least the indicated amount						Probability of mean or greater	Probability of zero [none]
	0.95	0.90	0.50	0.10	0.05	Mean		
Zn (t)	0	0	130,00	2,000,000	3,300,000	840,000	0.22	0.32
Pb (t)	0	0	32,000	730,000	1,400,000	340,000	0.19	0.35
Rock (t)	0	0	0	0	0	18,000,0	0.04	0.91

Tract SHam_T_EG_1 – SEDEX zinc type

Location and delineation of the permissive tract

The Triassic tract SHam_T_EG_1, located in the eastern and central part of the Jameson Land Basin, stretches from the southernmost part of the outer part of Scoresby Sund to the northernmost part of the outer Kong Oscar Fjord (Figure 95). The tract was assessed for SEDEX type deposits. Summary of the estimated undiscovered zinc resources can be found in Table 65. The SHam_T_EG_1 tract contains the Gipsdalen, Pingo Dal and Wordie Creek Formation down to an estimated depth of 1 km below surface. The extent of the tract is based on the mapped distribution of these three formations.

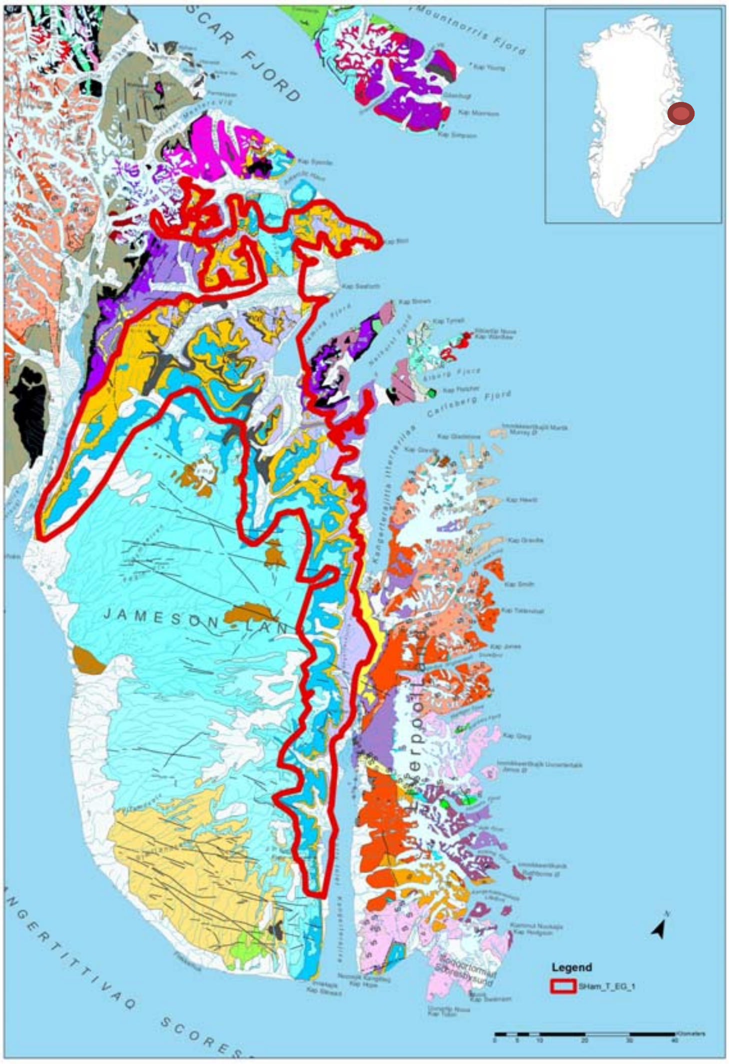


Figure 95. *The delineation of the Triassic tract SHam_T_EG_1 in the Jameson Land basin, central East Greenland. For geological legend see Appendix A.*

Table 65. *Summary of resource assessment results for the Triassic tract SHam_T_EG_1, assessed for SEDEX zinc type deposits.*

Assessment depth (km)	Tract area (km^2)	Known zinc resources (metric tons)	Mean estimate of undiscovered zinc resources (metric tons)
1 km	3,258	0	280,000

Geologic criteria and rationale for the estimate

The Triassic of the Jameson Land Basin consists of an approximately 1,700 m thick sequence of shallow marine to continental and lacustrine clastics with intercalations of evaporates and thin carbonates (Figure 96 + 97). Mineralisation of stratiform to stratabound character occurs at several stratigraphic levels (Table 55 & Harpøth *et al.* 1986). Based on the characteristics of the settings of the mineralisation in the transition zone between the Gipsdalen, Pingo Dal and Wordie Creek Formation and the geological setting of the host rock and established dispositional palaeo-environment the assessment panel found it justified to use the sediment-hosted zinc, SEDEX subtype (Taylor *et al.* 2009) as the appropriate grade and tonnage model in the estimation of undiscovered deposits.

The deposits estimates and the resulting undiscovered resource estimates from the Monte Carlo simulation can be found in Tables 66 and 67 respectively.

Table 66. *Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for tract SHam_T_EG_1. For further details see text associated with Table 5.*

Consensus undiscovered deposit estimate					Summary statistics					Area (km^2)	Deposit density (N/km^2)
N90	**N50**	**N10**	**N05**	**N01**	**N_{und}**	**s**	**Cv%**	**N_{known}**	**N_{total}**		
0	0	0	1	2	0.11	0.44	420	0	0.11	3,260	0.000032

	Estimated number of undiscovered deposits				
Estimator	**N90**	**N50**	**N10**	**N05**	**N01**
Individual 1	0	0	0	1	2
Individual 2	0	0	0	2	2
Individual 3	0	0	0	1	2
Individual 4	0	0	0	1	1
Individual 5	0	0	0	0	2
Individual 6	0	0	1	2	3
Individual 7	0	0	0	1	2
Individual 8	0	0	0	1	2
Individual 9	0	0	0	1	3
Individual 10	0	0	1	1	2
Individual 11	0	0	0	0	1
Individual 12	0	0	0	0	2
Individual 13	0	0	0	0	0
Consensus	**0**	**0**	**0**	**1**	**2**

Table 67. *Results of Monte Carlo simulations of undiscovered resources in the Triassic tract SHam_T_EG_1. [t = metric tons; Mt; megatonne or million tons]*

Material	Probability of at least the indicated amount						Probability of mean or greater	Probability of zero [none]
	0.95	**0.90**	**0.50**	**0.10**	**0.05**	**Mean**		
Zn (t)	0	0	0	0	510,000	280,000	0.06	0.92
Pb (t)	0	0	0	0	250,000	140,000	0.06	0.92
Rock (t)	0	0	0	0	0	5,100,000	0.01	0.97

Figure 96. *Aerial view of Devondal in East Greenland, with a well exposed sequence of the Gipsdalen Formation in the front of the photo. Photo from Thomassen (2009) workshop presentation at the copper assessment workshop in 2009 (Stensgaard et al.2011).*

Figure 97. *Typical exposure of the Gipsdalen Formation in Devondal, central East Greenland. Photo from Thomassen (2009) workshop presentation at the copper assessment workshop in 2009 (Stensgaard et al.2011).*

Palaeoproterozoic Ketilidian Pelite Zone, South Greenland

Sources of information

The principal sources of information used for the assessment of SEDEX-hosted zinc deposits in the Palaeoproterozoic track covering the Ketilidian Pellite Zone in South Greenland type are given in Appendix A.

Regional geology

The following description is derived from Garde *et al.* 2002. South Greenland is dominated by the Palaeoproterozoic Ketilidian Orogen (1900–1750 Ma), which covers the southern tip of Greenland and the middle Proterozic Gardar province that includes pronounced intrusive complexes (1300–1120 Ma) in the central part of the area (Figure 98).

The Ketilidian fold belt

The Ketilidian fold belt began with the development of an active plate margin between the stable Archaean basement block to the north and a newly formed ocean to the south. The oceanic plate was pushed down beneath the margin of the continental block (subducted) resulting in a down warping in the continental block, which allowed the deposition of a series of Ketilidian sedimentary and volcanic rocks. In connection with the subduction, parts of the mantle above the sinking plate melted, and the magmas generated ascended to form a volcanic island arc south of the continent, while at lower levels the roots of this arc crystallised as granite-like bodies. The granite roots were subsequently exhumed to the surface of the crust, where they were eroded producing sediments that were deposited as a thick sequence of sandstones and mudstones on the margin of the ocean.

The development of the fold belt continued with intense deformation and metamorphism of all the rock units, until near the end of the orogeny where numerous cross-cutting granitic bodies were emplaced in the southernmost areas.

The clastic sediments are composed mainly of erosion products of the Julianehåb batholith e.g. psammitic and semipelitic gneisses with local marbles and basic metavolcanic rocks, produced more or less contemporaneously with its emplacement; they are interpreted to represent a fore-arc basin. The rocks underwent highgrade, low-pressure metamorphism, up to granulite facies, and widespread anatexis occurred at c. 1790 Ma.

The Boundary Zone with the unaffected Archaean rocks occurs as an approximately 50 km wide zone of gneisses about 2800 Ma old, upon which the 1900-1850 Ma Ketilidian sedimentary and volcanic rocks were deposited prior to the start of deformation in the fold belt. These supracrustal rocks are now preserved in the Ivittuut region. The Granite Zone is characterized by the Julianehåb batholiths. This developed over a period of about 60 Ma as a series of large, lens-formed granitoid intrusions (batholiths) that now form one coherent mass. The Granite Zone is up to 150 km across and makes up the predominant part of the fold belt at the present day exposure on the surface. The Psammite Zone is 30-40 km wide, and was formed immediately south of the batholiths by deposition of coarse erosion products from the rivers. The Pelite Zone is found farthest south and comprises transformed, finer grained deposits that were laid down at greater water depths, beyond the Psammite Zone.

After deposition of the sediments south of the batholiths about 1800 Ma ago, the whole of the fold belt was subjected to intense deformation and folding took place in several phases. At the same time the sedimentary rocks were metamorphosed and, the deeper parts of the Pelite Zone, locally melted to form migmatites. The latest group of rocks in the Ketilidian fold belt is a series of late granites (rapakivi granite) that were emplaced about 1750–1725 Ma ago into the southern part of the fold belt, for the most part after deformation has ceased.

The Quaternary glaciation covered the region, possibly with the exception of the highest peaks. The ice cap, the Inland Ice, still remains over most of Greenland with glaciers extending towards the coast trough valleys and fjords. Holocene marine terraces, common along the coasts, testify to Holocene uplift.

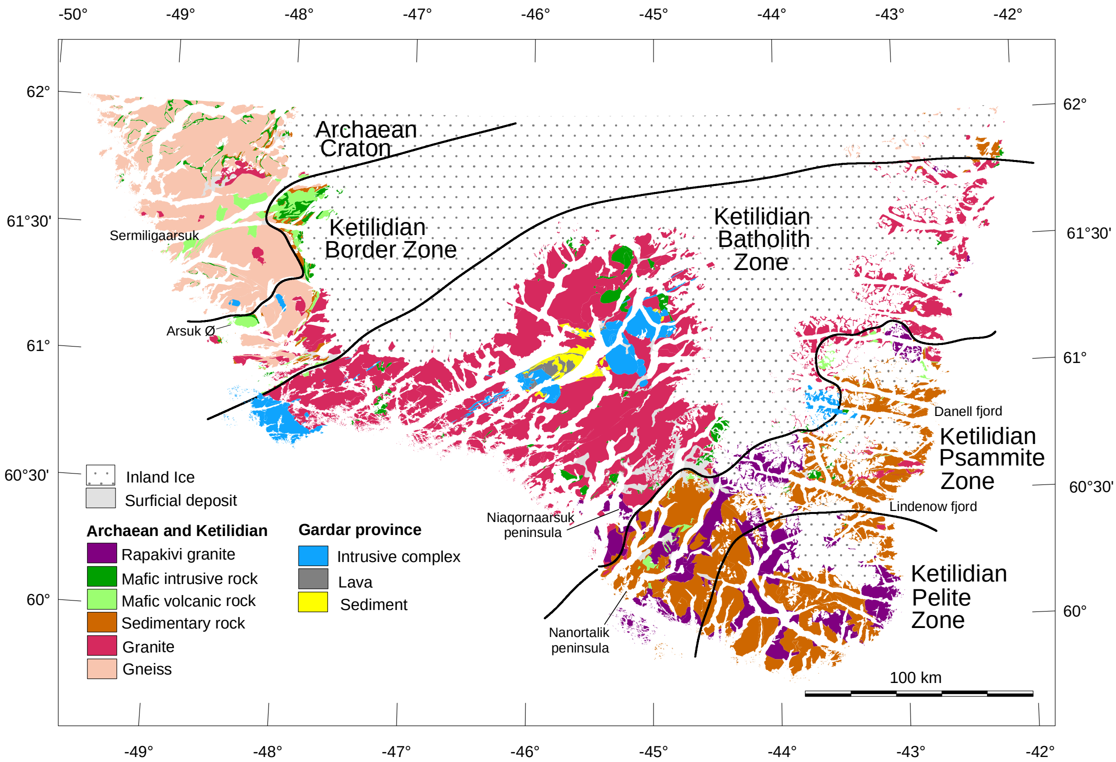


Figure 98. *Simplified geological map of South Greenland. Division of the Ketilidian orogen after Chadwick & Garde (1996). The map is a simplified version of the digital geological map on the CD-ROM.*

Exploration history

South Greenland has a long history of mineral exploration activities and geological investigations, much of which were carried out by the Geological Survey of Greenland GGU (in 1995 merged with the Geological Survey of Denmark to form GEUS). This is documented in the GEUS report no. 2000/57 by Schjøth *et al.* (2000). The report includes a CD-ROM, which has more than 2000 entries including published articles, internal Survey reports and field notes. The CD-ROM also lists 204 company reports on mineral exploration conducted within the region.

Since 2000 various exploration companies have been active in the region but mainly concentrated to areas around the Gardar province and the Nanortalik and Niaqornaarsuk peninsula.

Known prospects, mineral occurrences or related deposit types

No known sediment-hosted zinc deposits.

However, South Greenland is highly enriched in zinc as the following description and figure from Schjøth *et al.* (2000) illustrates.

Geochemical data for Zn, Pb are shown in Figure 99 together with data for Cr and V. The means of stream sediment Zn (Figure 99) show that Zn is highly enriched in the Gardar magmas and is elevated in the rapakivi suite. This suggests that the magmas have a considerable amount of Zn in their source region or that they have been contaminated with Zn during their ascent. An estimation of the zinc resource has been made for the body of lujavrite at Kvanefjeld, the Ilímaussaq complex. A total of 2.25 million tons of zinc is estimated to be contained in ore grading 0.23% Zn (Greenland Minerals & Energy 2012 press release).

Most of the high Zn values in stream sediments from the Sediment domain are derived from stream draining the rapakivi suite, but the anomalies on the Niaqornaarsuk and Nanortalik peninsulas are not within rapakivi granites and suggest mineralisation. Likewise the cluster of Zn and Pb anomalies east of Nanortalik peninsula, which is located in metasediments, attracts interest. Many sulphide-graphite-mineralised horizons have been recorded and sampled during the SUPRASYD project within the Sediment domain, but few yielded encouraging concentrations (Stendal *et al.* 1997); see also descriptions of mineral occurrences on the CD-ROM. The concentration of Pb is generally low in these horizons. The pronounced rust zones are laterally extensive and 10 to 100 metres wide. The dominant sulphide is pyrrhotite, whereas chalcopyrite and sphalerite rarely exceed 5-10 vol.%. One occurrence of massive sulphides found in metasediments below the Stendalen gabbro has yielded 0.8% Cu, 0.5% Ni and 0.1% Co.

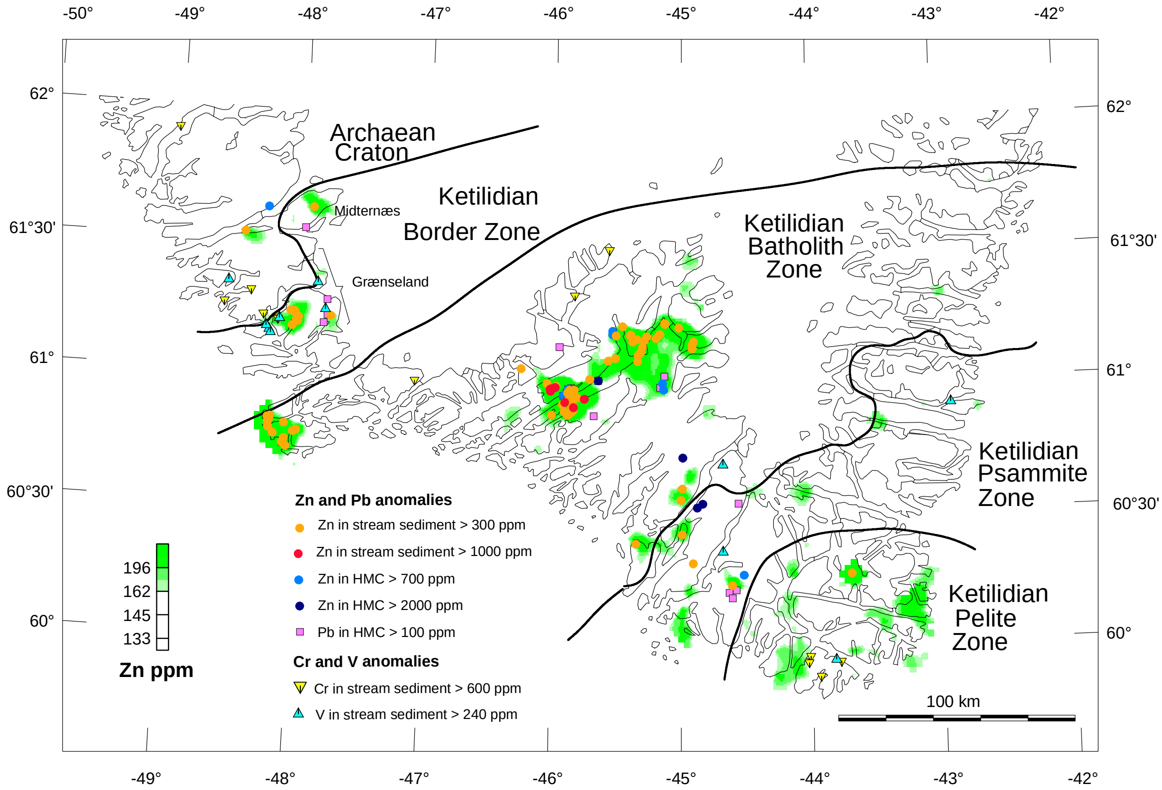


Figure 99. *Distribution of high grid values for zinc (Zn) in stream sediment together with anomalies for Zn, lead (Pb), chromium (Cr) and vanadium (V) in stream sediment (< 0.1 mm) and heavy mineral concentrates (HMC) of stream sediment. From Schjøth et al. (2000).*

Grade and tonnage model selection

Based on the discussion and the reviews of previous work by various researchers on the mineralisation, the assessment panel found it justified, using the sediment-hosted zinc, SEDEX subtype (Taylor *et al.* 2009) as the appropriated grade and tonnage models in the estimation of undiscovered deposits.

Individual tracts assessed during workshop

Tract SHme_S_1 – SEDEX zinc type

Location and delineation of the permissive tract

The tract SHme_S_1 is located in the South Greenland between Sermilik Fjorden in the west to the Kangerluluk area in the east (Figure 100). The tract was assessed for SEDEX type deposits. Summary of the estimated undiscovered zinc resources can be found in Table 68.

The SHme_S_1 tract includes the Pelite Zone of the Ketilidian Orogen. The extent of the tract is based on the mapped and interpretated distribution of the Pelite Zone down to an estimated depth of 1 km below surface.

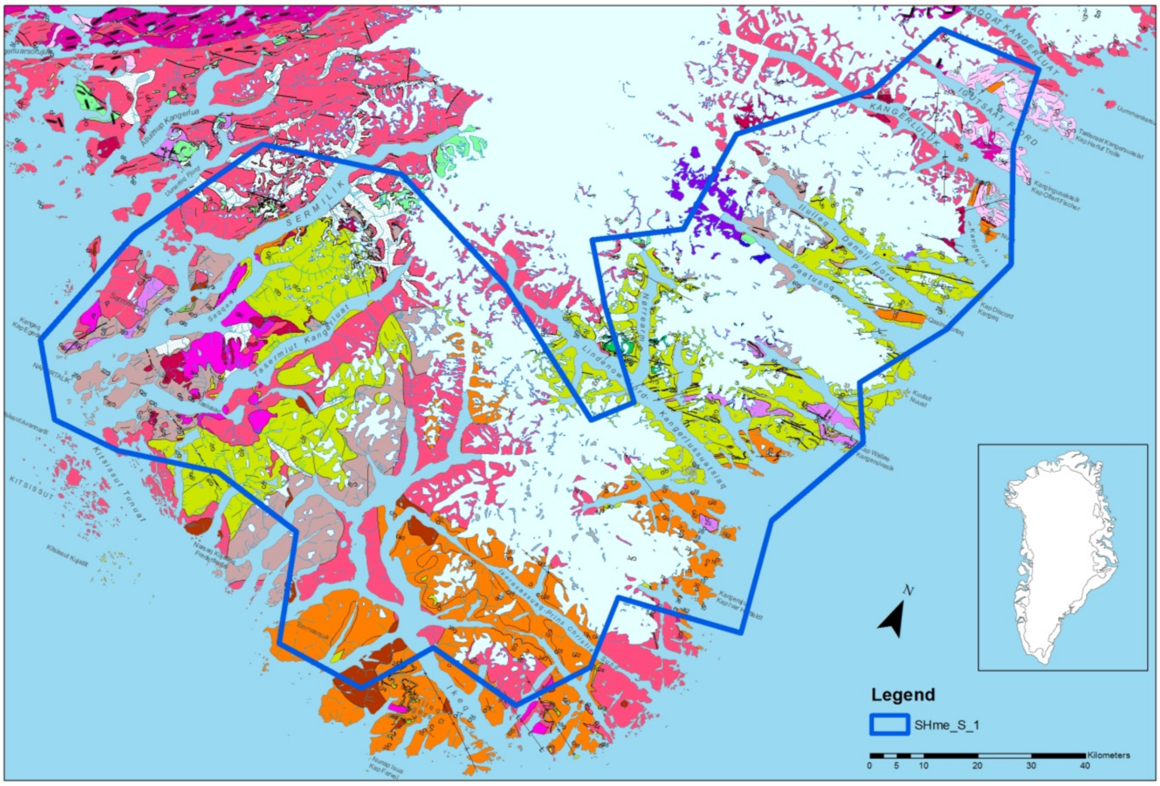


Figure 100. *Distribution of tract SHme_S_1 assessed for undiscovered SEDEX type zinc deposits. For geological legend see Appendix A.*

Table 68. *Summary of resource assessment results for the tract SHme_S_1 assessed for SEDEX type zinc deposits.*

Assessment depth (km)	Tract area (km^2)	Known zinc resources (metric tons)	Mean estimate of undiscovered zinc resources (metric tons)
1	1,065	0	150,000

Geologic criteria and rationale for the estimate
The defined tracts outline a very large area were very limited exploration activity have been carried out for SEDEX deposits, so a potential for undiscovered mineralisations is present. The clastic sediments of the Pelite Zone are interpretated to have been formed in a fore-arc basin which could be favourable conditions for formation of SEDEX deposits. Geochemical zinc anomalies exist in the area that is not related to known deposits which could also indicate undiscovered SEDEX deposits in the region.

The deposits estimates and the resulting undiscovered resource estimates from the Monte Carlo simulation can be found in Tables 69 and 70 respectively.

Table 69. *Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for tract SHme_S_1. For further details see text associated with Table 5.*

Consensus undiscovered deposit estimate					Summary statistics					Area (km^2)	Deposit density (N/km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}		
0	0	0	0	2	0.06	0.37	610	0	0.06	1,070	0.000056

	Estimated number of undiscovered deposits				
Estimator	**N90**	**N50**	**N10**	**N05**	**N01**
Individual 1	0	1	2	2	4
Individual 2	0	0	0	0	1
Individual 3	0	0	0	0	0
Individual 4	0	0	0	0	3
Individual 5	0	0	0	0	0
Individual 6	0	0	0	1	2
Individual 7	0	0	0	0	0
Individual 8	0	0	0	0	1
Individual 9	0	0	0	0	2
Individual 10	0	0	0	0	3
Individual 11	-	-	-	-	-
Individual 12	0	0	0	0	0
Individual 13	0	0	0	0	0
Consensus	**0**	**0**	**0**	**0**	**2**

Table 70. *Results of Monte Carlo simulations of undiscovered resources for the tract SHme_S_1. [t=metric tons; Mt; megatonne or million tons]*

Material	Probability of at least the indicated amount						Probability of mean or greater	Probability of zero [none]
	0.95	0.9	0.5	0.1	0.05	Mean		
Zn (t)	0	0	0	0	0	150,000	0.03	0.96
Pb (t)	0	0	0	0	0	77,000	0.03	0.96
Rock (t)	0	0	0	0	0	2,600,000	0.01	0.99

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Appendix A: Bibliography - Sediment-hosted zinc in Greenland

The bibliography covers the most important references on sediment-hosted zinc mineralisations in Greenland and some of the most important references on regional geology for areas. The bibliography was compiled by Bo Møller Stensgaard and Lars Lund Sørensen. References marked with ***** are considered key papers.

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Appendix B: Operational classification of sediment-hosted and volcanogenic-hosted zinc-lead deposits

Sediment-hosted and volcanogenic-hosted Zinc-Lead deposits – Type Deposits

Operational classification of sediment-hosted and volcanogenic-hosted Zinc-Lead deposits is based on observable geologic units reported in the scale of maps.

Carbonate-hosted:						
Type Deposit [abbreviation]	**Type Zn Deposit [description]**	**Known relevance in Greenland**	**Examples in Greenland**	**Description**		
				Host-rock [USGS]	**Affected? [USGS]**	**Mineral deposit models**
CAam	**CA**rbonate-hosted **am**agmatic	1	⚒ Petermann Prospect (Cambro-Ordovician platform carbonates, NG.) ⚒ Cass Prospect (Cambro-Ordovician platform carbonates, NG.) ⚒ Silurian occurrences (Silurian reef carbonate, NG.) ⦿ XXX carbonate formations (platform carbonate sediments in NG.) ⦿ XXX carbonate formations (buildups/reef carbonate sediments in CEG.)	**Carbonate (CA):** This category includes rocks of massive carbonate sequences and carbonate-shale intercalations. Fifty percent of these deposits are hosted by dolomite and dolomitic rocks and 50percent by limestone. The "dolomite index" increases to 72 percent in SEDEX and to 62 percent in MVT deposits. Carbonaceous rocks, mainly interlayered shale, only occur in 8 percent of these predominantly carbonate-hosted deposits (17 percent in SEDEX).	**Amagmatic (am):** includes deposits without igneous manifestations and signs of contact metamorphism in the deposit area and vicinity. Regional metamorphism of country rocks range from "unmetamorphosed" to pre-greenschist and greenschist facies. This group contains 90 percent of MVT deposits and 59 percent of SEDEX deposits. The deposits commonly have simple ore mineralogy.	**SEDEX** **MVT**
CAig	**CA**rbonate-hosted and **ig**neous related	2	Non??		**Igneous related (ig):** consists of deposits with various igneous intrusions, also sills and numerous dikes, and signs of contact metamorphism of country rocks in the deposit area or in its vicinity, independent of the grade of regional metamorphism. Igneous events that are clearly older than host rock were ignored. Also not counted were ultramafic rocks, basalt sills, and diabase dikes. All polymetallic replacement and skarn deposits are in this category. SEDEX and a few MVT deposits affected by intrusions and contact metamorphism can have similar complicated mineralogical ore compositions that may be difficult to distinguish from skarns and replacements.	**Zn Skarn** **Zn polymetallic replacement** **(?SEDEX)** **(?MVT)**
CAme	**CA**rbonate-hosted exhibiting high-grade **met**amorphism	1	⚒ Black Angel, cWG. ⦿ Maarmorilik Formation, cWG.		**Metamorphic (me):** includes deposits exhibiting high-grade metamorphism of amphibolite to amphibolite-to-granulite facies including 20 deposits commonly classed as SEDEX and generally hosted by Proterozoic rocks with single Cambrian rock ages. Aside from carbonate marble beds, the original host-rock lithology cannot be recognized reliably. Mineralogical ore compositions are close to deposits of the previous category (ig) but are not as diverse. Data on this category are scarce.	**SEDEX** **MVT** **BHT**

Sediment-hosted and volcanogenic-hosted Zinc-Lead deposits – Type Deposits

Operational classification of sediment-hosted and volcanogenic-hosted Zinc-Lead deposits is based on observable geologic units reported in the scale of maps.

Shale-hosted:						
Type Deposit [abbreviation]	**Type Zn Deposit [description]**	**Known relevance in Greenland**	**Examples in Greenland**	**Description**		
				Host-rock [USGS]	**Affected? [USGS]**	**Mineral deposit models**
SHam	**SH**ale-hosted **am**agmatic	1	⚒ Citronen Fjord, NG. ⊙ XXX clastic formations/ trough sediments, NG.) ⊙ Permian, Jurassic shale formations in CEG	**Shale (SH):** This lithological category includes argillite, mudstone, phyllite, siltstone, and slate, according to terminologies from original descriptions of deposits. Forty-seven percent of deposits of the group are hosted by dolomitic shale and/or shale associated with dolomite in the ore-hosting strata. Carbonaceous (or graphitic) shale is characteristic for 62 percent of the deposits. A presence of tuff and tuffaceous rocks is noted in 42 percent of the deposits.	**Amagmatic (am):** includes deposits without igneous manifestations and signs of contact metamorphism in the deposit area and vicinity. Regional metamorphism of country rocks range from "unmetamorphosed" to pre-greenschist and greenschist facies. This group contains 90 percent of MVT deposits and 59 percent of SEDEX deposits. The deposits commonly have simple ore mineralogy.	**SEDEX** **MVT**
SHig	**SH**ale-hosted and **ig**neous related	2	Non??		**Igneous related (ig):** consists of deposits with various igneous intrusions, also sills and numerous dikes, and signs of contact metamorphism of country rocks in the deposit area or in its vicinity, independent of the grade of regional metamorphism. Igneous events that are clearly older than host rock were ignored. Also not counted were ultramafic rocks, basalt sills, and diabase dikes. All polymetallic replacement and skarn deposits are in this category. SEDEX and a few MVT deposits affected by intrusions and contact metamorphism can have similar complicated mineralogical ore compositions that may be difficult to distinguish from skarns and replacements.	**Zn Skarn** **Zn polymetallic replacement** **(?SEDEX)** **(?MVT)**
SHme	**SH**ale-hosted exhibiting high-grade **me**tamorphism	1	⚒ ? occurrences in Karrat Grp.?, CWG. ⊙ Karrat Group, CWG. ⊙ Eleonore Bay Supergroup, CEG.		**Metamorphic (me):** includes deposits exhibiting high-grade metamorphism of amphibolite to amphibolite-to-granulite facies including 20 deposits commonly classed as SEDEX and generally hosted by Proterozoic rocks with single Cambrian rock ages. Aside from carbonate marble beds, the original host-rock lithology cannot be recognized reliably. Mineralogical ore compositions are close to deposits of the previous category (ig) but are not as diverse. Data on this category are scarce.	**SEDEX** **MVT** **BHT**

Sediment-hosted and volcanogenic-hosted Zinc-Lead deposits – Type Deposits

Operational classification of sediment-hosted and volcanogenic-hosted Zinc-Lead deposits is based on observable geologic units reported in the scale of maps.

Mixed lithology-hosted:						
Type Deposit [abbreviation]	**Type Zn Deposit [description]**	**Known relevance in Greenland**	**Examples in Greenland**	**Description**		
				Host-rock [USGS]	**Affected? [USGS]**	**Mineral deposit models**
MLam	Mixed lithology-hosted **am**agmatic	Not relevant	Not relevant	**Mixed lithology (ML):** This category could be considered "questionable" or "problematic" because the group includes highly metamorphosed deposits, such as Broken Hill, where researchers interpreted either sedimentary or volcanic original rock compositions. It is possible that host rocks of such deposits had contained mafic (amphibolite) and felsic (mica schist) volcanics, as well as carbonate rocks (calc-silicate rocks) and clastic rocks (mica schist). The group mostly coincides with the Broken Hill-type (BHT) in popular classifications (Penney and others, 2004a,b; Leach and others, 2005). BHT really is characterized by complex mixed lithology, including such exotic rocks as garnet quartzite, gahnite quartzite, tourmalinite, and sulfide-bearing iron-formation.	**Amagmatic (am):** includes deposits without igneous manifestations and signs of contact metamorphism in the deposit area and vicinity. Regional metamorphism of country rocks range from "unmetamorphosed" to pre-greenschist and greenschist facies. This group contains 90 percent of MVT deposits and 59 percent of SEDEX deposits. The deposits commonly have simple ore mineralogy.	**SEDEX** **MVT**
MLig	Mixed lithology-hosted and **ig**neous related	3	⚒ Blyklippen?, cEG ⦿ Blyklippen Member, cEG		**Igneous related (ig):** consists of deposits with various igneous intrusions, also sills and numerous dikes, and signs of contact metamorphism of country rocks in the deposit area or in its vicinity, independent of the grade of regional metamorphism. Igneous events that are clearly older than host rock were ignored. Also not counted were ultramafic rocks, basalt sills, and diabase dikes. All polymetallic replacement and skarn deposits are in this category. SEDEX and a few MVT deposits affected by intrusions and contact metamorphism can have similar complicated mineralogical ore compositions that may be difficult to distinguish from skarns and replacements.	**Zn Skarn** **Zn polymetallic replacement** **(?SEDEX)** **(?MVT)**
MLme	Mixed lithology-hosted exhibiting high-grade **me**tamorphism	3	Non?		**Metamorphic (me):** includes deposits exhibiting high-grade metamorphism of amphibolite to amphibolite-to-granulite facies including 20 deposits commonly classed as SEDEX and generally hosted by Proterozoic rocks with single Cambrian rock ages. Aside from carbonate marble beds, the original host-rock lithology cannot be recognized reliably. Mineralogical ore compositions are close to deposits of the previous category (ig) but are not as diverse. Data on this category are scarce.	**SEDEX** **MVT** **BHT**

Appendix C: CD-ROM with workshop presentations

Presenter	**Title**	**Presentation number** (on CD-ROM)
Bo M. Stensgaard (GEUS)	Objectives of the workshop and procedure for the assessment of sediment-hosted zinc deposits in Greenland	1
Denis Schlatter (Helvetica Exploration Services GmbH)	Descriptive and genetic models of volcanic-hosted massive sulphide (VMS) deposits with special focus on Zn-rich VMS deposits (Keynote)	2
Poul Emsbo (USGS)	Geology and genesis of sediment-hosted Zn-Pb deposits (Keynote)	3
Agnete Steenfelt (GEUS)	Overview of Greenland geochemical stream sediment data with focus on geochemistry related to zinc occurrences	4
Niels Henriksen (GEUS)	Geological settings of North-Northeastern Greenland with focus on the Franklinian Basin	5
Henrik Stendal (BMP)	Known sediment-hosted zinc occurrences in North-Northeastern Greenland	6
Kristine Thrane (GEUS)	Geological settings of North-West, Central West & Southern West Greenland with main focus on the Karrat Group	7
Bjørn Thomassen (Avannaa Resources Ltd)	Known sediment-hosted zinc occurrences related to the Mârmorilik Formation of the Karrat Group	8
Bjørn Thomassen (Avannaa Resources Ltd)	Known sediment-hosted zinc occurrences related to the Nûkavsak/Qeqertarssuaq Formation of the Karrat Group	9
Mikael Petersen (GEUS)	Geological settings of the Permian-Triassic parts of central East Greenland	10
Niels Henriksen (GEUS)	Caledonian foldbelt_East Greenland	11
Bjørn Thomassen (Avannaa Resources Ltd)	Known zinc occurrences of the Permian-Triassic parts in central East Greenland including Blyklippen	12
Henrik Stendal (BMP)	Geological setting and zinc potential of the Ketilidian Mobile Belt, South Greenland with focus on the Psammite & Pelite zones	13
Peter Dawes (GEUS)	The Proterozoic Thule Basin - An intracratonic sedimentary volcanic depocentre across Baffin Bay	14
Jon R. Ineson (GEUS)	Proterozoic basins of eastern North Greenland – northern NE Greenland	15