DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2014/76

Tungsten potential in Greenland

Reporting the mineral ressource assessment workshop 3-5 December 2013

Diogo Rosa, Lars Lund Sørensen & Bo Stensgaard

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G E U S

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(1 CD-ROM included)

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GEUS

Contents

Executive summary

Within the framework of the Global Mineral Resource Assessment Project, Greenlandic tungsten resources were estimated down to a depth of 1 km. Two tungsten deposit types, and respective grade/tonnage models, were considered. Eight permissive tracts were assessed for both vein-type deposits and skarn-type deposits.

The statistical mean estimate number of undiscovered vein-type deposits is of 11, with 8 expected undiscovered skarn-type deposits. At a 50% probability, these are estimated to contain at least 123.000 and 121.000 tons of W, respectively. The best potential for both vein-type and skarn-type deposits is located in East Greenland, and is related to Caledonian and Devonian granitic intrusions emplaced into metasedimentary rocks of the Krummedal Sucession (Meosproterozoic) and of Eleonore Bay Supergroup (Neoproterozoic). Within this area, the best potential lies mainly within a large tract that extends from northern Scoresby Land to Hochstetter Land, and which includes the Ymers Ø, Knivbjergdal and Alpefjord occurrences, and, accessorily, in another tract, which includes northeastern Milne Land and southern Scoresby Land, as well as Liverpool Land, where the Kalkdal occurrence is located. Furthermore, a tract in South Greenland was considered to hold some potential for vein-type deposits.

Introduction

Quantitative information on mineral resources availability and distribution is required among decision makers from governmental agencies and from the private mining sector. For this reason, the United States Geological Survey (USGS) in 2002 launched the ’Global Mineral Resource Assessment Project’ (GMRAP), aimed primarily at identifying the main areas in the world with potential for undiscovered mineral resources, down to a depth of one kilometre.

The GMRAP makes use of available compiled information about geology, geochemistry, geophysics, and previous exploration results in the context of modern quantitative grade/tonnage 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 Ministry of Industry and Mineral Resources of Greenland (MIM) and the Geological Survey of Denmark and Greenland (GEUS) participate in GMRAP. As result, workshops were held for the assessment of the copper, rare-earth elements, sediment-hosted zinc and magmatic nickel potential in Greenland, in 2009, 2010, 2011, and 2012 respectively. Within the same framework, GEUS and MIM organised a workshop held in Copenhagen 3-5 December 2013, to assess the potential for undiscovered tungsten deposits in Greenland.

It is expected that the results of this workshop, described in this report, will constitute a useful tool for the selection of areas for the exploration of tungsten and for promoting mineral exploration in Greenland.

Methods

The standardized methodology of the ‘Three-Part Form’ mineral resource assessment approach (Singer 1993, Singer & Menzie 2010) was followed, namely:

i) delineation of tracts of land where the geology is permissive for the formation of predefined types of tungsten deposits;
ii) selection of appropriate grade/tonnage models for each tract; and
iii) estimation of the number of undiscovered tungsten deposits in each tract consistent with the grade and tonnage model. The obtained number of deposits is combined with the grade and tonnage model to assess the total undiscovered tungsten endowment.

Assessed tungsten deposit types

Regardless of the classification, economic tungsten deposits are invariably linked to granitic rocks. Provided granitic magmas underwent the appropriate evolution, leading to progressive enrichment in tungsten, these magmas have the potential to generate economic tungsten deposits. Depending on the local geological setting, namely structural framework and type of country rocks, though, two different types of deposits can be formed: **W vein type** deposits and **W skarn type deposits**. However, it should be noticed that there is a gradation between these two deposit types, and very often both can be present in the same district or region. Nevertheless, each of these deposit types has a distinct grade/tonnage model which was considered during the workshop:

W vein type deposit model:

- Cox, D.P. & Bagby, W.C., 1986, Descriptive model of W veins, in Cox, D.P., and Singer, D.A., eds., Mineral Deposit models: U.S. Geological Survey Bulletin 1693, p. 64-66.

W skarn type deposit model:

- Cox, D.P. 1986, Descriptive model of W skarn deposits, in Cox, D.P., and Singer, D.A., eds., Mineral Deposit models: U.S. Geological Survey Bulletin 1693, p. 55-57.

While only these two deposit types were assessed during the workshop, a variety of additonal tungsten deposit types has been described in the literature. However some have no or only minor economic interest, such as the brine/evaporite, pegmatite and placer deposit types. The interest in these deposit types is very limited and no grade/tonnage models are available for them, so these were not assessed.

Other proposed deposit types can be aggregated to other, more encompassing, types. For example, the breccia and stockwork deposit types can be considered to be part of the vein-type deposits, for which a grade/tonnage model exists.

Finally, the stratabound tungsten deposit type, for which some authors propose an exhalative origin, was not assessed. This was due to their enigmatic and controversial nature and the absence of a grade/tonnage model. Nevertheless, a short review of the W mineralisations in the Nuuk region, which have been interepreted by some authors to correspond to this deposit type, will be presented.

Overall economic and geologic characteristics

The following table (table 1) summarizes the overall economic and geological characteristics of the vein and skarn type tungsten deposits used for the workshop. The table is based on data from Cox 1986, Cox & Bagby 1986 and SIDEX 2002.

Many areas in Greenland are anomalous in tungsten as despicted on the geochemical plots of stream sediment and heavy mineral concentrate on figures 1 & 2. Especially on the heavy mineral concentrate map (figure 2) it is very easy to identify 4 areas highly anomalous in tungsten. These areas (excluding the anomalous area of the Nuuk region) have thus been included in the tract proposals assessed during the workshop (figure 3).

Table 1. *Overall economic and geological characteristics of the two main types of tungsten deposits. Modified from SIDEX 2002.*

	Vein type	Skarn type
Economics		
Typical sizes	Veins: 10s to 100s of Kt.; groups of veins, stockworks: Mt to 10s of Mt	Most exploitable deposits contain >10,000 tons of W
Typical grades	0.3 to 1.5% WO_3 for veins, lower for stockworks	Underground mines generally grade >0.4% WO_3, and >1% in remote areas
Greenland examples (All central East Greenland)	Ymer Ø, 0.075 Mt @ 2.5% WO_3 & 0.042 Mt @ 0.7% WO_3; Scheelitdal, Galenadal and Trekantgletscher. No resource estimate	Knivbjergdal and Kalkdal, no resource estimate
Foreign examples	Panasqueira (Portugal), 31 Mt @ 0.3% WO_3; Mount Carabine (Australia), 35 Mt @ 0.1% WO_3; Hemerdon (Cornwall, UK), 42 Mt @ 0.43% WO_3; Appalachians: Burnthill (NB, Canada), 4 Mt @ 0.12% WO_3	Shizhuyuan (China), 170 Mt @ 0.33% WO_3 (including a stockwork); Tymyauz (Russia), 50.8 Mt @ 0.6% WO_3; Sangdong (South Korea), ~20 Mt @ 1.0% WO_3; King Island (Tasmania), 14 Mt @ 0.8% WO_3; Mactung (NWT), 33.0 Mt grading 0.88% WO_3; Cantung (NWT), 1.7 Mt @1.17% WO_3; Tabuaço (Portugal), 2.7 Mt @ 0.56% WO_3
Geology		
Tectonic context	Collision zones, continental arcs, continental rifts; granitic plutons derived from melting of continental crust	Orogens; continent-continent collision zones / subduction zones?
Characteristics of related intrusions		
Age	Late-orogenic to anorogenic, mostly Late Palaeozoic, Mesozoic and Cenozoic	Syn-orogenic (++) to late-orogenic (-), mainly middle Palaeozoic to Late Cretaceous
Geochemistry	Granites; strong fractionation, A- or S-type granites, enriched in lithophile and volatile elements, ilmenite-series if related to Sn mineralisation ('specialised granites')	Quartz diorite, quartz monzonite or granodiorite, calc-alkaline trend; type I or type S
Texture	Presence of aplites, porphyry, granophyric or micrograph. texture, comb-layered quartz	Coarse- to medium-grained intrusions, porphyry texture, K feldspar megacrysts, aplites and pegmatites

Emplacement depth; size	1-4 km; cupolas of batholith, small isolated cupolas/plutons, small subvolcanic intrusions	5-15 km; ranging in size from stocks to large batholitic plutons
Alteration	Greisen in upper parts: Li-, F-, and B-bearing minerals (topaz, tourmaline, fluorite, micas), ± albite, microcline, chlorite, quartz, dissem. sulfides; pervasive albitisation in deepest parts	Generally unaltered but intrusive borders can show argillic or greisen alteration
Host rock characteristics		
Lithology	No typical host rock, but often in thick, non-carbonate sedimentary piles - sandstone, shale and metamorphic equvialents	Platform carbonates and pelites, recrystallised during contact metamorphism
Alteration	Greisen selvages around veins; greisenisation may be pervasive throughout host rock in stockworks	Metasomatism of marbles and calc-silicate hornfels = skarns; Prograde phase: pyrox., garnet, calcite, dolom., qtz, vesuv., wollast.; Retrograde phase (highest W grades): hornbl., biot., plag., epid., sphene, chlor., actin., apatite
Ore characteristics		
Location and shape	Location: contained within parent magmatic rock/surrounding host rocks; tensional fractures in granitic plutons + wallrock; shape: veins <1 cm to several m-thick veins, typically 10-20 cm thick, distributed in single veins, narrow vein networks, sheeted vein zones, stockworks, or breccias	Mainly stratabound exoskarns (in recrystallised limestone), with orebodies reaching 100s of m in length (but <15 m in thickness); located 10s of m away from intrusion, along a lithological contact (e.g. limestone/pelite). Contacts and roof pendant of batholith, thermal aureoles of granites that intrude carbonate rocks
Mineralogy	W in wolframite [$(Fe,Mn)WO_4$], but sometimes in scheelite; accomp. by cassiterite, stannite, molybdenite, bismuthinite, chalcopyrite, sphalerite, pyrite, pyrrhotite, hematite, arsenopyrite	W in scheelite ($CaWO_4$); accompanied by chalcopyrite, sphalerite, molybdenite, pyrrhotite, late pyrite, magnetite, native bismuth, bismuthinite

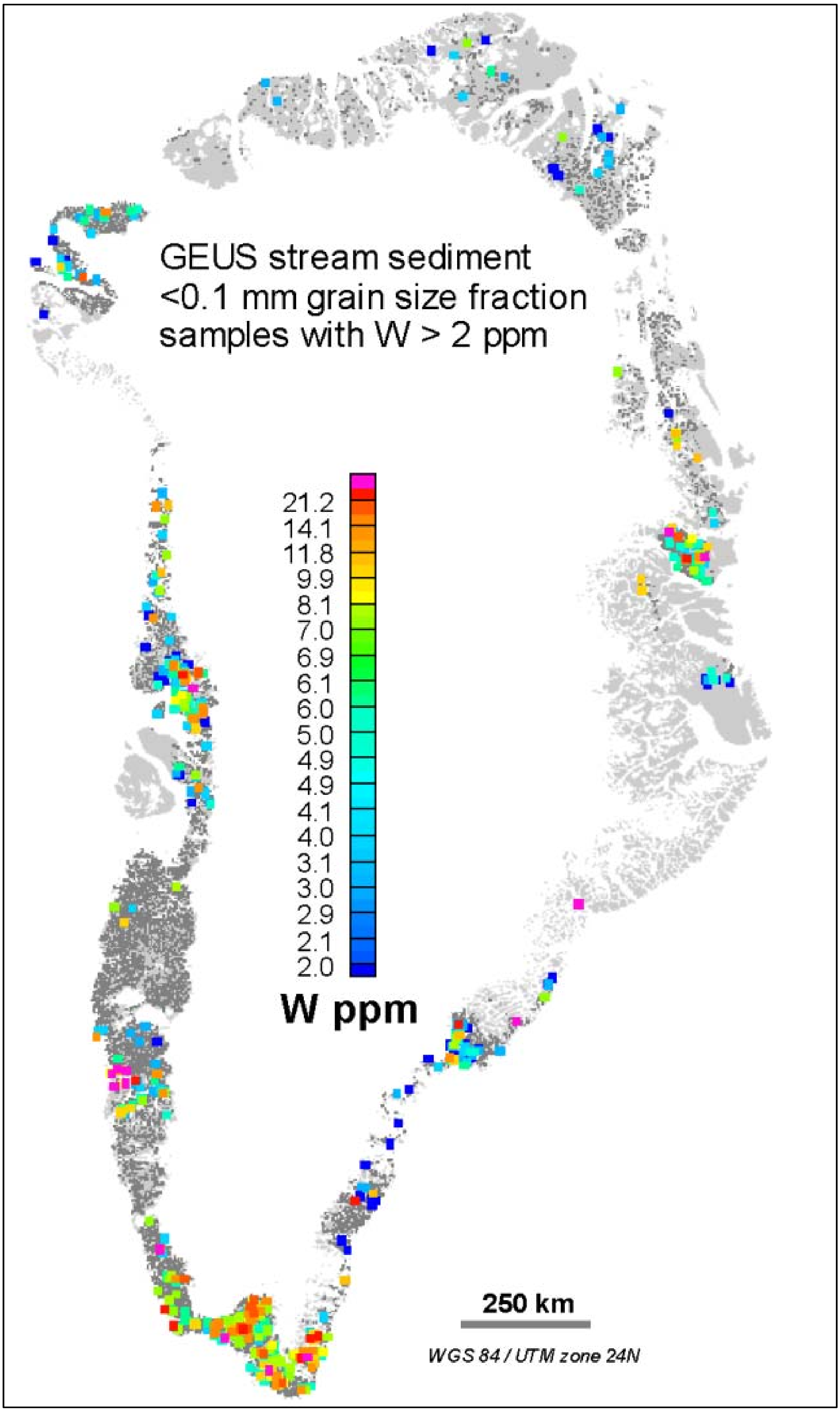

Figure 1. *Stream sediment localities with tungsten values higher than 2 ppm. From Steenfelt's (2013) tungsten workshop presentation – see CD-ROM in appendix C.*

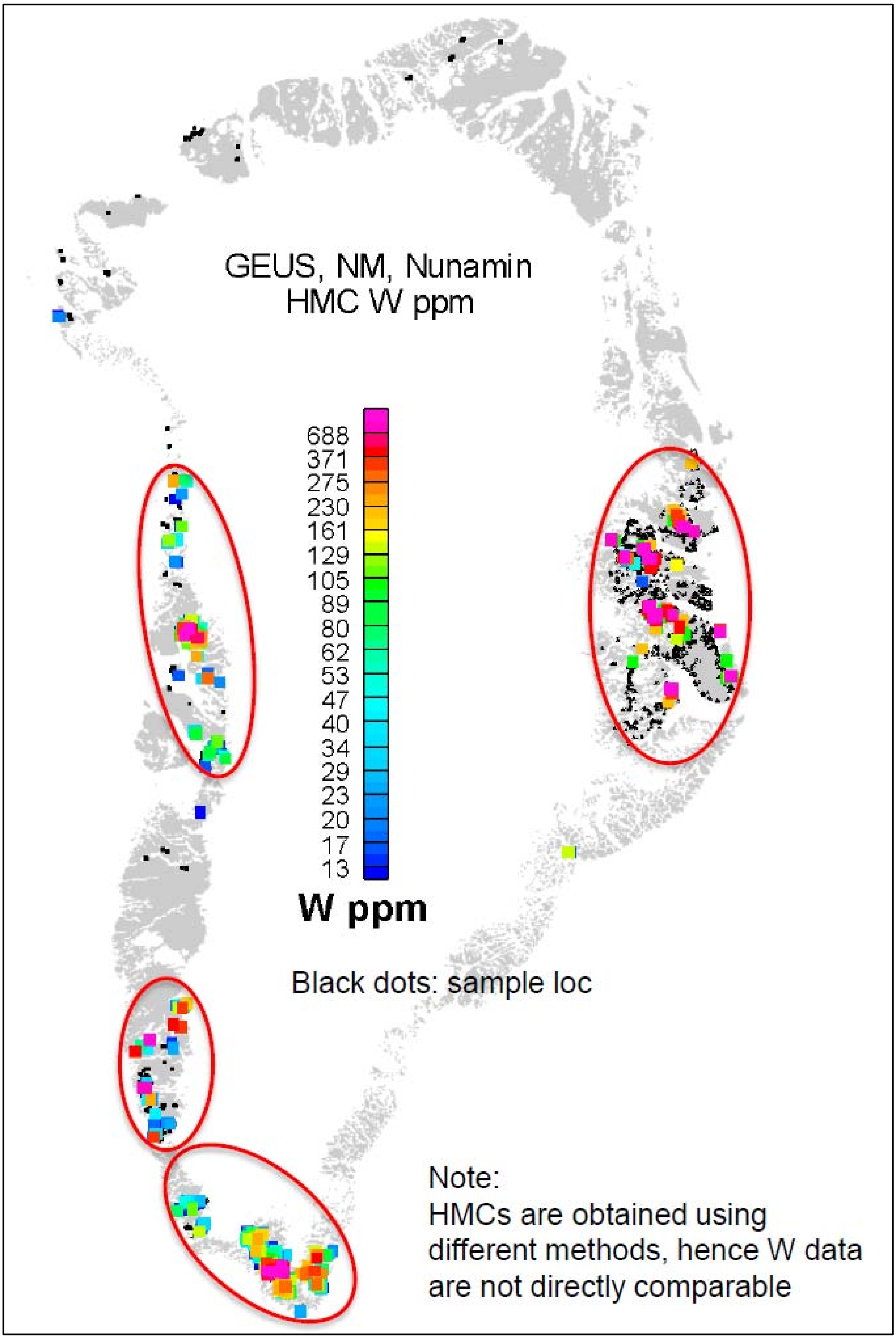

Figure 2. *Heavy Mineral Concentrate (HMC) sample localities collected by GEUS, Nordisk Mineselskab A/S NunaMinerals A/S. Red ellipses mark areas that are highly anomalous in tungsten. From Steenfelt's (2013) tungsten workshop* presentation – *see CD-ROM in appendix C.*

Tract delineation

Tracts, with potential of hosting non-discovered tungsten deposits were delineated by an internal GEUS assessment group prior to the workshop. Considering that the specific type of tungsten deposit to form is controlled by local features, rather than the regional framework guiding tract delineation, the outline of the proposed tracts is identical for both deposit types that were assessed.

The tract proposals covered areas with geological settings found to be permissive to host tungsten deposits. These include the presence or inference of suitable granitic intrusions, the existence of anomalous W concentrations in stream sediment samples and heavy mineral concentrates or, whenever available, the presence of scheelite in heavy mineral concentrates.

Considering the lack of information on the presence of hidden granitic intrusions a 20 km-wide buffer was applied surrounding outcropping granitic intrusions. The obtained areas were subsequently grouped together within larger tracts, considering similarities in known granite ages and geochemistry.

In the course of the workshop, some of the tracts proposed by the internal GEUS assessment group, were modified according to the consensus view of the assessment panel team, 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. An overview of the final defined tracts can be found on figures 3 & 4.

Tungsten Tracts

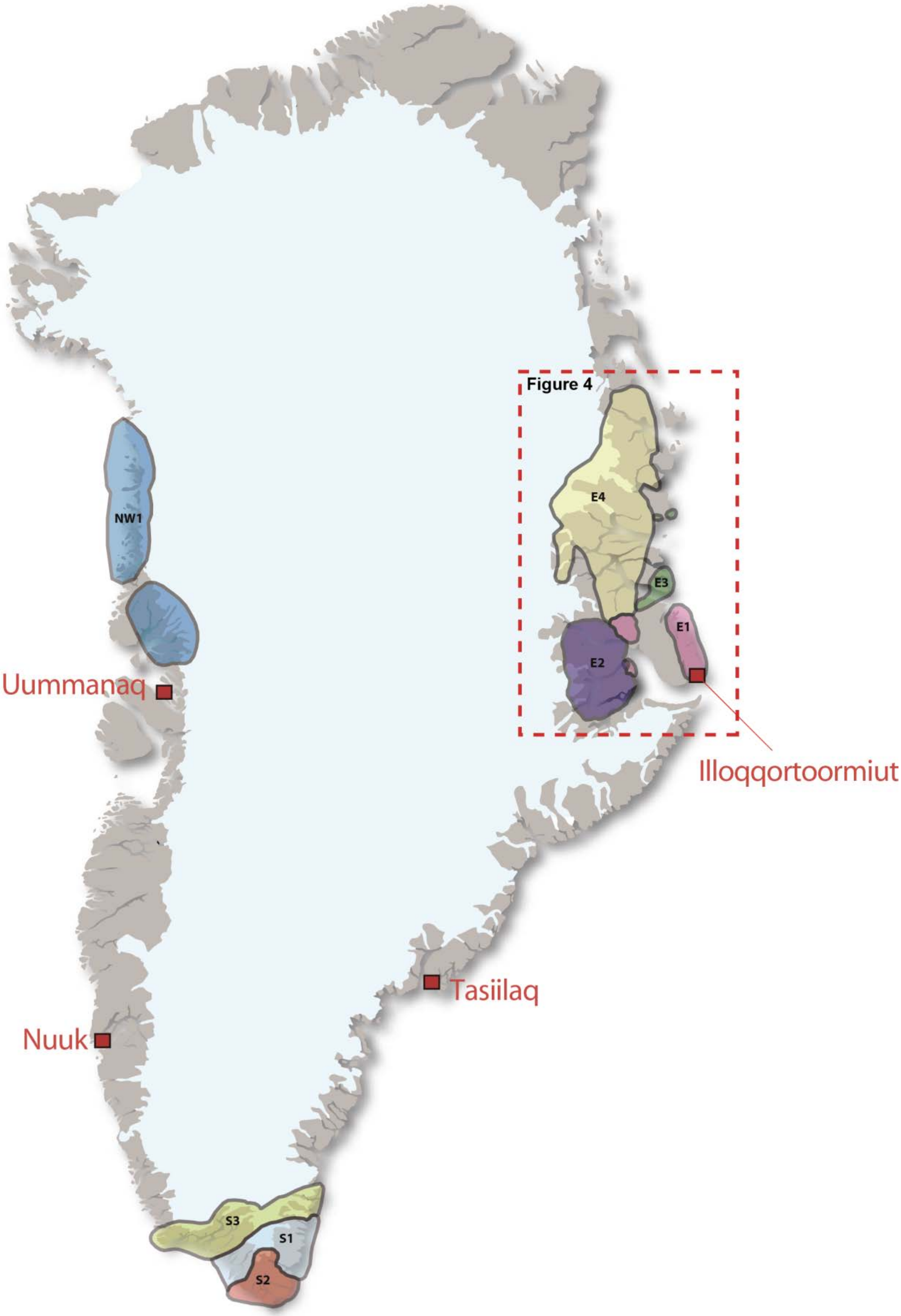

Figure 3. *Overview of the assessed tract groups. See figure 4 for a close-up of the insert map of central East Greenland.*

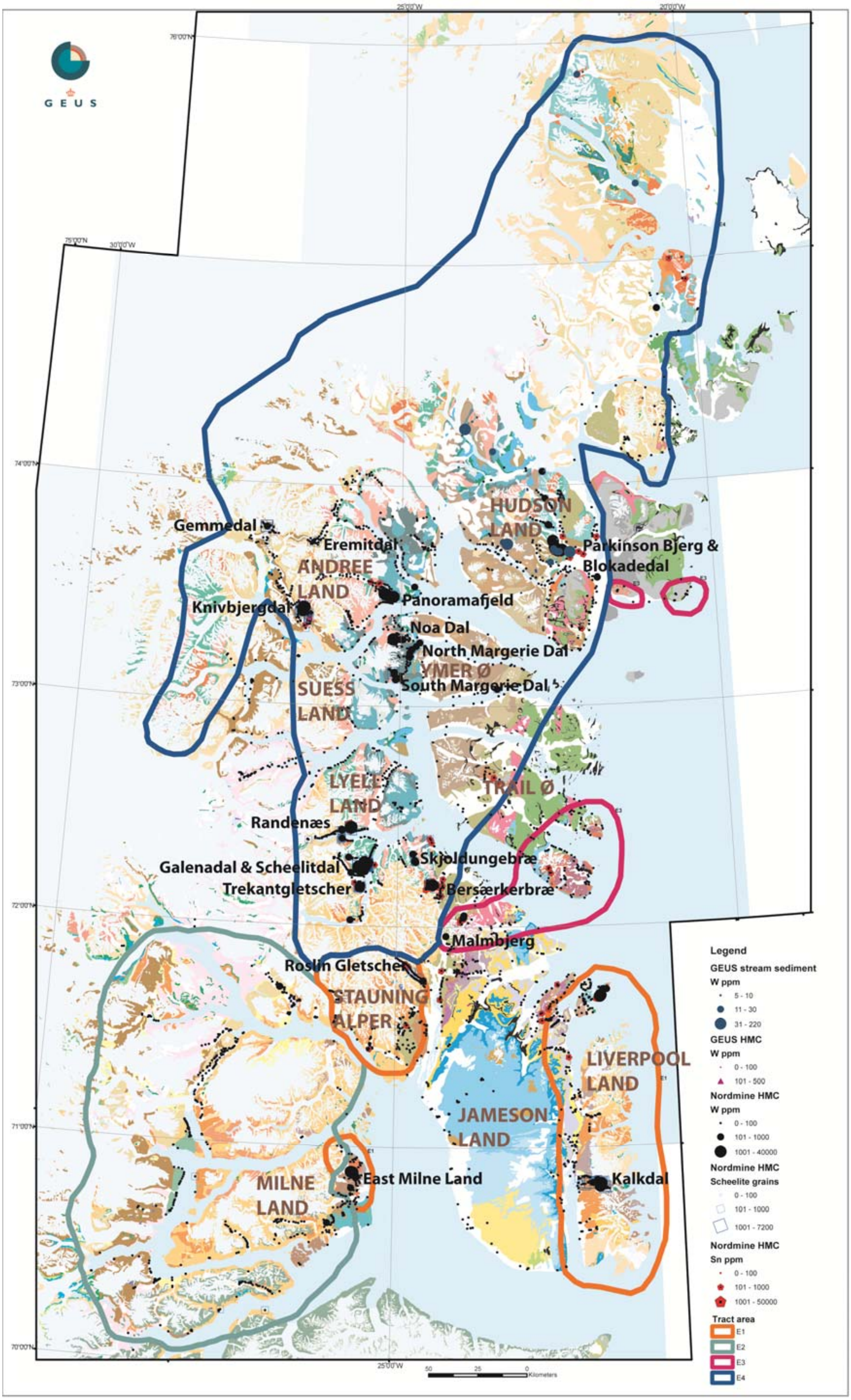
GEUS
Gemmedal
Eremitdal
ANDREE LAND
Knivbjergdal
Panoramafjeld
HUDSON LAND
Parkinson Bjerg & Blokadedal
Noa Dal
North Margerie Dal
YMER Ø
South Margerie Dal
SUESS LAND
LYELL LAND
TRAIL Ø
Randenæs
Galenadal & Scheelitdal
Trekantgletscher
Skjoldungebræ
Bersærkerbræ
Malmbjerg
Roslin Gletscher
STAUNING ALPER
LIVERPOOL LAND
JAMESON LAND
MILNE LAND
East Milne Land
Kalkdal
Legend
GEUS stream sediment
W ppm
5 - 10
11 - 30
31 - 220
GEUS HMC
W ppm
0 - 100
101 - 500
Nordmine HMC
W ppm
0 - 100
101 - 1000
1001 - 40000
Nordmine HMC
Scheelite grains
0 - 100
101 - 1000
1001 - 7200
Nordmine HMC
Sn ppm
0 - 100
101 - 1000
1001 - 50000
Tract area
E1
E2
E3
E4

Figure 4 (previous page). *Geological map of central East Greenland showing the location of the E1–E4 tracts and selected tungsten-mineralised areas. Geochemical anomalies of W, Sn and scheelite grains in pan samples (HMC) and from stream sediment samples collected by GEUS and Nordisk Mineselskab A/S are also included on the map. For legend please refer to* http://data.geus.dk/map2/geogreen/G500_Legend.pdf

Grade/tonnage models used

Grade/tonnage models were obtained through the compilation of published data from known deposits that are formed through the same genetic process and can be mined and processed using similar methods, considering careful aggregation procedures. The models are used as input to the estimation of undiscovered tungsten endowment for the different tracts and deposits models.

As seen on table 2, grade/tonnage and total resource depend on the deposit type. The skarn deposits tend to be larger but lower grade than the vein-type deposits. The data compilations are available in Appendix A and included on the CD-ROM accompanying this report.

Table 2. *Worldwide summary statistics for the mean tonnage and grade for tungsten deposits. Based on data from Cox (1986) and Cox & Bagby (1986).*

Deposit type means	Tonnage ore metric tons	Tungsten grade WO_3 %	Number of deposits
W vein	560,000	0.91	16
W skarn	1,100,000	0.67	28

Assessment panel

At the workshop, the estimation of the number of undiscovered deposits within each tract was done by an assessment panel that included twelve geologists from the USGS, GEUS, MIM, and exploration companies, each of whom have knowledge on aspects of Greenland geology and/or expertise on tungsten deposits. The following persons were part of the assessment panel:

- Bo M. Stensgaard (GEUS)
- Diogo Rosa (GEUS)
- Henrik Stendal (MIM)
- John Pedersen (Private consultant)
- Jorge Valente (Colt Resources)
- Kirsten Rasmussen (Ph.D. UBC)
- Lawrence D. Meinert (USGS)
- Martin Ghisler (GEUS)

- Peter Appel (GEUS)
- Peter Pollard (Pollard Geological Services Pty. Ltd.)
- Søren L. Jensen (Scandinavian Highlands)
- Thomas Kokfelt (GEUS)

Key literature

Key literature on the deposit models covered by this assessment and on the assessment procedure, as well as the initial tract proposals, was forwarded to the team members prior to the workshop. The full bibliography is available in Appendix B.

Workshop presentations

At the workshop, presentations on the assessment procedure, deposit models and regional geology were given by selected speakers. This constituted an opportunity to review the important facts, before providing individual estimates. The presentations of this review are listed in Appendix C and included as PDF files on the CD-ROM accompanying this report.

Process at the Workshop

The first day of the workshop was used to present and discuss the tungsten deposit types subject to assessment. Additionaly, presentations and discussions were held to ensure that the assessment panel had a common understanding of the premises for the evaluation procedures. Subsequently, the assessment panel assessed the deposit models one at a time. Each assessment was started with presentations on the tract distribution, their regional geological framework, and the known tungsten occurrences and exploration history.

Following the pertinent presentations and discussions of the information/data available, the tract outline was discussed and the outline was then, based on a decision of the assessment panel, either kept or changed.

Each of the panel members was subsequently asked to provide independent estimates on how many deposits of median size and grade would be possible to find in the various 'tracts', under the best possible circumstances, in the uppermost 1 km of the crust. Each expert independently estimated the number of undiscovered deposits at the 90%, 50%, 10%, 5% and 1% probability levels. Subsequent to the discussions, and the opportunity for panel members to adjust their estimate, a consensus bid was obtained for each tract.

After the workshop, each of the consensus bids was used as input for a series of Monte Carlo simulations. This was achieved by using the EMINERS software (Duval 2012, Bawiec & Spanski 2012), which combines the probability distributions of the estimated number of undiscovered deposits, the grades, and the tonnages of the selected models to obtain the probability distribution of ore and metal tonnages in undiscovered deposits within each tract.

Known prospects, mineral occurrences or related deposit types

East Greenland potential

The following description of the East Greenland potential is derived from Hallenstein & Pedersen (1983). Numerous scheelite-mineralised areas have been found in a 350 km long belt in central East Greenland. Outcropping scheelite occurrences are thus known from at least 12 areas with footprints varying from 1 to 20 km^2 in size, and scheelite-bearing boulders have been located in another two areas. The location of all areas is indicated on the map on page 13 (figure 4). It is possible to divide the scheelite-mineralised areas into three groups on account of their geological setting. The groups and their respective areas are as follows:

- Scheelite mineralisation in Upper Proterozoic metasediments, often spatially associated with Caledonian or older granitic intrusions. The areas assigned to this group are **Kalkdal**, East Milne Land, **Knivbjergdal**, Gemmedal and Eremitdal.

- Scheelite mineralisation in the Lower EBG sediments, up to 7 km from outcropping Caledonian granites. The areas of this group comprise Bersærkerbræ, Skjoldungebræ, **Trekantgletscher, Galenadal & Scheelitdal** and Randenæs.

- Scheelite mineralisation in fault zones in Upper EBG sediments without spatial relation to granitic rocks. The areas of this group comprise **North and South Margerie Dal on Ymer Ø**, Panoramafjeld & Eleonores Bugt and Noa Dal.

The areas in bold are further described in the following section:

Kalkdal (Part of the E1-tract)
Kalkdal is an EW-trending valley in Liverpool Land with several scheelite mineralisations occurring within a 20 km^2 area of the valley. The geology of Kalkdal comprises ESE-striking metasediments intruded by pinkish biotite granite in the west and grey foliated granodiorite in the east. The metasediments are dominated by biotite-hornblende-garnet schist and paragneiss, with some dolomitic marble beds and amphibole gneiss. Skarn has developed in marble when in contact with granodiorite and in a marble horizon several kilometres from outcropping intrusive rocks. Skarn does not occur at granite-marble contacts.

Scheelite mineralisation in Kalkdal has been located in the skarns and in a few pegmatite and quartz veins which cut the skarns. Tungsten contents in hand-sized samples may reach 1%, but the overall content of the skarn is less than 100 ppm. The scheelite is molybdeniferous. Lenses of molybdenum-free scheelite mineralisation, up to several metres long, occur in the skarn, and are accompanied by sericitisation of plagioclase and scapolite. The lenses contain up to 2% W, but the tungsten content of the entire skarn is less than 500 ppm. The scheelite-bearing skarn are enriched in lithium (up to 100 ppm) and beryllium (up to 100 ppm).

Alpefjord (Scheelitdal, Galenadal and Trekantgletscher) (Part of the E4-tract)

Scattered scheelite mineralisation has been located along 15 km of the west coast of Alpefjord. The geological setting of this area comprises quartzitic sediments of the Nathorst Land Group of the Lower EBS (Neoproterozoic) and Caledonian intrusive granites. Scheelite mineralisations are known from the following localities:

- **Trekantgletscher**, at the contact of the lowermost-preserved sediments of the Lower EBS and granite in the south of the area and at Scheelitdal and Galenadal which respectively are 1 km and 3 km stratigraphic higher than the sediments at Trekantgletscher, and which are 5 to 7 km east of the outcropping granite. At Trekantgletscher, scheelite occurs in centimetre- to metre-dimensioned lenses of contact metamorphosed calcareous quartzite – the skarnoid rocks. The lenses are often zoned, with an approximately 1 cm thick, greenish hornblende-diopside-clinozoisite rim and a calcareous core usually dominated by garnet-hornblende skarnoid. The garnet-hornblende skarnoid comprises quartz, grossularite, diopside, hornblende, clinozoisite, plagioclase, scapolite and calcite. Most scheelite occurs in the garnet-hornblende skarnoid. Tungsten contents of grab samples vary from 0.1 to 0.8% W. The average content of an entire skarnoid lens is only a few hundred ppm tungsten. The skarnoids are also enriched in beryllium (300 ppm), tin (200 ppm) and bismuth (100 ppm).

- At **Scheelitdal/Galenadal**, scheelite is associated with concordant quartz veins. The veins are from fifty to several hundred metres apart, are up to 3 m thick, and can be followed for up to 500 m. In addition to coarsegrained quartz, the veins contain coarsegrained arsenopyrite and rare scheelite as centimetre large idiomorphic crystals. The scheelite occurs near the contact to the wall rocks. In an approximately 5 km^2 area south of Scheelitdal/Galenadal, quartz veins and fracture zones are mineralised with arsenopyrite and scheelite. The mineralised veins and fracture zones occupy 1 to 2% of the volume of the sediments. At one locality, more intense scheelite mineralisation has been located in 2 to 6 m wide, E–W-striking quartz-vein swarms. The swarms are not continuously exposed, but it appears as if one continues for 800 m along its strike. Detailed field observations of the swarms have revealed the existence of several generations of quartz veins. The oldest veins contain most of the scheelite, whereas arsenopyrite, galena, chalcopyrite, pyrrhotite and bismuthinite occur in the youngest veins. Systematic sampling of the vein swarms indicates an average content of 0.1% W and 0.2% As.

North and South Margerie Dal on Ymer Ø (Part of the E4-tract)

Geochemical anomalies for tungsten and antimony were identified in the streams of west Ymer Ø in the mid-seventies by Nordisk Mineselskab A/S. Subsequent exploration from 1979–1983 located small, high-grade scheelite and stibnite lenses. Initial drilling revealed approx. 75,000 tons @ 2.5% WO_3 at South Margerie Dal, and 42,000 tons @ 0.7% WO_3 + 108,000 tons with 3.5% Sb at North Margerie Dal. Since 2008, the Greenlandic exploration company, NunaMinerals A/S, has made additional investigations on Ymer Ø, including geochemical sampling and airborne magnetic and electromagnetic surveys to identify possible new targets.

Margerie Dal is a 20 km long, NNE-striking valley on west Ymer Ø. Scheelite mineralisation is known in two areas, North and South Margerie Dal – about 12 km from each other. In Margerie Dal, Upper EBS sediments of the Ymer Ø Group are cut by large EW-striking faults, over 10 km long and with throws of 100 to 1000 m. The northern blocks are generally downthrown. Many second-order faults, up to a few hundred metres long, branch off the main faults. The throws of the second-order faults are up to 100 m, but diminish away from the main faults. The sediments of Margerie Dal form part of the easterly dipping flank of an open anticline. On the structural contour map, it can be seen that the anticline forms a dome culmination on west Ymer Ø.

Mineralisation in North and South Margerie Dal occurs in the 100 m thick, lowermost limestone unit of the Upper EBS as veins in second-order structures. In North Margerie Dal, the largest vein contains both scheelite and stibnite in a breccia zone striking 80° and dipping 75°N.

Stibnite predominates in the 65 m of the breccia zone nearest the main fault. It occurs as decimetre-thick massive veins and as thin veinlets in the hanging wall of the breccia zone in the limestone.

Scheelite has been observed in the brecciated limestone of this 65 m long zone, but only as scattered grains. West of the stibnite-dominated zone, the brecciated limestone is mineralised along strike for 110 m, mostly with scheelite, but also with stibnite. Sampling of the entire 110 m long zone indicates contents of 0.8% W and 2.4% Sb with a thickness averaging 3 m. Dolomitisation and silicification of the limestone are also present in the breccia zone.

Several other mineralised lenses occur in an overlying limestone unit up to 40 m north of the main fault. They are up to 1 m thick, 10 to 15 m long and contain about 1% W but no antimony. The tungsten (scheelite) occurs as breccia fillings in second-order fault structures. Similar small scheelite-mineralised lenses have been located in second-order structures in the overlying limestone approximately 200 m east of the main mineralisation.

The main mineralisation of South Margerie Dal is in a vein in an ENE-striking breccia zone, dipping 80°N, and without any noticeable amount of displacement. The zone is up to 3 m wide and can be followed from the bottom to the top of the 100 m thick, lowermost limestone unit. Scheelite occurs as breccia fillings in the limestone, and is particularly concentrated in the breccia zone in the lower half of the unit. The tungsten content averages nearly 3% over an average width of 2.5 m. Dolomitisation and silicification are pronounced and correlate well with the distribution of scheelite.

According to Pedersen & Stendal (1987) the mineralising event on Ymer Ø was contemporaneous with folding and faulting during the Caledonian orogeny. Basemetal and silver mineralisation occurs at the base of a 1500-m stratigraphic sequence and antimony-gold-tungsten mineralisation is found further up the succession. High-grade scheelite mineralisation is associated with the first major appearance of carbonaceous limestone, and high-grade stibnite is hosted in the overlying evaporitic shale-dolomite member.

Precipitation of the ore-forming fluids took place at temperatures of 170-240°C from saline solutions with 2-6 wt% NaCl equivalent. The origin of the hydrothermal solutions may have been either igneous or metamorphic; the fluids were probably channelled to the surface along deepseated NNW-SSE-striking structures.

South Greenland potential

Based on the regional geology and the distribution of tungsten stream sediment anomalies, it was decided to divide South Greenland into three different tracts S1–S3.

The S1 tract corresponds to a transitional zone between tracts S2 and S3, within the Ketilidian Mobile Belt (Palaeoproterozoic), characterised by the presence of both Julianehåb batholith and rapakivi intrusions. Several tungsten anomalies associated with gold and/or arsenic anomalies in stream sediments are present in the Nanortalik area which also hosts known gold ± arsenic ± tungsten occurrences. Additionally, the Nalunaq gold mine operated in this same area until 2013. It has been suggested that both tungsten and gold are related to an intrusion-related mineralisation continuum. This tract was considered to hold a moderate potential for tungsten vein deposits. In contrast, skarn-type deposits were considered to be insignificant, due to the absence of carbonate rocks. A typical hydrothermal element association within the batholith has been described as Au-Bi-W-Cu-Pb-(Mo) (Stendal & Frei 2000).

The S2 tract is centred on the southernmost Palaeoproterozoic rapakivi granitic intrusions of the Ketilidian Mobile Belt. These intrusions are mostly emplaced into the pelite zone, where no carbonate rocks are known. It was considered to have a limited potential for both tungsten vein and skarn deposits.

The S3 tract is centred on the northernmost part of the Palaeoproterozoic Julianehåb batholith of the Ketilidian Mobile Belt. This batholith is a large composite body, which has been deeply eroded. The tract also includes the alkaline Mesoproterozoic Gardar rift zone, to which some stream sediment tungsten anomalies, associated with uranium, appear to be related. Furthermore, no carbonate rocks are known in the area. No deposits are known, so it was not considered favourable. As a result, the tract was considered to have a limited potential for both tungsten vein and skarn deposits.

West Greenland potential

An area which stretches from Maarmorilik to Steenstrup Glacier in North-West Greenland with stream sediment tungsten anomalies is included in tract NW1. The NW1 tract includes the Proterozoic Prøven granite batholith which is intruded into the Karrat Group metasedimentary rocks (Palaeoproterozoic), including marbles and the basement. Pegmatites and anatectic melt veins are abundant on both sides of Prøven batholith. It appears however that the granite batholith has been intensively eroded, so that what is now exposed corresponds to its roots rather than its top, where the more favourable apical zone/cupolas would have been located. As a result, the tract was considered to have a limited potential for both tungsten vein and skarn deposits.

Assessment of W vein deposits

Descriptive model

W vein deposits deposits tend to be the high grade, yet low tonnage deposits. These can often also produce tin and, occasionaly, gold. The main W mineral is wolframite, which tends to occur in quartz veins, stockworks or breccias, in greisenized granitic and/or metasedimentray country rocks. The granitic magmas associated with this deposit type are derived from the remelting of continental crust (ilmenite series, volatile- and lithophile-rich S magmas) and these magmas should be emplaced as small granitic cupolas, rather than large baholiths. Representative deposits include Mount Carabine (Australia), Hemerdon (UK), Panasqueira (Portugal) and the Xihuashan deposits in China.

Tract distribution

The tracts were based on an extraction of granitic intrusions on the 1:500 000 scale geological map. These units were extracted as georeferenced polygons. Extensions to known intrusions or the presence of additional intrusions at depth is, however, possible elsewhere. Therefore, a buffer of 20 km was added around the extracted polygons and the resulting polygons were further grouped together within larger tracts, considering similarities in known granite ages and geochemistry, as well as comparable levels of knowledge/investigation (see figure 3/table 3).

Table 3. *Overview of the individual tracts that were assessed for vein type W deposits at the workshop.*

Tract name	Tract type	Tract size (km^2)	Tract area name	Comments
E1_V	**vein**	11,350	Liverpool Land, northeastern Milne Land and southern Scoresby Land, East Greenland	This tract includes the Kalkdal occurrence, with both skarn- and vein-type mineralisation
E2_V		24,900	Renland and southwestern and central Milne Land, East Greenland	
E3_V		4,110	Northeastern Scoresby Land, easternTraill Ø, and southern Hold with Hope; East Greenland	
E4_V		66,600	Northern Scoresby Land to Hochstetter Land; East Greenland	This tract includes the Alpefjord, Scheelitdal & Gale-nadal occurrences and the North and South Margerie Dal deposits on Ymer Ø
NW1_V		41,160	Maarmorilik to Steenstrup Glacier, North-West Greenland	
S1_V		16,420	South Greenland	
S2_V		10,290	South Greenland	
S3_V		22,960	South Greenland	

Individual tracts assessed during the workshop

E1_V Liverpool Land, northeastern Milne Land and southernScoresby Land, East Greenland

Peraluminous Caledonian and Devonian granites in this fragmented tract intrude Proterozoic gneisses and the Krummedal Sucession. Significant amounts of scheelite grains and concentrations of tungsten in heavy mineral concentrates have been identified. Futhermore, this tract includes the Kalkdal occurrence, with both skarn- and vein-type mineralisation.

Considering its relatively small extent, this tract was considered to hold a good potential for vein deposits.

Table 4. *Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for tract E1_V.*
[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). In cases where individual estimates were tallied in addition to the consensus estimate, individual estimates are listed]

Consensus undiscovered deposit estimates					Summary statistics					Tract Area (km^2)	Deposit density (N_{total}/km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}		
1	1	3	4	6	1.70	1.40	82.0	0	1.70	11,350	0.000150

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

Table 5. *Results of Monte Carlo simulations of undiscovered resources in tract E1_V. [T – metric tons, Mt – million metric tons]*

Material	Probability of at least the indicated amount						Probability of	
	0.95	0.9	0.5	0.1	0.05	Mean	Mean or greater	None
W (T)	0	350	14,000	100,000	150,000	33,000	0.27	0.06
Rock (Mt)	0	0	2	18	23	5	0.25	0.06

E2_V Renland and southwestern and central Milne Land, East Greenland

This large and contiguous tract is largelly unexplored but is known to include peraluminous Caledonian and Devonian granites intruding Proterozoic gneisses. The heavy mineral samples collected along its coastal areas failed, however, to yield significant amounts of scheelite grains or tungsten concentrations. Nevertheless, likely because of the lack of data from the unexplored large areas further inland, the tract was considered to hold a limited potential for W vein deposits.

Table 6. *Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for tract E2_V. For further details see text connected to table 4.*

Consensus undiscovered deposit estimates					Summary statistics					Tract Area (km^2)	Deposit density (N_{total}/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	0.41	24,900	0.000016

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

Table 7. *Results of Monte Carlo simulations of undiscovered resources in tract E2_V. [T – metric tons, Mt – million metric tons]*

Material	Probability of at least the indicated amount						Probability of	
	0.95	0.9	0.5	0.1	0.05	Mean	Mean or greater	None
W (T)	0	0	0	20,000	48,000	8,400	0.18	0.70
Rock (Mt)	0	0	0	3	6	1	0.18	0.70

E3-V Northeastern Scoresby Land, easternTraill Ø, and southern Hold with Hope, East Greenland

This scattered track was delineated around Paleogene felsic intrusions. These intrusions can be related to porphyry molybdenum occurrences or deposits, such as Malmbjerg. This deposit type can be related to W veins. However, the heavy mineral samples collected failed to yield significant amounts of scheelite grains or tungsten concentrations. As a result, only a limited potential for vein-type deposits was estimated.

Table 8. *Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for tract E3_V. For further details see text connected to table 4.*

Consensus undiscovered deposit estimates					Summary statistics					Tract Area (km^2)	Deposit density (N_{total}/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	0.41	4,110	0.000099

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

Table 9. *Results of Monte Carlo simulations of undiscovered resources in tract E3_V. [T – metric tons, Mt – million metric tons]*

Material	Probability of at least the indicated amount						Probability of	
	0.95	0.9	0.5	0.1	0.05	Mean	Mean or greater	None
W (T)	0	0	0	20,000	42,000	7,900	0.18	0.70
Rock (Mt)	0	0	0	3	6	1	0.17	0.70

E4_V Northern Scoresby Land to Hochstetter Land, East Greenland

This large tract, with peraluminous Caledonian and Devonian granite intrusions intruding mostly the Eleonore Bay Supergroup metasedimentary rocks, was well explored by Nordmine (Harpøth et al, 1986). It includes the Alpefjord, Scheelitdal & Galenadal occurrences and the North and South Margerie Dal deposits on Ymer Ø. The latter constitutes deposits that have been drilled, and the proven resources have been included in the grade and tonnage model statistics (Table 10). Collected heavy mineral samples often contain significant amounts of scheelite grains and/or tungsten concentrations.

As a result of its large size and positive signs, including known occurrences, this tract was ranked the most favourable for vein-type deposits.

Table 10. *Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for tract E4_V. For further details see text connected to table 4.*

Consensus undiscovered deposit estimates					Summary statistics					Tract Area (km^2)	Deposit density (N_{total}/km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}		
4	6	8	12	15	6.10	2.80	46.0	1	7.10	66,600	0.000110

Estimator	Estimated number of undiscovered deposits				
	N90	N50	N10	N05	N01
Individual 1	4	8	12	16	20
Individual 2	4	8	10	12	16
Individual 3	2	4	6	9	12
Individual 4	6	8	12	18	25
Individual 5	0	1	2	3	5
Individual 6	6	12	15	18	20
Individual 7	1	4	5	8	10
Individual 8	-	-	-	-	-
Individual 9	-	-	-	-	-
Individual 10	2	4	6	10	16
Individual 11	3	5	8	12	15
Individual 12	3	5	8	12	15
Consensus	**4**	**6**	**8**	**12**	**15**

Table 11. *Results of Monte Carlo simulations of undiscovered resources in tract E4_V. [T – metric tons, Mt – million metric tons]*

Material	Probability of at least the indicated amount						Probability of	
	0.95	0.9	0.5	0.1	0.05	Mean	Mean or greater	None
W (T)	12,000	24,000	100,000	260,000	320,000	130,000	0.40	0.02
Rock (Mt)	1	3	14	38	49	18	0.42	0.02

NW1_V Maarmorilik to Steenstrup Glacier, Northwest Greenland

This tract includes the Proterozoic Prøven granite batholith intruding the Karrat Group metasedimentary rocks. Pegmatites and anatectic melt veins are abundant on both sides of Prøven batholith. It appears however that the granite batholith has been intensily eroded, so that what is now exposed corresponds to its roots rather than its top, where the more favourable cupolas would have been located. As a result, this tract ranked the worst in terms of vein deposits.

Table 12. *Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for tract NW1_V. For further details see text connected to table 4.*

Consensus undiscovered deposit estimates					Summary statistics					Tract Area (km^2)	Deposit density (N_{total}/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	41,160	0.000003

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

Table 13 *Results of Monte Carlo simulations of undiscovered resources in tract NW1_V. [T – metric tons, Mt – million metric tons]*

Material	Probability of at least the indicated amount						Probability of	
	0.95	0.9	0.5	0.1	0.05	Mean	Mean or greater	None
W (T)	0	0	0	0	7,500	4,500	0.06	0.93
Rock (Mt)	0	0	0	0	1	1	0.06	0.93

S1_V South Greenland

This tract corresponds to a transitional zone between tracts S2 and S3, within the Ketilidian Fold Belt, characterized by the presence of both Julianehåb batholith and rapakivi intrusions. Several tungsten stream sediment anomalies, associated with gold and/or arsenic anomalies and occurrences, have been identified north of Nanortalik. Additionaly, the Nalunaq gold mine operated in this same area until 2013. It has been suggested by Stendal & Frei 2000 that both tungsten and gold are related to an intrusion-related mineralisation continuum. As such, this tract was considered to hold a moderate potential for tungsten vein deposits.

Table 14. *Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for tract S1_V. For further details see text connected to table 4.*

Consensus undiscovered deposit estimates					Summary statistics					Tract Area (km^2)	Deposit density (N_{total}/km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}		
0	1	3	4	5	1.40	1.50	110.0	0	1.40	16,420	0.000086

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

Table 15. *Results of Monte Carlo simulations of undiscovered resources in tract S1_V. [T – metric tons, Mt – million metric tons]*

Material	Probability of at least the indicated amount						Probability of	
	0.95	0.9	0.5	0.1	0.05	Mean	Mean or greater	None
W (T)	0	0	9,100	90,000	140,000	28,000	0.27	0.30
Rock (Mt)	0	0	1	16	22	4	0.25	0.30

S2_V South Greenland

This tract is centered on the southernmost Paleoproterozoic rapakivi granitic intrusions of the Ketilidian Fold Belt. It was considered to have a limited potential for W vein deposits.

Table 16. *Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for tract S2_V. For further details see text connected to table 4.*

Consensus undiscovered deposit estimates					Summary statistics					Tract Area (km^2)	Deposit density (N_{total}/km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}		
0	0	1	1	2	0.33	0.62	190.0	0	0.33	10,290	0.000032

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

Table 17. *Results of Monte Carlo simulations of undiscovered resources in tract S2_V. [T – metric tons, Mt – million metric tons]*

Material	Probability of at least the indicated amount						Probability of	
	0.95	0.9	0.5	0.1	0.05	Mean	Mean or greater	None
W (T)	0	0	0	17,000	36,000	7,100	0.17	0.70
Rock (Mt)	0	0	0	2	5	1	0.17	0.70

S3_V South Greenland

This tract is centered on the northernmost part of the Late Paleoproterozoic Julianehåb batholith of the Ketilidian Fold Belt. This batholith is a large composite body, which has been deeply eroded.

The tract also includes the alkaline Mesoproterozoic Gardar rift zone, to which some W stream sediment anomalies, associated with U anomalies, appear to be related. However, no deposits are known in this type of setting, so it was not considered favorable.

As a result, the tract was considered to have a limited potential for W vein deposits.

Table 18. *Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for tract S1_V. For further details see text connected to table 4.*

Consensus undiscovered deposit estimates					Summary statistics					Tract Area (km^2)	Deposit density (N_{total}/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	0.41	22,960	0.000018

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

Table 19. *Results of Monte Carlo simulations of undiscovered resources in tract S3_V. [T – metric tons, Mt – million metric tons]*

Material	Probability of at least the indicated amount						Probability of	
	0.95	0.9	0.5	0.1	0.05	Mean	Mean or greater	None
W (T)	0	0	0	19,000	47,000	8,100	0.18	0.70
Rock (Mt)	0	0	0	3	7	1	0.18	0.70

Assessment of W skarn deposits

Descriptive model

In contrast to the W vein deposits, the W skarn deposits tend to be lower grade but higher tonnage deposits. Their main W mineral is scheelite, which tends to occur in tabular or lenticular bodies within metasomatized marbles and calc-silicate hornfels, at variable distances to ilmenite or magnetite series granitic intrusions (endoskarns to exoskarns). Representative deposits include Mactung and Cantung (Canada), Sangdong (South Korea), and Tymyauz (Russia).

Tungsten skarn deposits are more reduced than their copper and zinc counterparts, reflecting reduced magmas and/or magmas that become reduced as they are emplaced in carbonaceous rocks at high depths. This affects the type of iron sulphide present (pyrrhotite > pyrite), silicate ratios (pyroxene > garnet), and mineral chemistry (ferric garnet, iron-rich and magnesium poor pyroxene).

Tract distribution

As stated above, considering that the specific type of tungsten deposit to form is controlled by local features, rather than the regional framework guiding tract delineation, the proposed tracts and their outlines is identical to those put forward for the W vein-type deposits.

Table 20. *Overview of the individual tracts that were assessed for skarn type W deposits at the workshop.*

Tract name	Tract type	Tract size (km^2)	Tract area name	Comments
E1_S	**skarn**	11,350	Liverpool Land, northeastern Milne Land and southern Scoresby Land, East Greenland	This tract includes the Kalkdal occurrence, with both skarn- and vein-type mineralisation
E2_S		24,900	Renland and southwestern and central Milne Land, East Greenland	
E3_S		4,110	Northeastern Scoresby Land, easternTraill Ø, and southern Hold with Hope; East Greenland	
E4_S		66,600	Northern Scoresby Land to Hochstetter Land; East Greenland	This tract includes the Knivbjergdal & Trekantgletcher occurrences
NW1_S		41,160	Maarmorilik to Steenstrup Glacier, North-West Greenland	
S1_S		16,420	South Greenland	
S2_S		10,290	South Greenland	
S3_S		22,960	South Greenland	

Individual tracts assessed during the workshop

E1_S Liverpool Land, northeastern Milne Land and southernScoresby Land, East Greenland

Peraluminous Caledonian and Devonian granites in this tract intrude Paleoproterozoic gneisses and the Mesoproterozic Krummedal Sucession. Significant amounts of scheelite grains and concentrations of tungsten in heavy mineral concentrates have been identified. Futhermore, this tract includes the Kalkdal occurrence, with both skarn- and vein-type mineralisation.

Considering its relatively small extent, this tract was considered to hold a good potential for skarn deposits, even more so than for vein deposits.

Table 21. *Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for tract E1_S. For further details see text connected to table 4.*

Consensus undiscovered deposit estimates					Summary statistics					Tract Area (km^2)	Deposit density (N_{total}/km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}		
1	2	4	5	7	2.40	1.70	70.0	0	2.40	11,350	0.000210

Estimator	Estimated number of undiscovered deposits				
	N90	N50	N10	N05	N01
Individual 1	1	2	3	4	5
Individual 2	0	1	2	3	4
Individual 3	0	1	2	3	5
Individual 4	0	1	3	5	8
Individual 5	1	2	4	5	6
Individual 6	4	8	12	15	20
Individual 7	0	0	1	2	3
Individual 8	-	-	-	-	-
Individual 9	-	-	-	-	-
Individual 10	0	0	1	2	4
Individual 11	1	4	6	8	12
Individual 12	1	1	2	3	4
Consensus	**1**	**2**	**4**	**5**	**7**

Table 22. *Results of Monte Carlo simulations of undiscovered resources in tract E1_S. [T – metric tons, Mt – million metric tons]*

Material	Probability of at least the indicated amount						Probability of	
	0.95	0.9	0.5	0.1	0.05	Mean	Mean or greater	None
W (T)	0	300	28,000	240,000	360,000	82,000	0.28	0.07
Rock (Mt)	0	0	4	39	53	12	0.29	0.07

E2_S Renland and southwestern and central Milne Land, East Greenland

This large and contiguous tract is largelly unexplored but is known to include peraluminous Caledonian and Devonian granites intruding Paleoproterozoic gneisses. The heavy mineral samples collected along its coastal areas failed, however, to yield significant amounts of scheelite grains or tungsten concentrations. Nevertheless, likely because of the lack of data from the large areas further inland, the tract was considered to hold a limited potential for W skarn deposits, similarly to what was established for vein-type deposits.

Table 23. *Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for tract E2_S. For further details see text connected to table 4.*

Consensus undiscovered deposit estimates					Summary statistics					Tract Area (km^2)	Deposit density (N_{total}/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	0.41	24,900	0.000016

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

Table 24. *Results of Monte Carlo simulations of undiscovered resources in tract E2_S. [T – metric tons, Mt – million metric tons]*

Material	Probability of at least the indicated amount						Probability of	
	0.95	0.9	0.5	0.1	0.05	Mean	Mean or greater	None
W (T)	0	0	0	23,000	75,000	14,000	0.13	0.70
Rock (Mt)	0	0	0	4	12	2	0.13	0.70

E3-S Northeastern Scoresby Land, easternTraill Ø, and southern Hold with Hope; East Greenland

This scattered track was delineated around Paleogene felsic intrusions. These intrusions can be related to porphyry molybdenum occurrences or deposits, such as Malmbjerg. However, this corresponds to an environment that is too shallow and, therefore, too oxidized to generate W skarns. As a result, this tract potential for skarn-type deposits was considered negligible.

Table 25. *Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for tract E3_S. For further details see text connected to table 4.*

Consensus undiscovered deposit estimates					Summary statistics					Tract Area (km^2)	Deposit density (N_{total}/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	0.03	4,110	0.000007

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

Table 26. *Results of Monte Carlo simulations of undiscovered resources in tract E3_S. [T – metric tons, Mt – million metric tons]*

Material	Probability of at least the indicated amount						Probability of	
	0.95	0.9	0.5	0.1	0.05	Mean	Mean or greater	None
W (T)	0	0	0	0	0	980	0.03	0.97
Rock (Mt)	0	0	0	0	0	0	0.02	0.97

E4_S Northern Scoresby Land to Hochstetter Land; East Greenland

This large tract, with peraluminous Caledonian and Devonian granite intrusions intruding mostly the Neoproterozoic Eleonore Bay Supergroup metasedimentary rocks, was well explored by Nordmine (Harpøth et al., 1986). It includes the Knivbjergdal & Trekantgletcher occurrences. Collected heavy mineral samples often contain significant amounts of scheelite grains and/or tungsten concentrations.

As a result of its large size and positive signs, including known occurrences, this tract was ranked the most favourable for skarn-type deposits, albeit slightly less than for vein-type deposits.

Table 27. *Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for tract E4_S. For further details see text connected to table 4.*

Consensus undiscovered deposit estimates					Summary statistics					Tract Area (km^2)	Deposit density (N_{total}/km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}		
2	5	7	9	13	4.80	2.70	56.0	0	4.80	66,600	0.000073

Estimator	Estimated number of undiscovered deposits				
	N90	N50	N10	N05	N01
Individual 1	2	4	6	8	10
Individual 2	2	4	6	8	10
Individual 3	1	2	4	6	8
Individual 4	6	10	15	20	30
Individual 5	0	1	2	3	5
Individual 6	6	12	15	18	20
Individual 7	1	2	3	5	6
Individual 8	-	-	-	-	-
Individual 9	-	-	-	-	-
Individual 10	2	4	6	10	15
Individual 11	2	4	6	8	12
Individual 12	2	4	6	8	10
Consensus	**2**	**5**	**7**	**9**	**13**

Table 28. *Results of Monte Carlo simulations of undiscovered resources in tract E4_S. [T – metric tons, Mt – million metric tons]*

Material	Probability of at least the indicated amount						Probability of	
	0.95	0.9	0.5	0.1	0.05	Mean	Mean or greater	None
W (T)	200	6,800	93,000	440,000	600,000	170,000	0.34	0.04
Rock (Mt)	0	1	15	64	79	25	0.36	0.04

NW1_S Maarmorilik to Steenstrup Glacier, Northwest Greenland

This tract includes the Proterozoic Prøven granite batholith intruding the Karrat Group metasedimentary rocks, including marbles. It appears however that the granite batholith has been intensily eroded, so that what is now exposed corresponds to its roots rather its favorable apical zone. As a result, this tract ranked among the lowest in terms of undiscovered skarn deposit potential.

Table 29. *Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for tract MW1_S. For further details see text connected to table 4.*

Consensus undiscovered deposit estimates					Summary statistics					Tract Area (km^2)	Deposit density (N_{total}/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	0.06	22,960	0.000003

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

Table 30. *Results of Monte Carlo simulations of undiscovered resources in tract NW1_S. [T – metric tons, Mt – million metric tons]*

Material	Probability of at least the indicated amount						Probability of	
	0.95	0.9	0.5	0.1	0.05	Mean	Mean or greater	None
W (T)	0	0	0	0	0	2,200	0.03	0.96
Rock (Mt)	0	0	0	0	0	0	0.04	0.96

S1_S South Greenland

This tract corresponds to a transitional zone between tracts S2 and S3, within the Ketilidian Fold Belt, characterized by the presence of both Julianehåb batholith and rapakivi intrusions. Several tungsten stream sediment anomalies, associated with gold anomalies and occurrences, have been identified north of Nanortalik. However, as discussed above, it was considered that these positive signs are indicative of the presence of vein-type deposits. In contrast, skarn-type deposits were considered to be insiignificant, due to the absence of carbonate rocks.

Table 31. *Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for tract S1_S. For further details see text connected to table 4.*

Consensus undiscovered deposit estimates					Summary statistics					Tract Area (km^2)	Deposit density (N_{total}/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	0.06	16,420	0.000004

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

Table 32. *Results of Monte Carlo simulations of undiscovered resources in tract S1_S. [T – metric tons, Mt – million metric tons]*

Material	Probability of at least the indicated amount						Probability of	
	0.95	0.9	0.5	0.1	0.05	Mean	Mean or greater	None
W (T)	0	0	0	0	0	2,300	0.03	0.96
Rock (Mt)	0	0	0	0	0	0	0.03	0.96

S2_S South Greenland

This tract is centered on the southernmost Paleoproterozoic rapakivi granitic intrusions of the Ketilidian Fold Belt. These intrusions are mostly emplaced into the pelite zone, where no carbonate rocks are known. As a result, the tract was ranked, together with tracts E3_S and S3_S, as the lowest in the terms of undiscovered skarn deposit potential.

Table 33. *Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for tract S2_S. For further details see text connected to table 4.*

Consensus undiscovered deposit estimates					Summary statistics					Tract Area (km^2)	Deposit density (N_{total}/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	0.03	10,290	0.000003

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

Table 34. *Results of Monte Carlo simulations of undiscovered resources in tract S2_S. [T – metric tons, Mt – million metric tons]*

Material	Probability of at least the indicated amount						Probability of	
	0.95	0.9	0.5	0.1	0.05	Mean	Mean or greater	None
W (T)	0	0	0	0	0	900	0.02	0.97
Rock (Mt)	0	0	0	0	0	0	0.02	0.97

S3_S South Greenland

This tract is centered on the northernmost part of Paleoproterozoic Julianehåb batholith of the Ketilidian Fold Belt. This batholith is a large composite body, which has been deeply eroded. Furthermore, no carbonate rocks are known in the area. As a result, the tract was ranked, together with tracts E3_S and S2_S, as the lowest in the terms of undiscovered skarn deposit potential.

Table 35. *Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for tract S3_S. For further details see text connected to table 4.*

Consensus undiscovered deposit estimates					Summary statistics					Tract Area (km^2)	Deposit density (N_{total}/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	0.03	22,960	0.000001

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

Table 36. *Results of Monte Carlo simulations of undiscovered resources in tract S3_S. [T – metric tons, Mt – million metric tons]*

Material	Probability of at least the indicated amount						Probability of	
	0.95	0.9	0.5	0.1	0.05	Mean	Mean or greater	None
W (T)	0	0	0	0	0	1,600	0.03	0.96
Rock (Mt)	0	0	0	0	0	0	0.03	0.96

Tungsten mineralisation in the Nuuk region

Stratabound mineralisation, as scheelite in tourmalinites and mafic metavolcanic rocks is known from Store Malene, Sermitsiaq, Storø and Ivisârtoq, in the Nuuk fjord (Appel, 1983). The similarities between these scheelite occurrences to what has been described at the Mittersill mine (Austria), drew some interest to them for a while, before the tungsten price collapse of the 80´s. At that time the prevailing view was that this type of occurrence is of syngenetic nature, formed after exhalative tungsten deposition in the sea floor. However, more recently, a number of authors working on Mittersill have been arguing that there is a link to granite fluids, the mineralisation is clearly epigenetic and its “stratabound” character results from subsequent deformation. The same could be the case for the tungsten occurrences of the Nuuk region, where there is a spatial association between mineralisation and the presence of pegmatites. In this case, the association of the mineralisation with pillow lavas, presented as an argument for its syngenetic origin, could instead simply result from their reactivity ensuring a previous carbonatisation event. As such, these occurrences should rather be compared to skarns.

The highest-grade tungsten occurrences are found in the Ivisaartoq area. Channel samples revealed grades of 0.44% WO_3 over 2.5 m and 0.48% WO_3 over 1.5 m. The scheelite-rich zones can be traced with intervals for more than 10 km along strike.

Regardless of the genesis of the tungsten mineralisation found in the Nuuk region, it is unlikely that it can be of economic interest due to their intermittency. Because of the uncertainty of the genesis of the stratabound tungsten mineralisation, the assessment panel decided not to assess the potential for undiscovered tungsten deposits. For more information on the tungsten occurrences in the Nuuk region please refer to Appel (1990).

Conclusions

In the course of the workshop a total of 8 tracts were assessed for undiscovered tungsten deposits, in strict accordance with the guidelines provided by the USGS. Each of these tracts was assessed for both W skarn and W vein deposit types, using their respective grade/tonnage models,

The statistical mean estimate number of undiscovered W vein deposits and of W skarn deposits if of 11 and 8, respectively. At a 50% probability, these are estimated to contain at least 244,000 tons of W.

Considering the scarce information available for most of the tracts, which is mainly because of logistical constraints of undertaking exploration in Greenland, the estimate on the number of deposits and their tungsten endowment can be considered significant. This warrants further exploration efforts which should focus on East Greenland.

Table 37. *Summary of assessment results including undiscovered deposit estimates, deposit numbers, tract area and deposit density for tracts.*

Tract name	Tract type	Tract Area (km2)	Consensus bid on number of undiscovered tungsten deposits at different confidence levels					Summary statistics			
			N90	N50	N10	N05	N01	Number of unknown deposits	Deposit density	Mean estimate of undiscovered tungsten resources [metric tons]	Rank
E1_V	vein	11,350	1	1	3	4	6	1.70	0.000150	33,000	2
E2_V		24,900	0	0	1	2	3	0.41	0.000016	8,400	4
E3_V		4,110	0	0	1	2	3	0.41	0.000099	7,900	6
E4_V		66,600	4	6	8	12	15	6.10	0.000110	130,000	1
NW1_V		41,160	0	0	0	1	3	0.14	0.000003	4,500	8
S1_V		16,420	0	1	3	4	5	1.40	0.000086	28,000	3
S2_V		10,290	0	0	1	1	2	0.33	0.000032	7,100	7
S3_V		22,960	0	0	1	2	3	0.41	0.000018	8,100	5
Total amount of undiscovered resources related vein-type tungsten deposits in Greenland (metric tons)										227,000	
E1_S	skarn	11,350	1	2	4	5	7	2.40	0.000210	82,000	2
E2_S		24,900	0	0	1	2	3	0.41	0.000016	14,000	3
E3_S		4,110	0	0	0	0	1	0.03	0.000007	980	7
E4_S		66,600	2	5	7	9	13	4.80	0.000073	170,000	1
NW1_S		41,160	0	0	0	0	2	0.06	0.000002	2,200	5
S1_S		16,420	0	0	0	0	2	0.06	0.000004	2,300	4
S2_S		10,290	0	0	0	0	1	0.03	0.000003	900	8
S3_S		22,960	0	0	0	0	1	0.03	0.000001	1,600	6
Total amount of undiscovered resources related skarn-type tungsten deposits in Greenland (metric tons)										273,980	

[NXX - Estimated number of deposits associated with the xxth percentile, Nund – expected number of undiscovered deposits, s – standard deviation, Cv% - coefficient of variance, Nknown – number of known deposits in the tract that are included in the grade and tonnage model, Ntotal – 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 km2. Nund, S, and Cv% are calculated using a regression equation (Singer and Menzie, 2005). In cases where individual estimates were tallied in addition to the consensus estimate, individual estimates are listed]

While the assessment process is formalised into models and methodology in order to reduce bias, and make these results comparable with those obtained elsewhere, the estimated total 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. New information, new discoveries, new investigations etc. within a tract should thus, whenever possible, be taken into account while evaluating an area, as this could either decrease or increase its estimated potential.

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References

Appel, P.W.U. 1983: Tungsten in the Godthåb area, West Greenland. In: Report of activities 1982. Grønlands Geologiske Undersøgelse Rapport 115, p. 59-63.

Appel, P.W.U. 1990: Tungsten mineralization in the Nuuk region, West Greenland. GGU Open File Series No. 90/4, 51 pp. (in archives of Geological Survey of Denmark and Greenland, GEUS Report File 20025)).

Bawiec, W.J., and Spanski, G.T. 2012: Quick-start guide for version 3.0 of EMINERS—Economic Mineral Resource Simulator: U.S. Geological Survey Open-File Report 2009–1057, 26 pp.

Cox, D.P. 1986: Descriptive model of W skarn deposits, in Cox, D.P., and Singer, D.A., eds., Mineral Deposit models: U.S. Geological Survey Bulletin 1693, p. 55-57

Cox, D.P. & Bagby, W.C. 1986: Descriptive model of W veins, in Cox, D.P., and Singer, D.A., eds., Mineral Deposit models: U.S. Geological Survey Bulletin 1693, p. 64-66

Duval, J.S. 2012: Version 3.0 of EMINERS—Economic Mineral Resource Simulator: U.S. Geological Survey Open-File Report 2004–1344.

Hallenstein, C.P. & Pedersen, J.L. 1983: Scheelite Mineralization in Central East Greenland.Mineralium Deposita 18, p. 315–333.

Harpøth, O., Pedersen, J.L., Schønwandt, H.K. & Thomassen, B. 1986: The mineral occurrences of central East Greenland. Meddelelser om Grønland, Geoscience 17, 139 pp.

Pedersen, J. & Stendal, H. 1987: Geology and geochemistry of tungsten-antimony vein mineralization on Ymer Ø, East Greenland. Transactions of the Institution of Mining and Metallurgy 96, B31–B36.

SIDEX 2002: Exploring for tungsten in Quebec. Strategic Diversification Newsletter, 4 pp.

Singer, D.A. 1993: Basic concepts in three-part quantitative assessments of undiscovered mineral resources: Nonrenewable Resources, v. 2, no. 2, p. 69-81.

Singer, D.A., and Menzie, W.D. 2005: Statistical guides to estimating the number of undiscovered mineral deposits: an example with porphyry copper deposits, in Cheng, Qiuming and Bonham-Carter, Graeme, eds., Proceedings of IAMG – The annual conference of the International Association for Mathematical Geology: Geomatics Research Laboratory, York University, Toronto, Canada, p. 1028–1033.

Singer, D.A., and Menzie, W.D. 2010: Quantitative mineral resource assessments: New York, Oxford University Press, 219 pp.

Stendal, H. & Frei, R. 2000: Gold occurrences and lead isotopes in Ketilidian Mobile Belt, South Greenland. Transactions of the Institution of Mining and Metallurgy Section B-Applied Earth Science 109, B6-B13.

Appendix A: Grade/tonnage data used in the assessment

Tract name	Tract type	Tract Area (km^2)	Consensus bid on number of undiscovered tungsten deposits at different confidence levels					Summary statistics					Deposit density (N_{total}/km^2)	Material	Probability of at least the indicated amount						Probability of	
			N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}			0,95	0,9	0,5	0,1	0,05	Mean	Mean or greater	None
E1_V	vein	11.350	1	1	3	4	6	1,70	1,40	82	0	1,70	0,000150	W(T)	0	350	14.000	100.000	150.000	33.000	0,27	0,06
														Rock (Mt)	0	0	2	18	23	5	0,25	0,06
E2_V	vein	24.900	0	0	1	2	3	0,41	0,82	200	0	0,41	0,000016	W(T)	0	0	0	20.000	48.000	8.400	0,18	0,70
														Rock (Mt)	0	0	0	3	6	1	0,18	0,70
E3_V	vein	4.110	0	0	1	2	3	0,41	0,82	200	0	0,41	0,000099	W(T)	0	0	0	20.000	42.000	7.900	0,18	0,70
														Rock (Mt)	0	0	0	3	6	1	0,17	0,70
E4_V	vein	66.600	4	6	8	12	15	6,10	2,80	46	1	7,10	0,000110	W(T)	12.000	24.000	100.000	260.000	320.000	130.000	0,40	0,02
														Rock (Mt)	1	3	14	38	49	18	0,42	0,02
NW1_V	vein	41.160	0	0	0	1	3	0,14	0,56	420	0	0,14	0,000003	W(T)	0	0	0	0	7.500	4.500	0,06	0,93
														Rock (Mt)	0	0	0	0	1	1	0,06	0,93
S1_V	vein	16.420	0	1	3	4	5	1,4	1,5	110	0	1,4	0,000086	W(T)	0	0	9.100	90.000	140.000	28.000	0,27	0,30
														Rock (Mt)	0	0	1	16	22	4	0,25	0,30
S2_V	vein	10.290	0	0	1	1	2	0,3	0,6	190	0	0,3	0,000032	W(T)	0	0	0	17.000	36.000	7.100	0,17	0,70
														Rock (Mt)	0	0	0	2	5	1	0,17	0,70
S3_V	vein	22.960	0	0	1	2	3	0,41	0,82	200	0	0,41	0,000018	W(T)	0	0	0	19.000	47.000	8.100	0,18	0,70
												11,90		Rock (Mt)	0	0	0	3	7	1	0,18	0,70
Total amount of undiscovered resources related vein-type tungsten deposits in Greenland (metric tons)																				227.000		
E1_S	skarn	11.350	1	2	4	5	7	2,40	1,70	70	0	2,40	0,000210	W(T)	0	300	28.000	240.000	360.000	82.000	0,28	0,07
														Rock (Mt)	0	0	4	39	53	12	0,29	0,07
E2_S	skarn	24.900	0	0	1	2	3	0,41	0,82	200	0	0,41	0,000016	W(T)	0	0	0	23.000	75.000	14.000	0,13	0,70
														Rock (Mt)	0	0	0	4	12	2	0,13	0,70
E3_S	skarn	4.110	0	0	0	0	1	0,03	0,24	810	0	0,03	0,000007	W(T)	0	0	0	0	0	980	0,03	0,97
														Rock (Mt)	0	0	0	0	0	0	0,02	0,97
E4_S	skarn	66.600	2	5	7	9	13	4,8	2,70	56	0	4,80	0,000073	W(T)	200	6.800	93.000	440.000	600.000	170.000	0,34	0,04
														Rock (Mt)	0	1	15	64	79	25	0,36	0,04
NW1_S	skarn	41.160	0	0	0	0	2	0	0	610	0	0	0,000002	W(T)	0	0	0	0	0	2.200	0,03	0,96
														Rock (Mt)	0	0	0	0	0	0	0,04	0,96
S1_S	skarn	16.420	0	0	0	0	2	0,06	0,37	610	0	0,06	0,000004	W(T)	0	0	0	0	0	2.300	0,03	0,96
														Rock (Mt)	0	0	0	0	0	0	0,03	0,96
S2_S	skarn	10.290	0	0	0	0	1	0,03	0,24	810	0	0,03	0,000003	W(T)	0	0	0	0	0	900	0,02	0,97
														Rock (Mt)	0	0	0	0	0	0	0,02	0,97
S3_S	skarn	22.960	0	0	0	0	1	0,03	0,24	810	0	0,03	0,000001	W(T)	0	0	0	0	0	1.600	0,03	0,96
												7,82		Rock (Mt)	0	0	0	0	0	0	0,03	0,96
Total amount of undiscovered resources related skarn-type tungsten deposits in Greenland (metric tons)																				273.980		

Appendix B: Bibliography

21st North 2012: The Hudson Land Prospect. Polymetallic Ag-Au-Pb-Zn-Cu veining & granite hosted Sn-W-Mo-Nb-REE mineralisation in Central East Greenland, 5 pp.

Appel, P.W.U. 1983: Tungsten in the Godthåb area, West Greenland. In: Report of activities 1982. Grønlands Geologiske Undersøgelse Rapport 115, p. 59-63.

Appel, P.W.U. 1984: Tungsten mineralisation in the Godthåb area, West Greenland. In: Report of activities 1983. Grønlands Geologiske Undersøgelse Rapport 120, p. 51-54.

Appel, P.W.U. 1987: Scheelite occurrences in granulite facies metamorphosed supracrustals, West Greenland. In: Report of activities 1986. Grønlands Geologiske Undersøgelse Rapport 135, p. 42-45.

Appel, P.W.U. 1988a: On an Sn-W-Bearing Iron-Formation in the Archaean Malene Supracrustals, West Greenland. Precambrian Research 39, 7 pp.

Appel, P.W.U. 1988b: Stratiform Tourmalinites in the Archaean Tungsten Province of West Greenland. Mineralogy and Petrology 39, p. 79 - 91.

Appel, P.W.U. 1989: Investigations of heavy mineral concentrates from stream sediment samples collected during the period 1982 to 1986 in the Nuuk area, West Greenland, 17 pp. (in archives of Geological Survey of Denmark and Greenland, GEUS Report File 20324)).

Appel, P.W.U. 1990: Tungsten mineralization in the Nuuk region, West Greenland. GGU Open File Series No. 90/4, 51 pp. (in archives of Geological Survey of Denmark and Greenland, GEUS Report File 20025)).

Appel, P.W.U. & Garde, A.A. 1987: Stratabound scheelite and stratiform tourmalinites in the Archaean Malene supracrustal rocks, southern West Greenland, 29 pp. (in archives of Geological Survey of Denmark and Greenland, GEUS Report File 22297)).

Appel, P.W.U., Garde, A.A., Jørgensen, M.S., Moberg, E., Rasmussen, T.M., Schjøth, F. & Steenfelt, A. 2003: Economic potential og the greenstone belts in the Nuuk area. General geology and evaluation of compiled geophysical, geochemical and ore geological data Danmarks og Grønlands Geologiske Undersøgelse Rapport 2003/94, 140 pp.

Arctic Consulting Group & Sweco 1982: Scheelite Project, Ymers Ø. Pre Feasibility Study, Nordisk Mineselskab, 47 pp. (in archives of Geological Survey of Denmark and Greenland, GEUS Report File 21046).

Baker, T. 2005: New constraints on the chemistry of magmas and fluids associated with intrusion-related gold deposits. New Zealand Conference 2005, p. 56-64.

Baker, T., Pollard, P.J., Mustard, R., Mark, G. & Graham, J.L. 2005: A Comparison of Granite-Related Tin, Tungsten, and Gold-Bismuth Deposits: Implications for Exploration: SEG Newsletter, 9 pp.

Baumgartner, W. 1976: Montagegeologischer Berict. Über die Gebiete Skjoldungebrae - Linné Gletscher und zentraler Teil der Traill Ö., Nordisk Mineselskab, 38 pp. (in archives of Geological Survey of Denmark and Greenland, GEUS Report File 20776).

Bawiec, W.J. & Spanski, G.T. 2012: Quick-start guide for version 3.0 of EMINERS—Economic Mineral Resource Simulator, 26 pp.

Beus, A.A. 1986: Geology of tungsten, 271 pp. United Nations.

Briskey, J.A. & Schultz, K.J. 2000: Proceedings for a Workshop on Deposit Modeling, Mineral Resource Assessment, and Their Role in Sustainable Development. 31st International Geological Congress, Rio de Janeiro, Brazil, 148 pp.

British Geological Survey 2011: Tungsten Mineral Profile. In: NERC (ed.): Commodity Profiles, 34 pp.

Cox, D.P. & Singer, D.A. 1986: Mineral Deposit Models: U. S. Geological Survey Bulletin, 400 pp.

Downes, M.J. & Gardiner, W.W. 1986: Greenland Tungsten Project - #985. Report of Field work - 1985, Kidd Creek Mines Ltd., 32 pp.(in archives of Geological Survey of Denmark and Greenland, GEUS Report File 20036).

Garde, A.A., Hamilton, M.A., Chadwick, B., Grocott, J. & McCaffrey, K.J.W. 2002: The Ketilidian orogen of South Greenland: geochronology, tectonics, magmatism, and fore-arc accretion during Palaeoproterozoic oblique convergence. Can. J. Earth Sci. 39, p. 765-793.

Geyti, A. 1980: Drilling and mapping in the EGMO concession area. Prospekterings Rapport 13/79., Nordisk Mineselskab A/S, 69 pp. (in archives of Geological Survey of Denmark and Greenland, GEUS Report File 20713).

Geyti, A., Hallenstein, C., Schønwandt, H.K. & Thomassen, B. 1979: A compilation of mineral exploration projects in Nordisk Mineselskab A/S' East Greenland concession, Nordisk Mineselskab, 51 pp. (in archives of Geological Survey of Denmark and Greenland, GEUS Report File 20786).

Hallenstein, C. 1976: Uranium and Thorium prospecting in Nordmines concession, East Greenland., Nordisk Mineselskab A/S, 113 pp. (in archives of Geological Survey of Denmark and Greenland, GEUS Report File 20778).

Hallenstein, C. 1979: Scheelite Exploration in the Rendal, W Ymers Ø, Alpefjord and Kalkdal areas, East Greenland. Prospekterings rapport 5/79., Nordisk Mineselskab, 31 pp. (in archives of Geological Survey of Denmark and Greenland, GEUS Report File 20708).

Hallenstein, C. 1981: Scheelite exploration in the West Andrees Land, East Andrees Land, Ymers Ø, East Milne Land. Areas of East Greenland. Prospekterings Rapport 5/80, Nordisk Mineselskab, 25 pp. (in archives of Geological Survey of Denmark and Greenland, GEUS Report File 20716).

Hallenstein, C. 1982: Scheelite Exploration in Andrees Land, Ymers Ø and NE Suess Land. Prospekterings Rapport 5/81, Nordisk Mineselskab A/S, 73 pp. (in archives of Geological Survey of Denmark and Greenland, GEUS Report File 20725).

Hallenstein, C.P. & Pedersen, J.L. 1983: Scheelite Mineralization in Central East Greenland.Mineralium Deposita 18, p. 315–333.

Harpøth, O. 1984: Nordisk Mineselskab Prospecting Report, Precious metal and Tin exploration in Hudson Land and Andrées Land, Central East Greenland, Nordisk Mineselskab A/S, 51 pp. (in archives of Geological Survey of Denmark and Greenland, GEUS Report File 20782).

Harpøth, O. 1986: The Noa Dal antimony-gold vein on Ymer Ø, central East Greenland. Report on field work by group 1, 1986. Internal report, Nordisk Mineselskab A/S, 14 pp., 3 app (in archives of Geological Survey of Denmark and Greenland, GEUS Report File 20862).

Harpøth, O., Pedersen, J.L., Schønwandt, H.K. & Thomassen, B. 1986: The mineral occurrences of central East Greenland. Meddelelser om Grønland, Geoscience 17, 139 pp.

Henriksen, N., Higgens, A.K., Kalsbeek, F. & Pulvertaft, T.C.R. 2009: Greenland from Archaean to Quaternary. Descriptive text to the 1995 Geological map of Greenland 1:2 500 000. 2nd edition., 126 pp.

Higgens, A.K. & Kalsbeek, F. 2004: East Greenland Caledonides: stratigraphy, structure and geochronology, 93 pp.

Higgens, A.K., Elvevold, S., Escher, J.C., Frederiksen, K.S., Gilotti, J.A., Henriksen, N., Jepsen, H.F., Jones, K.A., Kalsbeek, F., Kinny, P.D., Leslie, A.G., Smith, M.P., Thrane, K. & Watt, G.R. 2004: The foreland-propagating thrust architecture of the East Greenland Caledonides 72–75N. Journal of the Geological Society 161, p. 1009-1026.

Kalsbeek, F. & Taylor, P.N. 1985: Isotopic and chemical variation in granites across a Proterozoic continental margin the Ketilidian mobile belt of South Greenland. Earth and Planetary Science Letters 73, p. 65-80.

Kalsbeek, F., Thrane, K., Nutman, A.P. & Jepsen, H.F. 2000: Late Mesoproterozoic to early Neoproterozoic history of the East Greenland Caledonides: evidence for Grenvillian orogenesis? Journal of Geological Society 157, p. 1215-1225.

Kalsbeek, F., Thrane, K., Higgins, A.K., Jepsen, H.F., Leslie, A.G., Nutman, A.P. & Frei, R. 2008: Polyorogenic history of the East Greenland Caledonides. In: Higgins, A.K., Gilotti, J.A. & Smith, M.P. (eds): The Greenland Caledonides: Evolution of the Northeast Margin of Laurentia. Geological Society of America Memoir 202, p. 55-72.

Kelly, W.C. & Rye, R.O. 1979: Geologic, Fluid Inclusion, and Stable Isotope Studies of the Tin-Tungsten Deposits of Panasqueira, Portugal. Economic Geology 74, p. 1721-1822.

Lethbridge, R.F. 1955: Prospecting Operations in East Greenland, Nordisk Mineselskab A/S, 13 pp. (in archives of Geological Survey of Denmark and Greenland, GEUS Report File 20614).

Lind, M. 1980: Scheelitprospektering i Forsblads Fjord, Alpefjord, Jelsdal, Ymers Ø og Kalkdal. Prospekterings rapport 10/79, Nordisk Mineselskab A/S, 43 pp. (in archives of Geological Survey of Denmark and Greenland, GEUS Report File 20712).

Mathieson, G.A. & Clark, A.H. 1984: The Cantung E Zone Scheelite Skarn Orebody, Tungsten, Northwest Territories: A Revised Genetic Model. Economic Geology 79, p. 883-901.

Olsen, H. & Larsen, P.H. 1993: Lithostratigraphy of the continental Devonian sediments in North-East Greenland, 108 pp.

Pedersen, J. 1980: Scheelite exploration in the Ymers Ø, Niklausdal, Nord Stauning Alper, Kalkdal and Alpefjord Areas, Central East Greenland. Prospekterings Rapport 7/79, Nordisk Mineselskab A/S, 47 pp. (in archives of Geological Survey of Denmark and Greenland, GEUS Report File 20710).

Pedersen, J. 1982: Scheelite exploration in the Alpefjord, Ymers Ø and East Andrees Land Areas, Central East Greenland. Prospekterings Rapport 7/81, Nordisk Mineselskab A/S, 52 pp. (in archives of Geological Survey of Denmark and Greenland, GEUS Report File 20689).

Pedersen, J. & Olesen, B.L. 1984: Vein type Tungsten and Antimony mineralization in Central East Greenland, Nordisk Mineselskab A/S, 147 pp. (in archives of Geological Survey of Denmark and Greenland, GEUS Report File 20730).

Pedersen, J. & Stendal, H. 1987: Geology and geochemistry of tungsten-antimony vein mineralization on Ymer Ø, East Greenland. Transactions of the Institution of Mining and Metallurgy 96, B31–B36.

Rasmussen, K.L., Lentz, D.R., Falck, H. & Pattison, D.R.M. 2011: Felsic magmatic phases and the role of late-stage aplitic dykes in the formation of the world-class Cantung Tungsten skarn deposit, Northwest Territories, Canada. Ore Geology Reviews 41, p. 75-111.

Reece, A. 1956: Prospecting in North East Greenland, 54 pp. (in archives of Geological Survey of Denmark and Greenland, GEUS Report File 20616).

Schmidt, S., Bergbau, W. & Hütten, A.G. 2012: Tungsten - From Deposit to Concentrate: The Basics of Tungsten Mining Part 1: Project Generation and Project Development: ITA Newsletter: International Tungsten Industry Association, 20 pp.

Schmidt, S., Bergbau, W. & Hütten, A.G. 2012: Tungsten - From Deposit to Concentrate: The Basics of Tungsten Mining Part 2: Operational Practices and Challenges: ITA Newsletter: International Tungsten Industry Association, 20 pp.

Schultz, K.J. 2003: The Global Mineral Resource Assessment Project. USGS Fact Sheet FS-053-03, 4 pp.

SIDEX 2002: Exploring for tungsten in Quebec. Strategic Diversification Newsletter, 4 pp.

SRK Consulting (UK) Limited 2013: A Preliminary Economic Assessment on the Tabuaço Tungsten Project, Portugal. Prepared For Colt Resources Inc., 176 pp.

Steenfelt, A. 2001: Geochemical atlas of Greenland - West and South Greenland. Danmarks og Grønlands Geologiske Rapport 2001/46, 39 pp. incl. maps

Steenfelt, A., Thomassen, B., Lind, M. & Kyed, J. 1998: Karrat 97: reconnaissance mineral exploration central West Greenland. Geology of Greenland Survey Bulletin 180, p. 73-80.

Stendal, H. 1980: Scheelite exploration in the Alpefjord and Schaffhauser Dal regions. Prospekterings rapport 9/79, Nordisk Mineselskab A/S, 96 pp. (in archives of Geological Survey of Denmark and Greenland, GEUS Report File 20670).

Stendal, H. 1981: Scheelite investigations in the Hudson Land, Andree Land, Ymers Ø, and Nathorst Land. Prospekterings rapport 9/80, Nordisk Mineselskab A/S, 107 pp. (in archives of Geological Survey of Denmark and Greenland, GEUS Report File 20720).

Stendal, H. & Frei, R. 2000: Gold occurrences and lead isotopes in Ketilidian Mobile Belt, South Greenland. Transactions of the Institution of Mining and Metallurgy Section B-Applied Earth Science 109, B6-B13.

Swiatecki, A. & Damtoft, J.S. 1981: VLF.-Geophysics. Blyklippen, Pings Elv, Oksedal, Bredehorn, Ymers Ø. Special report 1/1980, Nordisk Mineselskab A/S, 42 pp. (in archives of Geological Survey of Denmark and Greenland, GEUS Report File 20644).

Sørensen, L.L., Stensgaard, B.M. & Rosa, D. 2014. Tungsten potential in Greenland. Geology and Ore, No. 25, 12 pp.

Thomassen, B. 1979: Note on anomalous pan samples in and around the Caledonian-Devonian intrusives, Nordisk Mineselskab A/S, 10 pp. (in archives of Geological Survey of Denmark and Greenland, GEUS Report File 20994).

Thomassen, B. 2009: Nordmine Archives: Part 2. Overview of heavy mineral concentrates and stream sediment samples from Nordisk Mineselskab A/S, including microscopic observations. Danmarks og Grønlands Geologiske Undersøgelse Rapport 2009/72, 15 pp.

Thomassen, B. & Tukiainen, T. 2010: Hyperøst 2008-09: Ground check of hyperspectral anomalies in Werner Bjerge - Wollaston Forland region, North-East Greenland. Part 1: analytical results. Danmarks og Grønlands Geologiske Undersøgelse Rapport 2010/54, 21 pp.

Thomassen, B., Kyed, J. & Tukiainen, T. 1999: Upernavik 98: mineral exploration in the Upernavik – Kap Seddon region, NW Greenland. Danmarks og Grønlands Geologiske Rapport 1999/35, 72 pp.

Thomassen, B., Kyed, J., Steenfelt, A. & Tukiainen, T. 1999: Upernavik 98: reconnaissance mineral exploration in North-West Greenland. Geology of Greenland Survey Bulletin 183, p. 39-45.

Thrane, K., Baker, J., Connelly, J. & Nutman, A. 2005: Age, petrogenesis and metamorphism of the syn-collisional Prøven Igneous Complex, West Greenland. Mineral Petrology 149, p. 541-555.

Tirsgaard, H. & Sønderholm, M. 1997: Lithostratigraphy, sedimentary evolution and sequence stratigraphy of the Upper Proterozoic Lyell Land Group (Eleonore Bay Supergroup) of East and North-East Greenland, 64 pp.

Werner, A.B.T., Sinclair, W.D. & Amey, E.B. 1998: International Strategic Mineral Issues Summary Report - Tungsten, 80 pp.

Appendix C: CD-ROM - Presentations from the workshop

Presenter	**Title**	**Presentation number** (on CD-ROM)
Henrik Stendal (MIM)	Welcome	1
Bo M. Stensgaard (GEUS)	Outline of the objectives of the workshop and the procedure for the assessment of tungsten deposits in Greenland	2
Larry Meinert (USGS)	Overview of tungsten deposits – major deposit types and characteristics	3
Larry Meinert (USGS)	Skarn deposits – Characteristics of W skarns and how to explore for them	4
Peter Pollard (Pollard Geological Services Pty. Ltd.)	Granites, greisens, and veins – what are the signa-tures connected to W mineralisation?	5
Kirsten Rasmussen (UBC)	The world-class Cantung Tungsten skarn deposit, Northwest Territories, Canada	6
Jorge Valente (Colt Resources)	The Tabuaço tungsten project in Portugal	7
Agnete Steenfelt (GEUS)	Overview of exploration geochemistry data with focus on potential for tungsten mineralisations	8
Thorkild Rasmus-sen (GEUS)	Overview of geophysical data from Greenland - with focus on areas judged to be potential for tungsten mineralisation	9
Adam Garde (GEUS)	Geological history and setting of South Greenland	10
Henrik Stendal (MIM)	Known tungsten deposits and occurrences – and associated mineralisation types in South Greenland	11
Niels Henriksen (GEUS)	Geological history and setting of central and north-ern East Greenland	12
Agnete Steenfelt (GEUS)	Granitic rocks in central and northern East Green-land	13
John Pedersen (Private consultant)	Mineralising event with tungsten and associated elements at Ymer Island, central East Greenland	14
Henrik Stendal (MIM)	Known tungsten mineralisations in central and northern East Greenland	15

Adam Garde (GEUS)	Geological history and setting of northern West Greenland – Rinkian orogeny	16
Adam Garde (GEUS)	Geological history and setting of southern West Greenland – Archaean craton	17
Peter Appel (GEUS)	Known tungsten deposits and occurrences – and associated mineralisation types in southern West Greenland	18