PGC PUBLISHING

Stensgaard, B.M., Kolb, J., Stendal, H. and Porter, T.M., 2010 - The Potential for Iron Oxide Copper-Gold Occurrences in Greenland; *in* Porter, T.M., (ed.), Hydrothermal Iron Oxide Copper-Gold and Related Deposits: A Global Perspective, v. 4 - Advances in the Understanding of IOCG Deposits; *PGC Publishing, Adelaide*, pp. 357-378.

THE POTENTIAL FOR IRON OXIDE COPPER-GOLD OCCURRENCE IN GREENLAND

[1] Bo Møller Stensgaard, [1] Jochen Kolb, [2] Henrik Stendal and [3] T. Mike Porter

[1] *Department of Economic Geology, Geological Survey of Denmark and Greenland, Copenhagen, Denmark*
[2] *Bureau of Minerals and Petroleum, Nuuk, Greenland*
[3] *Porter GeoConsultancy Pty Ltd, Adelaide, South Australia*

Abstract - Focused exploration for iron oxide copper-gold ±Ag±Nb±P±REE±U (IOCG) style deposits in Greenland has, to date, been limited. However, tantalising indications, including regional-scale sodic and iron-oxide alteration, crustal- to local-scale structural preparation and magmatic complexes thought to be fertile for the formation of IOCG mineralising systems are found in many tectonic provinces in Greenland. Furthermore, several Cu-Au-(±Co±Nb±P±REE) occurrences possibly represent IOCG type mineralisation, although more detailed investigations are necessary to confirm such a classification.

The two tectonic provinces that are regarded as being the most prospective are the Palaeoproterozoic Ketilidian and Inglefield Land mobile belts in southern and northwestern Greenland, respectively. The Ketilidian mobile belt, which is situated south of the Archaean North Atlantic craton, represents an arc environment with wide-spread calc-alkaline magmatism and later syn- to post-tectonic A-type granitic intrusion. Within this environment, widespread, structurally controlled sodic alteration has been recorded within a known metallogenic province of copper, gold and uranium mineralisation, locally with associated iron oxides. In particular, the Au-Bi-Ag-As-W-Cu-Mo mineralisation at Niaqornaarsuk and at Qoorormiut is interpreted to be genetically related to the ca 1780 Ma calc-alkaline intrusions of the Julianehåb batholith and hydrothermal iron oxide-albite alteration.

The Inglefield Land mobile belt hosts a 1950 to 1915 Ma meta-igneous complex, which comprises intrusions, mainly of dioritic, quartz dioritic, granodioritic and tonalitic composition, with subordinate metagabbro and magnetite-rich phases. Late post-tectonic granites, including monzogranite and syenite complexes (1785 to 1740 Ma), were emplaced during subsequent deformation. The northeastern part of the mobile belt embraces the 70×4 km “North Inglefield Land gold belt”, which coincides with a crustal-scale lineament and hosts an extensive string of fault controlled hematite matrix breccias, locally enriched in Cu and Au, as well as associated hydrothermal pyrite-barite-hematite alteration.

Other provinces, that may potentially host IOCG mineralising systems, include areas within the North Atlantic craton in southern Greenland, the Palaeoproterozoic Nagssugtoqidian orogen and the Ammassalik mobile belt in West and East Greenland respectively, and the East Greenland Caledonides, which include large blocks of Palaeoproterozoic basement.

Although there are no known IOCG deposits and major prospects in Greenland, the geology is favourable for this type of hydrothermal mineralisation and some occurrences within the outlined areas have the potential for detailed exploration.

Introduction

Tectonically and geologically, Greenland was sandwiched between Labrador in Canada, and Scandinavia in northern Europe (Fig. 1), prior to the opening of the Atlantic Ocean. Significant IOCG and related deposits are mined and/or are known in Sweden (e.g., Aitik and Kiruna) and in Finland, while a range of IOCG occurrences are found in the Central Mineral Belt of Labrador. Consequently it is likely that where the continuation of these mineralised districts project through Greenland, similar potential may exist.

Despite the large areas of Proterozoic rocks in Greenland, representing about 40% of the ice-free area (Henriksen *et al.*, 2000), only a very few occurrences have been recognised to date as being of potential IOCG-style mineralisation. The explanation for the lack of IOCG occurrences in Greenland may, to a large degree, be related to the fact that there has been no specific assessment of the potential for, or exploration targeted at, this relatively new mineralisation style that has only been recognised in recent decades. In this paper, we analyse geological settings and mineral occurrence data from Greenland to assess the potential for IOCG-style mineralisation.

Characteristics of Iron Oxide Copper-gold Deposits

Iron oxide copper-gold deposits include a wide spectrum of sulphide-deficient, mono- to polymetallic deposits, occurring as either breccias, veins, disseminations or massive lenses, generally containing more than 10 to 20% low-Ti magnetite and/or hematite (Corriveau, 2007). In some districts however, very similar, cogenetic deposits occur in which host-rock influences appear to have suppressed the formation of significant amounts of iron oxide (e.g., Williams, 2001; Knight *et al.*, 2002). The orebodies were emplaced in extensional, anorogenic or orogenic settings, representing intracratonic or intra-arc rifts, continental magmatic arcs/provinces, back-arc basins or continental margin environments. A spatial relationship to orogenic collapse and subduction-related extension along continental margins is seen in many cases (Hitzman *et al.*, 1992; Pollard *et al.*, 1998; Sillitoe, 2003).

Hydrothermal systems with IOCG-related characteristics are numerous and widely distributed in space and time. They are found on all continents, and range in age from the Late Archaean to Cenozoic times. There does not

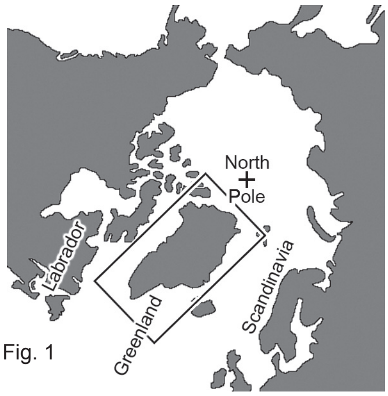


Figure 1: Simplified map showing the distribution of Archaean and Palaeoproterozoic provinces in Greenland. Major geographic names mentioned in the text are also included (modified after Henriksen, 2000).

appear to have been any obvious time dependence or concentration. Local maxima in the temporal distribution usually represent individual or spatially related provinces, including the Carajás (Brazil) region in the Neoarchaean (2.75 to 2.55 Ga); northern Laurentia and some Australian districts (including northern Sweden, the Great Bear district in Canada and Tennant Creek in Australia) during the Palaeoproterozoic (~1.9 Ga); most of the Australian, some Canadian (Wernecke Breccias) and the United States midcontinent systems in the Mesoproterozoic (1.6 to 1.5 Ga); Pan-African events of southern and central Africa in the Neoproterozoic; the Altaides across central Asia in the Mid- to Late-Palaeozoic; Central Siberia in the Late Palaeozoic; and the American Cordillera in the late Mesozoic to Cenozoic. The largest currently known economic copper-gold deposits are in the Archaean (Carajás, Brazil), Mesoproterozoic (Olympic Dam and Ernest Henry in Australia) and Cretaceous (Candelaria and Mantoverde in Chile).

Most IOCG deposits have a strong structural control, ranging from local fault intersection related extensional dilation zones in a regional transpressive domain e.g., Olympic Dam (Direen and Lyons, 2007), to those formed proximal to, or along large-scale (>100 km), transcrustal structures such as regional fault and shear zones and their associated splays e.g., Salobo, Brazil (Requia and Fontboté, 2000) and Candelaria, Chile (Marschik and Fontboté, 2001). These structural features are inferred to have acted as pathways for large volumes of fluids and/or melts over relatively long distances (Kolb *et al.*, 2006; Pollard, 2006; Rosenberg and Handy, 2000).

The site of metal deposition may be localised in brittle, brittle-ductile or ductile deformed rocks at crustal levels ranging from near surface, through sub-greenschist to upper-amphibolite facies metamorphic environments (Groves and Vielreicher, 2001b; Kolb *et al.*, 2006; Pollard, 2006; Sillitoe, 2003; Williams *et al.*, 2005). IOCG deposits often have a tabular to pipe-like orebody geometry. Deposits which formed in a brittle regime are usually associated with breccias that range from the huge, magmatic related diatreme-maar complex within a granitoid mass at Olympic Dam (Reeve *et al.*, 1990; Williams *et al.*, 2005) to structurally controlled pipe-like breccias localised by shears e.g., Ernest Henry (Williams *et al.*, 2005), to those of thrust-tectonic origin at e.g., Guelb Moghrein, Mauritania (Kolb *et al.*, 2006). Those formed at greater depth in ductile deformed hosts are commonly more tabular, and occupy dilational zones in shears developed along surfaces defined by ductility contrasts e.g., Osborne which formed (or was reworked) at a depth of as much as 10 km (Adshead *et al.*, 1998; Williams *et al.*, 2005). These breccias and shear zones provide the permeability for the ore forming fluids.

Many, but not all, IOCG deposits and districts are spatially and temporally, although not necessarily genetically, associated with extensive masses of continental A- to I-type alkaline-carbonatitic to shoshonitic igneous rocks of the magnetite-series with a compositional range between diorite and syenogranite. Granitoids, such as the Williams-Naraku batholith which occurs in the vicinity of numerous similar aged IOCG deposits, including Ernest Henry, in the Cloncurry district of northwest Queensland, Australia, may cover areas in excess of 1500 km^2 (Hitzman *et al.*, 1992; Pollard, 2006; Pollard *et al.*, 1998; Sillitoe, 2003).

Most IOCG provinces contain multiple mineralised systems that have abundant iron oxides, accessory Cu, Au, Co, and/or REE, and typically, exceptionally voluminous, (generally pervasive, but also as widely distributed discrete zones) alkali-rich hydrothermal alteration recognised over areas of tens to hundreds of square kilometres. This includes extensive Na and Na-Ca alteration, characterised by albite and/or scapolite; widespread iron oxides occurring as secondary pervasive and veinlet hematite or magnetite; and/or K silicate alteration which may occur either locally, or over wide areas and can be recognised even in granulite facies terranes in the eastern United States where it is represented by microcline-magnetite gneisses (Williams, *et al.*, 2005). These regional scale alteration systems are generally present in districts with significant deposits and are the most obvious and diagnostic indications of a favourable IOCG environment. They are usually too large to be used as a vector to individual deposits.

Host rocks within and surrounding actual orebodies display intense hydrothermal alteration. In the immediate vicinity of the ore, the variable pressure-temperature conditions of alteration and mineralisation are reflected in a spectrum of deposits ranging from those in which the dominant iron oxide is magnetite and alteration is characterised by minerals such as biotite, K feldspar and amphibole, through to hematite-dominated systems in which the main silicate alteration phases are sericite and chlorite. Albite-pyroxene and biotite-K feldspar assemblages form at deeper crustal levels, whereas shallower systems are dominated by muscovite-chlorite-carbonate mineralogies. Na and Na-Ca alteration, is generally more extensive, deeper than, and usually predates, K-Fe alteration and mineralisation. Carbonates are commonly abundant, particularly in association with, or postdating, Cu-bearing sulphides that tend to be paragenetically late and postdate high-temperature silicate alteration in the deeper seated deposits (Williams, *et al.*, 2005).

The ore comprises sulphide-deficient iron oxide (magnetite and/or hematite) enriched in incompatible elements. The main bulk of the iron oxides are invariably emplaced at an early stage, followed paragenetically by copper sulphides and by gold, although further pulses of iron oxide introduction and particularly of late hematite are not uncommon (e.g., Williams, *et al.*, 2005). The mineralising fluids appear to be of a $H_2O \pm CO_2$ composition, with up to 50 wt.% $NaCl_{eq.}$, where gold and copper are most likely transported as a chloride complex (Davidson and Large, 1998; Hauck, 1990; Haynes *et al.*, 1995; Marshall *et al.*, 2006; Reeve *et al.*, 1990). Other elements commonly associated with copper-gold mineralisation include REE, Ag, As, Ba, Co, F, Fe, Mo, Nb, P, Th and U (Groves and Vielreicher, 2001b; Marschik and Fontboté, 2001; Partington and Williams, 2000; Sillitoe, 2003). The ore fluid is often inferred to be sourced from the spatially associated intrusions (Marshall *et al.*, 2006; Pollard, 2006; Sillitoe, 2003), although, their exposed dimensions are sometimes insufficient to produce the volumes of hydrothermal fluid for the large-scale deposits (Groves and Vielreicher, 2001b).

There is evidence that in individual IOCG systems, the separate components (e.g., Fe, Cu, Au, U, REE, saline transporting brines, etc.) may not have a common source, and the ultimate mineralisation may be the result of the mixing of more than one fluid, or overprinting of an earlier formed assemblage by a later, differently sourced fluid. Alternative, and complementary, fluid sources include meteoric surface waters, or shallow, saline basinal fluids (particularly from basins containing evaporitic sequences), or from mid- to deep-crustal metamorphic to anatectic environments (Barton and Johnson, 2000; Haynes, 2000; Hitzman, 2000). However, observations infer larger, higher grade, IOCG deposits form from ultra-saline fluids with a strong magmatic contribution (Baker, *et al.*, 2008).

As detailed above, copper sulphides and gold usually paragenetically follow the bulk of the iron oxides in IOCG deposits. The iron oxides need not be the product of the same event or evolving process that culminated in the introduction and deposition of copper-gold (e.g., at Olympic Dam or Ernest Henry) but may be either recently pre-existing, or substantially older, unrelated ironstones (e.g., Starra and Tennant Creek, in Australia). In ironstone-hosted deposits, sulphides selectively replace iron minerals *in situ*, or are restricted to structural sites where magnetite was altered to hematite during sulphide deposition in open spaces. The distribution of copper and gold may be partly independent of the location of ironstone at district to mine scales, with ore occurring where the two overlap (Williams, *et al.*, 2005). In some cases, as documented from several Proterozoic examples in Australia, the driving mechanism appears to have been sulphate reduction by magnetite to form hematite (Gow *et al.*, 1994; Rotherham, 1997; Skirrow and Walshe, 2002). In others, comparatively reduced fluids sulphidised iron oxides in a process that formed pyrrhotite-bearing and hematite-free ore (Huston *et al.*, 1993; Skirrow and Walshe, 2002). In other cases, the presence of carbonaceous rocks may facilitate the precipitation of sulphides, accompanied by graphite destruction in favour of carbonate, and the presence of hematitic alteration, which is commonly better developed in nearby graphite-free lithologies (Knight *et al.*, 2002; Williams, *et al.*, 2005).

IOCG mineralisation exhibits spatial associations with, and/or has, similar mineral associations to several other types of iron and copper ore deposit styles. The chief among these that may be considered in the context of IOCG prospectivity are: (1) Kiruna-type iron oxide-apatite (IOA) deposits, many of which contain copper sulphides and gold and which often have a regional and local spatial and temporal association with IOCG deposits. IOA deposits share the same geological and tectonic environment, have very similar host rocks, and comparable regional and local alteration haloes. They occur as moderate to very large tonnage, massive, to disseminated and veinlet magnetite-apatite deposits with minor element associations (e.g., Cu, Au, P, F, REE, U) that overlap with typical IOCG occurrences (Williams, *et al.*, 2005). These deposits are regarded by some authors to represent a continuum of the IOCG ore style (e.g., Corriveau, 2007), while others regard them as an associated, but different, style of mineralisation (e.g., Williams *et al.*, 2005). (2) Predominantly diorite-associated, gold-rich porphyry copper deposits and their associated iron±copper skarns that characteristically contain large amounts of hydrothermal magnetite (e.g., Sillitoe, 1997; Williams *et al.*, 2005). (3) Phalaborwa-style carbonatite-hosted, magnetite-rich copper deposits. Some authors (e.g., Groves and Vielreicher 2001; Corriveau, 2007) have included copper-apatite-magnetite-uranium-REE bearing carbonatites, specifically Phalaborwa in South Africa, in the continuum of IOCG deposits. They suggest such iron, apatite and volatile-enriched alkaline magmas, could, at depth, be the source of both Olympic Dam- and Kiruna-style mineralisation and as such be a guide to IOCG ores. This relationship has been disputed by Williams *et al.*, (2005). Corriveau (2007) and other authors (e.g., Smith and Chengyu, 2000) also regard the Bayan Obo-style magnetite/hematite-rich, copper-gold deficient, REE (-Nb) deposit, hosted by carbonate country rocks distal, but intimately related, to an alkaline-carbonatite plutonic source, to be another in the continuum of IOCG deposits and again another indicator of the potential for IOCG mineralisation within a province.

Geology of Greenland

Approximately half of the ice-free area of Greenland consists of Archaean and Palaeoproterozoic rocks (Fig. 1). Southern West and East Greenland constitute the North Atlantic craton (Fig. 1), which is linked to the Nain craton in eastern Labrador, Canada. The exposed rocks of the North Atlantic craton largely comprise Mesoarchaean (3075 to 2820 Ma) TTG (=tonalite-trondhjemite-granodiorite) gneisses, mafic meta-volcanic as well as mafic intrusive rocks, anorthosites and, locally, meta-sedimentary rocks (Henriksen *et al.*, 2000). The latter are mostly found as up to 2 km wide lenses or belts within the gneisses. These rocks were metamorphosed to granulite and amphibolite facies grades. In the Nuuk region, southern West Greenland, Eoarchaean (3.9 to 3.6 Ga) rocks of the Itsaq gneiss complex occur in four terranes that were amalgamated together with three Mesoarchaean terranes at about 2620 Ma (Friend

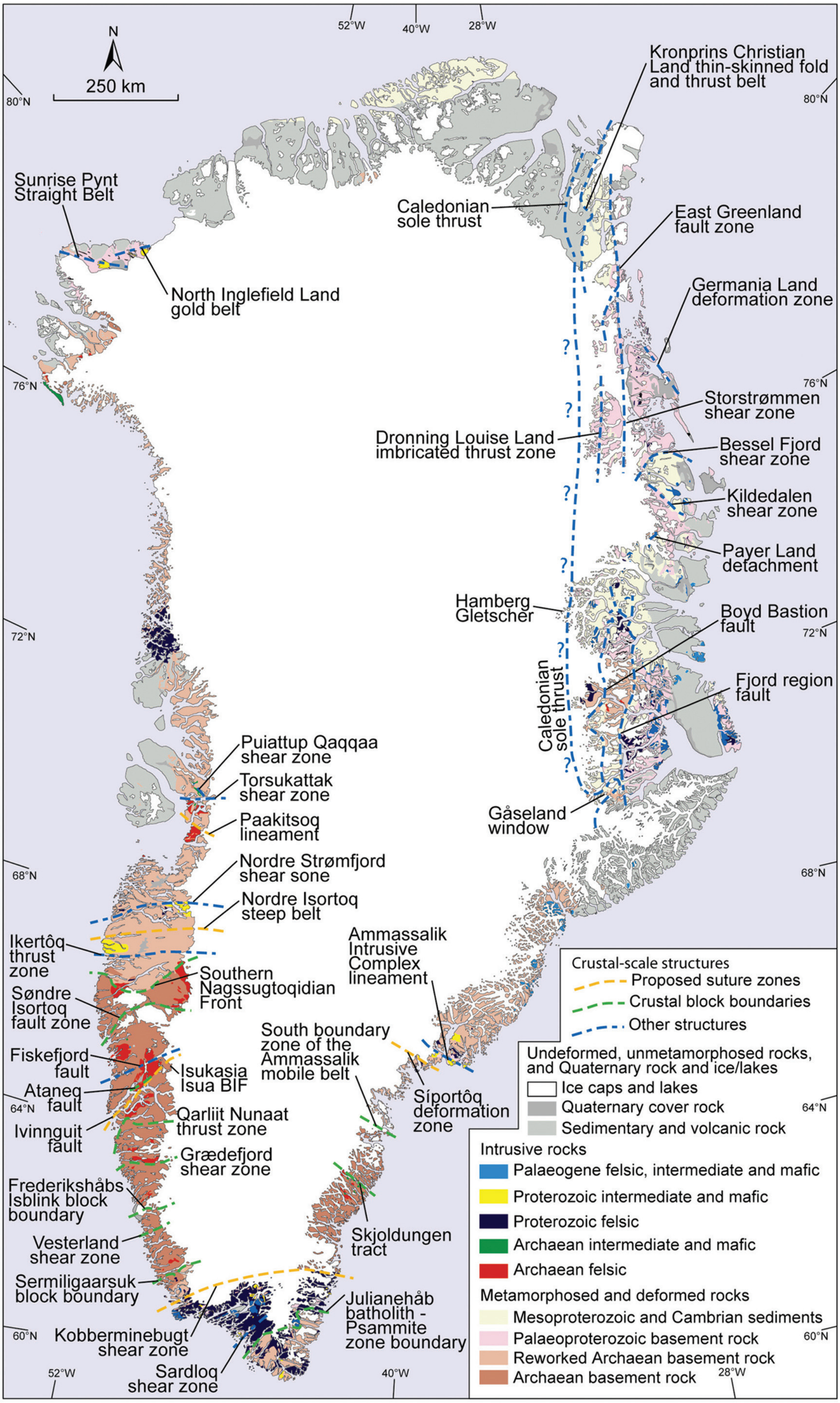


Figure 2: Geology and distribution of crustal-scale fault, thrust and shear zones in Greenland. The structures have been divided into: I) proposed suture zones, II) crustal terrane/block boundaries, and III) other crustal-scale structural features.

and Nutman, 2005). The blocks and terranes of the craton are separated by Archaean faults and shear zones and are in most cases characterised by having proximal or distal late- to post-tectonic plutons associated with them.

The North Atlantic craton is bounded both to the north and south by Palaeoproterozoic orogenic belts (Fig. 1). The ENE-WSW-trending 2.0 to 1.8 Ga Nagssugtoqidian orogen in central West Greenland and the NNW-SSE-trending Ammassalik mobile belt in southern to central East Greenland (Fig. 1) occur north of the craton (Chadwick *et al.*, 1989; Kalsbeek and Nutman, 1996; van Gool *et al.*, 2002). The orogen and the mobile belt are dominated by Archaean (mainly 2.8 to 2.7 Ga) orthogneisses with a complex deformation history. Small restricted belts and slivers of Archaean and Palaeoproterozoic metasediments and metavolcanics are intercalated within the gneisses. The gneisses are penetratively overprinted by Palaeoproterozoic deformation throughout. Palaeoproterozoic calc-alkaline tonalitic to granodioritic rocks were emplaced in the central part of the Nagssugtoqidian orogen. The centre of the Ammassalik mobile belt is intruded by a Palaeoproterozoic complex of leuconoritic to charnockitic rocks. Granulite facies conditions prevail in the centre of the orogenic systems, whereas amphibolite facies metamorphism is found in the marginal parts of the systems.

The Rinkian mobile belt north of Disko Bugt in West Greenland (Fig. 1), which may have close relationships with, or may be a direct continuation of the Nagssugtoqidian orogen (van Gool *et al.*, 2002), occurs north of the latter. The Rinkian mobile belt is lesser-studied than the orogen, and is predominately underlain by Archaean granitoid orthogneisses that are unconformably overlain by voluminous Palaeoproterozoic passive margin sediments. The 1.86 Ga Prøven igneous complex is intruded in the central part of the Rinkian mobile belt.

Even further north, in northwestern Greenland, the Palaeoproterozoic Inglefield Land mobile belt (Fig. 1; Dawes, 2004) was formed during a long-lived convergent orogenic event, with associated juvenile magmatism and later syntectonic 1.98 to 1.95 Ga intermediate to felsic intrusions, as well as late post-tectonic granites.

In southern Greenland, the Palaeoproterozoic Ketilidian mobile belt (Fig. 1; Garde *et al.*, 2002b) bounds the North Atlantic craton. In contrast to other orogenic systems in Greenland, the Ketilidian mobile belt is largely juvenile. Its core is a 100 to 200 km wide continental, calc-alkaline magmatic arc. Reworked Archaean basement, unconformably overlain by metasedimentary and metavolcanic rocks of Ketilidian age, occur in a zone to the north of this arc. The area south of the magmatic arc is dominated by fore arc metasedimentary and metavolcanic rocks. Later intrusive rocks are also found within the fore arc. The northwestern part of the mobile belt hosts rift-related sediments, basalts and intrusive rocks of the 1300 to 1120 Ma Gardar Province.

During the Proterozoic, numerous sedimentary basins formed, mainly in northern and northeastern Greenland, but also, though much smaller, in southern Greenland (Henriksen *et al.*, 2000). These basins largely contain clastic sedimentary and minor volcanic rocks. Carbonates and evaporites become prominent in the late Proterozoic and Palaeozoic basins. No major intrusive activity has been recorded in these basins, and they are not regarded as having a high potential for IOCG-style mineralisation.

Palaeozoic orogenic deformation of these sedimentary packages occurred during the Ellesmere orogeny in North Greenland, forming the Ellesmerian fold belt (Soper and Higgins, 1990), and during the Caledonian orogeny in East Greenland, forming the East Greenland Caledonides (Fig. 1; Higgins and Leslie, 2008; Kalsbeek *et al.*, 2008b). The latter also incorporates reworked Precambrian basement complexes. Granodioritic to granitic intrusions dominate in the late stages of the Caledonian orogeny. During the Mesozoic, again, sedimentary rift basins dominate the geology of North and East Greenland (Henriksen *et al.*, 2000). The Tertiary is characterised by widespread volcanic rocks, mainly of basaltic composition, associated with the opening of the North Atlantic Ocean. Related to the same process are numerous alkaline felsic and layered mafic complexes, such as the Skaergaard intrusion in East Greenland (Nielsen, 2002). Tertiary and Quaternary sediments represent unconsolidated marine and glacial sequences.

Primary Data-sets for the Assessment

A combination of geological maps and aeromagnetic data covering the entirety of Greenland were used together with a review of the published and unpublished literature to extract features that are considered to be characteristic of IOCG deposits.

Map Data

The primary geological map data-set for this analysis is the 1:2 500 000 scale geological map of Greenland (Escher and Pulvertaft, 1995; Henriksen *et al.*, 2000). Figs. 2 and 3 in this paper are based on re-interpreted and re-coloured versions of the above map. A couple of larger intrusions, in West and North Greenland, that do not appear on the original map were added. For the outline of major structures, more detailed regional maps (1:500 000 and 1:100 000), as well as the published literature on the different areas, were used.

Magnetic Data

The iron-oxide-rich bodies of IOCG systems, together with associated igneous bodies which in many cases are also magnetite-rich, and regional crustal-scale structures and their splays, are all often reflected by magnetic patterns and anomalies. Consequently, regional, modern, high-resolution magnetic data from the Geological Survey of Denmark and Greenland (GEUS) has been assessed for some of the areas that are proposed to have potential for IOCG mineralising systems. The regional data from GEUS covers the entire southern, southern West and central West Greenland, as well as smaller areas in North Greenland, including the Inglefield Land mobile belt (see more in Rasmussen *et al.*, 2003). The data were surveyed in the period from 1992 to 2001 by fixed-wing aircraft in most cases. The regular line direction is generally perpendicular to the general structural trend of the geology in the different areas, with orthogonal tie-lines. Most of the surveys were flown with a line separation of 500 m and a terrane clearance of 300 m (draped). No modern regional magnetic survey data exists for southern East Greenland. A compilation of Arctic and North Atlantic magnetic data (Verhoef *et al.*, 1996), which is generally older and of significantly lower resolution than the modern data from GEUS, is used when addressing the Ammassalik mobile belt.

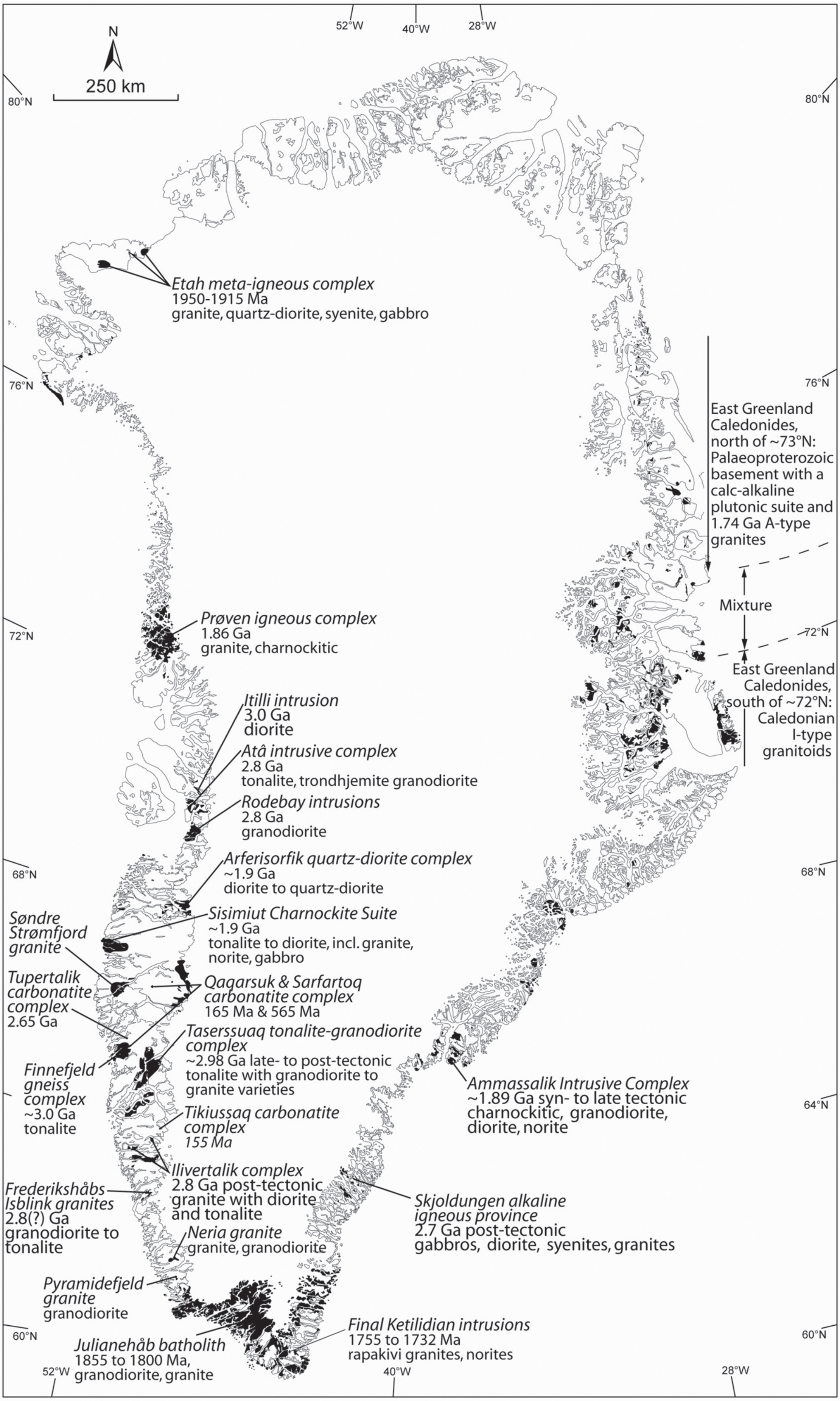


Figure 3: Distribution of intrusive rocks in Greenland. The intrusive rocks were extracted from the 1:2 500 000 Geological map of Greenland (Escher and Pulvertaft, 1995; Henriksen *et al.*, 2000) and their composition and settings were reviewed. Only intrusions that potentially, based on their composition and settings, could have played a role in an IOCG forming hydrothermal system, or are mentioned in the text for other reasons are named.

Iron Oxide Copper-Gold Potential and Prospectivity

The potential and the prospectivity for IOCG-style occurrence is assessed for the main geological provinces of Greenland, starting from the south with the Ketilidian mobile belt and moving anti-clockwise around Greenland, ending with the Ammassalik mobile belt in southern East Greenland. The setting of each of the main geological provinces of Greenland is reviewed, concentrating on characteristics pertinent to the occurrence of IOCG-style deposits, while known possible candidates are described. Currently, none of the IOCG candidates can be definitely classified as being of this style due to the lack of detailed information.

Ketilidian Mobile Belt

The Palaeoproterozoic Ketilidian mobile belt, which is located on the southern margin of the Atlantic craton in southern Greenland, evolved as an active arc regime with extensive associated late Palaeo- to Mesoproterozoic granitoid intrusions. It is a known metallogenic province embracing occurrences of copper, gold and uranium mineralisation, locally with associated iron oxides (Figs. 1, 4 and 5A). In addition, it has been subjected to widespread, structurally controlled sodic (albite) alteration. Consequently it is regarded as a promising area for the occurrence of IOCG mineralisation. Pertinent aspects of the tectonic setting, geology, regional alteration and metallogeny can be summarised as follows.

The Ketilidian mobile belt evolved during northward oblique subduction of an oceanic plate beneath the North Atlantic craton (Fig. 1). It has been divided into four segments: (1) the unreworked Archaean Foreland of the mobile belt, which is known as the Border Zone, contains Archaean basement unconformably overlain by Ketilidian metavolcanics and metasediments; (2) the Julianehåb batholith; (3) the Psammite Zone; and (4) the Pelite Zone (Figs. 4 and 5A). The Psammite and Pelite zones are dominated by deformed and metamorphosed sediments. These sediments were largely derived from erosion of the batholith, and were in part deposited unconformably on that batholith between 1795 and 1790 Ma (Garde *et al.*, 2002b). The Psammite and Pelite zones represent the fore-arc of the orogenic system, whereas the Border Zone is interpreted as a back-arc basin.

The calc-alkaline Julianehåb batholith (Figs. 3, 4 and 5A) covers more than 30 000 km^2 and was intruded in the period from ca 1855 to 1795 Ma (Garde, 1997; Garde *et al.*, 2002b; McCaffrey *et al.*, 2004). It comprises various intrusive units, including granodiorite and granite *sensu stricto*, with minor quartz monzodiorite, tonalite and quartz syenite (Garde, 1997; Garde *et al.*, 2002a; Garde *et al.*, 1997; McCaffrey *et al.*, 2004). The batholith forms the core of the mobile belt, and was developed at a mid-crustal level, below the juvenile plutonic component of the magmatic arc (Chadwick and Garde, 1996). The syn-magmatic transcrustal Sardloq shear zone (Figs. 4 and 5A) is about 1.5 km-wide and represents the largest of several similar crustal-scale shear zones with sinistral transcurrent displacement in the core of the mobile belt (Bridgwater *et al.*, 1973; Chadwick *et al.*, 1994; Garde *et al.*, 2002b). The fore arc segment was affected by intense deformation and extensive partial melting, and was intruded by I-type granite, diorite, gabbro and anorthosite in the interval from 1792 to 1785 Ma (Garde *et al.*, 2002b). In the final stages of transpression, I-type and A-type rapakivi granites and smaller associated norite bodies were intruded between 1755 and 1723 Ma (Becker and Brown, 1985; Garde, 1997; Garde *et al.*, 1997; Hamilton, 1997; Hamilton *et al.*, 1996). The Mesoproterozoic (1350 to 1125 Ma), rift-related Gardar Province (Fig. 4), is located over the northern part of the Julianehåb batholith. It is characterised by rift-related sedimentary and volcanic rocks, together with alkaline igneous activity (Henriksen *et al.*, 2000). The Gardar alkaline intrusive complex (ca 1300 to 1120 Ma) includes syenites, nepheline syenites, quartz syenites and granites with subordinate alkaline gabbros and syenogabbros.

Candidates for IOCG Mineralisation

Several examples of multi-element Au-Bi-Ag-As-W-Cu-Mo mineralisation characterise the area around the Søndre Sermilik fjord (Fig. 4) e.g., the Niaqornaarsuk and Qoorormiut gold occurrences, which occur as quartz veins with quartz-albite-magnetite alteration halos. The veins are up to 5 m wide and can be followed for about 200 m along strike. The mineralisation is structurally controlled by regional northeast-southwest, near vertical sinistral transcurrent shear zones, occurring in higher-order splays, and by northeast-southwest to east-west-trending veins (Stendal and Frei, 2000; Stendal *et al.*, 1995; Stendal and Schønwandt, 1997; Stendal and Swager, 1995). Gold mineralisation is richest (up to 380 g/t) in <1 m wide shear zones, in up to 6 m wide veins with as much as 147 g/t, and in the altered diorite-gabbro intrusion in the lower Niaqornaarsuk that contains 1 to 2 vol.% magnetite and up to 3.4 g/t Au (Gowen and Robyn, 1992; Olsen, 1995; Stendal *et al.*, 1995). Fluid inclusions comprise H_2O-CO_2 and H_2O-CO_2-CH_4, with up to 15 mole % CH_4 and salinities of between 6 and 20 wt.% $NaCl_{eq}$. The temperature of hydrothermal mineralisation is estimated at 200 to 400°C, emplaced at a pressure of between 0.5 and 1.5 kbar (Dyreborg, 1998; Fougt *et al.*, 1995). Structural control by syn-magmatic shear zones, the presence of mineralised and altered rocks within the Julanehåb batholith, and Pb-isotope studies all suggest that the multi-element hydrothermal mineralisation is coeval with, and may be genetically related to, the ca 1780 Ma calc-alkaline intrusions of the Julianehåb batholith and associated iron oxide-albite alteration, typical of IOCG-style deposits.

Copper was mined in the Kobberminebugt area (Figs. 2 and 4) between 1853 and 1855 and again from 1905 to 1914, from mineralisation containing up to 5% Cu, 1.5 g/t Au and 250 g/t Ag. The mineralisation, mainly bornite and chalcocite, is hosted in veins and breccias that are controlled by a high-order splay of the regional Kobberminebugt shear zone (Allaart, 1976; Garde *et al.*, 1998; Ghisler, 1968; Harry and Oen, 1964; Secher and Kalvig, 1987). The hydrothermal copper mineralisation comprises magnetite, hematite, chalcopyrite, electrum and native copper, and is accompanied by accessory ilmenite. Insufficient information is available to definitely classify the Kobberminebugt mineralisation as 'IOCG-style', particularly as there are apparently only minor associated iron oxides. However, structural control by the 15 km wide, syn-magmatic Kobberminebugt shear zone (Garde *et al.*, 2002b) is similar to the setting of the hydrothermal system described previously in the Søndre Sermilik fjord. The shear zone cuts both the Julianehåb batholith and metavolcanic rocks. Alkaline intrusive rocks of the Gardar Suite, which were emplaced during Mesoproterozoic rifting of the Ketilidian Orogen, are found immediately to the west of the hydrothermal mineralisation. The mineralisation at Kobberminebugt is most likely related to this extensional tectonic episode, as indicated by the Pb-isotope characteristics (H. Stendal and R. Frei, pers. com.) of the hydrothermal bornite which suggest an age between Ketilidian and Early Gardar. The magnetic expression of the Kobberminebugt shear zone can be followed beneath the ice from the west coast of Greenland to the east coast on aeromagnetic data (Fig. 5A; Thorning and Stemp, 1997), indicating a potential locus of structurally controlled magmatic-hydrothermal mineralisation in the region.

North Atlantic Craton

The North Atlantic craton is well known for its gold endowment in southern West and East Greenland (Fig. 1), occurring predominantly as orogenic-style gold deposits. However, gold is locally accompanied by copper and iron-oxides. The craton contains major banded iron formations, crustal-scale structures and widespread syn- to post-tectonic intrusions, including magnetic granites indicating the presence of anomalous iron oxides in the region. All of these characteristics suggest the craton may have potential as a target region for IOCG mineralising systems. However, the lack of other regional alteration and the absence of known Cu-Au mineralisation over much of the craton in West Greenland downgrades most areas. Both older Neoarchaean and younger late Neoproterozoic and Mesozoic magnetite and hematite bearing carbonatites, some of which are rich in REE and apatite, suggest a late IOCG affiliation and alkaline magmatism. Pertinent aspects of the tectonic-magmatic setting, geology, regional alteration and metallogeny can be summarised as follows.

The North Atlantic craton comprises several terranes or blocks that are separated by crustal-scale shear zones (Fig. 2; see e.g., Friend and Nutman, 2005; Nutman and Friend, 2007). The terranes/blocks are composed of rock sequences ranging from typical mid-crustal amphibolite to granulite grade granite-gneiss and supracrustal rocks, to upper crustal amphibolite-greenschist grade granite-greenstone rocks. Each block/terrane is interpreted to represent an Archaean micro-continent that developed by arc growth and crustal thickening, followed by collision and amalgamation to progressively form the North Atlantic craton. The region around the capital Nuuk, in particular, represents an area of complex incorporation of seven different terranes, as detailed later in this section (Nutman and Friend, 2007).

Intrusive magmatism took place at various times during the tectonic evolution of the craton, ranging from the igneous precursors of the gneisses, to post-tectonic plutons (Fig. 3; Henriksen *et al.*, 2000). Recognition of individual intrusive complexes or bodies is, in most cases, hampered by overprinting high grade metamorphism and deformation. However, several large masses of homogenous granitic to tonalitic rocks within the cratonic gneiss areas have been distinguished as distinct intrusions

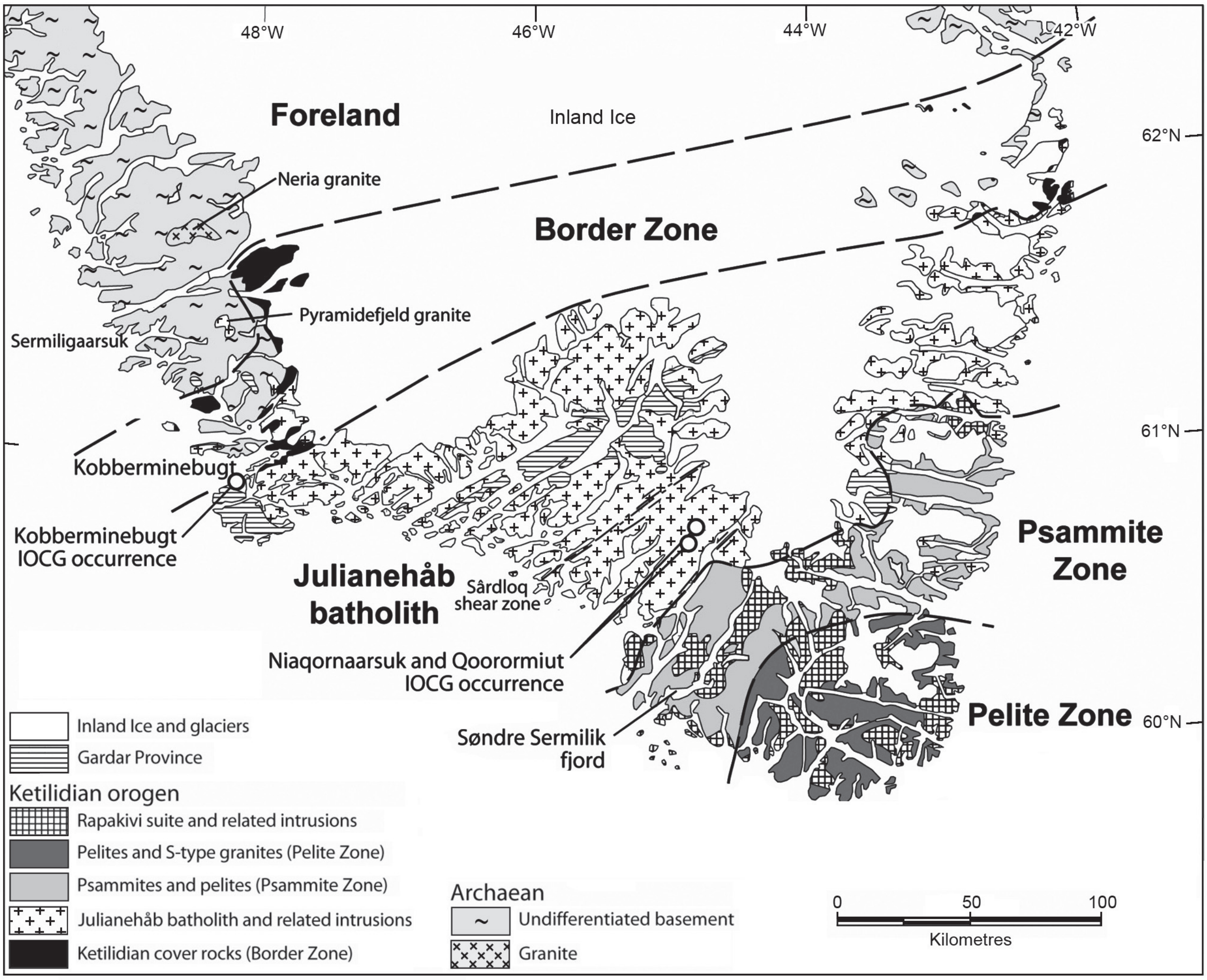


Figure 4. Geological map of the Ketilidian mobile belt in southern Greenland. Locations of possible IOCG occurrences are shown (modified after Garde *et al.*, 2002b). For the location in Greenland, see Fig. 1.

(Escher and Pulvertaft, 1995; Henriksen *et al.*, 2000). Some, e.g., the ca 3000 Ma Taserssuaq tonalite complex north of the inner Godthåbsfjord (Fig. 3), constitute the latest and least deformed igneous precursors of the gneisses. Other intrusions, e.g., the ca 2800 Ma Ilivertalik complex northeast of Grædefjord (Fig. 3), represent intrusive rocks that are clearly younger than the surrounding gneiss, but were overprinted by later deformation. This latter complex consists of a suite of biotite-, hornblende- and hypersthene-bearing granites in which dioritic and tonalitic sheets are found (Kalsbeek and Garde, 1989). It has been suggested that the Ilivertalik complex is comparable to the late rapakivi (A-type) granites which are characteristic of many Proterozoic orogens (Kalsbeek and Garde, 1989).

A highly magnetic calc-alkaline granitoid body, the Pyramidefjeld granite (Figs. 3, 4 and 5A), stands out in the aeromagnetic data covering the Archaean cratonic foreland of the Ketilidian mobile belt, and belongs to a generation of late Ketilidian granites (Allaart, 1975; Berthelsen and Henriksen, 1975; Bondam, 1956; Kalsbeek *et al.*, 1990). The larger Neria granite body (Figs. 3 and 4) occurs further to the north, in the foreland of the mobile belt, but within the North Atlantic craton. Map descriptions from the area state that the 'granites' may range in composition to granodioritic (Kalsbeek *et al.*, 1990; Kalsbeek and Leake, 1970). A possible Archaean crustal-scale structure, the Sermiligaarsuk block boundary (Fig. 2), may be located just south of the Neria granite. The presence of these magnetic intrusions suggests anomalous, regionally distributed iron oxide, representing either magnetite-series 'granitoids', or magnetite alteration.

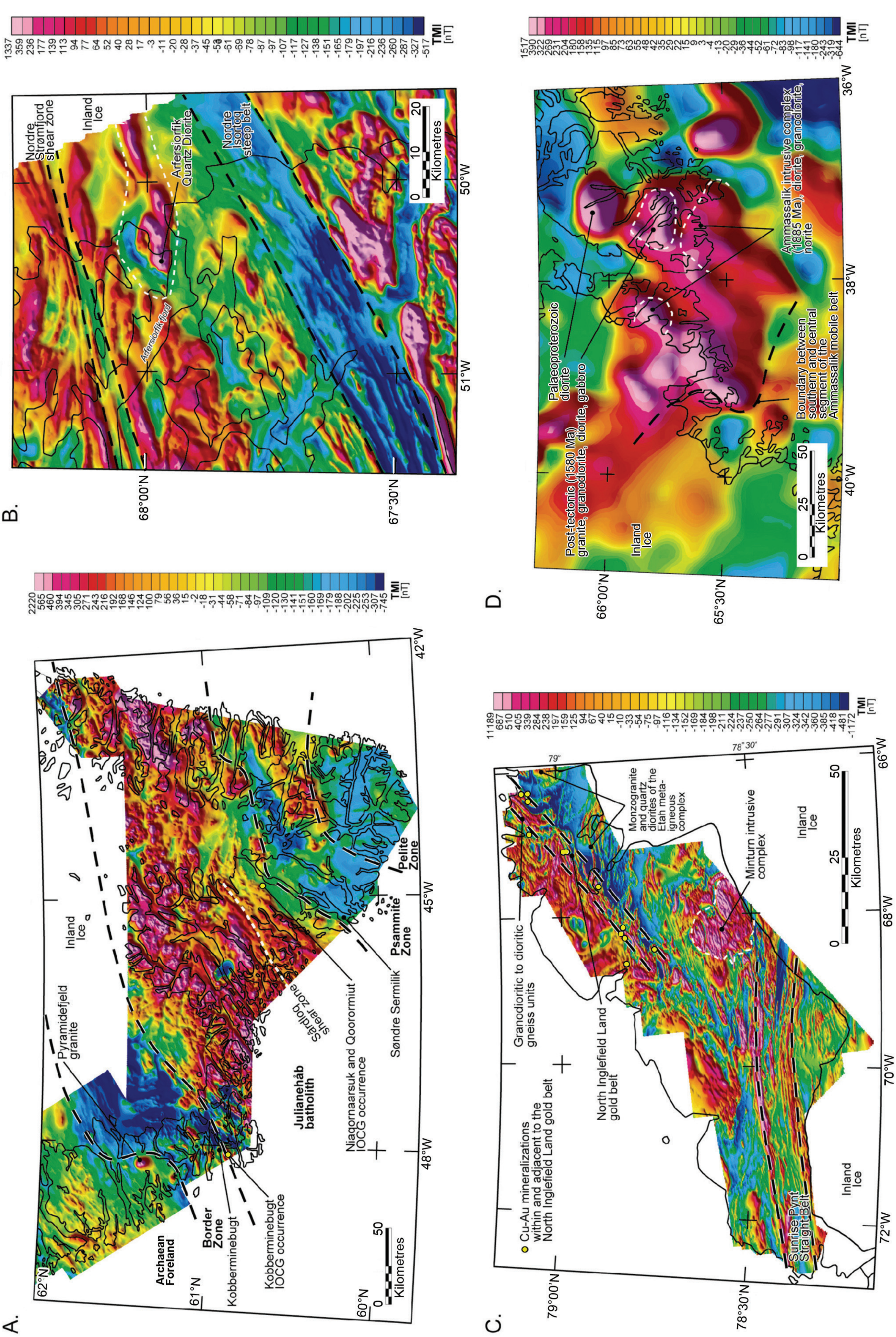
Further north, the Frederikshåb Isblink granites (Fig. 3; Hopegood, 1973; Kalsbeek and Garde, 1989) represent syn- to post-tectonic intrusions along a possible block/terrane boundary, the Frederikshåb Isblink block boundary (Fig. 2). Still further north, the Ilivertalik complex (Fig. 3) is a similar syn- to post-tectonic intrusion at a major structural break in Grædefjord (Fig. 2). The intrusive rocks comprise biotite, hornblende and hypersthene bearing granites, diorite and tonalite sheets (Kalsbeek and Garde, 1989). Ages of ca 2.8 Ga have been obtained from U-Pb zircon dating of a granite of the Ilivertalik complex (Pidgeon and Kalsbeek, 1975). Even further north, the Nuuk region is composed of four Eoarchaean and three Mesoarchaean terranes (Friend and Nutman, 2005) which were amalgamated during collisional tectonism between ca. 2.7 and 2.6 Ga (Friend and Nutman, 2005; Hollis *et al.*, 2006). Contemporaneously with this amalgamation, small granitoids were emplaced in the region. The crustal-scale Archaean (ca. 2720 to 2710 Ma; Friend *et al.*, 1987) Ivinnguit fault, marks the boundary between three of the terranes and is interpreted to represent an Archaean suture zone (Friend and Nutman, 2005; Friend *et al.*, 1987; Nutman and Friend, 2007). Towards the Inland Ice, the Ivinnguit and post-Archaean Ataneq faults merge. North of these faults, the large, uniform and homogenous, 2982±7 Ma (Garde *et al.*, 1986) Taserssuaq tonalite complex covers an area of more than 1500 km^2 (as described above; Fig. 3). Most of the intrusive complex consists of tonalitic rock, although granodioritic to granitic zones are found in its southern sections (Garde, 1997).

The Isua Greenstone Belt (IGB), in the Isukasia area (Figs. 1 and 2), on the margin of the Inland Ice in the northeastern part of the Nuuk region, is located just south of the merged crustal-scale Ataneq-Ivinnguit fault system (Fig. 2). The IGB hosts the largest BIF occurrence in the North Atlantic craton, including the 2 Gt of 34% Fe iron ore of the 3.8 Ga Isua BIF deposit, a classic Algoma-type iron-formation with oxide- silicate- and sulphide-facies. Two types of silicate facies iron formation are recognised. The first is composed of alternating bands of magnetite and almost pure, colourless grunerite, while the second comprises magnetite grains disseminated in massive actinolite. The latter locally contains small amounts of gold (~0.2 ppm Au). Other oxide facies beds are found throughout the entire IGB. The greenstone belt is divided into a number of tectonic slices or domains by smaller ductile faults. Extensive carbonate alteration has affected the different slices/domains. Several copper occurrences are hosted in various settings within the IGB, although the highest concentrations tend to be found in the mafic units and iron formations (Appel, 1979). The highest values (2 to 2.5% Cu) have been obtained from chalcopyrite-pyrite-bearing quartz veins and brecciated and silicified greenstone in the northwestern part of the belt (Appel *et al.*, 2000). The copper mineralisation is associated with gold (up to 10.4 g/t Au) and silver (up to 33 g/t Ag). The Isua BIF occurrence and other iron-oxide facies beds in the IGB potentially represent favorable hosts for IOCG mineralisation, similar to those of the Cloncurry district in Australia and Guelb Moghrein in Mauritania (Kolb *et al.*, 2006). However, the relatively intense past exploration in the IGB over several periods has failed to identify a definite candidate IOCG occurrence to date.

The North Atlantic craton extends below the inland ice to East Greenland (Fig. 1), which is more difficult to access than the western coast. The 2.7 Ga Skjoldungen alkaline igneous province (Fig. 3) hosts intrusive rocks that range in composition from ultramafic to felsic, and comprise, e.g., norite, diorite, monzonite, syenite, nepheline rich rocks and carbonatite (Blichert-Toft *et al.*, 1995). This igneous province is restricted to a ca. 30 km wide northwest-southeast trending tract (Fig. 2; Blichert-Toft *et al.*, 1995; Nielsen and Escher, 1988; Rosing *et al.*, 1992) which is cut by major northwest-southeast and northeast-southwest trending shear zones that predate emplacement of the alkaline igneous complex. The igneous province is interpreted to reflect a magmatic arc setting from an Archaean supra-subduction zone (Blichert-Toft *et al.*, 1995).

Candidates for IOCG Mineralisation

Despite the potential for IOCG mineralisation within the Atlantic craton, to date no definite Cu-Au rich IOCG-style mineralisation has been identified. Never the less, in the Paamiut area (Fig. 1) of southern West Greenland, in the same region that hosts magnetic granitoids (e.g., the Pyramidefjeld granite), gold-copper mineralisation occurs in a km-long zone dominated by disseminated to semi-massive sulphides, with local magnetite-rich zones, hosted within amphibolitic wall-rocks. The northwestern extension of this zone includes a brecciated unit, samples of which have returned values of up to 1 g/t Au and 1% Cu (Mortensen, 2006). While the timing of the mineralisation remains unclear, it appears to be structurally controlled by faults that represent splays from the major northwest-southeast trending Palaeoproterozoic crustal-scale Vesterland shear zone (Fig. 2). Although it is not possible from the current state of knowledge to classify this hydrothermal mineralisation, its characteristics, as described above, could point towards an IOCG-style system.


A.
Archaean Foreland
Border Zone
Kobberminebugt
Kobberminebugt IOCG occurrence
Pyramidefjeld granite
Inland Ice
Julianehåb batholith
Niaqornaarsuk and Qoorormiut IOCG occurrence
Søndre Sermilik
Sårdloq shear zone
Psammite Zone
Pelite Zone
0 50 Kilometres
62°N
61°N
60°N
48°W
45°W
42°W
TMI [nT]
B.
Nordre Strømfjord shear zone
Inland Ice
Arfersiorfik Quartz Diorite
Arfersiorfik fjord
Nordre Isortoq steep belt
0 10 20 Kilometres
68°00'N
67°30'N
51°W
50°W
TMI [nT]
C.
Cu-Au mineralizations within and adjacent to the North Inglefield Land gold belt
Granodioritic to dioritic gneiss units
North Inglefield Land gold belt
Monzogranite and quartz diorites of the Etah meta-igneous complex
Minturn intrusive complex
Inland Ice
Sunrise Pynt Straight Belt
0 25 50 Kilometres
79°00'N
78°30'N
72°W
70°W
68°W
66°W
TMI [nT]
D.
Post-tectonic (1580 Ma) granite, granodiorite, diorite, gabbro
Palaeoproterozoic diorite
Inland Ice
Boundary between southern and central segment of the Ammassalik mobile belt
Ammassalik intrusive complex (1885 Ma), diorite, granodiorite, norite
0 25 50 Kilometres
66°00'N
65°30'N
40°W
38°W
36°W
TMI [nT]

Carbonatites Within the North Atlantic Craton

Copper-apatite-magnetite-uranium-REE bearing carbonatites, (e.g., Phalaborwa in South Africa) and magnetite/hematite-rich, copper-gold deficient, REE (-Nb) deposits (e.g., Byan Obo in China), are regarded as either members/sub-types of the broad IOCG deposit spectrum (Barton and Johnson, 2000; Corriveau, 2007; Groves and Vielreicher, 2001) or as related deposit styles (Williams *et al.*, 2005).

One Neoproterozoic and two Mesozoic carbonatite complexes occur within the northern and central parts of the Atlantic Craton in southern West Greenland (Fig. 3). All three have associated hydrothermal alteration and mineralisation. The Neoproterozoic complex is related to the rifting associated with the opening of the Iapteus Ocean, whereas the two Mesozoic complexes accompanied the opening of the North Atlantic Ocean (Larsen and Rex, 1992; Larsen *et al.*, 1983; Secher *et al.*, 2008). These carbonatite complexes and adjacent areas of fenitisation and hydrothermal alteration are regarded as fertile for mineralisation of the Bayan Obo deposit type (e.g., Smith and Chengyu, 2000). No known copper mineralisation has as yet been found in association with any of the complexes, and consequently, they are currently not regarded as being promising for IOCG-style carbonatite copper deposits (Goff *et al.*, 2004; Groves and Vielreicher, 2001).

The 565 Ma Sarfartoq carbonatite complex (Fig. 3) is located at the boundary between the North Atlantic craton and the Nagssugtoqidian orogen (Larsen *et al.*, 1983; Secher *et al.*, 2008; Secher and Larsen, 1980). The intrusion of this complex was most likely related to the opening of the Iapetus Ocean (Larsen and Rex, 1992; Larsen *et al.*, 1983). The complex comprises a central, 15 km^2, downward tapering conical core of carbonatite, surrounded by a 75 km^2 marginal hydrothermal alteration zone of hematite-altered gneiss with carbonatite dykes. In the marginal zone, hydrothermal Nb-U-Ta-REE-P mineralisation occurs in veins together with hematite alteration. The known mineralisation comprises up to 40 wt.% Nb_2O_5, 1 wt.% Ta_2O_5 and 1 wt.% U_3O_8 (Hudson Resources Inc., 2008).

The 164 Ma Qaqqaarssuk complex (Fig. 3) occurs as a concentric ring dyke structure with dimensions of 3×5 km (Knudsen, 1991; Secher *et al.*, 2008). This complex hosts hydrothermal Nb-REE-Ta-P mineralisation with 3.5 to 6 wt.% P_2O_5, up to 15 wt.% Nb_2O_5 and 20 wt.% Ta_2O_5 (Knudsen, 1991). The main Nb mineralisation is hosted by hydrothermal pyrochlore that is associated with sodic alteration and massive magnetite.

The 152 Ma Tikiussaq carbonatite complex (Fig. 3) is located to the southeast of inner Godthåbsfjord (Secher *et al.*, 2008; Steenfelt *et al.*, 2007). Apart from magnetite-dykes/veins, no other mineralisation has been reported from this complex.

In addition, the small, 2.65 Ga, sheet-like Tupertalik carbonatite (Fig. 3), which is located several km north of the Sargartoq complex, covers an area of 500×200 m. It is composed of amphiboles, apatite, calcite, clinopyroxene, diopside, dolomite, magnetite, olivine and phlogopite, with accompanying spinel and zircon.

Figure 5: (Facing page) Total magnetic intensity field for various parts of Greenland.

- **A.** Ketilidian mobile belt and the Archaean Foreland in South Greenland. Locations of possible IOCG candidates are shown. The different segments of the mobile belt are clearly distinguishable from the magnetics, with the Julianehåb batholith reflected as a pronounced magnetic high.
- **B.** Area around Arfersiorfik fjord from the northeastern part of the Central Nagssugtoqidian orogen (CNO), central West Greenland. The central magnetite-rich part of the Arfersiorfik quartz diorite stands out as a highly magnetic anomaly. The crustal-scale Nordre Strømfjord shear zone and Nordre Isortoq steep belt are also indicated. A Cu-Co-Au-bearing rock sample was collected just south of the diorite near the margin of the Inland Ice.
- **C.** Inglefield Land mobile belt, north-west Greenland. Magmatic rocks are easily recognised in the magnetic data. Locations of possible IOCG candidates within the so-called 'North Inglefield Land gold belt' are shown.
- **D.** The Ammassalik mobile belt, East Greenland. Intrusive rocks of the Ammassalik intrusive complex stand out as anomalous magnetic highs. The survey parameters of the magnetic data displayed in the figure are described in the text.

The Nagssugtoqidian Orogen and Rinkian Mobile Belt

The Palaeoproterozoic Nagssugtoqidian orogen and contiguous Rinkian mobile belt (Fig. 1), located north of the North Atlantic craton in southern and central West Greenland, are proposed to be the product of a 1860 to 1840 Ma continent collision, preceded by subduction from around 1920 to 1870 Ma (van Gool *et al.*, 2002). Within the orogen, the close relationship between crustal-scale structures and magnetite-rich calc-alkaline intrusions in some areas, together and copper-gold-cobalt mineralised samples, suggest the potential for IOCG-style mineralisation. Elsewhere within the region, particularly at the transition between the Nagssugtoqidian orogen and the Rinkian mobile belt, strong regional sodic (albite) alteration associated with a major structural zone is a possible indicator of environments favourable for IOCG-style mineralisation. Pertinent aspects of the tectonic-magmatic setting, geology, regional alteration and metallogeny can be summarised as follows.

The Nagssugtoqidian orogen is divided into three segments: (1) The parautochthonous southern Archaean Foreland, which comprises granulite-facies gneiss cut by undeformed, late Archaean granites. The foreland is correlated with the Nain Province in Labrador (Korstgård *et al.*, 1987). The Southern Nagssugtoqidian Front (SNF; Fig. 2) represents the northern boundary of the North Atlantic craton (Kalsbeek and Nutman, 1996) and the foreland, with Palaeoproterozoic reworked Archaean basement rocks to the north and non-reworked basement rock of the North Atlantic craton to the south. The front consists of a set of *en-echelon*, reverse shear zones, with top-to-the-south displacement (Hageskov, 1995). (2) The Central Nagssugtoqidian Orogen (CNO), that is characterised by several crustal-scale structures that developed during subduction and collision. Large calc-alkaline magmatic complexes were intruded along these structures (Figs. 2 and 3). (3) The Northern Nagssugtoqidion Orogen (NNO), representing the transition zone to the Rinkian mobile belt to the north (Fig. 1). No definite boundary between the Nagssugtoqidian orogen and the Rinkian mobile belt can be drawn, due to the gradational northward decrease in structural intensity of the Palaeoproterozoic deformation. The similarities in lithology, tectono-metamorphic and magmatic evolution, together with the lack of any obvious structural boundary between the two, have recently led to discussion on the possibility that the Nagssugtoqidian orogen and the Rinkian mobile belt are closely related and perhaps even represent a single orogen (Garde *et al.*, 2002a; Mengel *et al.*, 1998; van Gool *et al.*, 2002).

Large intrusive granitic bodies are known within the orogen, including the Søndre Strømfjord granite north of the major SNF structure, and unnamed granitic intrusions near the margin of the Inland Ice to the south of the SNF, while the Sisimiut charnockite suite occurs just to the north of the western part of the syn-magmatic Ikertôq thust zone (Figs. 2 and 3). These structures, and the magmatic rocks, could reflect the primary setting for IOCG mineralising systems.

Further north, in the Disko Bugt region, within the transition zone to the Rinkian mobile belt, it has been suggested that the Paakitsoq lineament (Fig. 2) represents a Palaeoproterozoic orogenic suture zone (Connelly *et al.* 2006; Connelly and Thrane, 2008; Escher and Pulvertaft, 1976). This lineament constitutes a prominent, generally vertical, ENE-WNW trending shear zone with northwest-vergent thrust zones (Garde and Steenfelt, 1999). The gneiss to the south of the Paakitsoq lineament largely consists of the 2785±2 Ma Rodebay intrusion (Connelly *et al.* 2006; Fig. 3), which comprises fairly homogeneous fine- to medium-grained biotite-bearing granodioritic gneiss with large feldspar crystals. Smaller granitoid intrusions (2825±25 Ma; Kalsbeek and Taylor, 1999), in the form of clearly discordant pink microgranite and quartz-feldspar pegmatites, have been intruded into the gneiss terrain between the Atâ and the Rodebay intrusives, both within and north of the lineament. Pervasive regional albitisation is also found both within, and north of, the Paakitsoq lineament (Kalsbeek, 1992; Ryan and Escher, 1999), in places forming almost pure albitites (comprising >95% albite with rutile and apatite).

Further north still, the Torsukattak and the Puiattup Qaqqaa shear zones (Fig. 3), also in the Disko Bugt region, provide further examples of structures developed during Proterozoic reworking and defomation with a potential for hydrothermal mineralisation (Garde and Steenfelt, 1999). The major northwest-southeast trending Puiattup Qaqqaa shear zone exhibits a compressional flower structure opening to the south. This structure is cut by the major east-west-trending, oblique extensional Torsukattak shear zone which was developed during an episode of crustal extension. Nearby calc-alkaline intrusive masses include the large 2.8 Ga Atâ plutonic complex (Fig. 3) composed of tonalitic, trondhjemitic and subordinate granodioritic rocks (Kalsbeek and Skjernaa, 1999), and the earlier 3.03 Ga Itilli diorite (Fig. 3; Garde and Steenfelt, 1999; Stendal *et al.*, 2004). These intrusions predate the Proterozoic reworking. The area is known for gold-bearing volcanic-associated massive sulphide occurrences, BIF-hosted stratabound gold occurrences (Stendal *et al.*, 2004) and hydrothermal copper mineralisation within ca. 2.85 Ga supracrustal belts. The latter copper mineralisation occurs within small (2×10 m) lenses of semi-massive to massive iron- and copper-sulphides. The age of this hydrothermal mineralisation is not known. Although these occurrences do not necessarily represent IOCG-style mineralisation, the geochemistry, metallogeny, structure and intrusive rocks could be indicators of a setting conducive to the development of such mineralising systems.

Towards the northern margin of the Rinkian mobile Belt, just south of the Inglefield Land mobile belt, numerous sulphide occurrences are identified around Melville Bugt

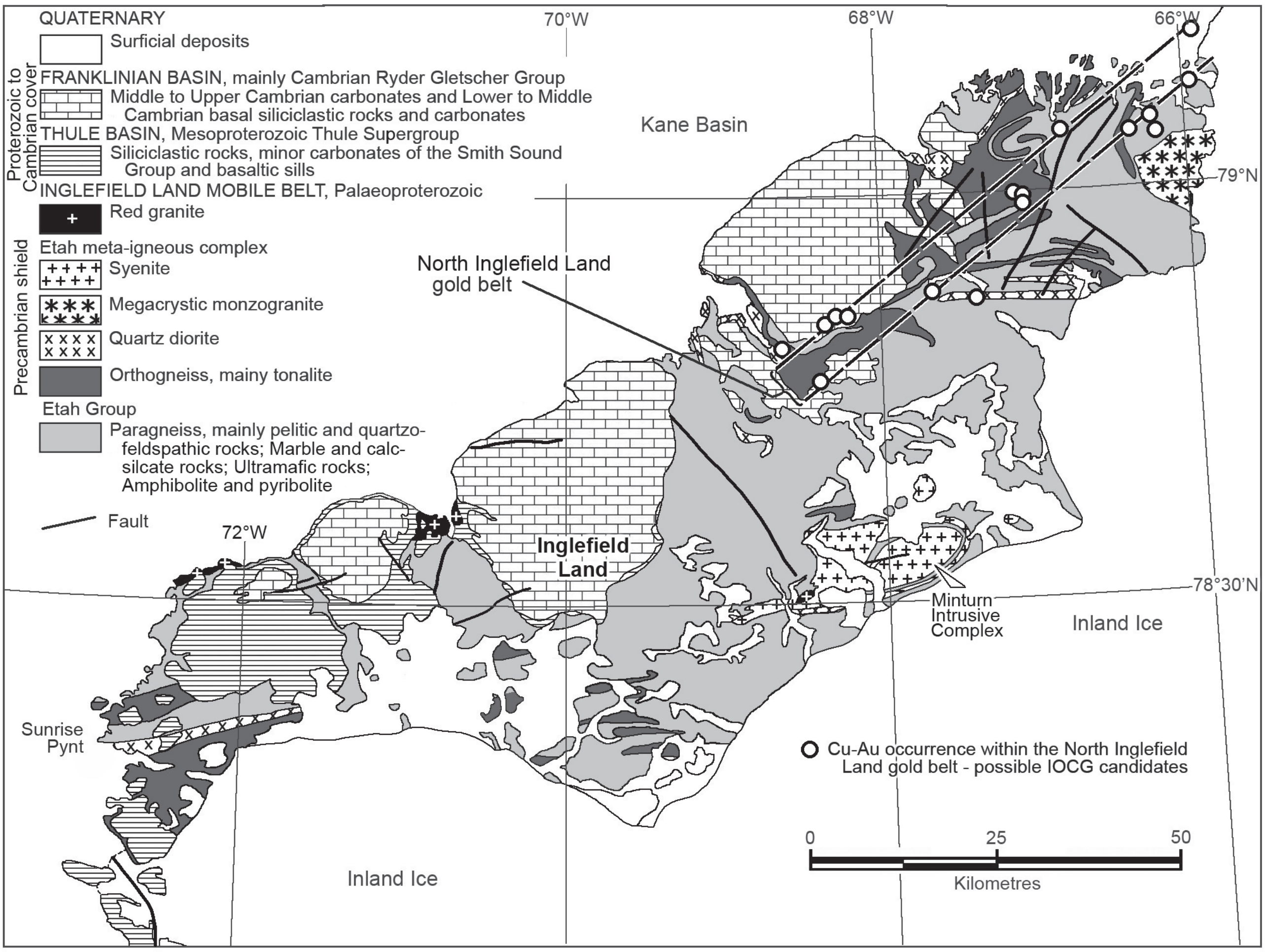


Figure 6. Geological map of the Inglefield Land mobile belt in North-West Greenland. The 'North Inglefield Land gold belt' is outlined together with locations of Cu-Au mineralisation (modified after Dawes *et al.*, 2000). For the location in Greenland, see Fig. 1.

(Fig. 1), where the entire coastal strip is to a variable extent underlain by BIF horizons (Kolb and Stensgaard, 2009).

Candidates for IOCG Mineralisation

The Arfersiorfik quartz-diorite complex (Figs. 3 and 5B), located within the CNO, at the margin of the Inland Ice, is known to be magnetite-rich in places (Sørensen *et al.* 2006). A mineralised amphibolite which assayed 0.79 g/t Au, 1.7 wt.% Cu and 520 g/t Co was found near the southeastern extension of the Arfersiorfik quartz-diorite by a local prospector. The 1920 to 1870 Ma Arfersiorfik quartz-diorite and the contemporaneous Sisimiut charnockite suite, which is located on the coast to the southwest, represent calc-alkaline Palaeoproterozoic plutonic complexes. These complexes are closely spatially associated with prominent regional structures, the Nordre Strømfjord shear zone and the Nordre Isortoq steep belt respectively (Fig. 2; van Gool *et al.*, 2002). The Nordre Isortoq steep belt occurs as a series of sinistral strike-slip shear zones and is interpreted to represent the orogen suture (van Gool *et al.*, 2002; van Gool and Marker, 2007). The Nordre Strømfjord shear zone is a near-vertical, up to 7 km wide, sinistral, transcurrent, ductile, middle amphibolite facies structure (Bak *et al.*, 1975; Sørensen, 1983; Sørensen *et al.*, 2006). The close relationship between crustal-scale structures and magnetite-rich calc-alkaline intrusions in the easternmost part of the Nordre Strømfjord shear zone, together with copper-gold-cobalt mineralised samples from the area, suggest the possibility of IOCG-style mineralisation.

The Inglefield Land Mobile Belt

The Palaeoproterozoic Inglefield Land mobile belt of northwestern Greenland (Figs. 1, 5C and 6; Dawes, 2004) consists mainly of granulite grade, 1980 to 1950 Ma supracrustal rocks. These supracrustal successions are intruded on all scales by a 1950 to 1915 Ma meta-igneous complex which predominantly comprises rocks of dioritic, quartz dioritic, granodioritic and tonalitic composition, with subordinate metagabbro and magnetite-rich rocks that show variable degrees of deformation and migmatisation. Deformation and partial melting gave rise to late post-tectonic granites, including monzogranite and syenite complexes (1785-1740 Ma).

Candidates for IOCG Mineralisation

A prominent northeast-trending aeromagnetic lineament within the Inglefield Land mobile belt is interpreted to represent a deep-seated crustal structural feature (Fig. 5c; Stemp and Thorning, 1995). This feature is informally termed the 'North Inglefield Land gold belt' (Figs. 2 and 6), and refers to the string of, what are often 'rust zones' at surface, accompanied by copper-gold occurrences, that define a 70×4 km corridor parallel and proximal to the lineament. The 'rust zones' reflect regional east-west trending fault zones hosting breccias that are cemented by hematite and enriched in copper and gold, with associated hydrothermal pyrite-barite-hematite alteration. Mineralisation is hosted by various lithologies and settings within the corridor; ranging from 'rust zones' in paragneiss or in amphibolites, malachite-stained quartzitic layers in granodioritic gneiss, and skarn at gneiss-marble contacts (Dawes, 2004; Dawes, 2000; Pirajno *et al.*, 2000; Thomassen *et al.*, 2000). Magnetite, either disseminated or as massive lenses, is common in amphibolite and associated gneissic rocks (Appel *et al.*, 1995; Dawes, 2000). Large monzogranite and smaller quartz dioritic bodies of the 1950 to 1915 Ma Etah meta-igneous complex (Figs. 3, 5C and 6) occur to the southeast of the belt. Assays of 6.9 g/t Au and 0.38% Cu are recorded from a hydrothermal alteration zone in paragneiss with intercalations of meta-pyroxenite and semi-massive pyrrhotite and chalcopyrite. Sheared calc-silicate rocks and orthogneiss, intruded by a layered mafic-ultramafic complex, contain up to 0.6 g/t Au and 0.91% Cu. In the northeastern part of the belt, the granodioritic gneiss is mineralised with bornite, chalcopyrite, chalcocite, covellite, magnetite, hematite and gold, containing 12.5 g/t Au and 1.28% Cu (Dawes, 2004; Thomassen *et al.*, 2000). The latter mineralisation in particular, could represent a possible candidate for IOCG-style mineralisation.

Outside of the corridor, numerous other hydrothermal alteration zones occur with disseminated pyrrhotite, pyrite, and chalcopyrite, but are especially wide-spread in the central and northern part of the mobile belt. The highest values recorded from this type of mineralisation are 1.4 g/t Au, 0.27% Cu and 0.15% Zn (Thomassen *et al.*, 2000).

Other areas with potential for IOCG-style mineralised systems include especially numerous lineaments associated with syn-tectonic intrusions. At the eastern extension of the 'Sunrise Pynt straight belt', the Minturn intrusive complex of the Etah meta-igenous complex (Figs. 3, 5C and 6) comprises rocks with monzonitic to syenitic affinities (Steenfelt and Dam, 1996). It is characterised by a strong positive magnetic signature, possibly related to regional-scale magnetite-alteration, as magnetite-rich boulders (>90% magnetite) are abundant in the area (Fig. 5c). Nearby, brecciated ultramafic-mafic rocks invaded by alkali granite have been reported to contain veins of magnetite, phlogopite, spinel and tourmaline (Dawes, 2004). The above settings and observations, in an area of Greenland that is especially under-explored, provide an interesting target area for IOCG-style mineralisation.

The Ellesmerian Fold Belt

The Cambrian sections of the southern Franklinian Basin in northernmost North Greenland were deformed and metamorphosed during the Ellesmerian (mainly Devonian; Fig. 1) orogeny, described as a thin-skinned fold and thrust zone which is referred to as the Ellesmerian fold belt of North Greenland (Soper and Higgins, 1990). The model for this thin-skinned fold and thrust zone involves basement uplift, with an early Cambrian basin margin extensional basement ramp becoming reactivated during Ellesmerian compression. No major intrusive activity has taken place in the Ellesmerian fold belt. Though very little information and data is available, the lack of magmatic rocks, together with no known regional alteration and copper-gold mineralisation suggest that it has little potential for IOCG-style mineralisation.

The Caledonian Orogen

The East Greenland Caledonides (Fig. 1) represent the northeastern extension of the Caledonian-Appalachian orogenic belt, formed as a consequence of the collision between Laurentia and Baltica in the Siluarian and the closure of the Iapetus Ocean. This produced a doubly vergent orogen, which is mimicked by the east-vergent Scandinavian and the west-vergent East Greenland Caledonides (Henriksen *et al.*, 2008). Deformation, metamorphism and emplacement of granitic intrusions associated with orogenesis took place from the Middle Ordovician to Early Carboniferous, overprinting the largest Palaeoproterozoic province in Greenland, with a strike-length of more than 800 km (Henriksen *et al.*, 2008).

No IOCG-style occurrences or candidates are known, although, only very limited exploration has been carried out over the orogen. The areas within and adjacent to crustal-scale structures in the East Greenland Caledonides may, together with a close proximity to calc-alkaline intrusions, be regarded as being potentially fertile for the development of IOCG-style mineralised systems.

The Palaeoproterozoic basement in the region north of 73°N (Fig. 3) is characterised by a volcanic arc, calc-alkaline plutonic suite, and ca. 1740 Ma, within-plate, A-type granites (Kalsbeek *et al.*, 2008b). In the southernmost part of the East Greenland Caledonides (south of 72°N), more mafic Caledonian I-type granitoid rocks (quartz diorite, granodiorite, quartz monzonite, syenite, etc.) have been mapped (Kalsbeek *et al.*, 2008a).

The Caledonian sole thrust (Fig. 2) defines the eastern boundary of the Caledonian orogen. This structure is mostly covered by the Inland Ice, although at Hamberg Gletcher and in the Gåseland window (Fig. 2), it crops out as an east-dipping shear zone (Higgins and Leslie, 2008). Late to post-kinematic intrusions occur at Hamberg Gletcher. In northern East Greenland, the sole thrust joins with the westernmost thrust of the Kronprins Christian Land thin-skinned fold and thrust belt (Fig. 2; Higgins and Leslie, 2008). The Germania Land deformation zone (Fig. 2), which is a 1 to 2 km wide, comprises two subparallel lineaments with a predominant dextral strike-slip sense. The Dronning Louise Land imbricated thrust zone (Fig. 2) is a major north-south-trending, up to 10 km wide, east-dipping imbricated thrust (Higgins and Leslie, 2008). The major NNE-SSW-trending Storstrømmen shear zone (Fig. 2) can be followed for several hundred kilometres along strike. This shear zone constitutes a several-kilometre-wide belt of steeply dipping mylonites with a sinistral sense of displacement at lower amphibolite-facies conditions (Higgins and Leslie, 2008; Strachan and Tribe, 1994). The Bessel Fjord shear zone (Fig. 2) is described as a south-dipping ductile structure separating high-grade Proterozoic gneiss complexes to the north from structurally higher levels of the orogen to the south, including supracrustal rocks (Frederichsen *et al.*, 1994; Higgins and Leslie, 2008). The Kildedalen shear zone (Fig. 2), further to the south, denotes a 1.2 to 3.5 km wide belt of amphibolite-facies gneiss that follows the southern boundary of a supracrustal sequence (Frederichsen *et al.*, 1994). The Payer Land detachment (Fig. 2), that occurs in the central part of the orogen, is described as a prominent southeast-dipping shear zone developed between high-pressure granulite-facies gneiss in the footwall, and low-grade supracrustal rocks in hanging wall (Higgins and Leslie, 2008). The prominent north-south-directed extensional Boyd Bastion and Fjord Region faults (Fig. 2) occur in the southern part of the Caledonian orogen. Both are associated with the extensional deformation related to the formation of the Devonian basins and orogenic collapse of the over-thickened Caledonian orogen (Larsen and Bengaard, 1991).

East Greenland is a harsh arctic area, which is not easily accessible. Therefore, there is only limited data available, which makes an evaluation of the potential for IOCG-style occurrences near impossible. However, numerous crustal-scale shear zones and the associated intrusive bodies which are found in the region are favourable for the development of hydrothermal systems including those responsible for IOCG-style deposits. This makes this area interesting for grassroots and remote-sensing based exploration.

The Ammassalik Mobile Belt

The Palaeoproterozoic Ammassalik mobile belt in southern East Greenland (Figs. 1 and 5D) is the eastern continuation of the Nagssugtoqidian orogen of West Greenland. The Ammassalik mobile belt is divided into three orogenic segments (Bridgwater *et al.*, 1990; Chadwick *et al.*, 1989) that resemble similar segments of the Nagssugtoqidian orogen (van Gool *et al.*, 2002): (1) The southern segment represents a parautochthonous foreland that is dominated by Palaeoproterozoic, south thrusted, amphibolite facies gneiss; (2) The central segment is characterised by accreted Palaeoproterozoic gneiss that is at amphibolite to granulite facies and intrusion of felsic and mafic rocks; (3) The northern segment comprises Archaean granulite facies gneiss that was variably reworked by Palaeoproterozoic deformation at amphibolite facies grade. The Ammassalik mobile belt is lesser studied than its western counterpart, which makes an evaluation of an IOCG potential more difficult.

Northwest-trending shear and thrust zones in the Síportôq deformation zone (Fig. 2) constitute a boundary between the southern and central segments of the mobile belt (Chadwick and Vasudev, 1989). Other steep shear zones of possible transcurrent character, overprinted by gently south-directed thrusting, characterise the southern segment of the mobile belt. Within the central segment, intrusions of the ca. 1886 Ma syn- to late-tectonic/metamorphic Ammassalik Intrusive Complex (Figs. 2, 3 and 5D) delineate an approximately 30 km wide, WNW-ESE-trending tract that can be followed from the margin of the inland ice to the coast (Friend and Nutman, 1989; Hansen and Kalsbeek, 1989; Kalsbeek *et al.*, 1998). The complex consists of granulite facies granitic (charnockitic), intermediate (granodioritic) and mafic rocks (norite, diorite; Fig. 5d). The roof of the norites is brecciated and strongly altered into a brownish unconsolidated rock by hydrothermal activity. Up to 30 cm wide veins with pronounced hematite and potassic feldspar alteration were observed. No geochemical analysis is available from this setting and the mineralisation was not followed up by further studies. Consequently, it is not possible, with confidence, to classify the mineralisation as an IOCG-style occurrence although favourable setting and IOCG characteristics are indicated. The Ammassalik mobile belt in southern East Greenland is a promising greenfield target for IOCG exploration and studies, because of its IOCG-like occurrences in association with a setting that includes syn- to post-tectonic calc-alkaline intrusions, prospective crustal-scale structures and its location near the Archaean craton margin. It is, however, difficult to access and only limited data is available.

Discussion

Due to the widespread occurrence of IOCG systems and provinces through time, tectonic, structural and geological setting, as detailed earlier in this paper, few definitive criteria based on these aspects can be reliably used to evaluate the prospectivity of a region for this style of mineralisation. The main, observable diagnostic characteristics of IOCG-style mineralisation are more empirical and include: (1) Regional pervasive alteration, particularly extensive Na and Na-Ca, characterised by albite and/or scapolite; widespread iron oxides occurring as secondary pervasive and veinlet hematite or magnetite; and/or localised to widespread K silicate (especially pink/red K feldspar) alteration (Williams, *et al.*, 2005). (2) Often extensive masses of continental A- to I-type alkaline-carbonatitic to shoshonitic igneous rocks of the magnetite-series with a compositional range between diorite and syenogranite. These intrusives commonly have a strongly positive expression on magnetic data sets (Hitzman *et al.*, 1992; Pollard, 2006; Pollard *et al.*, 1998; Sillitoe, 2003, Williams, *et al.*, 2005). (3) Iron-oxide (magnetite and/or hematite) bodies, as either hydrothermal massive lenses, veins or vein networks, as hematite/magnetite matrix breccias on various scales, veins and masses in shear zones, through to banded iron formations. These 'ironstones' may represent either actual IOCG deposits, or the pre 'Cu sulphide and gold phase' which could host IOCG mineralisation elsewhere in the district (Williams, *et al.*, 2005). (4) Known Cu, Au, U or REE mineralisation, preferably with some associated iron oxides (Williams, *et al.*, 2005). (5) Structural complexity to allow the channeling and concentration of ore fluids and dilation zones in which an IOCG deposit may have been accumulated. Such structures may vary from large continental scale faults/shears and their splays, to fields of significant intersecting faults, and large scale, commonly fault controlled breccia masses (Williams, *et al.*, 2005).

A number of copper-gold occurrences and small deposits associated with iron oxides in Greenland may potentially represent IOCG-style mineralisation. Those occurrences most characteristic of this ore style are located within the Ketilidian and Inglefield Land mobile belts. Both regions embrace known copper-gold occurrences, or geochemical anomalism, and extensive pervasive iron and/or sodic alteration, the principal indicators of IOCG-style settings, in association with coeval A- to I-type magmatism and controlling structures, which are regarded as being favourable for the formation of this style of deposit.

The Ketilidian mobile belt, which bounds the southern margin of the North Atlantic craton in South Greenland, is considered to have particular potential for the occurrence of IOCG systems. This mobile belt has been correlated with the Makkovik province of southern Labrador in neighbouring Canada (Garde *et al.*, 2002b; Kerr *et al.*, 1996; Ketchum *et al.*, 2002). The Makkovik province hosts part of the northeast trending Central Mineral Belt (CMB) which is considered a prospective district for IOCG-style deposits (Corriveau, 2007). The CMB is bounded by a crustal scale shear zone and seems to have spatial associations with this structure. It contains multiple phases of ca. 1.9 to 1.7 Ga intrusions; e.g., a 1.86 Ga bimodal volcanosedimentary basin, which embraces voluminous late-orogenic felsic A-type intrusions of the Aillik group (Ketchum *et al.*, 2002). The CMB hosts numerous U, Cu, and REE occurrences and deposits, together with lesser Fe(-K-U-Cu-Mo) mineralisation. The U-Cu mineralisation in the CMB is associated with hematitic-, widespread regional-scale Na-(Ca) albitic- and moderate intensity magnetite, biotite, chlorite, hornblende, pyroxene and/or actinolite alteration (Corriveau, 2007). The CMB also encompases part of the southernmost Nain province which, it is suggested, links up with the parautochthonous southern Archaean Foreland of the Nagssugtoqidian orogen and the North Atlantic craton.

As within the CMB in Canada, widespread albitisation, Cu, Au and U mineralisation, locally with associated iron oxides, as well as extensive I- and A-type granitoids are described from the Ketilidian mobile belt in Greenland. The comparable tectonic and magmatic setting, mineralisation and alteration, all suggest the Ketilidian mobile belt has a similar prospectivity for IOCG deposits as the CMB.

The combined Makkovik province-Ketilidian mobile belt may be correlated eastward, prior to the opening of the Atlantic Ocean, with the Palaeoproterozoic Fennoscandian shield in northern Sweden and Finland (Gower *et al.*, 1990). The Fennoscandian shield contains multiple 1.88 to 1.77 Ga intrusions in districts with the hallmarks typical of IOCG provinces, e.g., the Kiruna-Aitik district in northern Sweden (Weihed *et al.*, 2008) and the Kolari region in the western part of the Proterozoic Central Lapland greenstone belt in northern Finland (Niiranen *et al.*, 2007).

The deep-seated crustal structural feature expressed as a prominent northeast-trending aeromagnetic lineament within the Inglefield Land mobile belt (Stemp and Thorning, 1995) and its associated string of 'rust zones' is of particular interest. The 'rust zones' are hosted by a wide range of lithologies and reflect fault controlled zones, within regional structures, that host hematite cemented breccias, locally enriched in copper and gold, as well as associated hydrothermal pyrite-barite-hematite alteration. These occurrences, their alteration and mineralogy, and their wide distribution over a 70×4 km corridor provides considerable scope for the occurrence of IOCG mineralisation.

As areas with known BIF and/or hydrothermal iron oxide mineralisation are fertile for IOCG-style mineralising systems, small BIFs which occur in the numerous supracrustal belts of the North Atlantic craton, the largest being at Isukasia, and the numerous occurrences reported from the Palaeoproterozoic part of the Melville Bugt region, may represent prospective settings for IOCG-style deposits.

No definite examples of IOCG-style mineralisation have been recognised within the Palaeoproterozoic Nagssugtoqidian orogen in central West Greenland, and its eastern counterpart, the Ammassalik mobile belt in southern East Greenland. Exposures on both coastal belts include magmatic rocks with compositions that are potentially favourable for the formation of IOCG-style mineralised systems, while all lie within the influence of crustal-scale structures; e.g., the Nordre Strømfjord shear zone and the Nordre Isortoq steep belt in the Nagssugtoqidian orogen, and the lineament defined by the Ammassalik Intrusive Complex in the Ammassalik mobile belt. More significantly however, is the close relationship between these crustal-scale structures and the magnetite-rich calc-alkaline Arfersiorfik quartz diorite in West Greenland, together with associated anomalous copper-gold-cobalt rock samples. Similarly, un-assayed veins with pronounced hematite mineralisation and potassic feldspar alteration have been observed in norites of the Ammassalik Intrusive Complex in East Greenland. Elsewhere within the region, particularly at the transition between the Nagssugtoqidian orogen and the Rinkian mobile belt, strong regional sodic (albite) alteration associated with a major structural zone is one of the strongest indicators of environments favourable to IOCG-style mineralisation.

Kalsbeek *et al.* (2008a,b) pointed out that the geology of the Palaeoproterozoic of East Greenland (Fig. 1) in many ways resembles a more deformed version of the somewhat younger Ketilidian orogen of South Greenland (Garde *et al.*, 2002b). Magmatism, similar to the widespread calc-alkaline igneous activity in South Greenland, is also encountered in the Palaeoproterozoic basement province of East Greenland. The age and chemistry of A-type granites in East Greenland is similarly found to be comparable to the late high-FeO*/MgO granites (rapakivi) in the Ketilidian orogen. It has been suggested that the basement gneisses and metagranitic rocks in East Greenland represent an arc accreted along the margin of an Archaean crustal block that is now hidden by the Inland Ice, with accretion at ca. 2000 to 1800 Ma and subduction of a Palaeoproterozoic oceanic plate from the present-day east (Kalsbeek *et al.*, 2008a,b). The above settings, together with numerous crustal scale features in the Palaeoproterozoic basement province of East Greenland, provide an interesting grassroots target region for IOCG-style exploration. However, the lack of both known IOCG-style occurrences and recognised regional alteration reduce the prospectivity for such systems.

Several carbonatite complexes are known from western Greenland, three of which, the Sarfartoq, Qaqqaarssuk and Tikiussaaq complexes, are spatially associated with distal Nb, REE, U, Ta and P mineralisation. They are all situated close to major structures. The Sarfartoq complex is located at the boundary between the North Atlantic craton and the reworked Archaean Foreland of the Nagssugtoqidian orogen; the Qaqqaarssuk complex is exposed at the intrusive boundary of the large Finnefjeld granitic gneiss complex within a pronouced ENE-trending linear tract that also hosts the Maniitsoq kimberlite province, while the Tikiussaaq complex occurs next to what is interpreted to be the boundary between two Archaean terranes in the Nuuk region. The three mineralised carbonatite complexes may be classified to be of the Bayan Obo type (e.g., Smith and Chengyu, 2000). The recent discovery (2005) of the Tikiussaaq carbonatite complex (Steenfelt *et al.*, 2007) in the Nuuk region of southern West Greenland shows that potential exists for finding new carbonatite complexes, together with the possibility of associated hydrothermal mineralisation (Table 1). No known Cu mineralisation has been found in any of these complexes to date.

Conclusions

A large part of Greenland is characterised by its Archaean cratonic nucleus and surrounding Proterozoic orogenic domains, all of which include numerous intrusions with compositions ranging between diorite and syenogranite and, additionally, by later orogens and related magmatism. Areas within the Ketilidian and Inglefield Land mobile belts, in particular, are considered prospective for IOCG mineralisation. Good examples of mineral occurrences with many of the associated characteristics of IOCG-style deposits are known in both orogens, including structural preparation, widespread calc-alkaline to alkaline and magnetite-series magmatic activity, known copper and/or gold mineralisation, and both regional and local scale alteration of the type associated IOCG systems.

Other areas, with a lesser confirmed or speculative potential include, in decreasing order of priority, the Ammassalik mobile belt (and the Ammassalik Intrusive Complex), the Nagssugtoqidian orogen (the area around the Arfersiorfik quartz diorite) and the Palaeoproterozoic basement in East Greenland. No focused exploration or specific studies for/of IOCG systems in Greenland have been carried out to date. Geological counterparts/extensions of Greenland provinces in both Canada and Scandinavia are considered prospective, or are classical IOGC districts, where focused exploration and scientific investigations have been successfully carried out. Greenland awaits such activities.

Acknowledgement

Colleagues at the Geological Survey of Denmark and Greenland are acknowledged for their willingness to share observations from the different parts of Greenland and opinions on the IOCG potential in Greenland. The paper is published by permission of the Geological Survey of Denmark and Greenland.

Table 1: Possible IOCG occurrences in Greenland.

Deposit style	Region	Locality	Mineralisation	Alteration	Commodity	Ore type
Olympic Dam	Ketilidian mobile belt	Niaqornaarsuk/ Qoorormiut	Fe-Cu sulphides with Au, magnetite	Sodic	Au, Bi, Ag, As, W, Cu, Mo	Veins, shear zones
		Kobberminebugt	Cu sulphides with Au, magnetite, hematite	Epidote, fluorite, potassic	Cu, Au, Ag	Veins, breccias
	Ammassalik mobile belt	Ammassalik	Iron oxide, sulphides	Potassic	?	Breccias
	Nagssugtoqidian orogen	Arfersiorfik				
Cloncurry	North Atlantic craton	Paamiut	Fe-Cu sulphides with Au, magnetite	Carbonate	Cu, Au	Veins, breccias
	Inglefield Land mobile belt	Inglefield Land gold belt	Fe-Cu sulphides with Au, magnetite, hematite	Sodic, barite	Cu, Au	Veins, breccias, shear zones
Bayan Obo	North Atlantic craton	Sarfartoq	Hematite	Potassic, sodic	Nb, U, Ta, REE, P	Veins, layers
		Qaqqaarssuk	Magnetite	Sodic	Nb, REE, P	Veins, layers

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