The Search for Gold in Greenland

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Introduction

Gold is one of the first metals that was worked by humans and has been exploited and intensively used for more than 5000 years. Today gold is an increasingly important mineral resource, with over half of the global annual mineral exploration budget spent on the pursuit of gold deposits. More than half of the global gold production is used in the production of jewellery, whereas the remainder is used for financial reserves or for industrial applications such electronics, medicine, and space technologies. The main producers of this precious metal are China, Australia, the U.S.A., Russia and South Africa. However, gold can be found worldwide and, notably, in Greenland.

Gold occurrences have been discovered throughout Greenland in Archaean, Paleoproterozoic and Paleozoic terranes. However, it is fair to say that although mapping and sample collection in the known gold belts in Greenland were performed systematically, targeted exploration and applied research is lacking and the genesis of known deposits remains poorly understood and this in turn has resulted in a lack of identified gold resources (Kolb *et al.* 2017). Despite the clear potential, to date only one gold deposit in Greenland has commercially produced gold. The Nalunaq mine is located in the middle of the Napasorsuaq valley in south Greenland, about 30 km northeast of the village Nanortalik (Fig. 1). The mine was in production from 2004 to 2013, and produced approximately 713,000 tonnes of ore with an average gold grade of 15 g/t, corresponding to 10.67 tonnes of gold (Bell *et al*. 2017).

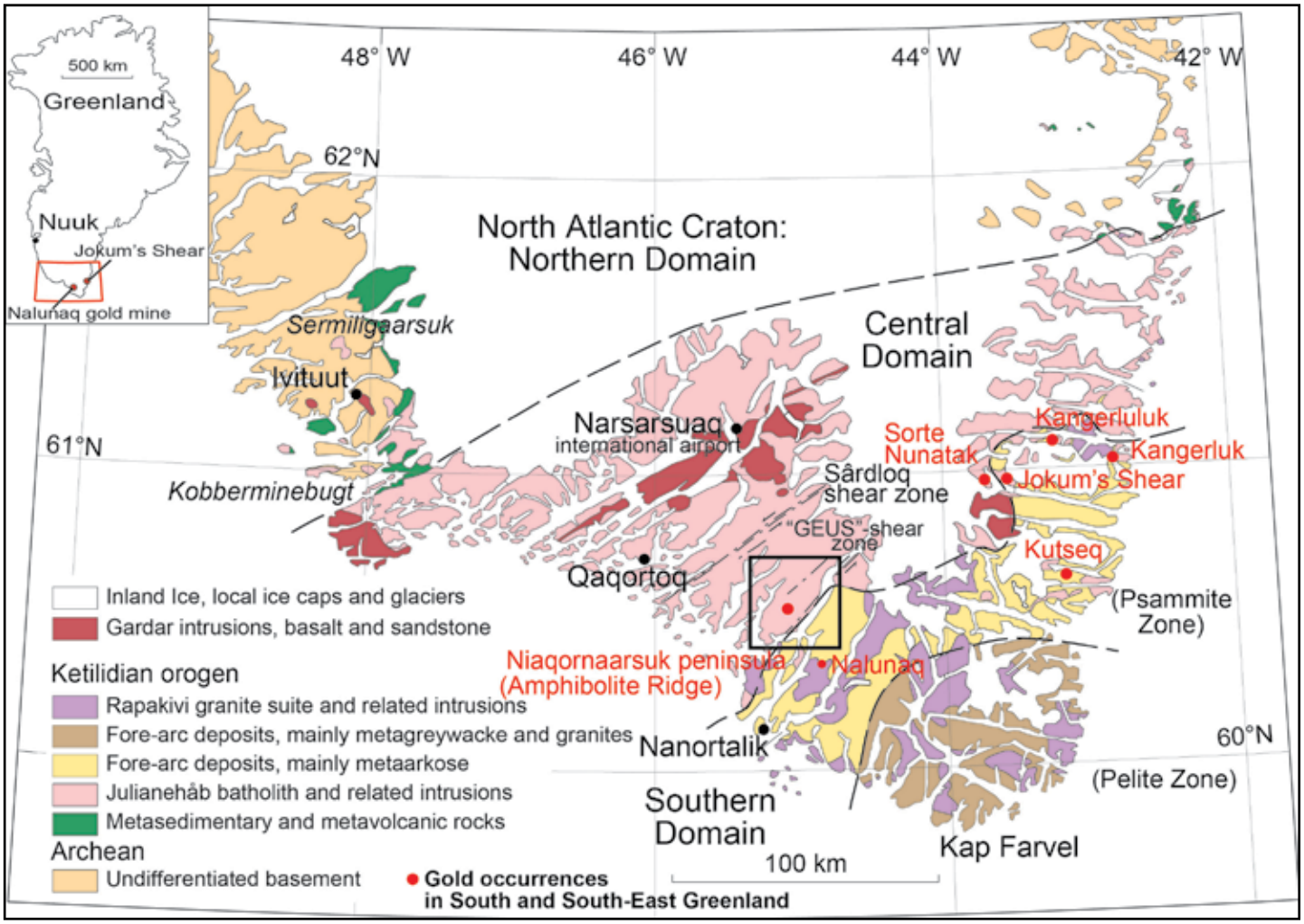

Figure 1. The geological map of south Greenland showing in the north the Archean North Atlantic craton and in the south the Paleoproterozoic granites, metavolcanics and metasediments. Gold occurrences are indicated with red dots and define the Nanortalik gold belt. The black box shows the area where in Figure 4A a detailed map is provided (Illustration: Denis M. Schlatter, after Chadwick and Garde 1996)

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What did the Vikings know?

The Vikings inhabited south and west Greenland between 985 and 1450 A.D. Viking knowledge of the presence of gold in Greenland is recorded in the Icelandic Sagas, although the accuracy of this source is debated among archaeologists. One likely candidate for the gold mentioned in the Sagas could be the gold occurrences of the Napasorsuaq valley where the Vikings maintained settlements connected to farms and some hunting shelters located on the slopes of the valley. These conclusions are supported by the archaeological structural remains and radiocarbon dating of recovered textiles to 1380 to 1400 A.D. Further interesting discoveries are reported by a Greenlandic field assistant that has apparently found some pieces of wood and a small metal shell with three suspension holes in the rim that the Vikings possibly used as a gold scale. It can be speculated that the Vikings extracted gold by panning stream sediments in the nearby river, and in smaller creeks higher up the valley, although the only Viking gold that is found so far comprises two gold rings from Igaliku that is a larger Viking settlement about 75 km northwest of the Napasorsuaq valley. In 2017, the archaeological remains of the Vikings settlements (an area totalling 35,000 ha) in south Greenland were inscribed on the UNESCO World Heritage List under the title “Kujataa Greenland - Norse and Inuit Farming at the Edge of the Ice Cap”. The gold projects described here, however, are located outside of the areas protected under the Kujataa Greenland UNESCO site.

Geology of the Nanortalik Gold Belt

The Nalunaq gold deposit was formed about 1.77 Ga (Bell *et al.* 2017) at temperatures of 580°C and at a pressure of about 3 Kilobars, which corresponds to a crustal depth of about 10 km (Kaltoft *et al.* 2000). Nalunaq is located in the recently recognised “Nanortalik Gold Belt” which extends for more than 150 kilometres from south to south-east Greenland (Schlatter & Hughes 2014). Only the coast of south Greenland and some small areas in south-east Greenland are not covered by the Greenland Ice Sheet. However, the rest of the Nanortalik gold belt is covered by the massive inland ice sheet, which covers about 80 percent of surface of Greenland.

Geologically, the Nanortalik gold belt forms part of a Paleoproterozoic orogeny that resulted from northward oblique subduction of oceanic crust below the Archean North Atlantic craton (Kolb 2013). The gold occurrences and anomalies are grouped in clusters along the southwest-northeast trending southern margin of the Julianehåb Igneous Complex. South Greenland is characterized by high relief and the topography is generally very steep with some near vertical cliffs rising from sea level to over 2500 metres elevation. The rocks in south Greenland are mainly granite, gneiss, metasediments and metavolcanics metamorphosed to amphibolite facies. In southeast Greenland, glaciation is intense with outcrops largely restricted to nunataks.

The gold of the Nanortalik gold belt mainly occurs in quartz veins with some of the auriferous quartz having exceptionally high gold content (Fig. 2), including samples grading above 1000 g/t gold. Samples

Figure 2. Quartz with visible gold from the Nalunaq mine in South Greenland. (Photograph credits: Sven Monrad Jensen, H.B. Madsen and Jakob Lautrup)

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from the auriferous Main Vein at Nalunaq mine have yielded up to 5240 g/t gold (Kaltoft et al. 2000). Common accessory minerals are pyrrhotite, arsenopyrite, sheelite and biotite.

The long-lasting search to the discovery of the Nalunaq-deposit

Geologists started to investigate the ground of south Greenland in the 1980's for potential gold occurrences. Early regional exploration consisted of panning for gold in stream sediments. Numerous panned samples contained gold grains, most notably samples from Napasorsuaq. Based on these encouraging results, the prospecting efforts were intensified and scree and additional stream sediments were sampled to assess the gold content. Systematic geological mapping and outcrop sampling finally led to the discovery of the auriferous quartz vein at Nalunaq in 1992. This vein contains abundant visible gold and is located in a zone of sheared metavolcanics and metadolerites. It was precisely this single 0.2 to 2 meter thick quartz vein that was afterward exploited in the Nalunaq underground mine.

Once the known ore resources had been mined the Nalunaq mine was closed at the beginning of 2014, although efforts are now being made by Canadian junior exploration company, Alopex Gold Inc. (CVE:AEX), to add new resources through an ongoing exploration program.

Now the question remains: which other exploration models and methods could be applied to find new gold occurrences with commercial interest in south and in southeast Greenland? For example Bell *et al.* (2017) suggest

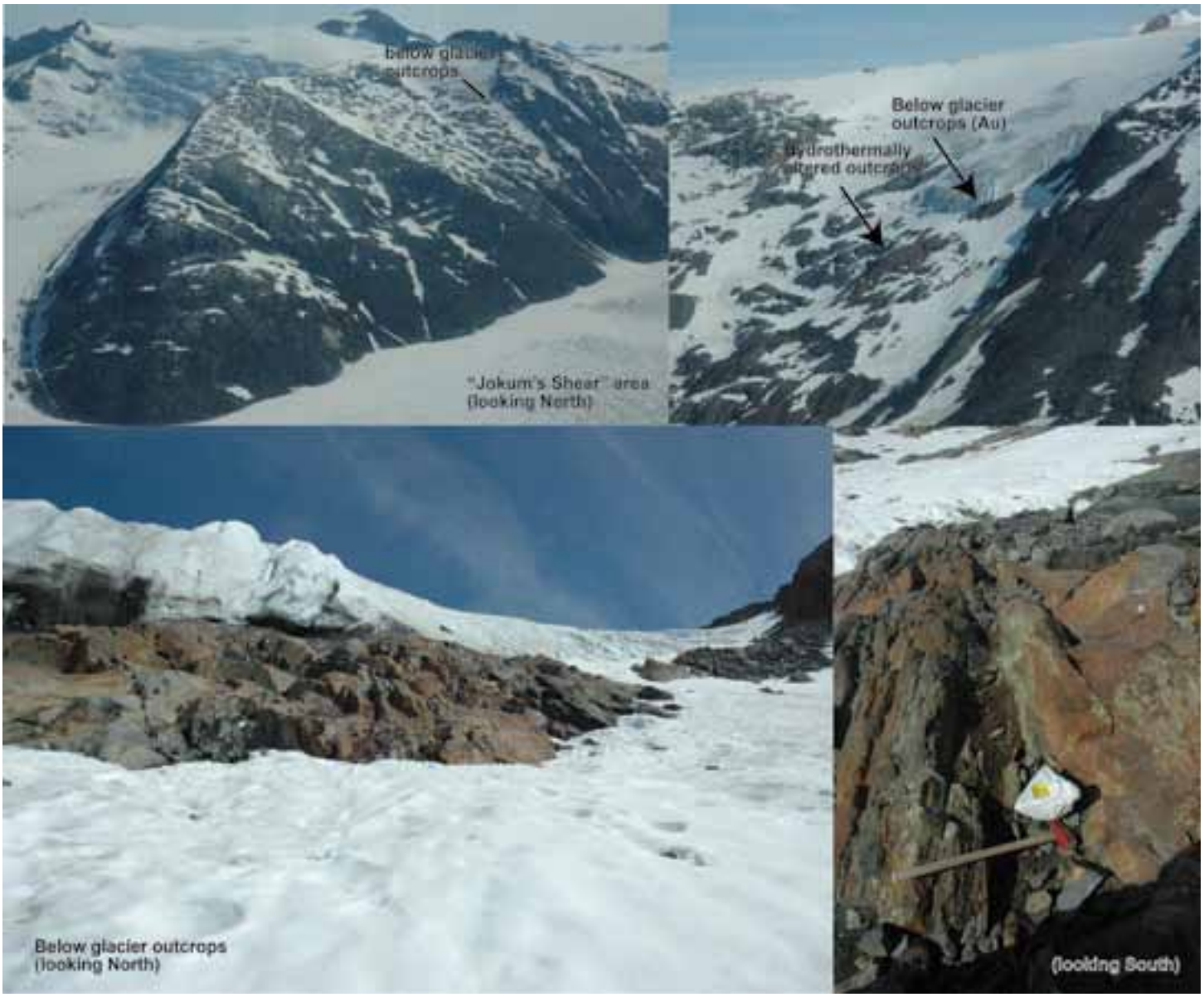

Figure 3. "Jokum's Shear" area in remote South East Greenland. The arrow shows the gold mineralized outcrops at the "below glacier outcrops" where 3.1m long channel samples possess 9.3 g/t gold.

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that reactivated shear zones are where the Au mineralization occurs in the Nalunaq mine – and this represents a type of exploration model worth investigating. The Swiss consulting firm Helvetica Exploration Services GmbH has been involved for numerous years in Greenlandic gold exploration. Experts from Helvetica Exploration Services GmbH and NunaMinerals A/S carried out systematic geochemical sampling of scree sediments and stream sediments on the Niaqornaarsuk Peninsula between 2012 and 2014. NunaMinerals A/S was the national and partially state-owned mineral exploration company of Greenland, until the company went bankrupt in 2016. The NunaMinerals A/S - Helvetica Exploration Services GmbH team identified areas with high gold contents over 15 km^2 at Niaqornaarsuk with scree sediments of up to 1.4 g/t gold. Surface samples also yielded extraordinarily high gold contents up to 2533 g/t gold in grab samples. Even in remote areas of southeast Greenland the experts found new gold prospects, such as the "Jokum's Shear" (Fig. 3); from which channel samples yielded up to 3.1 metres at 9.3 g/t gold (Schlatter & Hughes 2014).

Gold occurrences in 18 sub-areas

There are currently 18 target areas on the Niaqornaarsuk Peninsula (Figs. 1 & 4A). A cluster of gold targets centre around to so-called "Amphibolite Ridge" (Fig. 4B). Initial diamond drilling at Amphibolite Ridge has shown that gold is contained in both quartz veins and in hydrothermally altered granitic rocks (Bradley 2013; Schlatter et al. 2013). Channel

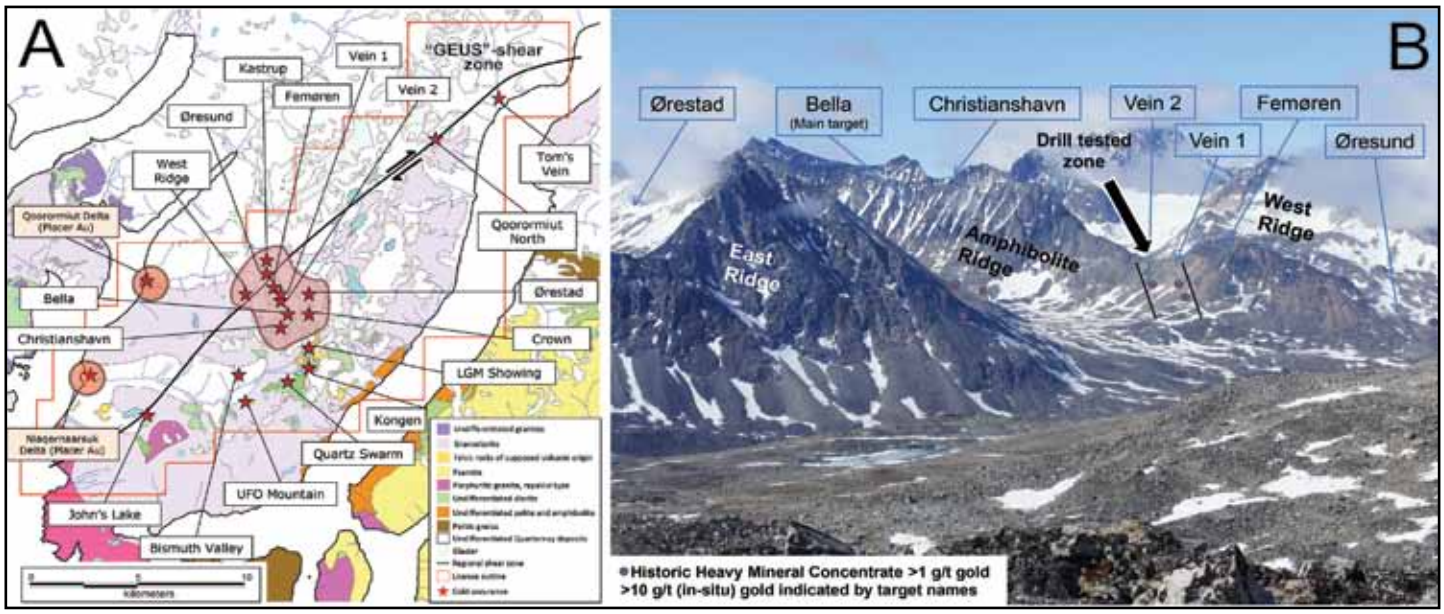

Figure 4. (A) Areas on the Niaqornaarsuk peninsula that are favourable for future gold exploration with 18 subareas where in situ gold values are higher than 10 g/t and heavy mineral concentrates are higher than 1 g/t gold. The location of the detailed map of Fig. 4A is shown in a black box on the regional map of the Fig.1. (B) Photograph showing some of the targets with in situ gold > than 10 g/t; the arrow indicates the drill tested zone of the "Amphibolite Ridge".

sampling profiles, carried out with rock saws, yielded up to 11 meters with 82.6 g/t gold. The majority of channels began or terminated in gold mineralisation, hence the true extent is yet to be confirmed and future work aims to refine the extent of gold mineralization since this has not yet been accomplished.

The next steps comprise the exploration and sampling of the remaining exploration target areas with the aim of identifying the most promising of all the targets in terms of the potential to host a future economic gold deposit. The salient goal is to demonstrate the existence of a significant gold belt and to infer the existence of significant gold occurrences in the nunataks and in the non-glaciated coastal areas of east Greenland. This is best done by finding numerous gold mineralized outcrops along the Nanortalik gold belt, and these outcrops can be located by recognizing favourable altered shear zone that can be tested for their gold contents. However it has to be kept in mind that a future mine not only needs to be profitable, but also that the environment remains protected and that workers are sourced from the local area.

At a recent Mineral Resource Assessment workshop in Copenhagen co-hosted by the Geological Survey of Denmark and Greenland and the Government of Greenland an expert panel has assessed the potential of undiscovered orogenic gold deposits very favourably. The panel comprised geoscientists with knowledge on orogenic gold mineralisation and/or Greenland geology and has assessed all data, literature, former work, map, etc. and discussed and assessed the possibilities of undiscovered orogenic gold deposits within predefined areas. They concluded that four gold deposits with

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a 90 percent probability occur in south Greenland and that two gold deposits with 50 percent probability exist in southeast Greenland (Kolb 2015).

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