# Greenland geological environments favourable for mining

**The Greenland shield was created during the Archaean era by the amalgamation of oceanic and new arc-formed crust, followed by emplacement of granitic plutons. This was succeeded by orogenic deformation and greenschist to granulite facies metamorphism. From the Palaeoproterozoic era, orogenic activity and rifting evolution have resulted in strong possibilities for the existence of viable economic occurrences.**

## Greenland scenarios

Because it is a 'greenfield' region with rather high exploration and mining expenses, development of mineral resources in Greenland has been based on knowledge about a large number of key occurrences in a limited area. Large parts of Greenland have never been the subject of detailed exploration campaigns, although there is potential for some of the important mineralisation types and commodities.

## Archaean environments

The Mesoarchaean to Neoarchaean eras were the most prolific periods for crustal production in the entire history of the Earth, and consequently characteristic for major global mineral deposits, as can also be seen in the geological evolution of Greenland. These environments were associated with deformation and metamorphism from greenschist to granulite facies conditions.

In southern West Greenland the well-studied Nuuk region reflects the prevailing shield formation and cratonisation of the Archaean era. The oldest recorded plate tectonic events observed in Greenland are recognised in the 3.8–3.7 Ga Isua greenstone belt. Centrally in region the Mesoarchaean Qussuk-Bjørneøen supracrustal belt is interpreted as an island-arc complex aged at 3.1 Ga. The various Archaean terranes in the Nuuk region were juxtaposed by accretionary plate tectonic processes through the Mesoarcgaean to Neoarchaean eras, with associated orogenic deformation and metamorphism. The infracrustal rocks in this part of Greenland are dominated by 3.8–2.7 Ga gneiss and granite that host supracrustal rocks, with minor mafic and ultramafic rock sequences, granite bodies and pegmatites attached. Apart from the Nuuk region, supracrustal rock environments are found in the Disko Bay in central West Greenland; in the Melville Bay in NW Greenland; and in the Sermiligaar-suk region in SW Greenland. Within the granite-greenstone terranes, the main mafic to ultramafic magmatic complexes carry major deposits such as chromitite in layered

*A general view from the Qingaaq Mountain on Storø, southern West Greenland, towards north-east with the central part of Godthåbsfjord. The camp is placed on the ridge (Little Qingaaq) in a supracrustal sequence intruded by pegmatites and later dolerite dykes. The Aappalaartoq mountain(1440 a.s.l.) located 4–5 km further north is partly hidden in the clouds.*

anorthosite complexes (Qeqertarsuatsiaat) and in gabbroic complexes, with magnetite, ilmenite (Sinarsuk ) and olivine in the peridotite-dunite complexes (Seqi).

## Palaeoproterozoic environments

World wide the Palaeoproterozoic era is characterised by crustal amalgamation and formation of large orogenic belts from collision and subduction around 1900 Ma. The established Archaean to early Palaeoproterozoic stable lithospheric plates permitted the formation of sedimentary basins, deposition of platform sediments and the development of continental margin troughs.

Good examples are the South Greenland Ketilidian orogen and the Inglefield Land mobile belt in Northwest Greenland. Supracrustal belts, including greenstones, are sparse within these orogens, but occur as thin sequences dominated by amphibolitic rocks and subordinate metasedimentary rocks. Within the Nagssugtoqidian orogen, several supracrustal sequences like those at Naternaq and Ataneq, contain syngenetic massive sulphide occurrences. Some of the major discoveries have been made within the central West Greenland Rinkian orogen. The SEDEX-type Black Angel deposit and the sulphide-gold occurrences in the Karrat Isfjord are prominent. The juvenile Ketilidian orogen is a gold province with several prospects in different settings, including the Nalunaq Gold Mine.

*Section through the Triassic sediments at the south side of Devondal, central East Greenland. The top of the cliff-face is at elevation c. 700 m a.s.l.*

## Intrusive events

Major intrusive events are found in the South Greenland Mesoproterozoic Gardar Province in the Neoproterozoic North Atlantic alkaline province, and in the Jurassic province of carbonatites in West Greenland. Other known major intrusions are granites in East Greenland associated with Caledonian events, intrusions associated with the rifted Palaeogene basaltic provinces in East and West Greenland as well as the alkaline granitoid intrusions in East Greenland. Regions dominated by extrusive volcanism are the Palaeogene flood basalt provinces in East and West Greenland.

Mineral occurrences in the Proterozoic and Mesozoic scenarios are mainly associated with a stable craton or incipient rifting and initial basin formation. The Mesoproterozoic Gardar Province comprises three intrusive phases related to initial rifting, of which alkaline phases carry large deposits of speciality metals and cryolite.

The carbonatites of the North Atlantic alkaline province occurring in West Greenland have a definite potential for niobium and rare earth elements. The Neoproterozoic kimberlite dykes/sills in the Kangerlussuaq - Maniitsoq region hold a promising diamond potential. The mineral occurrences in the Palaeogene magmatic environment comprise deposits like the porphyry molybdenum deposits in East Greenland and associated vein systems with gold and silver. The Skaergaard gabbro intrusion conceals a world-class deposit with gold and PGE, while the Palaeogene mafic igneous rocks together with the flood basalt provinces in East and West Greenland are distinctive potential nickel resources.

## Sedimentary basins

Rift-related sedimentary successions are recognised as the Mesoproterozic Thule Group, the Independence Fjord Basin and the Krummedal succession in North and East Greenland, the Neoproterozic Eleonore Bay Supergroup in East Greenland and the Phanerozoic sedimentary Franklinian basin in East and North Greenland, with huge thicknesses of sediments with clastic sediments and carbonates. The North Greenland environment is the platform type with dominant carbonates and flysch sediments. SEDEX lead-zinc type deposits in the shale sequences are found in the sedimentary basin in North Greenland. Carbonate-hosted lead-zinc (MVT) is found discovered in platform carbonates both in North and East Greenland.

## Concluding remarks

An obvious place to look for mineral deposits is where accretion of crust formation occurs. This is demonstrated in several places in Greenland. Prosperous periods for metal formation are the Eoarchaean with BIF; the Meso–Neoarchaean with arc-related and orogenic gold and BIF; the Palaeo-proterozoic, with gold in the Ketilidian orogen; the Mesoproterozoic rift-related Gardar alkaline province and the Caledonian Neoproterozoic sediments in East Greenland. The Phanerozoic sediments are targets for stratiform and stratabound SEDEX and MVT deposits. The Neoproterozoic carbonatites and kimberlites have good potential for exceptional commodities as diamond and REE. Real giant tonnage deposits are located within the Palaeogene complexes such as Skaergaard and Malmbjerg.

The promising exploration targets fall within these categories with priorities for gold, platinum group elements, diamonds, coloured gemstones (ruby and sapphire), zinc, molybdenum, nickel and iron. Speciality metals and unique industrial minerals are also potential targets.

## Key references


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