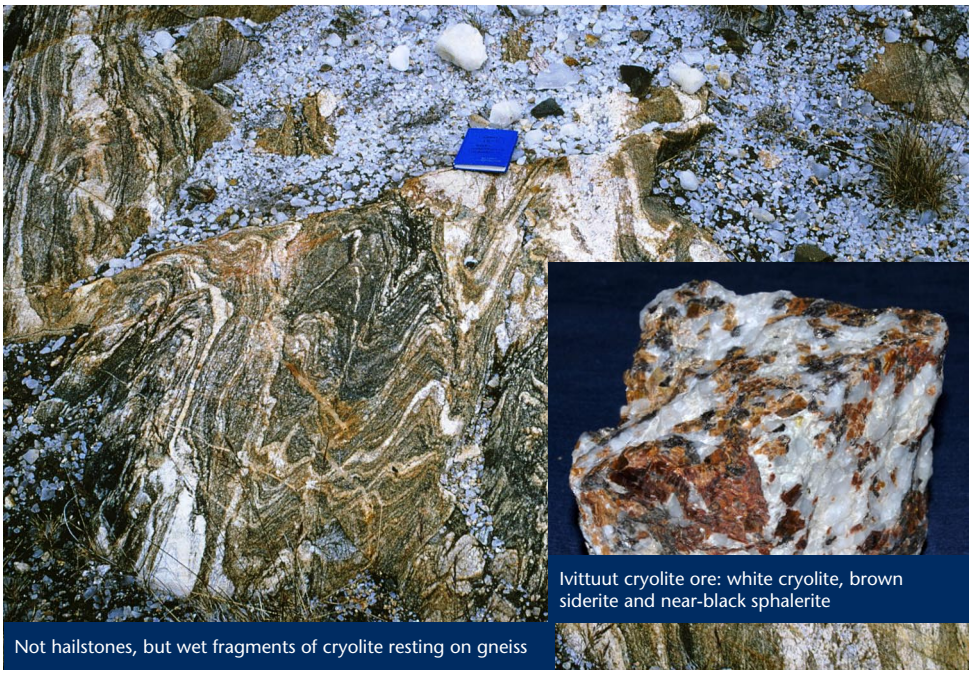
## MINERAL CONNECTIONS

I have a house in the West Highlands of Scotland, near the small town of Fort William, which nestles at the base of Britain's highest mountain, Ben Nevis. As I drive to the local supermarket, I see, straight ahead on the Ben's western flank, five massive steel pipes which emerge from the mountainside about 200 m above the town. In my mind's eye, they conjure up a memory of a remote place in southern Greenland and an unexpected web of mineralogical connections.

The now water-filled Ivittuut quarry. The mountain across Arsuk Fjord is Kûngnât, a syenite intrusion.



Not hailstones, but wet fragments of cryolite resting on gneiss

Ivittuut cryolite ore: white cryolite, brown siderite and near-black sphalerite

The five pipes are connected to two large, artificially dammed lakes through a 24 km long, 4.5 m diameter tunnel driven through the Ben Nevis massif. Tunnel construction began in 1924, and it was, until 1970, the longest water-carrying tunnel in the world. The pipes carry water to the turbine house of the Fort William aluminium smelter, operated by Rio Tinto Alcan. The company is about to replace the 1929 turbines, increasing aluminium output to 50,000 tonnes per year, actually the smallest output of any aluminium smelter operated by Alcan. Notwithstanding its lowly standing in the world list of aluminium producers, the numbers associated with Fort William's plant are still impressive. The hydropower station generates 65 MW of electricity, most of which finds its way to the 80 cells in which alumina is reduced electrolytically. The cells run 24 hours a day, 7 days a week, and each draws direct current at a jaw-dropping 175,000 amps, at 5 volts.

As I'm sure readers will know, a crucial component in this process is the rare mineral cryolite ($Na_3AlF_6$). In the system cryolite–alumina there is a eutectic at 90% cryolite and ~965°C, and the carbon-lined cells are heated to this temperature with fuel oil. Alumina dissolves in the eutectic cryolite melt, the cell wall acts as a cathode and carbon rods lowered into the liquid provide anodes. Oxygen from the alumina combines with carbon from the anodes to produce $CO_2$, and liquid aluminium is periodically tapped from each cell. Cryolite is an exceedingly uncommon mineral and has been extracted commercially at only one locality on Earth, Ivittuut (which used to be called Ivigtut) on Arsuk fjord in southwest Greenland at 61°13' N, where it forms a core about 150 m wide to a small peralkaline granite stock. Cryolite was quarried there from the mid-19$^{th}$ century, initially for soda, until 1987, when it was worked out; cryolite used for aluminium production today is synthetic. J. W. Tayler, in 1856, reported to the Geological Society of London that the local Greenlander (Inuit) population used it to make snuff: "They grind the tobacco-leaf between two pieces of cryolite, and the snuff so prepared contains about half its weight of cryolite powder. This snuff they prefer to any other." Well, *chacun à son goût!*

Ivittuut cryolite was the reason behind one of the earliest actions of the United States in the Second World War. On May 3, 1940, three weeks after the occupation of Denmark by Germany and 18 months before Germany declared war on the United States, the local Greenland government asked for American protection for the cryolite mine. Perhaps it was not a coincidence that on May 10 the British invaded Iceland. The United States sent its first diplomatic representative to Greenland, and in July American newspapers announced an 'unofficial protectorate over Greenland'. A naval base, known as Bluie West 7, was established at Grønnedal, 5 km east of Ivittuut, which remains today the headquarters of Danish Naval Command Greenland.

Today Ivittuut is a sad little place (although, because of Scandinavian influence, very tidy) with its empty buildings and sizeable graveyard with memorials to miners and to ships lost at sea. Handling and navigating square-rigged sailing ships through the sea-ice in the short sub-Arctic days cannot have been easy. Nice examples of the beautiful cryolite–siderite ore can still be found, and on wet days gravel made of cryolite fragments allows the mineral to show off the property which gave it its name, which means 'ice-stone'. Cryolite is monoclinic, 2/m, at room temperature, but strongly pseudo-cubic, with refractive indices of 1.338 for α and 1.339 for λ, almost the same as water (1.333). It has no cleavage and tends to break into rounded lumps. When wet it looks exactly like a layer of freshly fallen hailstones. Hailstones of a mineral that underpins one of the most power-hungry but essential processes in the industrial world, a mineral that had a role in the course of World War II and that gave nasal pleasure to the indigenous people of the world's northernmost land mass.

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