

December 16, 2024

## News and notes

Before going on to discuss the geology and geopolitics of [Greenland](#), here are some news items I thought were interesting.

## Free Geology Books

Free geology books can be downloaded from these sites:

- [OreZone Readers and Experts Telegram Channel](#); the Ore Zone channel also shows employment opportunities for geologists.
- [The Groundwater Project](#).

## Geopolitics



**Example of the Role of Geoscience in U.S. Foreign Policy**

**Credit: USGS, public domain**

- From the United States Geological Survey: [Tracking down commodity sources: The surprising role geoscience can play in assisting U.S. foreign policy.](#)
- [Syria will be chaotic for the foreseeable future – John Mearsheimer.](#)

- Countdown to WWII: [NATO chief says it's 'time to shift to a wartime mindset'](#).
- [Global scramble for critical minerals fuelling protectionism](#)
- [China Begins Ban of Rare Earth Minerals to the US.](#)
- [Mexico to review bill to ban open pit mining.](#)
- [Guinea plans sovereign wealth fund backed by iron ore income.](#)
- [How a uranium mine became a pawn in the row between Niger and France.](#)
- [A New Resource War Is Looming as America Runs Out of Ammo.](#)

## Research and News

- [Magnetic Fabric as a Marker of Thermal Maturity in Sedimentary Basins: A New Approach for Reconstructing the Tectono-Thermal Evolution of Fold-and-Thrust-Belts.](#)
- Geochronology research: [Removing Climatic Overprints in Sedimentary Cosmogenic Beryllium Records: Potentials and Limits.](#)
- [Stratigraphy and faunas of the Durness Group \(Cambrian–Middle Ordovician\) of Northwest Scotland: constraints on tectonic models and the development of the Great American Carbonate Bank.](#)
- [Lithospheric Foundering in Progress Imaged Under an Extinct Continental Arc.](#)
- [A Spectral Directors Method for Modeling the Coupled Evolution of Flow and CPO in Polycrystalline Olivine.](#)
- Related to today's posting: [The Upper Devonian to Lower Carboniferous Billefjorden Group on Bjørnøya, Svalbard, and Its North-Eastern Greenlandic Provenance.](#)
- Using fish bones in stratigraphy: [The \*Teichichnus\* Ichnofacies: Its neoichnological basis and identification in the rock record.](#)
- [Challenges to the ancient methane seep search strategy: The Bedford Canyon Formation \(Middle Jurassic, Santa Ana Mountains, California\).](#)
- [Geology of the Mulkhura River Valley, Georgian Caucasus.](#)
- [Probing iron in Earth's core with molecular-spin dynamics.](#)
- [Cold Tectonics of Kos, Central Dodecanese: Oligocene Bivergent Extension of the Pelagonian Domain.](#)
- [Three-Dimensional Geometry of Sedimentary Basins and Moho Beneath Western Canada from Ambient Seismic Noise Tomography.](#)

- [A revised chemical weathering and sediment provenance history for the Late Miocene to recent Laxmi Basin, Arabian Sea.](#)
- [Bedrock Origins from Petrology and Geochemistry: Volcanic Gravel Clasts from the Rawhide Terrace in the Pleistocene Ancestral Mississippi River Pre-Loess Terrace Deposit.](#)
- [The reconstruction of coastal carbonate sequence stratigraphy: A modern-systems approach.](#)
- [Flood basalt origin for Earth's largest Paleoproterozoic banded iron formation.](#)
- [The metamorphosed Neoproterozoic epithermal Vent prospect, Ontario, Canada.](#)
- [The Wattie Group of the Birrindudu Basin, northern Australia: a witness to the denudation of the Nuna-forming Isan/Chewings Orogeny.](#)
- [On the coexistence of rift-related silica-undersaturated and silica-saturated alkaline rocks – The Cretaceous Messum alkaline complex \(Namibia\) revisited.](#)
- [Syntectonic Late Devonian terrestrial sedimentation in the southern Bonaparte Basin, Western Australia.](#)
- Stable isotope analysis: [Linking the oxygen-17 compositions of water and carbonate reference materials using infrared absorption spectroscopy of carbon dioxide.](#)
- [Blueschist emplacement in the Sepik Headwaters region, Papua New Guinea: field relations, petrology, isotopic dating and tectonic setting.](#)
- Lacustrine geology: [Cd isotope evidence for elevated productivity in the Middle Triassic Ordos Basin.](#)
- [Effects of thermal intrusion on biomarker distributions in the Alum Shale from south-central Sweden.](#)
- [December 2024 Edition of Elements, all on Himalayan Leucogranites.](#)

## Paleontology

- [New insights into the evolution and paleoecology of mosasaurs.](#)
- [The largest sauropodomorph skull from the Lower Jurassic Lufeng Formation of China.](#)
- Burgess Shale: [Meet 5 'Otherworldly' Ancient Animals – Preserved In Stunning Detail At This Iconic Fossil Hunting Site.](#)
- Little dinosaurs: [Body size and evolutionary rate analyses reveal complex evolutionary history of Alvarezsauria.](#)
- [A 3D braincase of the early jawed vertebrate \*Palaeospondylus\* from Australia](#); SciNews summary [here](#).

- [Microbial mat textures from the Neoproterozoic Donimalai Formation \(Sandur Schist Belt\) in the Dharwar Craton of India.](#)
- [A new brachiopod fauna from the Telychian \(early Silurian\) of Southwest China and its palaeoecological significance.](#)
- [Quaternary plant macrofossils from Robertson Cave, Naracoorte, South Australia: vegetative remains.](#)

## Mining and Energy

- [Can Coal Ash Solve the Rare Earth Supply Chain Crisis?](#)
- [IEA: Fracking Could Play a Crucial Role in Advancing Geothermal Energy.](#)
- Related to today's posting, petroleum deposit geology: [The Life and Death of Hydrocarbon Traps in East Greenland: The Charge and Degradation Histories of Laplace Bjerg and the Mols Bjerger.](#)
- Nova Scotia: [Military grade ore could again be mined in Hants County](#); related story [here](#).
- [Evergold drills high-grade antimony in British Columbia.](#)
- Geothermal power plant: [Iceland is feeding a real monster under the magma: It keeps growing, and it's shocking experts.](#)
- [Barrick said to seek buyer for Ivory Coast mine as bullion soars.](#)
- Australia: [Two mineral sands mines in western Vic given environmental approval.](#)
- [El Salvador discovers a potential \\$3,000,000,000,000 worth of gold and no one is allowed to mine it.](#)
- Exploration technique: [Geochemical Characteristics of Modern River-Sand and Its Bearing on the Mineral Exploration in the Manufahi Area, Timor-Leste.](#)
- Ore deposit geology: [Germanium, indium, gallium and cadmium in zinc ores: a mineral system approach.](#)
- More ore deposit geology: [Application of Ni, Cu and Fe isotopes as indicators of ore genesis – New insights from the epigenetic-hydrothermal Rajapalot Au-Co prospect, Finnish Lapland.](#)

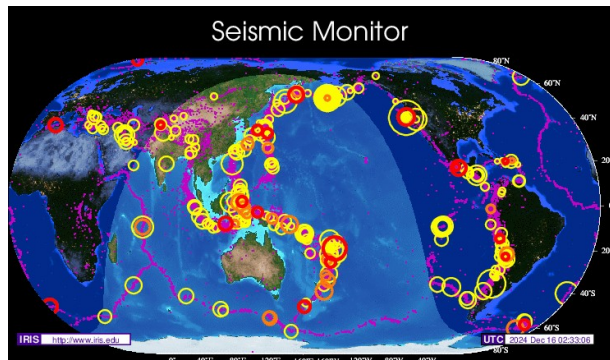
## Environmental Geology and Hydrogeology

- [Stanford Experts Sound Alarm on “Remarkably Harmful Toxin”](#), related research [here](#) and [here](#).
- [Eastman among companies sued for alleged decades-long ‘fraud and deception’ over plastic recycling](#); related video [here](#).
- PFAS remediation: [Cationic covalent organic framework for the fluorescent sensing and cooperative adsorption of perfluorooctanoic acid](#); Phys.org summary [here](#).

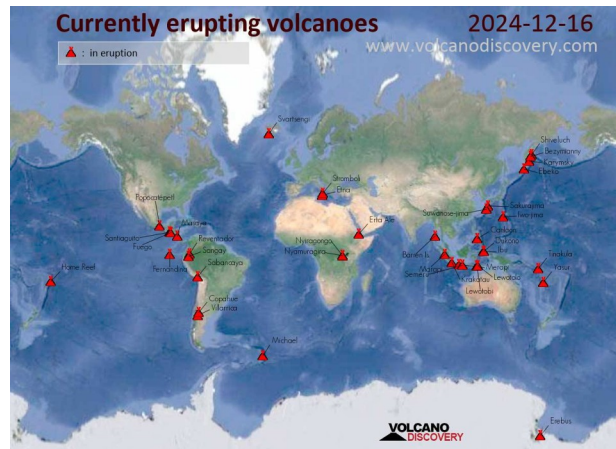
## Glaciers and Climate Change

- [3D seismic evidence for a single Early Pleistocene glaciation of the central North Sea](#); Phys.org summary [here](#).
- Related to today's posting: [One of world's largest glacier floods triggered in Greenland](#).
- [Enhanced warming of European mountain permafrost in the early 21st century](#);
- [Oxidation is a potentially significant methane sink in land-terminating glacial runoff](#); Phys.org summary [here](#).
- [No paleoclimatic anomalies are associated with the late Eocene extraterrestrial impact events](#); Phys.org summary [here](#).
- [Permafrost thaw subsidence, sea-level rise, and erosion are transforming Alaska's Arctic coastal zone](#); related [story here](#).

## Volcanoes, Earthquakes and Geohazards



[Seismic Monitor](#)



[Active Volcano Map](#)

## Volcanoes

- United States Geological Survey (USGS) [Volcano Watch: It's All About Perspective: How to Interpret an Interferogram](#).
- USGS Yellowstone Volcano Observatory: [The case of the missing cinders](#).
- [Smithsonian / USGS Weekly Volcanic Activity Report](#).
- Iceland: [Inflation detected around the country's most powerful volcano](#).
- [Magmatic processes associated with the 2020 eruption of Taal Volcano, Philippines, revealed by local seismic source estimates](#).
- Philippines: [Kanlaon Volcano Eruption Update 10 December 2024 03:30 AM](#); related story [here](#).

## Earthquakes

- [Euro-Mediterranean Seismological Centre \(EMSC\)](#).
- [Earthquakes Monitoring Live Worldwide](#).
- [M 6.4 – 56 km ESE of Molina, Chile](#).
- [Insights into tectonic hazards since the 2004 Indian Ocean earthquake and tsunami](#).
- [Estimating Secondary Earthquake Aftershocks from Tsunamis](#).
- [Numerous M5-6 earthquakes offshore the Aleutian Islands](#).
- [Induced Resonance and Forces Imparted on Buildings from Volcano Infrasonic](#).
- [Shake Movie of the December 5 Mendocino Earthquake from the USGS](#).
- [An Improved Pattern Informatics Method for Extracting Ionospheric Disturbances Related to Seismicity Based on CSES Data: A Case Study of the Mw7.3 Maduo Earthquake](#).
- Earthquakes and hydrocarbon gases: [Origin and significance of hydrocarbons in CO<sub>2</sub>-rich gases from Central Italy seismic areas](#).
- [Seismic clusters and fluids diffusion: a lesson from the 2018 Molise \(Southern Italy\) earthquake sequence](#).

## Upcoming Events

- The Geological Society: [Hybrid Conferences, January 16, 2025 – September 9, 2025, Climate and Ecology: Off the Rails](#).
- European Geosciences Union: [EGU General Assembly 2025, Vienna, Austria & Online 27 April–2 May 2025](#)
- [Sedimentary Geology and the Energy Transition Conference, June 2-5, 2025 – Salt Lake City, UT USA](#).
- [Geoscience Beyond Borders, GAC-MAC-IAH-CNC 2025 Ottawa, Ontario, May 11-14, 2025](#).
- [Society for Sedimentary Geology conference, Mountjoy IV – August 10-13, 2025, in Montreal, Canada](#).
- [Copper to the World Conference, Tuesday 26 – Wednesday 27 August 2025](#), in Adelaide, Australia; report on 2024 conference [here](#).
- 2024-2025 [Society of Petroleum Engineers Distinguished Lecturer Schedule](#).
- [List of geoscience events in 2025 from the International Union of Geological Sciences](#).
- [American Geophysical Union List of Upcoming Meetings](#).

December 16, 2024

## Geology and the Fate of Societies – Greenland



**Figure 1a – Greenland**

**Credit: [CIA World Factbook](#), public domain**



**Figure 1a – Location of Greenland**

**Credit: [CIA World Factbook](#), public domain**

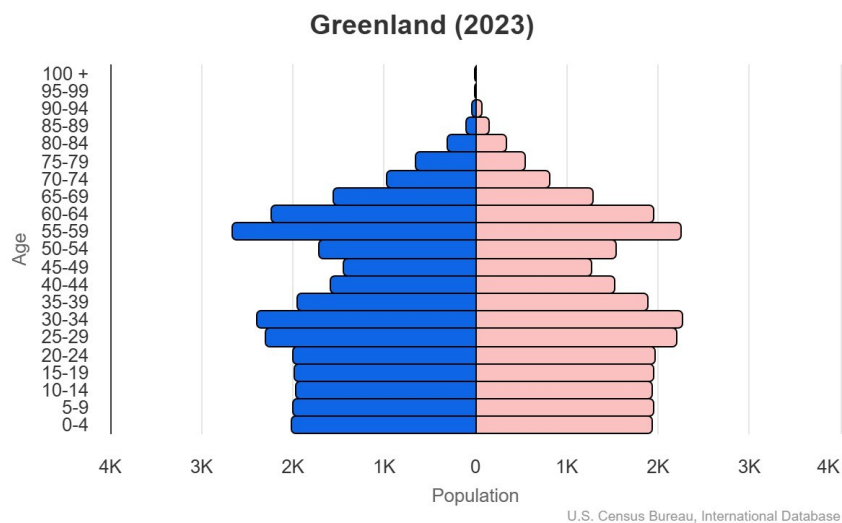
[Greenland](#) is an island to the northeast of [Canada](#); it is a self-governing territory of the [Danish Realm](#). It is not a [full part of the European Union](#). It has one land boundary, with Canada on [Hans Island](#) (the border was settled in the famous [Whiskey War](#)). To the north of Greenland is the [Arctic Ocean](#); to the

northeast is the [Greenland Sea](#); to the southeast, between Greenland and [Iceland](#), is the [Denmark Strait](#); to the south is the [North Atlantic Ocean](#); to the west is the [Davis Strait](#) and [Baffin Bay](#); and connecting Baffin Bay with the Arctic Ocean is the [Nares Strait](#).

As part of the Danish Realm, the Head of State for Greenland is the Danish King, [Frederik X](#), his [High Commissioner](#) in Greenland is [Julie Præst Wilche](#). The Prime Minister of Greenland is [Múte Bourup Egede](#); the Greenland legislature is called the [Inatsisartut](#); and the Speaker of the Inatsisartut is [Mimi Karlsen](#). Greenland also has two delegates in the Danish Parliament or [Folketinget](#). The Capital and largest city in Greenland is [Nuuk](#) (pop. 19,872).

According to the [Central Intelligence Agency](#)'s (CIA) [World Factbook on Greenland](#), the total land area of Greenland is 2,166,086 km<sup>2</sup>, 1,710,000 km<sup>2</sup> of which is covered by the [Greenland Ice Cap](#), a [continental glacier](#). Also according to the CIA World Factbook, 57,751 people live in Greenland, most of whom live along the southwest shoreline. Most, 88.1%, of Greenlanders are [Greenlandic Inuit](#). Of the remainder, 7.1% are [Danes](#), 1.6% are [Filipino](#), 0.9% are other [Nordic peoples](#), and the remaining 2.3% are something other such as [Thai workers](#). Most of the people in Greenland speak [Greenlandic](#), itself divided into West Greenlandic – [Kalaallisut](#) and East Greenlandic – [Tunumiit oraasiat](#). The Polar Eskimo in northern Greenland group speak [Inuktun](#). Other languages spoken in Greenland include [Danish](#) and [English](#).

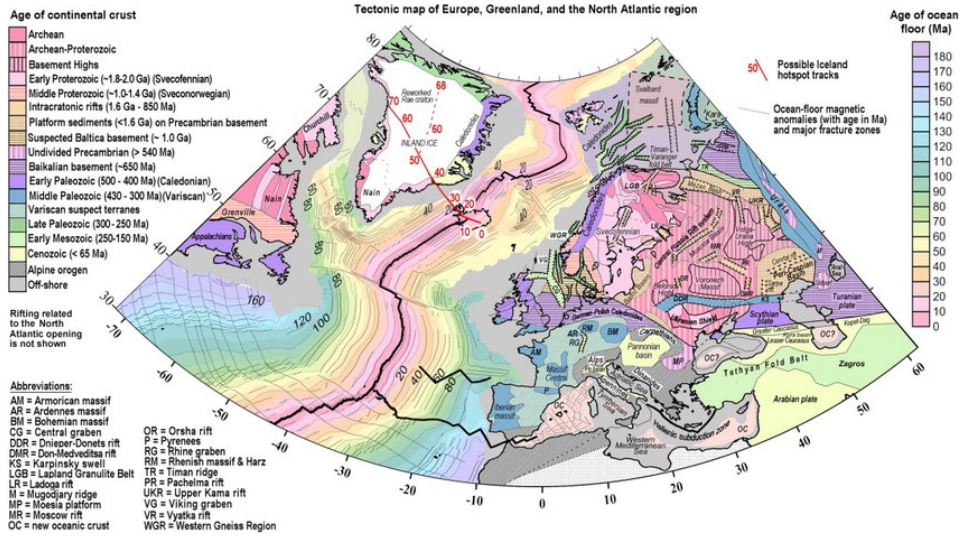
The official religion of Greenland is the [Church of Greenland](#), a [Lutheran](#) denomination. Many Greenlanders also follow [traditional Inuit folk beliefs](#). In terms of education, 100% of the population 15 years and old can read and write. Economically, the nominal per capita [GDP](#) is \$54,694; the [Gini coefficient](#) is 33.9, indicating medium inequality; and the [Human Development Index](#) is high at 0.786.



**Figure 2 – Demographic Profile of Greenland**  
**Credit: U.S. Census Bureau, International Database, public domain**

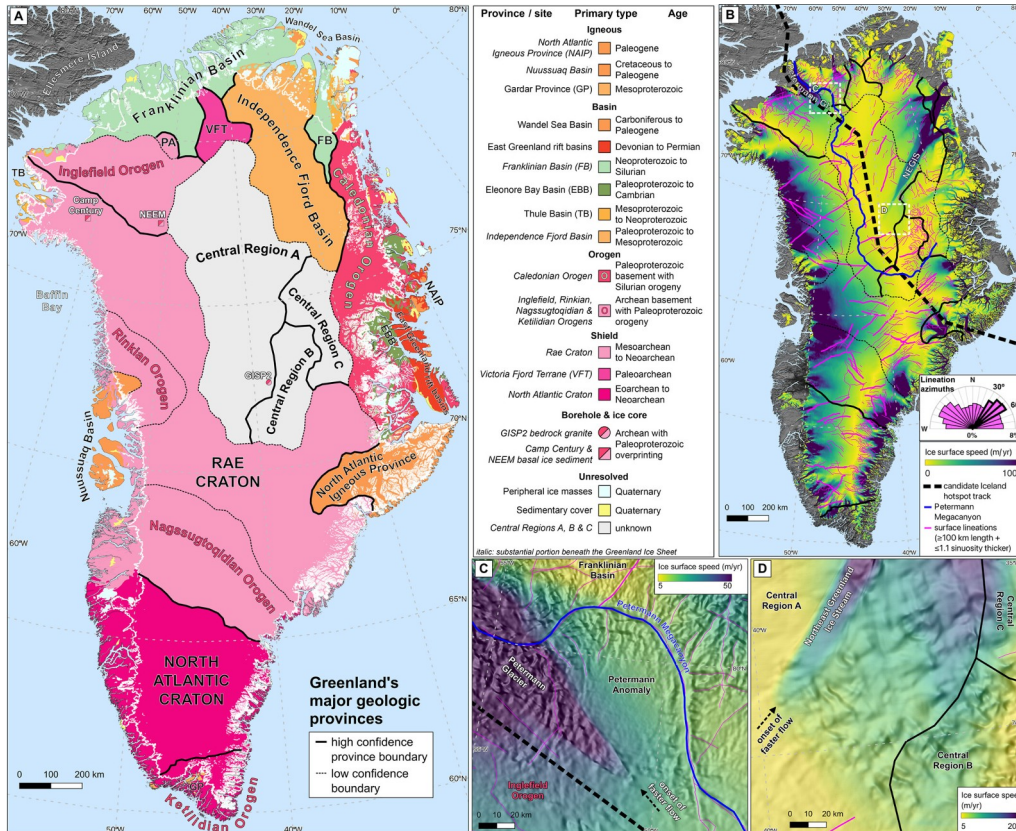
The demographic profile of Greenland shows a shrinking population where 67.1% of the people are between 15 and 64 years of age. The total fertility rate is 1.90 births per woman, below the replacement rate of 2.1. Combined with a net out-migration of -4.9 migrants/1,000 population, the resulting annual growth rate for the population is -0.04%. Life expectancy at birth for both sexes is 74.3 years.

# Geology



**Figure 3 - Tectonic Map of Europe, Greenland, and the North Atlantic Ocean**  
**Credit: Figure 3 in Artemieva & Thybo, 2013**

Greenland sits on the northeast side of the [North American Plate](#) and forms a [microplate](#). Separating the [Greenland Microplate](#) from the rest of the North American Plate is a [failed rift under the Davis Strait](#). This rifting event began during the [Upper Paleocene](#) and stopped during the [Lower Eocene](#).



Determining the geology of a place mostly covered by 2-3 km of ice is obviously difficult. However, a recent study (MacGregor *et al*, April 2024, *Geologic Provinces Beneath the Greenland Ice Sheet Constrained by Geophysical Data Synthesis*, Geophysical Research Letters, <https://doi.org/10.1029/2023GL107357>) has used geophysical methods to better extrapolate the geology known from outcrops at the edge of the island. While the geology of some areas remains unknown, the major geological provinces of Greenland are now tentatively mapped. Going from youngest to oldest, the main geological provinces of Greenland are:

### **Glacial Deposits**

- [Pleistocene](#) aged [glacial deposits](#).

### **Igneous Provinces**

- The [Paleogene](#) aged [North Atlantic Igneous Province](#);
- The [Cretaceous](#) to Paleogene aged [Nuussuaq Basin](#);
- The [Mesoproterozoic](#) aged [Gardar Province](#).

### **Basin Provinces**

- The [Carboniferous](#) to Paleogene aged [Wandel Sea Basin](#);
- The [Devonian](#) to [Permian](#) aged [East Greenland rift basins](#);
- The [Neoproterozoic](#) to [Silurian](#) aged [Franklinian Basin](#);
- The [Paleoproterozoic](#) to [Cambrian](#) aged [Eleonore Bay Basin](#);
- The Mesoproterozoic to Neoproterozoic [Thule Basin](#);
- The Paleoproterozoic to Mesoproterozoic [Independence Fjord Basin](#).

### **Orogen Provinces**

- [Caledonian Orogen](#): Paleoproterozoic [basement](#) with Silurian aged [orogeny](#);
- [Inglefield](#), [Rinkian](#), [Nagssugtoqidain](#), and [Ketilidian](#) Orogens: [Archean](#) aged basement with Paleoproterozoic orogeny.

### **Shield Provinces**

- The [Mesoarchean](#) to [Neoarchean](#) aged [Rae Craton](#);
- The [Paleoarchean](#) aged [Victoria Fjord Terrane](#);
- The [Eoarchean](#) to Neoarchean aged [North Atlantic Craton](#).

For further information on the geology of Greenland you might want to check out research articles from the [Geological Survey of Denmark and Greenland](#); they are pretty good.

## Resources

### Food Production



**Figure 5 – Fishing Boat at Aasiaat**

**Credit:** Karlbrix, [Creative Commons Attribution-Share Alike 4.0 International](#) license

While some livestock are exploited in Greenland, primarily [reindeer](#), the major area of food production in Greenland is from the [fishing industry](#). The fishing industry in Greenland employs about 6,500 people and accounts for 90% of the country's total exports. Most (~90%) marine product exports go to [Denmark](#) and other countries in the [European Union](#).

The types of animals harvested in the Greenland fishery include:

- **Marine invertebrates:** [Iceland Scallop](#), [Northern Prawn](#), and [Snow Crab](#);
- **Bony and cartilaginous fish:** [Atlantic Cod](#), [Atlantic Halibut](#), [Capelin](#), [Catfish](#), [Arctic Char](#), [Greenland Cod](#), [Greenland Halibut](#), [Greenland Shark](#), [Lumpsucker](#), and [Redfish](#).
- **Marine mammals:** [Harbour Seal](#), [Bearded Seal](#), [Harp Seal](#), [Hooded Seal](#), [Ringed Seal](#), [Walrus](#), [Beluga Whale](#), [Fin Whale](#), [Orca Whale](#), [Minke Whale](#), [Narwhal](#), [Pilot Whale](#), and [Giant Beaked Whale](#).

The most recent (December 12, 2024) statistics on fishery production in Greenland can be found [here](#).

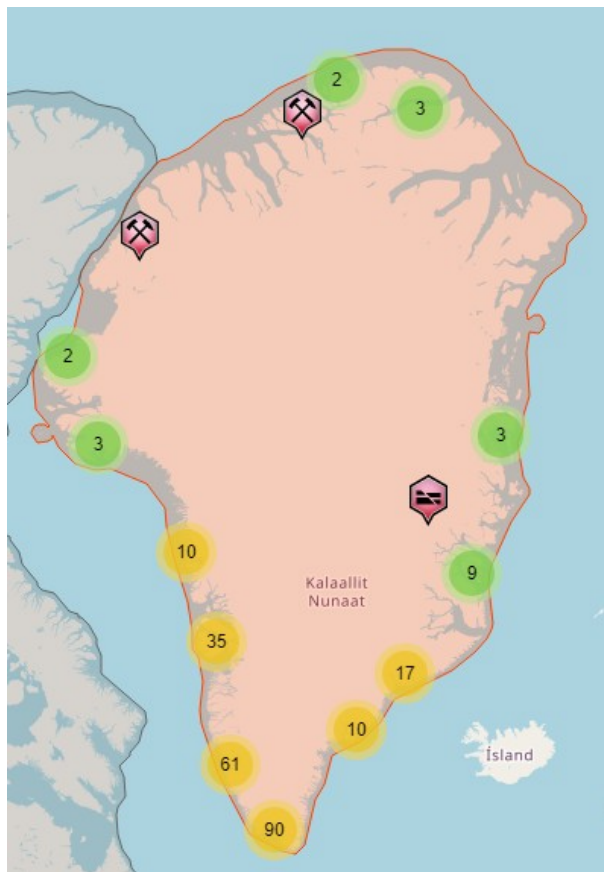
The [importance of the fishing industry](#) is part of the reason why Greenland is not a full member of European Union (EU). Following initial membership in the EU, the people of Greenland [voted to withdraw](#) from the common market in a 1982 referendum. The [Greenland Treaty](#) formalized the relationship between Greenland and the EU. The essential issue for Greenlanders was local control over their fishing industry.

## Mineral Resources



Figure 6 – Gold Ore from the [Nalunaq Gold Mine](#)

Credit: [James St. John, Creative Commons Attribution 2.0 Generic license](#)



According to the USGS publication “[The Mineral Industries of Denmark, the Faroe Islands, and Greenland](#)” and the most [recent statistics](#) from the USGS, mineral production in Greenland comes from three mines:

- Gold from the [Nalunaq Mine](#), which [recently announced](#) its first pour of gold;
- [Anorthosite](#) ([calcium plagioclase](#)) from the [White Mountain \(Qaqortorsuaq\)](#) mine; and
- [Corundum](#), rubies, and sapphires from the [Aappaluttoq](#) mine.

Figure 7 links to an interactive map of mineral occurrences in Greenland.

Figure 7 – Interactive Mineral Occurrences Map

Credit: [©Mindat.org](#)

Greenland has been [encouraging mineral exploration](#) and provides [information on mineral occurrences](#) to interested parties. However, the same cannot be said of petroleum/natural gas exploration. In 2021, after 50 years of repeated failures, Greenland suspended [all offshore petroleum exploration licences](#).

## Climate

Greenland map of Köppen climate classification



**Figure 8 – Köppen Climate Classification for Greenland**

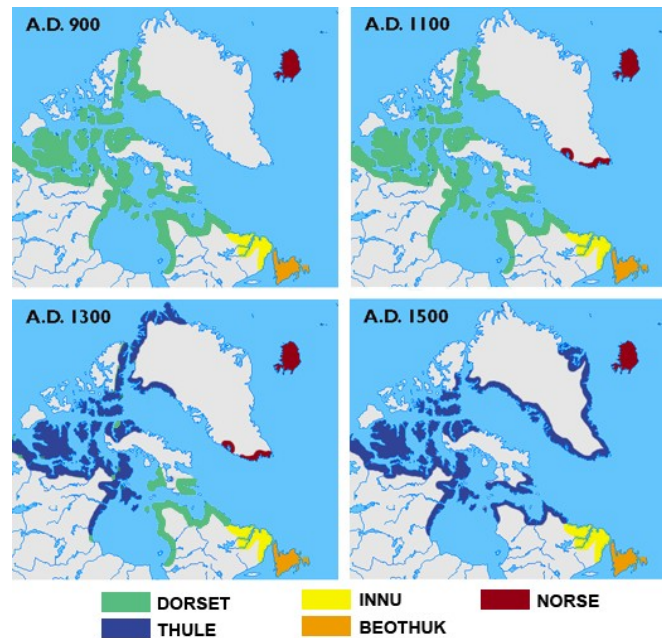
**Credit:** [Ali Zifan](#), [Creative Commons Attribution-Share Alike 4.0 International](#) license

The best way to describe the climate of Greenland is that it has two zones: cold, tundra climate ([ET](#)), and colder, the ice cap climate ([EF](#)). The only part of Greenland where human habitation is possible is where the tundra climate prevails, and the most pleasant part of the country is in the southwest.

You may want to visit Greenland. Travel advisories ([here](#) and [here](#)) for the country warn of dangerous and unpredictable weather. As a Canadian, I can tell you that cold can be a killer, so dress for the weather if you go. On the good side, the country is beautiful and fairly safe, just watch out for the clouds of tundra [mosquitoes](#) in the all-too-brief summer. Recently, a [new international airport opened at Nuuk](#), possibly making travel to Greenland easier. It remains to be seen if the country becomes a favoured tourism destination and if the locals really want their lives disrupted by foreign travellers.

## History and Geopolitics

### *A History of Great Migrations*



**Figure 9 – Arctic Cultures 900-1500**

**Credit:** [Masae](#) (original), [Premeditated Chaos](#) (this version), [Creative Commons Attribution-Share Alike 3.0 Unported](#) license

The earliest known inhabitants of Greenland were the peoples of what we now call the [Pre-Dorset](#), [Saqqaq](#), and [Dorset](#) cultures who arrived in Greenland around 2500 BC and whose presence lasted till around the beginning of the Christian Era.

Next in line, around 983 AD, came Norse adventurer [Erik Thorvaldsson](#) a.k.a Erik the Red who established a settlement on the southwest coast of Greenland (like all good Vikings, Erik's life is recorded in a [saga](#)). The [Norse Greenland Settlement](#) lasted until the 15<sup>th</sup> Century when a combination of worsening climate, isolation, and just plain bad luck doomed the community to extinction. (Paul Cooper has an excellent discussion of the Greenland Norse [here](#)).

The next group of people to move into Greenland were the ancestors of the current Greenlanders, the [Thule Inuit](#). The story of the Thule and their rapid migration to Greenland from their original home in Alaska is truly one of the great epics of the human race. Summaries of that migration can be found [here](#), [here](#), and [here](#).

The [Danes arrived in 1728](#) and have remained ever since, with the Danish monarch the titular head of state. Greenland gradually achieved self-rule beginning in 1953. They established the local legislature in 1979. More details on the history of Greenland can be found [here](#).

### *Geopolitics – Between a Rock and a Hard Place*



**Figure 10 – Satellite Communication Domes, Pituffik Space Base (Thule Air Base)**  
**Credit: [U.S. Air Force](#), photographer Michael Tolzmann, [public domain](#)**

Although the people of Greenland appear to [wish for greater autonomy](#) and control of their own affairs, complete independence is unlikely in the near future. One reason is that the Greenlanders are still fairly [dependent on Denmark](#), both as a market for their exports and to support their government administration.

[Denmark provides Greenland](#) with an annual block grant of DKK 3.9 billion – roughly USD 511 million – which accounts for approximately 20 percent of Greenland’s GDP and more than half of the public budget.

Another consideration is that Greenland is a harsh place and the same bad luck that doomed the Norse Greenlanders could easily descend upon their modern successors, who number only 58,000 or so. Having the backup of a larger polity like [Denmark](#) is a good hedge against disaster.

As part of the Danish Realm, Greenland is part of the [North Atlantic Treaty Organization](#) (NATO). This leads to the another reality, namely is that Greenland sits in between two rival Great Powers – the [United States](#) and [Russia](#). The United States maintains a military base at [Qaanaaq](#) (Thule), the [Pituffik Space Base](#). The main purpose of this base is to provide early warning of a nuclear attack on the USA by Russia. Greenland is therefore a target in any such conflict, whether they like it or not. As the Russian revolutionary [Leon Trotsky](#) famously said “You may not be interested in war, but [war is interested in you.](#)”

Unfortunately for the people of Greenland, their evident wish to live a quiet life is held hostage to the ambitions of the Great Powers. While we can sympathize with their plight, but there are few good alternatives for them. Like it or not, in the modern world, a big place like Greenland will attract the attention of Great Powers. That is the geopolitical reality for Greenland.

That winds up this short look at Greenland, follow up on the links if any of this interests you.

## **Standard Caveat**

### **[J. Robert Oppenheimer on freedom and scientific inquiry](#)**

The purpose of my weblog postings is to spark people's curiosity in geology. Don't entirely believe me until you've done your own research and checked the evidence. If I have sparked your curiosity in the subject of this posting, follow up with some of the links provided here. If you want to, go out into the field and examine some rocks on your own with the help of a good field guide. Follow the evidence and make up your own mind.

In science, the only authority is the evidence.