by Björn Sundquist[1], Ilmari Haapala[2], Jens Morten Hansen[3], Geir Hestmark[4], and Sigurdur Steinthorsson[5]

History of Geology in Norden

1 Department of Earth Sciences, Uppsala University, Villavägen 16, SE-75236 Uppsala, Sweden. *E-mail: bjorn.sundquist@geo.uu.se*
2 Department of Geology, University of Helsinki, P.O.Box 64, FI-00014 Helsinki, Finland. *E-mail: ilmari.haapala@helsinki.fi*
3 Geological Survey of Denmark and Greenland (GEUS), Øster Voldgade 10, DK-1350 København K, Denmark. *E-mail: jmh@geus.dk*
4 Institute of Biology, University of Oslo, P.O.Box 1066 Blindern, NO-0316 Oslo, Norway. *E-mail: geir.hestmark@bio.uio.no*
5 Department of Earth Sciences, University of Iceland, Jardarhaga 2-6, IS-107 Reykjavík, Iceland. *E-mail: sigst@raunvis.hi.is*

The Nordic countries of Denmark, Finland, Iceland, Norway, and Sweden have been closely connected for many centuries, not least from a geological point of view. Scientific cooperation as well as contentions have been common. The earliest known records of "geological" treatises are from the 16th century, but especially in the 18th century, when the natural sciences flourished all over Europe, Nordic scholars were in the forefront in geochemistry, mineralogy, and paleontology. This was also the century when "geology" started to be taught at the universities, and science academies were founded in Norden, adding greatly to "geological" studies. In the 19th century, like in so many other countries, national geological survey organizations and geological societies were founded. In Norden, geological research has long traditions within mineralogy and ore geology, paleontology and stratigraphy, tectonics and structural geology. During the last century, focus has turned also to Quaternary and glacial geology, igneous and metamorphic petrology, geochemistry, micropaleontology, petroleum geology, sedimentology, marine geology, geophysics, geochronology, and research related to geothermal energy and deposition of radioactive waste products. In many of these research areas, Nordic geoscientists have contributed greatly over the years to the development of the science of geology.

Introduction

Geology as a science was established around 1800. It was the fruit–however unripe–of many centuries of efforts, experiences, failures, and successes by precursors. Fundamental for geology to evolve as a science was the realization that the Earth had a history that went back long before Man, and that the order and fossil contents of sedimentary rock strata could reveal that history. Geology was a new science, building on the advances made in chemistry, physics and biology, but adding to them an "incomprehensible" time dimension. But also instrumental achievements were basic for important parts of the practical accomplishment, mainly the development of the microscope in the 1830s. In addition, an array of early cumbersome problems had been solved or put aside, e.g., the earth was not a divine gift, the earth was not a few thousand years old, Man was not the crown of Creation, fossils were not *lusus naturæ* but the remains of living creatures.

This brief chapter on the history of geology in Norden will cast light on some problems and endeavours engaging people — natural scientists, as well as physicians and clergy in the early days — in the Nordic countries contributing to this process.

A brief outline up to 1800

Basic knowledge about rocks, ores and soils were of course achieved from generations of experience in mining and agriculture. An early account of mining, minerals, rock carving and agriculture by a Northerner was given by Petrus Magni (c. 1465–1534; a Swedish monk, later bishop), written partly independently, in the early 16th century. Olaus Magnus (1490–1557; exiled Catholic archbishop of Sweden living in Rome) in his *Historia de gentibus septentrionalibus* ("History of the Nordic peoples"), published in 1555, also wrote on mining and natural conditions. Even the Icelandic sagas tell us about former climate conditions. Although not scientific, these books are important sources for understanding the level of knowledge and the mysticism that was linked to many natural objects at that time.

In the 17th century there appeared so-called "*physicæ*", i.e., general treatments of the entire visible nature and its characteristics; the heavenly bodies, the earth and its mountains, rivers, organisms, rocks and minerals. In Finland, Sigfrid Aronus Forsius (c. 1555–1624; vicar and astronomer) wrote *Physica* (1611, published 1952!) and *Minerographia* (1613, published 1643), summarizing the knowledge about rocks, minerals and metals. In Denmark, there was an early interest in the earth sciences. Caspar Bartholin the elder (1585–1629) wrote *Systema physicum* (1628) and Ole Worm (1588–1654), Thomas Bartholin (1616–1680) and Ole Borch (1626–1690) treated geology-related matters, minerals, metals, fossils. In the year 1669 two pioneering books written by Danes were published; Niels Stensen's (Nicolaus Steno, 1638–1686) *De solido intra solidum naturaliet contentum dissertationis prodromus* (published in Florence) and Erasmus Bartholin's (1625–1698) treatise on the bi-refringency of Iceland spar (published in Copenhagen).

In the 18th century, landscape descriptions became more frequent, many of which were carried out by clergymen publishing on the natural and cultural history of their parishes. But also scholars contributed to this genre. In Sweden, Urban Hiärne (1641–1724) was the first to investigate the nation's geological conditions by sending, in 1694, an inquiry to officials around the country asking for information. The results were published in the following decade. Carl von Linné (Linnaeus, 1707–1778) in his travel descriptions made many remarks on geological findings, and Daniel Tilas (1712–1772), a grandson to Hiärne, published on occurrences of ores and petroleum in central Sweden. In Denmark, the writer and playwright Ludvig Holberg (1684–1754) published a description of Denmark and Norway, and so-called natural histories were published on Norway by, e.g., Erich Pontoppidan (1698–1764). The seashore exposures and their fossil contents at Stevns Klint and Møns Klint in Denmark were described by Søren Abildgaard

(1718–1791), and Hans Strøm (1726–1797) wrote on Norwegian landscapes as well as on fossils. Early investigations of the natural conditions of Iceland were carried out by Eggert Olafsson (d. 1768) and Biarni Pálsson (1719–1779), and in their printed description of 1772 was also a chapter on the island's geological structure.

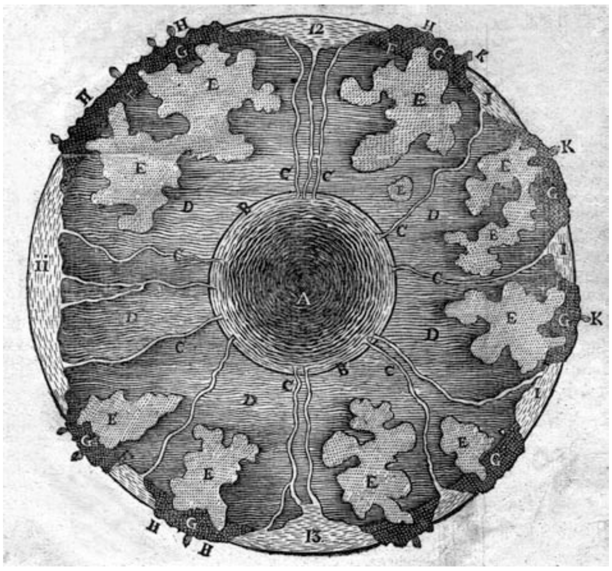

Figure 1 Earth's interior according to an early 18th century view. Ocean waters enter through canals (C) into the center of the earth (A) which is filled with fermenting mud. From there the rising steam is purified when passing through the porous earth (D), entering the "linia trivialis" (F) and eventually the surface. E marks "hydrophylacia", major cavities filled with water and fine sand. (From U. Hiärne, 1706: Den beswarade och förklarade anledningens andra flock, om jorden och landskap i gemeen, facing p. 150.).

Academies of sciences were founded in 1739 in Sweden, in 1742 in Denmark, and in 1760 in Norway. These came to have a great influence on the development of natural science in Norden. Two universities had been established in the 15th century, in Uppsala (Sweden) in 1477 and in Copenhagen (Denmark) in 1479, and two in the 17th century, in Turku (Åbo, Finland) in 1640 and in Lund (Sweden) in 1666. But is was not until the 1720s that mineralogy and paleontology began to be taught at universities in Norden. In Turku, for instance, teaching in this field was initially conducted by professors of medicine and economics, and from 1761 by Pehr Gadd (1727–1797) and later by Johan Gadolin (1760–1852), professors of chemistry, who also supervised a number of master dissertations on mineralogical and geological topics.

Rock classifications and mineral analyses, mainly by blowpipe, were strongly developed during the 18th century. In Sweden, so-called *Mineralogiæ* were published by well-reputed scientists like Magnus von Bromell (1679–1731), Johan Gottschalk Wallerius (1709–1785), Axel Fredrik Cronstedt (1722–1765) and Torbern Bergman (1735–1784), contributing greatly to the science, many of which ran through many editions and were translated into several languages. Even Linnaeus in his *Systema naturæ* (1735) included a "Regnum lapideum". Paleontological treatises began to appear, by, e.g., Magnus von Bromell and Kilian Stobæus (1690–1742) in Sweden, Hans Strøm in Norway, Morten Thrane Brünnich (1737–1827) and Peter Christian Abildgaard (1740–1801) in Denmark.

An issue that concerned many scholars in Sweden and Finland, e.g., Emanuel Swedenborg (1688–1772), Linnaeus, Anders Celsius (1701–1744), and Wallerius in Sweden, and Johan Browallius (1707–1755) and Per Kalm (1716–1779) in Finland, was the so-called "diminution of the sea". Already Hiärne had called attention to the observations that the shore of the northern Baltic Sea had moved seaward for centuries; old landing-stages were now far inland. This phenomenon was regarded as due to a diminishing amount of sea water, and it was not until the 19th century it was explained as due to the elevation of that region—later construed as being due to isostatic rebound following deglaciation.

Geology in Denmark and Greenland after 1800

Early in the 19th century a young naturalist and mineralogist, Henrik Steffens (1773–1845), made his spectacular entrance to Copenhagen. Under great public attention, he gave a series of lectures on European science and poetry. Together with, e.g., Alexander von Humboldt and the great German author and naturalist Johann Wolfgang von Goethe, Steffens had studied geology under Gottlob Werner. Through Steffens' friendship with Goethe the knowledge about the growing Romantic literature spread to Danish authors and leading cultural personalities such as N.F.S. Grundtvig and the national icon and poet Adam Oehlenschläger. These events are generally considered to mark the onset of the Romantic Movement in Danish poetry, painting *and science*, where the discoverer of electromagnetism, H.C. Ørsted (1820) together with Steffens became a leading figure with his Romantic thoughts and writings on 'The Spirit in Nature'.

However, the Norwegian-born Steffens soon left Copenhagen to take up a position as professor of geology in Kiel in Holstein. (Both Norway and Schlesvig-Holstein were united with Denmark until 1814 and 1864, respectively.) Soon thereafter the first professorship in geology (i.e., mineralogy and chemistry) was established at Copenhagen University, and Johan Georg Forchhammer (1794–1865) was appointed. Forchhammer was of a more specific scientific school than Steffens and Ørsted, and his geological studies were based on the methods of another Dane, Nicolaus Steno (1638–1686), who already in 1667 and 1669 had made important contributions to the foundation of the science that we now call geology. Forchhammer met Charles Lyell, and together they studied the chalk formations of eastern Denmark. They agreed that the

Figure 2 Stevns Klint at the east coast of Sealand is the international type locality of the Cretaceous-Tertiary (Maastrichtian-Danian) boundary. At the base of the Danian the boundary is marked by the so-called 'Fish Clay' containing a high concentration of the rare element iridium. At a conference in Copenhagen in 1979 lead by geology professor Tove Birkelund a major controversy started to evolve on the interpretation af the Ir-content. The geologist Walter Alvarez claimed that the Ir-deposition was caused by a large bolide impact also causing the mass extinctions at the K-T boundary, while others—especially people from Copenhagen University—claimed the Ir-deposition to be caused by the Deccan Trap volcanism in India 65 m.y. ago.

Danian limestone at Stevns Klint is younger than the Upper Cretaceous chalk. However, they disagreed on the formation of the large floes of white chalk piled up and interbedded with 'dilluvial' deposits in Møns Klint. Lyell suggested that Møns Klint, which is now a classic example of glaciotectonics, was formed by drifting masses of sea ice and icebergs. Forchhammer doubted Lyell's explanation and considered the large dislocations to be of volcanic origin associated with crustal earth movements.

In 1874 geology professor F. Johnstrup argued for a glacial origin of the surface deposits in Denmark. The zoology professor Japetus Steenstrup (1813–1897) confirmed Johnstrup's ideas about a glaciation in the recent past by studies of bogs in Northern Zealand where immigration of more and more warmth-demanding species followed the arctic species found at the base of the bogs. In 1888 the Geological Survey of Denmark (DGU) was founded with Johnstrup its first Director. Thereafter Quaternary geology and environmental history studies became a prominent part of Danish geology. In particular, during the first half of the 20th century Johannes Iversen's (1904–1971) development and use of pollen analysis provided a modern understanding of past climatic changes, the immigration and settlement of Man, and the temperate vegetation's migration into Denmark and Northern Europe.

During the first part of the 20th century the geology of Greenland also became a prominent part of Danish earth sciences subsequent to expeditions led by H. J. Rink, J. F. Johnstrup, K. I. V. Steenstrup, and N. V. Ussing to West Greenland. Most conspicuous were 'The Danish Expeditions to East Greenland' from 1926 to1958 including the 'Three Year Expedition' to North East Greenland (1931–1934). These dangerous expeditions were led by the charismatic geologist Lauge Koch. He worked directly under the Danish Government, and invited many foreign colleagues to join his expeditions. In the 1930s, however, after Koch had published his *Geologie von Grönland* and *Geologie der Erde*, a major controversy divided Danish geologist into two groups, respectively *pro et contra* Koch. At a meeting in the Geological Society of Denmark, Koch was seriously accused by eleven prominent Danish geologists to have stolen or misinterpreted their results. Koch took the accusers to court, and after a long and bitter trial he partly won the case after appealing to the Supreme Court. In 1934 Koch won another important trial as Danish delegation leader, namely the trial between Denmark and Norway at the International Court in The Hague about the High Supremacy over East Greenland.

Shortly after the Second World War the Geological Survey of Greenland (GGU) was founded. The first task for GGU concerned the geological mapping of West Greenland, where the population is concentrated. From 1970 to the end of the century the geological mapping progressed to East and North Greenland, mainly supervised by Niels ("Oscar") Henriksen.

In the late 1960s the Danish Underground Consortium (DUC) made the first oil discovery in the North Sea under the geological leadership of Theodor Sorgenfrei (1915–1972). Soon after, oil discoveries were also made in Norwegian and British parts of the North Sea. In 1981 a law on the exploration of the Danish 'underground' opened the Danish North Sea sector for other oil companies. This led to a considerable growth in oil and gas exploration in the Danish North Sea sector, and at the time of writing Denmark is Europe's third largest producer of hydrocarbons.

This work also stimulated the oil geology at the universities and at DGU. DGU's chief geologist Arne Dinesen made important decisions for the benefit of geological research and economic geology. A large geophysical division was established at DGU and important basic research in the sedimentology and dynamics of chalk reservoirs was undertaken by groups at DGU and Copenhagen University.

In 1971, the Danish Government appointed the world's first minister of the environment, and simultaneously environmental geology became an increasingly important issue in Danish geology with state geologists Lars Jørgen Andersen (hydrogeology) and Svend Thorkild Andersen (environmental history) from DGU, and professor Henning Sørensen (geochemistry) from Copenhagen University as leading personalities. At Århus University environmental geology culminated with Kurt Sørensen's outstanding development of geophysical methods for groundwater mapping.

In 1995, the DGU and GGU were merged to form one institution (the GEUS) working equally in Denmark and Greenland. On top of that, GEUS and the geological and geographical institutes at Copenhagen University formed a 'Geocentre Denmark' together with the Geological Museum and in 2007 also including the geological institute at Århus University.

Geology in Finland after 1800

After the 1808–1809 war between Russia and Sweden, Finland became part of the Russian Empire as an autonomous Grand Duchy. Governor-General Fabian Steinheil (in office 1811–1823) was deeply interested in mineralogy and emphasized the role of mining industry and exploration in pursuit of domestic raw materials for the country's iron works. The mining office was reorganized and Nils Nordenskiöld (1792–1866) was appointed superintendent. As the result of active and enthusiastic prospecting, several new minor iron deposits were discovered. Nordenskiöld urged systematic geological mapping as the basis for successful prospecting. In 1877, a ten-year budget was allocated to the "Geological Expedition" and in 1885 the Geological Commission (Geological Survey of Finland) was founded. The Geological Society of Finland was founded in 1886.

In 1828, the Academy of Turku was moved to Helsinki, later to become the University of Helsinki. A professorship of geology and mineralogy was established there in 1852, but it remained without a permanent incumbent for many years, as the young and talented mineralogist Adolf Erik Nordenskiöld (1832–1901) had to flee to Sweden for political reasons. In 1877, Fredrik Johan Wiik (1839–1909) was appointed to the post.

In the early and mid-19th century, Finland had several famous mineralogists, e.g., the above-mentioned persons and Axel Gadolin (1828–1892). The granite pegmatites and skarn deposits of southern Finland provided rewarding research opportunities for these scientists who mastered crystallographic and mineral-chemical research methods. The modern study of the Precambrian crystalline bedrock was, however, only made possible by the advent of the petrographic microscope. In Finland this was first used by Wiik, and for his students Jacob Johannes Sederholm (1863–1934) and Wilhelm Ramsay (1865–1928), as well as for Ramsay's student Pentti Eskola (1883–1964), it served as a basic research instrument.

Sederholm was Director of the Geological Survey from 1893 to 1933. In the 1890s, he applied the uniformitarian doctrine to the origin of the Precambrian bedrock of southern Finland, and later he made pioneering studies of the petrology of granites and migmatites.

Figure 3 Geological excursion to Skogböle (Kuovila), Pohja, southwestern Finland, on May 16, 1908. From left: P. Eskola, R. Stenberg, B. Frosterus, Miss E. Holmberg, J.J. Sederholm (with hammer), O. Trüstedt (discoverer of the Outokumpu deposit), W. Ramsay. Photo: W.W. Wilkman, Geological Survey of Finland, VK05671.

Wilhelm Ramsay followed Wiik as professor of geology and mineralogy. He discovered and studied the alkaline rocks of the Kola Peninsula and, subsequently, focused on the Finnish Quaternary geology and the history of the Baltic Sea. Ramsay's successor Eskola introduced his doctrine of regional metamorphic facies in 1915 and developed it in subsequent works. His studies on petrographic-tectonic classification and origin of granitic rocks were classics in their fields. The discovery of the large and rich Outokumpu copper ore in 1910 and the Petsamo (Pechenga) nickel deposits in the 1920s and 1930s enhanced the possibilities of exploration and mining industry in Finland.

The theory of a continental ice sheet gained support in Finland in the 1860s. Studies of Quaternary geology made rapid progress in the late 1880s and 1890s and, by the early 1900s, Ramsay and Sederholm, together with Finnish and Swedish colleagues, had outlined the history of the Baltic Sea as well as the origin of the Salpausselkä marginal formations and eskers. In 1924, Ramsay explained the Baltic Sea shore displacement as the result of postglacial isostatic rebound and water level fluctuations resulting from the melting of the continental glacier. Ramsay's work was continued by Matti Sauramo (1889–1958), professor of geology and paleontology, who also applied the varved clay method and microfossil studies. The prominent lakes of Finland and their discharge channels were studied by Ramsay and Väinö Auer (1895–1981) among others.

The decades after World War II were a period of steady progress for both mining industry and geological research. The staff of the Geological Survey increased from about 25 in 1935 to 900 in 1985. The bedrock and soils of the country have been mapped to the scale of 1:400,000, and more detailed mapping (1:100,000) covers most of the country. Airborne geophysical mapping was initiated by Aarno Kahma (1914–2004) and Maunu Puranen (1914–1999) in 1951 and completed in 1972, and a low-altitude survey is near completion. Other study and research objects of the Geological Survey have included geochemistry, isotope-geochemistry, mineralogy, marine geology, peat bogs, and nuclear waste disposal in hard rock.

For many years, the Department of Geology at the University of Helsinki was the only institution of its kind in Finland. A chair of geology and mineralogy was founded at the Swedish-language Åbo Akademi University in Turku in 1918. The universities of Turku and Oulu got chairs of geology and mineralogy and Quarternary geology in the late 1950s and in the 1960s. Currently, the departments of geology at the universities of Helsinki, Turku, and Oulu have 4–6 professorships, Åbo Akademi has two. Helsinki University of Technology has a chair of economic geology and Tampere University of Technology has a chair of engineering geology. The departments have produced important contributions to the geology of Finland and beyond. The Institute of Seismology at University of Helsinki has played an important role in the study of the deep structures of the lithosphere.

In the 1940s and 1950s, Thure Georg Sahama (1910–1983) and Kalervo Rankama (1913–1995), both professors of the University of Helsinki and authors of *Geochemistry*, rose to world fame as geochemists. In the 1950s, Sahama focused on mineralogy, and Rankama wrote and edited comprehensive books on isotope geology and Precambrian geology.

Between 1940 and 1980, thirty new base and ferrous metal mines were opened in Finland. Later, successful exploration has been focused more on precious metals. In recent years, the discovery of diamond-bearing kimberlites with deep crustal and mantle xenoliths has initiated cutting-edge studies on the nature and composition of the lithospheric mantle in eastern Finland.

During recent decades, the bedrock research have included plate tectonic modelling of the origin and evolution of the Finnish Precambrian and the origin of intracratonic igneous complexes. In Quaternary geology, the work of Sauramo has been continued by his students and younger geologists. New field data and dating methods have produced a great deal of information on the final stages of the Ice Age and postglacial climate evolution. Paleolimnological investigtion methods have been used successfully to gauge the state of the environment and its changes.

Geology in Iceland after 1800

The geology of Iceland is so radically different from that of the Continent that for most of the 19th century foreign geological interest centered mostly on the island's hot springs and volcanoes. However, a general description of Iceland had appeared in 1772, "Eggert Olafsson and Bjarni Palsson's *Travels Through Iceland*", based on an expedition (1750–1757) that was planned by the Royal Danish Academy of Sciences and Letters and funded by the Crown. This large illustrated book was duly translated into German (1775), French (1802) and English (1805) and remained the chief general source of information about Iceland's ethnology, geology, zoology and botany for over a century.

In 1839 Japetus Steenstrup (1813–1897) and Jonas Hallgrimsson (1807–1845) were sent to Iceland by Danish authorities to investigate the country's natural resources. Lignite samples they collected were later investigated in Zürich by Oswald Heer (1809–1884) who found them to be Miocene in age. Jonas Hallgrimsson intended to replace Olafsson and Palsson's book with a new description of Iceland to accompany the topographic map being made by the mathematician and surveyor Björn Gunnlaugsson (1788–1876). Hallgrimsson's plans were never realized due to his untimely death but Gunnlaugsson's map appeared in 1846 and remained the basis for geological work in Iceland until superseded by the Danish Geodetic Survey maps in the 20th century.

The 1845 Hekla eruption attracted a number of foreign scientists to Iceland the following year, including R. W. Bunsen and W. S. von Waltershausen. They visited Hekla and Geysir and traveled around southwest Iceland collecting rock samples which Bunsen subsequently analyzed, finding that intermediate lava compositions were more scarce than silicic; and in 1851 he postulated that there were two magma types beneath Iceland, basaltic and silicic, with the intermediate rocks being mixtures of the two. Waltershausen, having studied "palagonite" (he coined the term) in Sicily, suggested that the Icelandic palagonites were formed in submarine eruptions.

C. W. Paijkull (1836–1869) traveled about parts of Iceland in 1865 and produced the first geological map of the country. Also, the Plio-Pleistocene sedimentary and volcanic sequence of the Tjörnes peninsula attracted renewed attention. Eggert Olafsson had described it in his *Travels* and found fossils of shells not living around Iceland at the time, indicative of a different climate.

The 19th century ended in a grand crescendo with Thorvaldur Thoroddsen's (1855–1921) expeditions between 1882 and 1898 to explore and describe the whole of Iceland. A prolific writer, Thoroddsen produced a continuous flow of books and papers from about 1880 till his death. With his work he put Iceland, literally speaking, on the map, and for a long time no geological research could be undertaken without first consulting Thoroddsen. An overview of his geological work was contained in a geological map (1901) and his book *Island*, *Grundriss der Geographie und Geologie* (1906).

Thoroddsen's 19th-century view that the Ice Age was a single, long cold spell was challenged in 1900 by Helgi Pjetursson (1872–1949) who, in both terrestrial and marine sequences, including Tjörnes, found evidence of at least three warm/cold cycles during the Ice Age. The Tjörnes peninsula is now a type locality for the Pliocene-Pleistocene transition, where almost 20 cold/warm cycles can be discerned.

In the 20th century, and especially after 1970, growth in earth-science activity has been exponential and only a few milestones can be pointed out here. Inspired by Wegener's continental-drift theory, Arthur Holmes (1918) suggested that Iceland must be underlain by sialic crust, thus explaining both the country's elevation above sea level and the relative abundance of silicic rocks. This idea prevailed until 1965 when it was disproved by isotope geochemistry. Increasing exploitation of geothermal energy in the 1930s engendered

Figure 4 Ice-carved Tertiary landscape. View to the NE across the fjord Breiddalsvik, E Iceland, showing typical westward-dipping basalt sequences. Photo: Oddur Sigurdsson.

increased geothermal research and in 1943 geophysicist Trausti Einarsson (1912–1986) postulated that geothermal fluids are in fact recycled meteoric water. Icelandic geothermal know-how is now being exported to all corners of the world.

The Hekla eruption 1947–48 was the first eruption thoroughly researched by Icelandic scientists. The Iceland Science Society (founded 1918) published a four-volume collection of articles about the eruption, edited by T. Einarsson, G. Kjartansson (1909–1972) and S. Thorarinsson (1912–1983), all of whom were very active in the research. Having started his tephra studies ten years before, Thorarinsson now continued to develop his tephrochronology as well as being active in other volcanological and glaciological research. When the Natural History Museum in Reykjavík was taken over by the State in 1947, Thorarinsson became a permanent member of staff.

The Iceland Glaciological Society, which became a mainstay of glaciological research in the country, was founded in 1950 and a year later founded the journal *Jökull*, which is now the main Icelandic earth-science periodical.

After 1950, Trausti Einarsson and Thorbjörn Sigurgeirsson (1917–1988) started paleomagnetic mapping in southwest Iceland, and in 1955 George Walker began systematic geological mapping of the Tertiary plateau basalts in eastern Iceland. This work has been actively continued to the present day, assisted by radiometric datings. After 1970, plate-tectonic theory has been central to the understanding of Icelandic geology.

Before the Second World War, Icelandic geologists (except Thoroddsen), were either gymnasium teachers or had professions other than geology. But in the 1940s, earth science in Iceland gradually became 'institutionalized' and the number of earth scientists grew. Founding members of the Iceland Geoscience Society in 1966 were thirteen—now the Society counts about 270. The energy sector increased greatly in the 1970s and 1980s owing to the development of geothermal and hydroelectric projects. Geology and geophysics were taken up at the University of Iceland in 1968. Sigurdur Thorarinsson was first professor, supported by staff from the University Science Institute. In 1973 the Nordic Volcanological Institute was founded with Gudmundur E. Sigvaldason (1932–2004) as first Director. The Institute has been particularly active in petrology and in geophysical monitoring of crustal movements. The Meteorological Office runs a seismic monitoring network, employing a number of geoscientists; the Natural History Museum is responsible for the publication of geological maps, and a number of more specialized research and service institutions have earth scientists in their employ.

Geology in Norway after 1800

The development of geological science in Norway has to a substantial degree been determined by the fact that the capital is situated in the middle of an extremely geodiverse area—the Oslo paleorift (also known as the Oslo graben or Kristiania territory)—exhibiting Paleozoic sedimentary rocks that are very rich in fossils, a great variety of igneous rocks mostly of Permian age, and abundant Quaternary deposits and geomorphological features created by ice ages.

A Norwegian university was established in Christiania (now Oslo) in 1811, and the mineral collections, library, models and instruments from the Kongsberg *Berg-Seminarium* were transferred there in 1813–1814. One of the lecturers from Kongsberg became the University's first geology professor: Jens Esmark (1762–1839), a student of Abraham Werner in Freiberg. Esmark established the new mining science school at the university; which remained the only centre of natural science study in Norway until the 1850s. In 1824 Esmark published evidence of a former large scale glaciation of Norway, and thus became an early advocate of Ice Age theory.

The first comprehensive national survey and map of the geology of Norway was published by Baltazar M. Keilhau (1797–1858) in his 3-volume *Gæa Norvegica* (1838–1850). His successor as professor, Theodor Kjerulf (1825–1888), revolutionized Norwegian geology by introducing biostratigraphical methods, new laboratory methods in the study of rock chemistry, and ice age theory. He founded the Geological Survey of Norway in 1858. His pupil Waldemar C. Brøgger (1851–1940) made significant contributions to the study of the mineralogy of pegmatites, and Paleozoic paleontology and stratigraphy. In 1881 he established the mineralogical institute of Stockholm University in Sweden. Brøgger's students from Stockholm afterwards filled a number of geology chairs in the Nordic countries. After succeeding Kjerulf in the Oslo professorship in 1890, Brøgger concentrated on the origin of igneous rocks, developing theories of magmatic differentiation inspired by biological evolutionary theory in his seven-volume *Die Eruptivgesteine des Kristianiagebietes* (1895–1933). Brøgger was also one of the initiators of the Natural History Museum building complex at Tøyen in Oslo, including the mineralogical-geological and paleontological museums. The physico-chemical theory of magmatic differentiation was further explored in a series of benchmark works by Johan H. L. Vogt (1858–1932), who also contributed many studies of ore-bodies and marbles in Norway, providing knowledge for commercial developments.

Figure 5 The building of the mining academy – Det Kongelige Norske Berg-Seminarium – at Kongsberg, Norway. The academy, one of the first of its kind, was established in 1757 and associated with the Royal Silver Works. The building is from 1786 and is today part of the Norwegian Museum of Mining. Photo: Norsk Bergverksmuseum, B. I. Berg.

The beautifully developed contact metamorphoses between sedimentary and igneous rocks in the Oslo region had been studied by Keilhau, Kjerulf, and Brøgger, but it was for Victor M. Goldschmidt (1888–1947) with his comprehensive *Die Kontakt-Metamorphose im Kristiania-Gebiet* (1911) to make the region and its geological phenomena a classic area for the study of metamorphism. A pupil of Brøgger and the son of a professor of chemistry, Goldschmidt became one of the founders of geochemistry, exploring the principles of the quantitative distribution of the elements in his nine-volume *Geochemische Verteilungsgesetze der Elemente* (1923–1938). His *Geochemistry* appeared posthumously in 1954. Tom F.W. Barth (1899–1971) combined the research traditions of Brøgger and Goldschmidt in several influential works and textbooks.

In parallel with this focus on rock origins and chemistry, the phenomena of Quaternary geology, so prominent in the Norwegian landscape, were explored by Amund Helland (1846–1918) in pioneer works on the glacial erosion of fjords and lakes, and through his studies of glacier movement in Greenland. In Finnmark in 1889, Hans H. Reusch (1852–1922), Kjerulf's successor as Director of the Geological Survey, discovered traces of 'an ice age long before the ice ages', today known as the Varangerian ice age (c. 650 Ma). Reusch was the main initiator of the Norwegian Geological Society in 1905, which continues to publish the *Norwegian Journal of Geology*.

Throughout the 19th century a number of prominent foreign geologists visited Norway, providing impetus to the local scientific community, e.g., Leopold von Buch, Friedrich L. Hausmann, Carl Naumann, Alexandre and Adolphe Brongniart, Charles Lyell, Roderick I. Murchison, James D. Forbes, Harry Rosenbusch, Georg Williams, Joseph Paxton Iddings, and Archibald Geikie. This flow of visiting geologists continued in the 20th century, when Norwegian geologists also increasingly participated in large international projects, including the Deep Sea Drilling Project.

Paleontology was professionalized by Johan A. Kiær (1869–1933), a pupil of Brøgger and von Zittel in Munich. In his steps followed Leif Størmer, Olaf Holtedahl, Anatol Heintz, Ove Arbo Høeg, Gunnar Henningsmoen and Niels Spjældnes, with studies on the Oslo region Paleozoic and more recent formations on Svalbard which became part of Norway by international treaty in 1920.

The advent of methods for the absolute dating of rocks revolutionized the understanding of the evolution of the geology of Norway, a country which, outside the Oslo-region and Svalbard, is almost devoid of fossils, and dominated by a complex patchwork of more or less heavily metamorphosed rocks of Precambrian or Paleozoic age. The theory of plate tectonics contributed greatly to the reconstruction of the history of Norway, where a main feature has been the Caledonian orogeny and large overthrusts created by continent collision.

The Polar explorer Fridtjof Nansen (1861–1930) did pioneering work on the continental shelf in the Barents Sea and along the Norwegian coast. The discovery of oil on the continental shelf in the North Sea in 1969 (Ekofisk Field) brought radical change to Norway's economy and industry. Geology departments in the universities experienced an explosion in the number of students, and curricula were hastily remodelled. The majority of Norwegian geologists are today employed in the oil industry. Norway has been in the forefront among nations to secure that natural energy resources should primarily benefit the citizens; oil revenues have been a significant contribution to the welfare state. The state has shareholder control of the major companies StatoilHydro and Petoro. The extraction of oil has spurred sophisticated scientific and technological innovation, computer software for 'visualizing' reservoirs, supply vessels, drilling platforms, equipment for deep drilling and oil exploration in Arctic waters.

Recent years have seen an increased focus on industrial minerals, and with the development of infrastructure in a modern society there has also been an increased demand for applied engineering and environmental geology.

Geology in Sweden after 1800

One might say that while the earth in earlier centuries was the subject of much theorizing, mainly about its origin and interior, the 19th century was the beginning of its close and extensive investigation. Minute studies of rocks and rock sections were commenced. Stratigraphies were established for different places and regions, and correlations were elaborated, even world-wide. Rudimentary stratigraphies had been recognized in the 18th century, in which development Swedenborg, Linnaeus and Bergman in Sweden had taken part. But with the recognition in the early 19th century that sedimentary rock strata could be characterized by their fossil content, work in the field expanded and biostratigraphy developed.

Among those who made extensive field work, Wilhelm Hisinger (1766–1852) should receive specially mention. His series of descriptions of the geology of various parts of Norway and Sweden from the late 1790s to 1840 were pioneering endeavours. Another giant in the 19th century natural sciences was Sven Nilsson (1787–1883), who published primarily in zoology, but also in paleontology, geology, and archaeology. Nils Peter Angelin (1805–1876), the first holder of the chair in paleozoology at the Swedish Museum of Natural History in Stockholm, published descriptions of several hundred trilobite species, and was the first in Sweden to make use of biostratigraphy.

During the 19th century geology and geological investigations were organized and institutionalized in various ways. A school of mining was established at Falun in central Sweden in 1819, in 1868 replaced by mining technical departments in Stockholm, and later in Luleå. The school in Falun came to be a breeding ground for generations of geologists later to take leading positions at universities and the Survey.

Another important centre for geological reasearch in Sweden was the Swedish Museum of Natural History in Stockholm. With roots in the 18th century, it was formally established in 1819 with departments of, among others, mineralogy (1841), paleozoology (1864), and paleobotany (1884). At the turn of the century, outstanding researchers like Alfred G. Nathorst (1850–1921) in paleobotany, Gerhard Holm (1853–1926) in paleozoology, and Hjalmar Sjögren (1856–1922) in mineralogy, were professors at the Museum, making it a stronghold for geology in Sweden.

The first chair in geology (with mineralogy) in Sweden was established at Uppsala University in 1852 (Lars Peter Walmstedt, 1782–1858), and a second (with paleontology) was established at Lund University in 1867 (Otto Torell, 1828–1900). In Uppsala, the professorship grew from the mineralogical-chemical part of science, while in Lund it grew from the zoological-biological. Stockholm University was established in 1878, and its first professor of geology and mineralogy was the great Norwegian geologist Waldemar Brögger (1851–1940), appointed in 1881. The University of Gothenburg was founded in 1891, and geological research begun there in the 1950s.

A third important establishment in the 19th century for the development of geology in Sweden was that of the Geological Survey. On the initiative of Axel Erdmann (1814–1869), the Survey was founded in 1858 with Erdmann its first Director. For more than a century the Survey had a strong research activity, producing about a thousand papers and treatises in pure science, in addition to ordinary maps and map descriptions. In later decades the Survey has become a central government agency responsible for matters relating to the geology of Sweden and the management of mineral resources.

A fourth important establishment was that of the Geological Society of Sweden in 1871, and the start, in 1872, of the publication of a scientific journal, still today published (under the name of *GFF*). This new publication became the most important forum for Swedish geologists for more than a century.

The debate about the nature of the "dimunition of water", which had started in the early 18th century, was revived with the finding that striations on bedrock surfaces and eskers were orientated in certain directions. Various explanations were presented, but it was not until the idea of a former extensive ice cover that it was found that these were parts of one and the same phenomenon; the Great Ice Age. This issue interested not only geologists but also scholars like the chemist J. Jacob Berzelius (1779–1848) and the botanist Göran Wahlenberg (1780–1851). The leading figure in Sweden on glacial geology was Otto Torell, who developed Agassiz' theory and successfully convinced colleagues about its validity. In the late 19th century Gerard De Geer (1858–1943) came up with the idea that the varves in glacial clay deposits represented annual deposits, and he developed his clay varve chronology, later elaborated to give an age in absolute years for the last deglaciation in Norden. The pollen analysis, developed by Lennart von Post (1884–1951) in the 1910s, was of great importance for the reconstruction of the migration of plants into formerly glaciated areas, as well as for dating of soils.

Another field of major concern was the structure and development of the Caledonide mountains in Scandinavia. Swedish and Norwegian geologists had for long debated its geology, but the complex tectonics involved made conclusions about its origin vague. It was not until the 1880s that Alfred E. Törnebohm (1838–1911) suggested that huge nappes had been transported from the west, overriding the Lower Paleozoic sedimentary rocks and basement by some 100 km. The idea of nappe tectonics was not new, but movements of that magnitude had not been demonstrated previously. Törnebohm was also one of the pioneers in Sweden who made use of the petrographic microscope for regular research.

Arctic expeditions started in the mid 19th century and continued for many decades into the 20th century. People such as Torell, Nathorst, Adolf Erik Nordenskiöld (1832–1901), and De Geer carried out pioneering studies in paleontology and Quaternary geology. Around the year 1900, there were also expeditions to Antarctica, led by Otto Nordenskjöld (1869–1928) and others.

During the first seven to eight decades of the 20th century, geological research developed strongly in Sweden. The number of professorships increased and research became more specialized. The main fields of research have been in mineralogy, petrology, paleontology and micropaleontology, Quaternary geology, marine geology, geochronology, isotope geology, tectonics, and ore geology.

Concluding remarks

Studies in the Earth Sciences have a long tradition in the Nordic countries; early accounts are from the 16th century. Scientific research started there in the 17th century, and in the following century reached international fame primarily by works in chemistry, mineralogy, and paleontology. The 19th and 20th centuries marked the break-through for geology as a science, in Norden as well as internationally. State geological surveys were founded, geological societies, journals, and university chairs were established.

From an international point of view, Nordic geoscientists have contributed greatly to geology, and in some disciplines directed its development, particularly regarding the petrology, mineralogy, and geochemistry of igneous and metamorphic rocks, glacial and Quaternary geology, paleontology and stratigraphy, and structural geology and nappe tectonics. Also, expeditions to the Arctic areas were significant endeavours.

In later years, geology related to the energy issue has been much in focus in the Nordic countries. The discovery of oil on the continental shelf in the North Sea in the late 1960s brought radical change to, in particular, Norway's and Denmark's economy and industry, as well as to geological and geophysical research and university curricula. In Iceland, an increase in exploitation of geothermal energy in the 1930s engendered increased geothermal research. Icelandic geothermal know-how is now being exported to all corners of the world.

Acknowledgements

We are grateful to David Oldroyd (Sydney) and Algimantas Grigelis (Vilnius) for constructive reviews.

References

Literature on A brief outline up to 1800

Frängsmyr, T., 1969, Geologi och skapelsetro. Föreställningar om jordens historia från Hiärne till Bergman (With an English summary): Lychnos-Bibliotek, v. 26, 379 pp.

Frängsmyr, T. and Königsson, L.-K., eds, 1990, The development of modern geology in Norden: Striae, v. 31, 58 pp.

Gabrielsen, R.H., Bruton, D.L., Bryhni, I., and Ramberg, I. B., 2005, On the shoulders of giants—Musings on the history of geoscience in Norway: Norwegian Journal of Geology, v. 85, pp. 3–22.

Garboe, A., 1959, Geologiens historie i Danmark. I. Fra myte til videnskap: C.A. Reitzels Forlag, Copenhagen, 283 pp.

Holtedahl, O., 1953, Av geologiens historie i Norge i eldre tid, in Holtedahl, O., Norges geologi: Norges Geologiske Undersøkelse, no. 164, pp. 1–26.

Regnéll, G., 1949, On the Position of Palaeontology and Historical Geology in Sweden before 1800: Arkiv för mineralogi och geologi, v. 1, pp. 1–64.

Regnéll, G., 1979, The Primaeval Earth as Conceived by Swedish 18th Century Naturalists', *in* Kupsch, W.O. and Sarjeant, W.A.S. (eds), History of Concepts in Precambrian Geology: Geological Association of Canada Special Paper, 19, pp. 171–180.

Regnéll, G., 1995, Three Centuries of Scandinavian Stratigraphy in a European Context, *in* Giglia, G., Macgagni, C., and Morello, N. (eds), Rocks, Fossils and History: Proceedings of the 13th INHIGEO Symposium, Pisa-Padova (Italy) 24 September-1 October 1987, pp. 157–167.

Tanskanen, H., ed, 1986, The Development of Geological Sciences in Finland: Geological Survey of Finland, Bulletin 336, 344 pp.

Literature on Denmark and Greenland after 1800

Garboe, A., 1961, Geologiens historie i Danmark. II. Forskere og resultater: C.A. Reitzels Forlag, Copenhagen, 522 pp.

Rasmussen, L.B., 1988, En jordisk krønike. Træk af DGU's historie 1888–1988: Danmarks Geologiske Undersøgelse, Miljøministeriet, Copenhagen, 144 pp.

Thisted, K., ed, 2005, Grønlandsforskning. Historie og perspektiver: Det Grønlandske Selskabs Skrifter, v. 38, Copenhagen, 312 pp.

Literature on Finland after 1800

Donner, J., 2003, Summing up: half a century of Quaternary geology: Annales Academiae Scientiarum Fennicae, Geologica-Geographica 164.

Haapala, I., 2000, Geologia, *in* Tommila, P. and Tiitta, A., eds: Suomen tieteen historia [The history of Science in Finland], pt. 3, pp. 268–305.

Haapala, I., 2006, Geology, *in* Tommila, P. and Korppi-Tommola, A., eds: Research in Finland, Helsinki University Press, pp. 255–260.

Haapala, I., 2005, History of Finnish bedrock research, *in* Lehtinen, M., Nurmi, P.A., and Rämö, O.T., eds, Precambrian Geology of Finland - Key to the Evolution of the Fennoscandian Shield: Elsevier, Amsterdam, pp. 681–702.

Hausen, H., 1968, The history of geology and mineralogy in Finland 1828–1818: The history of Learning and Science in Finland 1828–1918, pt. 7 a, Societas Scientiarum Fennica, Helsinki, pp. 1–147.

Tanskanen, H., ed., 1986, The development of geological sciences in Finland: Geological Survey of Finland, Bulletin 336, pp. 1–344.

Virkkala, K., 1986, Geologian tutkimuskeskuksen 100-vuotishistoriikki, Summary: History of the Geological Survey of Finland 1886–1986, Geological Survey of Finland, Espoo, pp. 1–93.

Literature on Iceland after 1800

Garboe, A., 1959, Geologiens historie i Danmark. I. Fra myte til videnskap: C.A. Reitzels Forlag, Copenhagen, 283 pp.

Imsland, P., ed, 1992, Íslenskar jarodfræodirannsóknir. Saga, ástand og horfur (Icelandic Earth-Science Research. Past, Present, Future): Iceland Science Society, Reykjavík, 294 pp.

Jacoby, W. and Gudmundsson, M.T., eds, 2007, Hotspot Iceland. Special issue of Journal of Geodynamics, v. 43(1), 186 pp.

Kristjansson, L., Historical Notes on Earth Science in Iceland by German Expeditions, 1819–1970 at *http://www.raunvis.hi.is/~leo/greinar/thysk_exp.pdf*

Sæmundsson, K., ed, 1979, Geology of Iceland. Special issue of Jökull, v. 29, 101 pp.

Thoroddsen, Th., 1902–1904, Landfrædissaga Íslands, III–IV. The Iceland Literary Society, Copenhagen, 334+410 pp.

Literature on Norway after 1800
Bjørlykke, K., 1991, Norsk kontinentalsokkelforskning og oljeindustrien: Norsk Vitenskapshistorisk Selskap, Årbok 1989–1991, pp. 106–123.
Blom, G.A., 1957, Fra Bergseminar til teknisk høyskole. Oslo: Aas & Wahls Boktrykkeri.
Drivenes, E.-A. and Jølle, H.D., 2004, Norsk Polarhistorie. II. Vitenskapene. Oslo: Gyldendal.
Gabrielsen, R H., Bruton, D.L., Bryhni, I., and Ramberg, I.B., 2005, On the shoulders of giants—Musings on the history of geoscience in Norway: Norwegian Journal of Geology, v. 85, pp. 3–22.
Hestmark, G., 1991, Fridtjof Nansen and the geology of the Arctic: Earth Sciences History, v. 10, pp. 168–212.
Hestmark, G., 1999, Vitenskap og Nasjon. W.C. Brøgger 1851–1905. Oslo: Aschehoug.
Kidingstad, T. and Hagemann, F., 2002, Norges oljehistorie. Stavanger: Wigestrand.

Literature on Sweden after 1800
Eriksson, G., 1978, Kartläggarna. Naturvetenskapens tillväxt och tillämpningar i det industriella genombrottets Sverige 1870–1914 (with English summary: The growth and application of science in Sweden in the early Industrial Era). Umeå Studies in the Humanities, No. 15, 230 pp.
Frängsmyr, T., 1976, Upptäckten av istiden. Studier i den moderna geologins framväxt (with English summary: The discovery of the Ice Age). Lychnos-Bibliotek No. 29. 188 pp.
Frängsmyr, T. (ed.), 1989, Science in Sweden. The Royal Swedish Academy of Sciences 1739–1989. Science History Publications, U.S.A. 291 pp.
Lundqvist, G., 1958, Kvartärgeologisk forskning i Sverige under ett sekel. Sveriges Geologiska Undersökning, Ser. C, No. 561. 57 pp.
Nordlund, C., 2001, 'On Going Up in the World': Nation, Region and the Land Elevation Debate in Sweden: Annals of Science, v. 58, pp. 17–50.
Regnéll, G., 1958, The pre-Quaternary fossil-bearing systems outside the High Mountains. Recent results and current lines of research within phytopaleontology, invertebrate paleontology, and historical geology in Sweden: Geologiska Föreningens i Stockholm Förhandlingar, v. 80, pp. 407–422.
Sundquist, B. and Nordlund, C., 2004, Science and honour: The 11th International Geological Congress in Stockholm 1910: Episodes, v. 27, 284–292.

A note on "Norden"

Norden is a collective term, used for some 300 years, denoting the Nordic countries of Denmark (incl. Greenland and the Faroe Islands), Finland (incl. Åland), Iceland, Norway, and Sweden. The Nordic countries have since early medieval times been closely connected to each other by trade, political treaties, royal marriages, and in part language. Modern Danish, Norwegian and Swedish are very similar written languages. Iceland and the Faroe Islands retain languages closer to Old Norse (the language of the Vikings), while Finnish is a very different language, closely related to Estonian, more distantly to Hungarian. Finland, Norway and Sweden have groups of indigenous people speaking several Sami languages, and Greenland has an indigenous population speaking the official Inuit language Greenlandic (Kalaallisut).

Borders and political unions between the Nordic countries have changed much through history, and wars have been frequent, particularly during the 16th, 17th and early 18th centuries. Finland in the 13th century became part of Sweden, and so remained until 1809, when it was joined to the Russian Empire as an autonomous Grand Dutchy, and eventually, in 1917, became an independent republic. Iceland, for several centuries an independent republic founded by Norwegian emigrants, was in 1262 forced to recognize the Norwegian king. In 1380 Greenland, Iceland and the Faroe Islands came under joint Danish-Norwegian rule, after Norway, through royal marriages, had been joined in union with Denmark to constitute the dual Kingdom Denmark-Norway. The latter remained until 1814 when Norway was forced into a union with Sweden. Iceland remained under Danish rule until 1918 when it was united with Denmark; this lasted to 1944 when Iceland again became an independent republic. The union beween Norway and Sweden lasted until 1905 when Norway again became an independent kingdom.

—Geir Hestmark and Björn Sundquist.

Björn Sundquist *has a Ph.D. in Historical Geology and Paleontology (Lund University). His present research concerns Swedish history of geology in the period 1650–1800. He worked for the Geological Survey of Sweden 1984–1985, and served as Chief Editor of the Geological Society of Sweden's journals 1985–2001. He now acts as Science Programme Coordinator for 33rd IGC.*

Ilmari Haapala *was Geologist and State Geologist at the Geological Survey of Finland 1966–1981 and Professor of Geology and Mineralogy at the University of Helsinki 1982–2002. His research has focused on petrology and metallogeny of granites. Haapala was leader of IGCP-315 "Rapakivi Granites and Related Rocks", and is presently chairman of the geoscience group of the Finnish Academy of Science and Letters.*

Jens Morten Hansen *is State geologist at the Geological Survey of Denmark and Greenland (GEUS) and affiliated professor of natural philosophy at Copenhagen Univertsity's Niels Bohr Institute. 1998– 2006 he was managing director of the Danish Research Councils after a period as vice-managing director of GEUS (1990–1998). Hansens research concerns stratigraphy, and the science philosophy of Steno and the Enlightenment.*

Geir Hestmark*, biologist and historian, is professor at the University of Oslo, Norway, and Fellow of the Norwegian Academy of Science and Letters. He has published several books on the history of science in Norway. His 900-page biography of geologist Waldemar C. Brøgger was awarded the Freedom of Speech Prize in 2000.*

Sigurdur Steinthorsson *was born 1940 in Reykjavik, Iceland. Studied geology in St. Andrews University, Scotland (B.Sc. Honours 1964) and Princeton University, U.S.A. (Ph.D. 1974), with main emphasis on igneous petrology and geochemistry. Since 1970, research at the Science Institute, University of Iceland. Associate Professor (docent) 1974, Full Professor 1983, Dean of the Science Faculty 1993–1995.*