THE DISCOVERY OF THE ICE AGE : A SWEDISH PERSPECTIVE

Tore Frängsmyr

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Of all scientific disciplines geology was the one that developed most slowly. In a way this was very natural. The geologists were a kind of historians, but in order to reveal the history of the earth they had to work with scientific methods. They had to do with historical source material that had disappeared, totally disappeared. New geological events had swept away the marks of those earlier processes they wanted to study.

Besides that the geologists had to fight ideological battles, or at least to face an opinion based on Genesis in the Bible. For many of them it was not, however, a personal conflict but rather a question of making a distinction between the Bible and science. As the Swedish chemist Torbern Bergman put it, the goal for the Bible was to give moral wisdom and not to be a text-book in science. This distinction was accepted by most serious scientists around 1800.

But even so, the most difficult problems for the geologists were of course connected with their specific geographical home areas. This statement is also true about Swedish conditions. For a long time Swedish geologists had been conscious of the special problems that pertained to the geological structure of Sweden. Among these problems were the questions of the changing shore lines of the Baltic, the transport of the erratic blocks, the scratches on bedrock surfaces of primary rock, and the long ridges of "diluvial" material (eskers).

Many of these problems were solved by the glacial theory that Louis Agassiz (1807-73) published in 1840, *Etudes sur les glaciers.* Agassiz was a young man, 29 years old, when he studied the glaciers in the Alps. He found that the effects on the rocks and on the ground from those active glaciers could also be found in other areas, far away from the Alps in Switzerland and even in other countries. And so he drew the conclusion that the whole Northern hemisphere had once a long time ago been covered by an enormous ice sheet, caused by the extension of a large amount of glaciers. As for Agassiz, it can be mentioned that after some years as a professor at Neuchâtel in Switzerland he moved to the United States, staying at Boston, Charleston and finally at Harvard, where he founded the Museum of Comparative Anatomy.

But still as a young scientist with brilliant ideas, Agassiz was met by deep scepticism. The opposition against his glacial theory was hard and arrogant, not a least in Britain. Some of his opponents found his theory too speculative. George Greenough described the glacial theory as a "climax of absurdity in geological opinions", Roderich Murchison said that nowadays everything is explained as effects of the ice; soon the day will come when even Hyde Park and Belgrave Square are regarded as formed by a glacier. William Conybear expressed the opinion that the glacial theory was "a glorious example of hasty unphilosophical entirely insufficient induction". But even those who did not make a joke of his arguments were sceptical. We must remember that geology was a very new discipline, it still had to face a lot of fundamental questions. For most leading geologists in England, France, and Germany, there were different schools about the origin of stone (called neptunism and volcanism), and there were also different meanings of the nature of geological processes (called catastrophism and uniformitarianism). When Agassiz published his theory, they had to think in a new way. In short, the opposition followed two lines. The first argument was that the glacial theory indicated that the earth had been very cold and slowly became warmer, but from a general scientific standpoint that time, the process had been just the opposite — from heat to cold. This had been clear through measurings of the temperature inside the earth. The other argument was a methodological one. Many saw the glacial theory as a

catastrophist theory, like that of the Biblical Flood, and they were convinced of a more uniformitarian process. Others saw the theory as mere speculation, without any real connection with empirical work.

Agassiz' theory caused a great interest in Sweden. Agassiz himself and most European geologists had concentrated on the Alps and the British Isles, but the Scandinavian area was an essential part of the whole argumentation for a glacial period. And so Swedish geologists could to a great extent contribute to the development of this theory.

2.

But here, I think, it is necessary to say something about the Swedish background. Already in the 1690s a Swedish chemist and geologist, Urban Hiärne (1641-1724), discovered that the water level in the Baltic Sea had fallen, an observation earlier made by local fishermen. Because Hiärne and his contemporaries knew nothing about the glacial period, they did not think that the land had risen but that the water had decreased. This was the main problem in Swedish geology during the 18th century (and also most of the 19th), and almost all scientists and natural historians dealt with the question, such as Emanuel Swedenborg, Anders Celsius, Carl Linnaeus, Torbern Bergman, and Johan Gottschalk Wallerius. They all had different solutions to the question of what caused the phenomenon, but they agreed that it was a diminution of waters. In late 18th century it became more and more obvious that the reason probably was the upheaval of land in stead of diminution of waters, but these observations were not supported by any theoretical explanation.

Now, when we have the answer to this question, we know that it really was the key to understand the building and structure of the Swedish (and Scandinavian) landscape. The changing shore lines were caused by the upheaval of land; the earth's crust having been pressed down by the heavy ice sheet (about two kilometers thick) and now striving to regain the original level. (This process is still going on at the Swedish east coast). The erratic boulders had been transported by the

ice, the scratches on bedrock surfaces of primary rock had been caused by stones frozen in and carried by the ice, and the "eskers" had been formed when the ice melted and left the stones and other material on the ground.

Still, this is *our* solution to the problem. During the time it was debated, it was not so easy. Charles Lyell, having first denied the phenomenon as such, was convinced after a visit to Sweden in 1834 that there actually had been an upheaval of land. But even so, he wanted with his drift theory to explain the transport of the erratic boulders by floating icebergs; after being deposited at the sea bottom, the boulders had been lifted up by the land elevation. Another theory was published by the Swede Nils Gabriel Sefström. After studying more than 400 localities with scratches, he found their directions in general to be from north to south. He came to this conclusion by distinguishing between what he called the "shock" side of the primary rocks, which had been polished, from the "lee" side, which showed sharp fractures with parts of the stone rubbed off. Sefström thought that a great inundation, a "petridelaunic" flood (i.g. of rolled stones), had swept over the country. Because the "eskers" had the same direction as the scratches, he thought them to be of the same origin.

Among those in Sweden who did not believe in Agassiz' theory was Jacob Berzelius, the famous chemist. In his general statement he followed the investigations made by the physicists Cordier, Fourier, Bischof, and others, showing that the inner parts of the earth were warmer than the crust, and consequently he accepted Elie de Beaumont's theory of a cooling earth. In the next step he defended Sefström's idea of a "petridelaunic" flood, believing that the erratic boulders must have been transported by water. He referred to Edward Hitchcock's studies of erratic findings in North America. Although Hitchcock accepted Agassiz's theory, he wanted --as a complement to the glacial theory-- also to count upon a flood (or another kind of violent water) with stones and pebbles. In the third step he had methodological objections. The glaciologists had done their field studies with specific prejudices, which were without empirical facts. A speculation or a hypothesis should be

founded on empirical observations; otherwise there could be easy "slides to mistakes and errors". In this case he set up Sefström against Agassiz.

3.

But Berzelius belonged to an old generation. After him came a new generation with fresh appetite for new and exciting theories. His assistant for instance, Wilhelm Hisinger, was of another opinion. He pointed out that the erratic blocks around Berlin contained the same element as the Scandinavian mountains. Agassiz's arguments for an ice age he found most likely because of the findings of frozen elephants and buffaloes in Siberia. Sven Lovén, the zoologist, had still another attitude to the problem. As a young man he had, in 1836-37, gone on an expedition to Spitzbergen. Coming home he found that many of the fossil molluscs in Sweden were identical with the species found and still living in the Arctic area, and so he drew the conclusion that Scandinavia and Finland had been covered by a land ice of thickness of one thousand feet.

Löven's ideas were followed up by three geologists of a younger generation, Hampus von Post, Axel Erdmann, and Otto Torell.

Hampus von Post (1822-1922) was a very unusual man, making contributions to science as a geologist, entomologist, agricultural chemist, and botanist; after his university studies he worked as manager at Reijmyre glassworks for sixteen years (1852-1868), and after that as a teacher at Ultuna Agricultural High School. In three small papers, published in 1855-1856, he maintained that a special kind of stones were formed by the pressure of land ice, e.g. glaciers. He could not accept the glacial theory as a whole, but he was convinced that the ground soil in Sweden was created by the wearing of the ice.

Axel Erdmann (1814-1869) was influenced by von Post in his geological view. He was appointed the first chief of the Swedish Geological Survey in 1858. Ten years later he published the first handbook on the geological structure of Sweden, *Sveriges gvartära bildningar*. This is in many respects an important work, but the crucial

point is that this was the first standard text-book based on the glacial theory. Erdmann really believed that Scandinavia had once been covered by an enormous ice-sheet, and he tried to see the results of this far-reaching process in the Swedish landscape. Some of his conclusions are not valid today, but they were of great interest in his time.

Another geologist, Carl Wilhelm Paijkull, wrote that the eskers must have originated during the glacial period, when Sweden was covered by an ice-sheet. He found evidence for his theory in a journey to Iceland, where he studied the glaciers, and so he could not accept the speculative theory of Sefström's petridelaunic flood. Instead of such violent revolutions he found that the slow work of land ice was more acceptable for explaining the geological structure of Sweden. Paijkull was not only a qualified geologist, he could also analyse in popular text-books these theories which had not yet been accepted among all geologists.

4.

Otto Torell (1828-1900) became a pupil of Sven Lovén, when he was only twenty years old. Lovén's discovery of an arctic fauna in Sweden became the starting-point of his geological activity. As a young student he made the historic finding of the arctic fossil mussel *Yoldia arctica* on the West coast of Sweden. If this arctic creature had lived in Sweden, the nature and the climate must have been arctic in former days. But the glacial theory was not generally accepted, and therefore he felt that he had to do his own field research in order to secure his scientific stand-point: "Since the most outstanding European geologists at that time (the middle of the 1850s), such as Lyell, Murchison, v. Buch, E. de Beaumont, Studer, Forchhammer etc., were totally against the glacial theory - although they could not agree on an alternative - and finally Berzelius in our own country acted resolutely against it, it was thus very natural that the theory was not totally accepted at such a late date among Scandinavian scientists. I felt myself the burden of all these authorities so heavily that it took me two and a half years of study and travelling to Arctic areas and the Alps, before the last doubt gave in."

In 1856 Torell went to Switzerland to study the glaciers, the year after he went to Iceland and after that to Norway and Spitzbergen, all of it with the goal of studying the effects of active glaciers and comparing them with geological observations in Sweden. In 1859 he published his doctoral thesis on the mollusc fauna of Spitzbergen, but his conclusions were of a much wider range, because he applied the glacial theory to the whole of Scandinavia. When the same animals now living in the Arctic area are found fossilized in other countries, and when the scratches and eskers in these countries are completely identical with these originated by gliding glaciers, "then it must be reasonable to regard as proved what has previously been a hypothesis, namely the earlier further extension of the Arctic region". Besides Lovén, Torell referred to Edward Forbes, who had studied the flora and fauna in England and found that the climate must have been much colder formerly, and to Murchison, who found at the river Dvina molluscs that obviously originated from the Arctic Ocean.

Torell was quite clear about the fact that Scandinavia had been covered by the ice-sheet, and that it was a land ice mass. According to Gordon L. Davies' book *The Earth in Decay* it was first in 1861 that Archibald Geikie recognized that the ice was a land ice, but the discussion was not finished before 1875 with the publication of James Croll's book *Climate and Time in Their Geological Relations*. Torell's conclusion was that the primary cause of the ice age had to be found in a change of the climate, a sinking of the temperature. But he was also aware of the glacial erosion. Following indications from von Post and Erdmann he concluded that the loose earth-layer of Sweden was created by the ice through grinding material from the primary rock to gravel, sand, and clay. This was not a self-evident matter in those days. Some geologists recognized the dominant role of the ice, but many did not. In 1859 Archibald Ramsay published a paper on the effects of glacial erosion. Davies writes : "There was nothing novel in the concept of erosion by glaciers, but Ramsay nevertheless found himself at the centre of a major controversy when in 1859 he was bold enough to suggest that the Pleistocene glaciers had played a major role in shaping the Earth's present landscapes."

After his disputation Torell went to Greenland to study the land ice there. All his travels had so far been paid for by himself, out of his own money. Now he realized that expeditions of this kind demanded much more resources, and so he started to plan a large expedition to the Polar sea. This resulted in the first "official" Swedish polarexpedition in 1861. For this purpose he saw many experts, e.g. Leopold McClintock and Roderick I. Murchison. Among his assistants was Adolf Erik Nordenskköld, later the famous conqueror of the North-East-passage, but the results of the expedition were not very sensational. They studied the glaciers and were confirmed in their belief of the effects of these phenomena.

Torell was not an industrious writer, but in 1864 he read a paper in the Academy of Sciences in Stockholm about the erratic blocks. Torell critized Lyell's drift theory. He could not agree with the idea of a large sea with floating icebergs, arguing instead that the ice was a land ice mass from the North. The ice had come from the Scandinavian mountains, the Gulf of Bothnia and the Baltic, and moved to the East and to the South. Torell preferred to talk of ice-streams instead of glaciers, and he distinguished between five different ice-streams. He was then also able to explain the diverging direction of the scratches, observed in Sweden. But first of all he saw the whole area as covered by the same ice sheet, coming from the North, not as Agassiz had suggested extensions of glaciers from different centra. In this argument he improved and completed Agassiz's theory.

During the coming years, 1865-68, Torell continued his studies in Germany, the Netherlands, and Switzerland. In 1867 he won a competition about how to explain the origin and the transport of erratic boulders in the North of Holland, but unfortunately this work was never published. This manuscript, in French and holding 383 pages, would have made Torell an international figure, but he was not interested enough to publish his work. Happily we have the main lines of the manuscript, because Torell's pupil Leonard Holmström gave a detailed report in his memorial sketch (biography).

Torell's view was that the origin of the blocks in Holland was to be found in Gotland and Esthonia and had moved through the Baltic down to the North of the Continent. But in many ways Torell was before his time. In 1875, on the 3rd of November, he held a lecture before the Geological Survey of Berlin, presenting his theory. The reaction was very negative. The listening German geologists became dismayed and regarded the idea of such an extensive ice-sheet as "ganz ungeheurlich"; Torell's view was regarded as "barer Unsinn". But the situation changed quite soon. In 1880 Torell was elected chairman at a congress arranged by the same society, and now everybody listened to him without any manifestations of dissatisfaction. This episode shows the difficulties encountered by the glacial theory. Having admitted some kind of glaciation the geologists usually had a different view as to the extent of the glaciers, but the next step was to recognize the whole process of glacial erosion and deposits.

5.

After 1868 Torell travelled abroad a great deal, for study and scientific congresses, but most of all his time was occupied leading the Swedish Geological Surveys, of which he was appointed chief in 1871. Although he did not publish much, especially not in foreign languages, he seems to have been respected as a geologist on an international level. In 1869 he was elected as a member of a committee - consisting besides himself of A. Ramsay and H. Bauermann - to analyze the effects of the glacial epoch. The aim of his studies and travels was above all to confirm his theories. It can be mentioned that he went to America and wrote a paper on glacial phenomena in North America, holding the position that Greenland had been the original place for a glaciation of a much wider range than that in Europe. His observations have been regarded as very important for the emergence of the glacial theory among American geologists; he has been mentioned as a pioneer besides James Geikie and Thomas Chamberlin.

Torell was also one of those geologists who realized the practical consequences of geological research. He suggested an endless number

of projects, but it was not possible to carry out all of them. His was also the initiative of exploring different parts of Sweden in order to find natural resources. In this respect he was a kind of Enlightened scientist, always trying to find practical uses for his field of scientific research - for the good of his country.

Torell's work was in many ways brought to fruition by his pupil, the very famous geologist Gerard De Greer. He explained the phenomenon of land elevation by referring to and developing further the theory of Thomas F. Jamieson. He also demonstrated the origin of the eskers and introduced the method of geochronology by studying stratified loam. For understanding the geology of Sweden, the glacial theory was of definite importance. With the research contributions made by men like Lovén, Torell, and De Geer, a new foundation was given to geological research in Sweden, but also a contribution to the international development of science.

Note

This article is based on a study in Swedish, *Upptäckten av istiden : Studier i den moderna geologins framväxt* (With a Summary in English : The Discovery of the Ice Age), Lychnos-Bibliothek 29 (Almqvist & Wiksell International, Stockholm, 1976).