**Discovering the Ice Ages**

**发现冰河时代**

In the middle of the nineteenth century, Louis Agassiz, one of the first scientists to study glaciers, immigrated to the United States from Switzerland and became a professor at Harvard University, where he continued his studies in geology and other sciences. For his research, Agassiz visited many places in the northern parts of Europe and North America, from the mountains of Scandinavia and New England to the rolling hills of the American Midwest. In all these diverse regions, Agassiz saw signs of glacial erosion and sedimentation. In flat plains country, he saw moraines (accumulations of earth and loose rock that form at the edges of glaciers) that reminded him of the terminal moraines found at the end of valley glaciers in the Alps. The heterogeneous material of the drift (sand, clay, and rocks deposited there) convinced him of its glacial origin.

在19世纪中期，路易斯•阿加西是第一批研究冰川的科学家中的一个，他从瑞士移民到美国成为哈佛大学的一位教授，在那里继续研究地质和其他科学。从他的研究看，他访问了欧洲北部和北美的很多地方，从斯堪的纳维亚和新英格兰到美国中西部的波状丘陵地带。在所有这些不同的地区里，阿加西看到了冰川侵蚀和沉积的迹象。在平原国家，他看见了冰碛石(冰川边缘泥土和松散岩石的聚集体)，这些东西让他想起了在阿尔卑斯山谷冰川里发现的终碛石。漂流物(沉积的沙子、粘土和岩石)的混杂异质物使他相信这就是冰山的起源。

The areas covered by this material were so vast that the ice that deposited it must have been a continental glacier larger than Greenland or Antarctica. Eventually, Agassiz and others convinced geologists and the general public that a great continental glaciation had extended the polar ice caps far into regions that now enjoy temperate climates. For the first time, people began to talk about ice ages. It was also apparent that the glaciation occurred in the relatively recent past because the drift was soft, like freshly deposited sediment. We now know the age of the glaciation accurately from radiometric dating of the carbon-14 in logs buried in the drift. The drift of the last glaciation was deposited during one of the most recent epochs of geologic time, the Pleistocene, which lasted from 1.8 million to 10,000 years ago. Along the east coast of the United States, the southernmost advance of this ice is recorded by the enormous sand and drift deposits of the terminal moraines that form Long Island and Cape Cod.

这些碛石覆盖的区域是如此之大以至于那些使它们沉积下来的冰川肯定是比格林兰或者南极洲还要大的大陆冰川。最终，阿加西和他的支持者说服了地质学家和公众相信大型的大陆冰川已经把极地冰盖延伸到如今的温带气候地区。人们第一次开始讨论冰河时代。很明显冰川作用就发生在相对不远的过去，因为漂流物很软，像新鲜的沉积物。我们现在通过测量掩埋在漂流物中木头放射性的碳-14来精确确定冰川作用的时期。上次冰川作用的漂流物在最近的一个地质时期——更新世，从180万年持续到1万年前——被沉淀下来。沿着美国东海岸，最南边的冰川运动被来自长岛和科德角的大量的沙子和终磧石的漂流沉积物所记录下来。

It soon became clear that there were multiple glacial ages during the Pleistocene, with warmer interglacial intervals between them. As geologists mapped glacial deposits in the late nineteenth century, they became aware that there were several layers of drift, the lower ones corresponding to earlier ice ages. Between the older layers of glacial material were well- developed soils containing fossils of warm-climate plants. These soils were evidence that the glaciers retreated as the climate warmed. By the early part of the twentieth century, scientists believed that four distinct glaciations had affected North America and Europe during the Pleistocene epoch.

很快我们就知道了在更新代有多个冰川代，这中间还有温暖的间冰期。当地质学家绘制出19世纪后期冰河沉积的地图之后，他们开始意识到有好几层漂流物，底层漂流物对应的是早期冰河时代。在这些年代更久远的冰层里有永冻土，其中包含了温带植物的化石。这些土壤是冰川随气候转暖而消失的证据。到了20世纪初期，科学家们相信4个不同的冰川作用影响着更新世时期的北美和欧洲。

This idea was modified in the late twentieth century, when geologists and oceanographers examining oceanic sediment found fossil evidence of warming and cooling of the oceans. Ocean sediments presented a much more complete geologic record of the Pleistocene than continental glacial deposits did. The fossils buried in Pleistocene and earlier ocean sediments were of foraminifera—small, single-celled marine organisms that secrete shells of calcium carbonate, or calcite. These shells differ in their proportion of ordinary oxygen (oxygen-16) and the heavy oxygen isotope (oxygen-18). The ratio of oxygen-16 to oxygen-18 found in the calcite of a foraminifer's shell depends on the temperature of the water in which the organism lived. Different ratios in the shells preserved in various layers of sediment reveal the temperature changes in the oceans during the Pleistocene epoch.

在20世纪末期，当地质学家和海洋学家研究海洋沉积发现海洋变暖和变冷的化石证据时，这种观点得到了修正。相比大陆冰川沉积，海洋沉积呈现出更新世时期更完整的地质记录。埋在更新世时期的化石和更早的海洋沉积物是有孔虫类，它们是一种小的单细胞海洋生物，会分泌碳酸钙壳或者方解石。这些壳的普通氧(氧16)和重氧同位素(氧18)的比例不同。有孔虫类壳的方解石中氧16与氧18的比例取决于生物居住的水域的温度。不同沉积层中保存的壳有不同的含量，这显示出更新代海洋温度的变化。

Isotopic analysis of shells allowed geologists to measure another glacial effect. They could trace the growth and shrinkage of continental glaciers, even in parts of the ocean where there may have been no great change in temperature— around the equator, for example. The oxygen isotope ratio of the ocean changes as a great deal of water is withdrawn from it by evaporation and is precipitated as snow to form glacial ice. During glaciations, the lighter oxygen-16 has a greater tendency to evaporate from the ocean surface than the heavier oxygen-18 does. Thus, more of the heavy isotope is left behind in the ocean and absorbed by marine organisms. From this analysis of marine sediments, geologists have learned that there were many shorter, more regular cycles of glaciation and deglaciation than geologists had recognized from the glacial drift of the continents alone.

对壳的同位素分析使得地质学家能够测量一些其他的冰川影响。他们能够追踪大型冰川的增长和减小，即使是那些海洋中温度变化不太大的区域，比如说赤道附近。当大量水被蒸发并以雪的形式沉积形成冰川冰时，海洋中氧的同位素比率会发生变化。在冰川作用时期，轻一些的氧16比重一些的氧18更容易从海洋的表面蒸发。这样，更多的重氧同位素留在了海洋里并被有机物吸收。从这些海洋沉积物的分析来看，地质学家了解到有很多更短更有规律的冰川作用和去冰川作用的发生，这比之前地质学家仅仅从大陆冰川漂流物中识别出的要多。