Chapter 29

Polar Wander

By Frank N. Magill

Type of earth science: Geophysics
Field of study: Geomagnetism and paleomagnetism

Evidence from several of the earth sciences clearly demonstrates that the earth's magnetic and geographic poles have been located at widely separated places relative to its surface during the planet's geological history.

Principal Terms

ASTHENOSPHERE: a hypothetical zone of the earth that lies beneath the lithosphere and within which material is believed to yield readily to persistent stresses.

ICE AGES: periods in the earth's past when large areas of the present continents were glaciated.

LITHOSPHERE: the outer layer of the earth.

NORTH GEOGRAPHIC POLE: the northernmost region of the earth, located at the northern point of the planet's axis of rotation.

NORTH MAGNETIC POLE: a small, nonstationary area in the Arctic Circle toward which a compass needle points from any location on the earth.

PALEOMAGNETISM: the intensity and direction of residual magnetization in ancient rocks.

PLATE TECTONICS: the study of the motions of the earth's crust.

Summary of Phenomenon

Shortly before World War II, geophysicists discovered a method of determining the location of rocks on the earth's surface at the time they were formed, relative to the north magnetic pole. Thus began the study of paleomagnetism. Paleomagnetic studies quickly yielded very puzzling and often contradictory results. The new science produced evidence that the north magnetic pole has changed its location by thousands and even tens of thousands of miles hundreds of times during the earth's geologic history. Since earth scientists are generally agreed that the north magnetic pole has always corresponded closely with the north geographic pole, this evidence seemed to indicate that the earth's axis of rotation must have changed, a highly unlikely occurrence.

As the paleomagnetic evidence for different locations of the poles in the past accumulated through measurements of rock formations from around the world, more and more earth scientists began to accept the theory of continental drift. This theory offered an explanation of the paleomagnetic evidence without the necessity of postulating that the earth's axis of rotation had changed in the past. Alfred Wegener, early in the twentieth century, had drawn attention to the theory that the continents moved in relation to one another. Most geologists initially greeted his theories with derision, but many others agreed with him, causing an often bitter controversy in the earth sciences that lasted almost half a century. The ever-growing body of paleomagnetic evidence could be explained by postulation that the surface areas of the earth move in relationship to the planet's axis of rotation. This explanation proved to be more acceptable to geologists than the idea that the axis of rotation changed.

With the growing acceptance of the theory of continental drift in the 1940's, geologists began trying to explain the mechanism that caused it. They postulated that the earth has a stable and very dense core overlain by an area called the asthenosphere, which is made up of rock rendered plastic by heat and pressure. Floating on the asthenosphere is the earth's outer crust, or lithosphere. Dislocation within the earth caused by the action of heat and pressure result in the movement of the lithosphere relative to the core and to the axis of rotation. The initial attempts to explain continental drift have been considerably revised and refined into the modern theories of plate tectonics and ocean-bed spreading, but the basic premise remains the same: The surface areas of the earth move in relationship to its core and to its axis of rotation. The result of the movement of the earth's lithosphere is that the surface area located at the axis of rotation does not remain the same over long periods of time. This shifting accounts for the apparent "wandering" of the poles as well as for several other puzzling aspects of earth's geologic history.

Striking evidence that the surface areas of the earth have moved enormous distances during geologic history relative to its axis of rotation comes from the study of glaciers. Observations from around the globe show that almost all the land areas of the earth have been glaciated at some time in the past, including parts of Africa, India, and South America presently located on or near the equator. Without postulating either a substantial shifting of the earth's surface relative to its axis of rotation or a change in the axis, equatorial glaciation is inexplicable. If global temperatures dropped to levels sufficient to glaciate even the equator at some time in the past, all life on earth would have been destroyed. If, however, the areas of Africa, India, and South America which are presently located in tropical locales once shifted to the polar regions and shifted from there to their present locations, their ancient glaciation is not at all mysterious.

Shifting of the earth's surface relative to its axis of rotation is almost certainly a major cause of the so-called ice ages, the origins of which have puzzled glaciologists since the beginnings of that science. Previous explanations of ice ages - including global drops in temperature, the passage of the earth through exceptionally cold regions in space or through areas containing "spacedust" that blocked out a significant amount of the sun's radiation, and unexplained fluctuations in the amount of radiation generated by the sun - are all unsatisfactory. It seems much more likely that areas of the earth that were glaciated in the past, such as northern Europe and North America as far south as present-day New Jersey, were located much closer to one or the other of the poles at the time they were covered with ice.

The study of paleoclimatology has also produced evidence supporting the proposition of the shifting of the earth's crust relative to its axis of rotation. Paleoclimatologists study the climates of past ages on the various parts of the earth's surface. They have found that Antarctica once supported rich varieties of plant and animal life, many of which could only have lived in temperate and even subtropical climates. Explorations in the far northern regions of Canada, Alaska, and Siberia have revealed that those areas also supported multitudes of animals and luxurious forests in the past, as did many of the islands presently located within the Arctic Circle. Obviously, those regions must have had much warmer climates at the times when the plant and animal life flourished there, which can be explained in only one of two ways: either the climate of the entire world was much warmer in the past, or those areas now located near the poles were once located in much more temperate latitudes. If the entire world had warmed to the point that the polar areas had temperate climates, the tropical and subtropical areas of the earth would have been much too hot to support life, which is demonstrably untrue according to the fossil record. Thus, the areas now near the poles must have been located in temperate climatic latitudes in the past.

Earth scientists, using the evidence discussed above and paleomagnetism, have established an approximate chronology showing which areas of the earth's surface were located at its north rotational axis during past ages. At the beginning of the Cambrian period (roughly 600 million years ago), the area of the Pacific Ocean now occupied by the Hawaiian Islands was at or near the earth's north rotational axis. By the Ordovician period 100 million years later, the surface of the earth had shifted in such a manner that the area approximately 1,000 miles north and east of modern Japan was on or near the North Pole. Fifty-five million years later, during the Silurian period, modern Sakhalin Island north of Japan was within the Arctic Circle. During the next 20 million years, the area of modern Kamchatka in eastern Siberia shifted to a position very near the Pole. Earth scientists have identified ninety-nine separate locations that occupied the polar regions at one time or another during the ensuing 395 million years from the Silurian to the Pleistocene. During the past million years, forty-three different areas of the earth's surface have been on or near the north geographic poles, averaging over 1,500 miles distance from each other.

Although contemporary earth scientists have reached a consensus that the surface of the earth has shifted relative to the planet's axis of rotation many times in the past, several problems remain. *One area on which there is no unanimity of opinion is the mechanism responsible for crustal shift.* The answer most likely lies in high-pressure physics and the nature of the asthenosphere. *Another, more controversial, problem concerns the speed of crustal shifts.* During most of the twentieth century, almost all of the geologists who were daring enough to accept the theory of continental drift assumed that the movement of surface features of the earth relative to the axis of rotation and relative to one another was very slow, on the order of a few inches per year at most. Then an increasing number of earth scientists began arguing for short periods of relatively rapid movement of the earth's crust and long periods of stability.

Those problems notwithstanding, there can no longer be any doubt that the surface of the earth has shifted many times relative to its rotational axis. The phenomenon has led to the mistaken assumption that the rotational axis has moved relative to the earth's surface - thus the term "polar wander." The rotational axis of the earth has remained constant throughout its history; apparent polar wander is caused by the shifting of the earth's crust.

Methods of Study

The study of paleomagnetism during the twentieth century has yielded irrefutable evidence that many different areas of the earth's surface have occupied polar positions during the history of the planet. Scientists studying paleomagnetism measure the weak magnetization of rocks. Virtually all rocks contain iron compositions that can become magnetized. In the study of paleomagnetism, the most important of these compositions are magnetite and hematite, which are commonly found in the basaltic rocks and sandstones. Paleomagnetism may also be measured in less common rocks that contain iron sulfide. In igneous rocks, magnetization takes place when the iron compositions within the rocks align themselves with the earth's magnetic field as the rocks cool. In sedimentary rocks, small magnetic particles align with the magnetic field as they settle through the water and maintain that alignment as the sediments into which they sink solidify.

Magnetized rocks not only indicate the direction of the north magnetic pole at the time they were formed, but also show how far from the Pole they were at formation by the angle of their dip. Scientists call their horizontal angle of variation and their dip, the inclination. Variation reveals the approximate longitude of the rock sample at the time of its formation, relative to the north magnetic pole, and inclination gives its approximate latitude. By ascertaining the date at which the rock sample being examined was formed, using well-known methods, scientists are able to establish the area of the earth's surface relative to the north magnetic pole that was occupied by the rock at the time of its formation.

There are, however, many pitfalls for the unwary scientist investigating paleomagnetism. A rock whose magnetism is being studied may have moved considerable distances from its place of formation by glacial action or by crustal movement along a major fracture in the earth's surface, such as the San Andreas fault on North America's west coast. High temperatures, pressure, and chemical action can distort or destroy the magnetization of a rock. Folding and the movement of the continents relative to one another may also alter the original orientation of the rocks whose magnetism is being studied. All these pitfalls may be avoided through the expedient of basing estimates of the relative position of the north magnetic pole on a great number of rock samples of the same age, gathered from many different locations on all the continents.

Another problem in paleomagnetic studies involves the constant movement of the north magnetic pole relative to the north geographic pole. Recent studies show that the north magnetic pole moved from 70 degrees to 76 degrees north latitude (approximately 345 miles, or 576 kilometers) during the period 1831-1975. This phenomenon might accurately be called true polar wander, though it does not involve any alteration either of the earth's axis of rotation or of the surface of the planet relative to its axis of rotation. More geophysicists studying this movement have concluded that over a period of several thousand years, the average position of the north magnetic pole coincides with that of the north geographic pole. Thus, when scientists learn that the north magnetic pole was located near Hawaii 600 million years ago, it is a virtual certainty that modern Hawaii was at that time located near the north geographic pole.

Context

The most immediate and pressing question facing all residents of planet Earth concerning apparent polar wander is the speed with which the phenomenon may occur. An historian of science, Charles H. Hapgood, compiled a huge amount of compelling evidence in the 1950's that massive shifts of the earth's crust relative to its axis of rotation occur in geologically brief periods of time. Hapgood made a very strong case for the surface area of the Canadian Yukon, which is now located at approximately 62 degrees north latitude, and longitude 137 degrees west, having occupied the north geographic pole prior to 80,000 years ago. Then, in a massive movement which took less than 5,000 years, the earth's surface shifted in such a way that an area of the Greenland Sea now located at approximately 72 degrees north latitude, and longitude 10 degrees east occupied the north polar region. This shift involves a distance of almost 5,000 miles.

Hapgood offers further evidence that the earth's surface remained stable relative to its axis of rotation for approximately twenty thousand years, then began another massive shift resulting in the area of Hudson's Bay that now occupies the surface region located at about 60 degrees north latitude, and longitude 83 degrees west, moving to the earth's north rotational axis. This movement of approximately 3,500 miles took less than 5,000 years. Again the earth's surface became stable, according to Hapgood, this time for more than 30,000 years, until about 17,000 years ago. At that time, the earth's surface began another movement lasting nearly 5,000 years and resulting in the present surface-pole relationship.

If Hapgood is right about the surface of the planet shifting enormous distances in relatively short periods of time, the period during which the shift actually occurs must be a traumatic era for the earth's flora and fauna, including humankind. Such rapid movement would certainly produce earthquakes and volcanic action of almost unimaginable proportions throughout the globe. Weather and tidal patterns would be greatly and unpredictably altered, which could have fatal consequences for many plant and animal species. The last result offers yet another piece of powerful evidence for the rapid-shift hypothesis.

The earth's fossil record offers examples of the mass extinction and extermination of many species of flora and fauna during the geological history of the planet. The most recent such event occurred at the end of the Pleistocene epoch, about 12,000 years ago. Literally tens of millions of animals in North America alone died in a relatively short period of time, leaving their sometimes remarkably well-preserved remains lumped together in huge "boneyards," stretching geographically from Alaska to Florida. This mass extinction of fauna must have been caused by the events accompanying crustal displacement: volcanic action on a gigantic scale not only would throw huge amounts of ash into the air, causing a lowering of global temperatures and an increase in rainfall producing widespread flooding, but would also produce quantities of poisonous gasses lethal to animals and humans in the vicinity; rapid and pronounced weather changes would destroy food supplies which may have been the ultimate cause of the extinctions of many species; widespread earthquakes could also take a large toll on animal life.

If, as more and more geophysicists are coming to believe, the shifting of the earth's surface does take place rapidly at infrequent intervals and for reasons not currently well understood, the phenomenon is of the utmost importance. Modern civilization would not survive the enormous climatic dislocations that must accompany such a shift. It is therefore imperative that the phenomenon known as polar wander be studied to the point that it can be, if not prevented, at least predicted and prepared for.