4.2: Paleomagnetic Evidence for Plate Tectonics

Although Alfred Wegener would not live to see it, his theory of plate tectonics would gradually gain acceptance within the scientific community as more evidence began to accumulate. Some of the most important evidence came from the study of paleomagnetism, or changes in Earth’s magnetic field over millions of years.

Earth’s magnetic field is defined by the North and South Poles that align generally with the axis of rotation (Figure `\(\PageIndex{1}\)`). The lines of magnetic force flow into Earth in the Northern Hemisphere and out of Earth in the Southern Hemisphere. Because of the shape of the field lines, the magnetic force trends at different angles to the surface in different locations (red arrows of Figure `\(\PageIndex{1}\)`). At the North and South Poles, the force is vertical. Anywhere on the equator the force is horizontal, and everywhere in between, the magnetic force is at some intermediate angle to the surface.
In its fluid form, the minerals that make up magma are free to move in any direction and take on any orientation. But as the magma cools and solidifies, movement ceases and the mineral orientation and position become fixed. As the mineral magnetite \((\text{Fe}_3\text{O}_4)\) crystallizes from magma, it becomes magnetized with an orientation parallel to that of Earth’s magnetic field at that time, similar to the way a compass needle aligns with the magnetic field to point north. This magnetic record in the rock is called **remnant magnetism**. Rocks like basalt, which cool from a high temperature and commonly have relatively high levels of magnetite, are particularly susceptible to being magnetized in this way, but even sediments and sedimentary rocks, as long as they have small amounts of magnetite, will take on remnant magnetism because the magnetite grains gradually become reoriented following deposition. By studying both the horizontal and vertical components of the remnant magnetism, one can tell not only the direction to magnetic north at the time of the rock’s formation, but also the latitude where the rock formed relative to magnetic north.

In the early 1950s, a group of geologists from Cambridge University, including Keith Runcorn, Edward Irving and several others, started looking at the remnant magnetism of Phanerozoic British and European volcanic rocks, and collecting paleomagnetic data. They found that rocks of different ages sampled from generally the same area showed quite different apparent magnetic pole positions (green line, Figure \((\text{PageIndex}2))\). They initially assumed that this meant that Earth’s magnetic field had, over time, departed significantly from its present position, which is close to the rotational pole.
The curve defined by the paleomagnetic data was called a **polar wandering path** because Runcorn and his colleagues initially thought that their data represented actual movement of the magnetic poles (since geophysical models of the time suggested that the magnetic poles did not need to be aligned with the rotational poles). We now know that the magnetic data define movement of continents, and *not* of the magnetic poles, so we call it an **apparent polar wandering path** (APWP). Runcorn and colleagues soon extended their work to North America, and this also showed *apparent* polar wandering, but the results were not consistent with those from Europe (Figure $\PageIndex{2}$). For example, the 200 Ma pole for North America placed somewhere in China, while the 200 Ma pole for Europe placed in the Pacific Ocean. Since there could only have been one pole position at 200 Ma, this evidence strongly supported the idea that North America and Europe had moved relative to each other since 200 Ma. Subsequent paleomagnetic work showed that South America, Africa, India, and Australia also have unique polar wandering curves. Rearranging the continents based on their positions in Pangaea caused these wandering curves to overlap, showing that the continents had moved over time.

Additional evidence for movement of the continents came from analysis of **magnetic dip**. Recall from Figure $\PageIndex{1}$ that the angle of the magnetic field changes as a function of latitude, with the field directed vertically downwards at the north pole, upwards at the south pole, and horizontal at the equator. Every latitude between the equator and the poles will have a corresponding angle between horizontal and vertical (red arrows, Figure $\PageIndex{1}$). By looking at the dip angle in rocks, we can determine the latitude at which those rocks were formed. Combining that with the age of the rocks, we can trace the movements of the continents over time. For example, at around 500 Ma, what we now call Europe was south of the equator, and so European rocks formed then would have acquired an upward-pointing magnetic field orientation (Figure $\PageIndex{3}$). Between then and now, Europe gradually moved north, and the rocks forming at various times acquired steeper and steeper *downward-pointing* magnetic orientations.
This paleomagnetic work of the 1950s was the first new evidence in favor of continental drift, and it led a number of geologists to start thinking that the idea might have some merit.

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