

g5 Magnetic anomalies parallel to and mirrored across mid-ocean ridges < Morley, Vine >

Scientific credit often goes to the second person to make the observation or experiment. —an adage.¹

The geomagnetic field at the surface can be modeled as arising from a single dipole at Earth's center, and of a certain strength. This *main field* arises from the interaction of electric currents and fluid motions in Earth's outer core. Deviations from the main field strength in an area, are called *geomagnetic anomalies*. Stationary geomagnetic anomalies are due to rock magnetism. A magnetometer is the instrument used to measure these in milligals (thousandths of Earth's main-field strength). Geomagnetic anomalies contoured in maps have "rosewood-like" patterns in continental areas and "zebra-stripe" patterns in oceanic areas. Noticeably, the seafloor geomagnetic anomaly stripes parallel, and their widths are mirrored across, oceanic ridge segments. The stripes also terminate against, and their continuations are offset across, transverse linear seafloor escarpments.

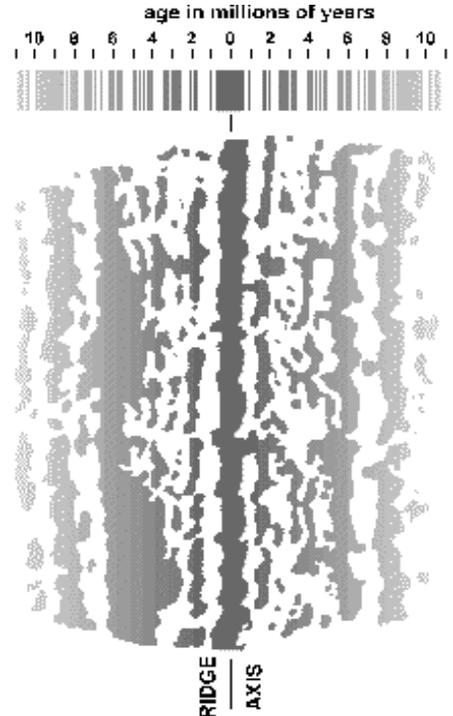
Earth's magnetic-field reversal history was originally determined from samples of volcanic flows on the land. In 1906, Bernard Brunhes, investigating lava baked rocks in Iceland, discovered a natural remanent magnetization opposite to the existing main geomagnetic field and speculated that the main geomagnetic field had been reversed at some time in the past. Motonari Matuyama working in China and Japan in the late 1920s found several magnetic reversals of different ages. He speculated that such could be used for worldwide stratigraphic correlations. The first polarity time-scales were published in the 1950s. In 1995, S. C. Cande and D. V. Kent published a revised calibration of the geomagnetic-polarity time scale for the Cenozoic and Late Cretaceous.² Noticeable is that geomagnetic-field polarity durations and reversal times are random (*unlike* Sun's magnetic field that reverses every 8-16 years and has been in keeping with the sunspot cycle historically). Where the remanent magnetization of crustal rocks is normal, its field adds to Earth's main geomagnetic field strength and so with respect to that datum, anomalously high (to plus 10 milligals) magnetometer readings result. When the reverse holds, the magnetometer readings are anomalously low (to minus 10 milligals).



In the "sea-floor spreading model," seafloor oceanic crust acquires its remanent magnetism at the ridge where new seafloor added to the plates cools to below the Curie temperature of its magnetizable minerals. Divergence of the plates, causes the newly added seafloor to split into two same-age widths. These move away symmetrically to either side of the ridge and remain parallel to it.

Seafloor magnetic anomalies with linear trends unrelated to the underlying local topography but parallel mid-ocean ridge segments, found by **Ronald (Ron) G. Mason** (who had arranged for an ASQ-3A fluxgate magnetometer to be towed behind the USCG ship *Pioneer*)³ and published in 1958⁴ and with A. D. Raff in 1961,⁴ for years resisted interpretation (except by Morley, see **Footnote g5.1**). In 1963, similar were noted by Fred Vine in oceanographic ship-survey maps across the Carlsberg mid-ocean ridge crest at 5°N, northwest Indian Ocean, returned by his supervisor Drummond (Drum) H. Matthews. A "fruitful," as Hess would later jocularly pun, seminal result of their collaboration is that "zebra-stripe" patterns of seafloor magnetic anomalies record geomagnetic field reversals.⁵ Tuzo Wilson marveled that to either side of the Juan da Fuca ridge, the reversal pattern is symmetrical to the ridge-line and published so with Vine in 1965.⁶ In 1966, W. C. Pitman III and J. R. Heirtzler found similarly for the Pacific-Antarctic Ridge⁷ and a detailed correlation of the magnetic linear-anomalies in Reykjanes ridge flown-survey map with the independently known geomagnetic-reversal history by Vine (**Figure g5.1**) left few skeptics as to the correctness of what is now called the "Vine-Matthews-Morley seafloor spreading hypothesis" and so the reality of continental drift. □

Figure g5.1⁸ Map of the submarine magnetic residual anomaly pattern obtained by a U.S. Navy aeromagnetic survey over the Reykjanes rise-ridge system. The ridge axis in the map strikes N35°E from long. 31°W, lat. 59°N to long. 26°W, lat. 62°N. The reversal history of Earth's magnetic field, known from reversal histories in land volcanic rocks (mirrored about the zero year), is shown above the map. Strips of the seafloor can be classified as having either normal remanent magnetism (shaded) or reversed remanent magnetism. By simply counting magnetic anomalies away from the ridge in any ocean and by knowing the history of magnetic field reversals *epochs* and events as the Jaramillo normal event, the age of the seafloor is also known. This can be checked by bringing up seafloor samples of the sediments that immediately overlie the volcanics and determining their age from their fossil content (the volcanics are too altered to be radiometrically dated directly). A program of deepsea drilling (JOIDES *Challenger*) was begun in the late 1960s and the predictions of "seafloor spreading" found confirmation by 1970.⁹



Why does the *detailed* reversal pattern known from a study of lava flows on land not show in the seafloor record? Consider the plate tectonics model in which the seafloor crust is made of basalt erupted at the ridge as lava. Linked to the mantle convection, the new seafloor (oceanic crust) across the crest of the ridge is tensionally stressed and from time to time is split to form a rift. New lava erupts as pillow lavas and cools to acquire remanent magnetizations that are normal or reversed according to the existing polarity of the geomagnetic field at the time. The fissure conduits in the rift are for the most part merely parallel to the ridge. They are not always in the same place within the rift. Not surprisingly, from the somewhat jumbled pillow lava record only the broad pattern of geomagnetic field reversal history is commonly discernible in the magnetometer surveys by surface ships and airplanes. A magnetometer survey performed closer to the seafloor does not improve the information obtained.

The fact that the magnetic stripes in their movement away from the ridge remain straight and parallel the ridge (are not flow deformed) led to the concept of *ridged* plates moving away for the ridge. This was the first evidence that suggested *plate tectonics* (see Topic g8).

Footnote g5.1 Lawrence Morley: "Raff and Mason's zebra map first appeared in August 1961 ... [It] remained in the literature for a year and a half with no plausible explanation. ... [Then] I spotted the Dietz paper on ocean floor spreading. Eureka! The idea came to me so suddenly that I sat down and submitted the following (unexpurgated) paper [now printed in full in *Plate Tectonics: An Insider's History of the Modern Theory of the Earth*, pp. 80-83, 2001, Naomi Oreskas, Ed.]¹⁰ to *Nature* in February 1963."



"Several investigators and authors writing on the subject of continental drift and convection currents in the earth's mantle have referred to the puzzling linear magnetic anomalies in the Eastern Pacific Ocean Basin reported by scientists of the Scripps Institution of Oceanography."

"If one accepts, in principle, the concept of mantle convection currents rising under the ocean ridges, travelling horizontally under the ocean floor and sinking at ocean troughs, one cannot escape the argument that the upwelling rock under the ocean ridge, as it rises above the Curie Point geotherm, must become magnetized in the direction of the earth's field prevailing at the time. If this portion of the rock moves upward and then horizontally to make room for new upwelling material and if, in the meantime, the earth's field has reversed, and the same process continues, it stands to reason that a linear magnetic anomaly pattern of the type observed would result. ..." [*Nature* rejected this submission, stating that they did not have room to print it, and, later, so did the *Journal of Geophysical Research*.]