Ocean Floor Spreading: Olduvai and Gilsa Events in the Matuyama Epoch

Abstract. *The magnetic anomaly usually associated with the Olduvai geomagnetic event (1.96 million years) should probably be associated with the Gilsa event (~ 1.65 million years). The Olduvai event can be correlated with a consistently appearing minor anomaly called W. This reassignment gives nearly uniform spreading rates for sections of the mid-ocean ridge system considered here.*

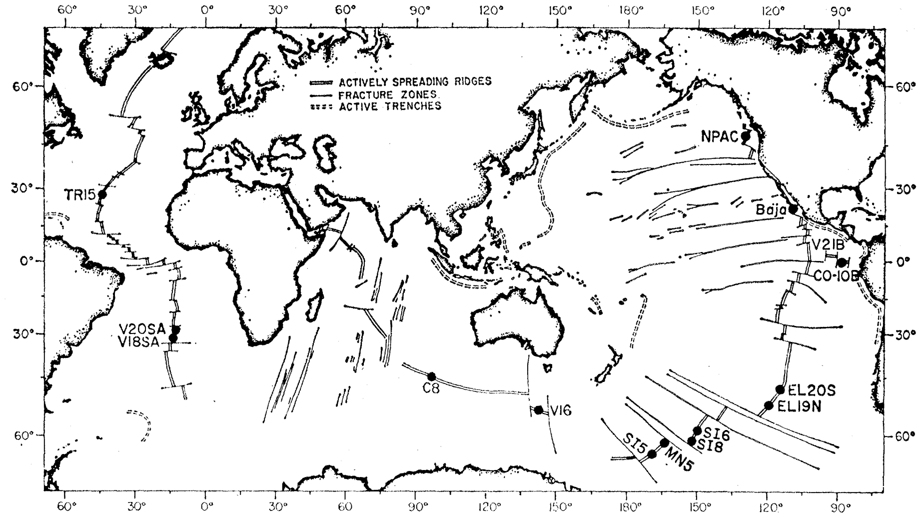


Fig. 1. Location of magnetic anomaly profiles for which spreading rate curves are constructed (*5*).

A worldwide similarity of magnetic profiles across the axial portion of the mid-ocean ridge system has been demonstrated, and sea-floor spreading rate curves based on the association of characteristic magnetic anomalies with the paleomagnetic time scale have been constructed by numerous investigators (*1*). The accuracy of these spreading rates depends both on the accuracy of the paleomagnetic time scale and on the proper correlation of a magnetic anomaly and the corresponding paleomagnetic event or boundary.

Spreading rate changes since the beginning of the Gauss normal epoch (3.32 million years) have been investigated for 15 published magnetic profiles from the Atlantic, Pacific, and Indian oceans (Figs. 1 and 2) (*2*). Only profiles in which the anomalies usually associated with the paleomagnetic epochs and events could be identified were considered. The correlations in Fig. 3 between the anomalies along each profile and the geomagnetic epoch or event represented are the same as those chosen in the original papers (Fig. 2). Because the distance of each normal-reverse boundary from the ridge axis is known with more confidence than the corresponding paleomagnetic ages, the distances are assumed to be known exactly; but age uncertainties are considered explicitly. Distances are plotted as points, but the confidence intervals are indicated for the ages (*3*). Straight line segments are then fitted so that the resulting curves are as close as possible to straight lines or uniform spreading. The similarity of plots from every profile in Fig. 3 is striking. Only the right side of SI6 (Fig. 3C) can be fitted by a nearly straight line; all the other profiles, including the left side of SI6, have the same characteristic form even with the smoothing introduced by the method of curve construction. Vine (*4*) noted similar deviations from linearity for two cases but did not give further discussion.

Two interpretations of Fig. 3 are possible. First, the postulated relations between the magnetic anomalies and the paleomagnetic time scale are assumed correct, and hence the graphs accurately represent spreading rates of the mid-ocean ridge system for the past 3.32 million years. Second, the spreading rates of the ridge system have been nearly constant for the past 3.32 million years, and hence some of the accepted relations between the anomalies and the paleomagnetic time scale are incorrect.

For the first case, the suggested spreading rates along the mid-ocean ridge system decreased about 2 million

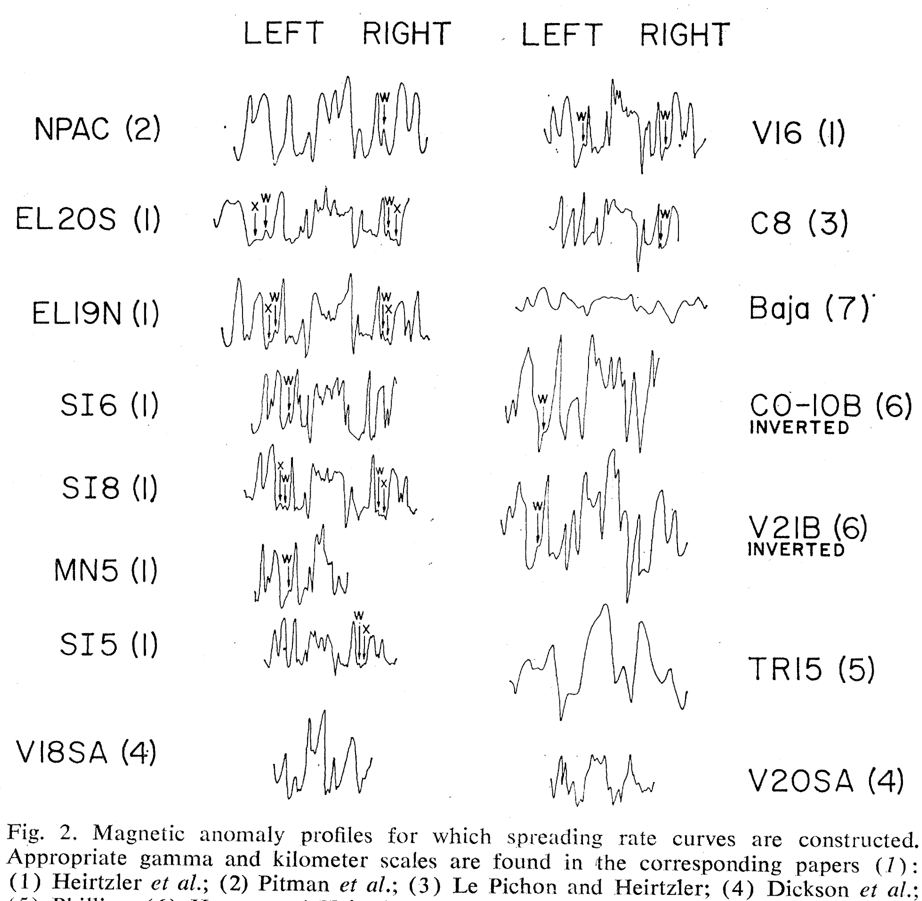
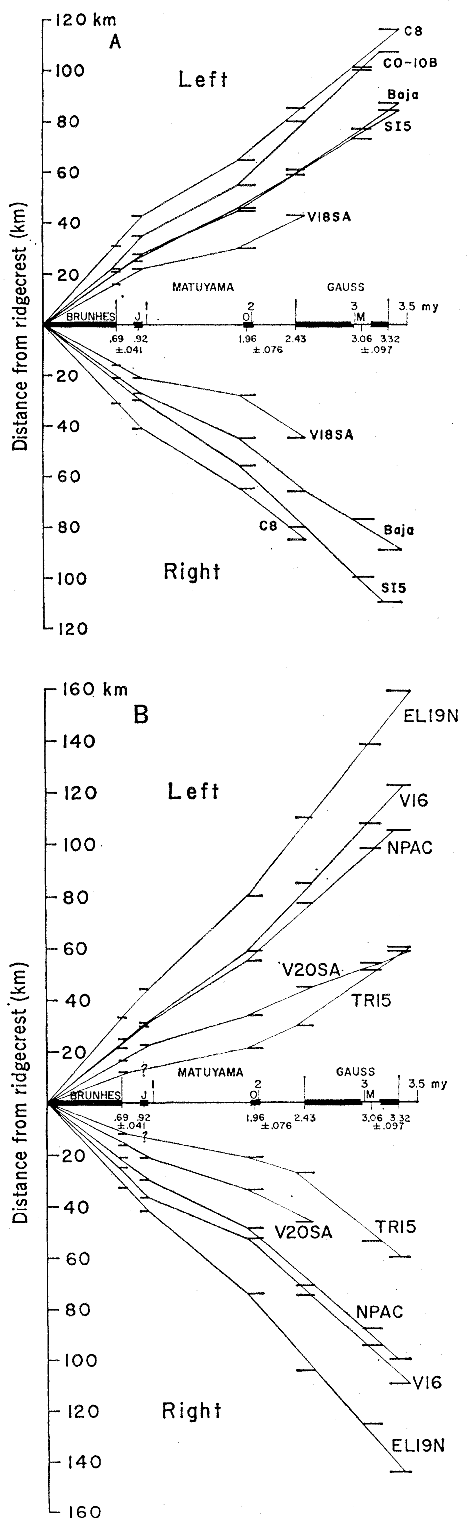


Fig. 2. Magnetic anomaly profiles for which spreading rate curves are constructed. Appropriate gamma and kilometer scales are found in the corresponding papers (*1*): (1) Heirtzler *et al.*; (2) Pitman *et al.*; (3) Le Pichon and Heirtzler; (4) Dickson *et al.*; (5) Phillips; (6) Herron and Heirtzler; (7) Larson *et al.* The minor anomalies *W* and *X* are discussed in the text.

years before present and then increased again at about 0.9 million years before present. This phenomenon of variable-rate, worldwide movement differs from episodic spreading, as discussed by Le Pichon (*5*) and Ewing and Ewing (*6*), where spreading from mid-ocean ridges is postulated to have stopped completely at various times in geologic history. Le Pichon (*5*) proposes that episodic spreading is strong evidence in favor of the block tectonic theory of sea-floor spreading, because, if spreading corresponds to the response of a thick, rigid lithosphere to an underlying stress pattern, then all source regions where new material is brought to the surface are interrelated. The dynamic characteristics of the source regions should persist until one or several of the lithosphere blocks becomes so poorly adjusted to the stress pattern that a readjustment in the worldwide spreading pattern is necessary. It is possible that a system poorly adjusted to the stress pattern might undergo minor readjustment and possibly result in the observed variable-rate spreading. We can find no apparent reason, however, for a worldwide consistent decrease and subsequent increase in spreading rates and would expect an increase in spreading in some parts of the system coupled with a decrease elsewhere.



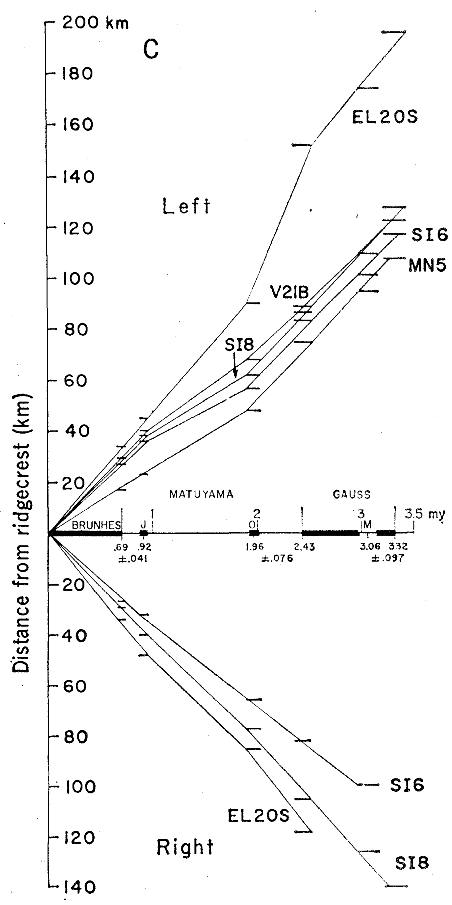


Fig. 3 (A–C). Spreading rate curves. "Left" and "Right" refer to those sides of the profiles in Fig. 2. The ordinate is the distance from the ridge crest.

If spreading rates have been more or less constant for the past 3.32 million years, then this implies that there are errors in the postulated relations between the magnetic anomalies and the paleomagnetic time scale. Major changes in slope of the spreading rate curves are controlled by the "Olduvai event" (Fig. 3). Constant, or nearly constant, spreading-rate graphs were constructed by omitting this event and by assuming that the start of the Gauss epoch, the center of the Jaramillo event, and the start of the Brunhes epoch are fixed. With this procedure only the Olduvai event consistently does not intersect the constant spreading-rate curves, and it always lies on the positive time axis side of the curve. This implies, under the hypothesis of constant spreading, that the anomaly usually associated with the Olduvai event should be associated with some younger normal event. The approximate age of such an event can be derived from the curves in Fig. 3. If the center of the "Olduvai interval," originally at 1.96 million years, is required to lie on a constant-spreading curve from 0.9 million years to 3.32 million years, then the age of this younger event is 1.66 million years (standard deviation, 0.08 million years). The im-

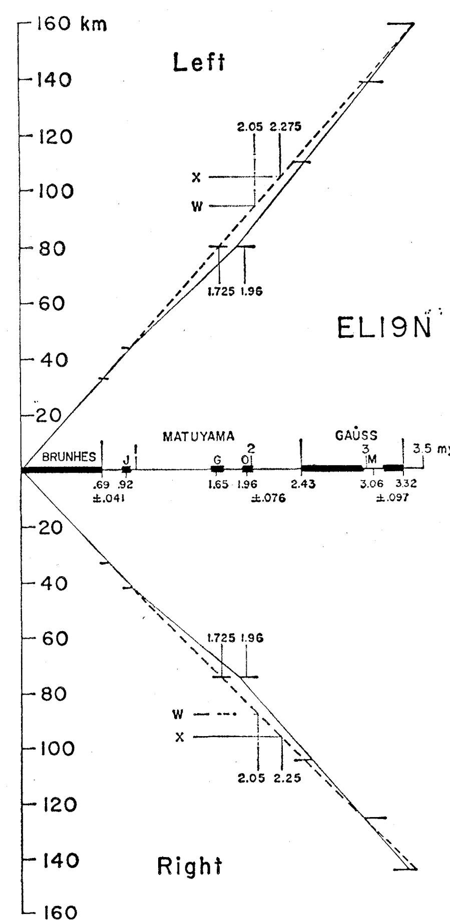


Fig. 4. Application of constant spreading hypothesis to profile EL19N. *G*, the Gilsa normal event.

plied age of the event is 1.73 million years in profile EL19N (see Fig. 4).

There is a younger normal event, the Gilsa event, dated at about 1.65 million years (*7*). No particular magnetic anomaly has been associated with the Gilsa event, because no obvious anomaly consistently appears between the ones usually associated with the Olduvai event (1.96 million years) and the Jaramillo event (0.92 million years). The above implies that the Gilsa anomaly, undefined until now, may be the anomaly usually associated with the Olduvai event. Similar ideas have been expressed by Cox (*8*), whereas, on the basis of age data from deep-sea sediment cores, Opdyke and Foster (*9*) prefer the usual Olduvai event-anomaly association.

There is extensive evidence for the existence of the Olduvai normal event at 1.96 million years, and it is reasonable to expect an anomaly associated with the event. Heirtzler *et al.* (*1*) discuss a minor anomaly, called X, which occurs with some consistency between the anomalies associated with the Olduvai event and the beginning of the Matuyama epoch. This anomaly, X, and a neighboring anomaly, W, which also consistently appears, are labeled in Fig. 2. Anomalies X and W sometimes occur as a doublet, and sometimes only one or the other appears. In the latter case it cannot be determined by simple examination of the profiles which anomaly is present. In order to overcome this difficulty the age of each pertinent anomaly was determined for all the profiles from the assumed constant spreading rates from 3.32 to 0.9 million years. Using only the profiles containing both anomalies, the average age of W turns out to be 2 million years (standard deviation, 0.06 million years) and the average age of X is 2.3 million years (standard deviation, 0.1 million years). The ages for X and W in EL19N are shown in Fig. 4. When a single anomaly occurred, it was subsequently labeled W or X depending on its relation to the previously determined average ages for W and X. All singly appearing anomalies were found to correspond to W; no ambiguities were encountered. The resulting average age of W (1.99 million years) corresponds very closely to the measured age of the Olduvai event (1.96 million years), and we postulate that under the assumption of constant spreading from 3.32 to 0.9 million years, W is the true Olduvai anomaly.

If the variable-rate spreading interpretation of Fig. 3 is accepted, then there is no anomaly that can be easily related to the Gilsa event. If a constant spreading rate from 3.32 to 0.9 million years is accepted, then both the Gilsa and the Olduvai events can be associated with consistently appearing anomalies. We regard the latter as more acceptable than the former because of the way it allows all the well-known paleomagnetic events to be associated with consistently appearing magnetic anomalies and does not require complications of the basic spreading hypothesis.

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Radionuclide Composition of the Allende Meteorite from Nondestructive Gamma-Ray Spectrometric Analysis

Abstract. *The concentrations of beryllium-7, sodium-22, aluminum-26, potassium-40, scandium-46, vanadium-48, chromium-51, manganese-54, cobalt-57, cobalt-60, and thorium-232 (thallium-208) have been measured in the Allende meteorite by nondestructive gamma-ray spectrometry. The high cobalt-60 content of the meteorite is indicative of a preatmospheric body with a minimum effective radius of 50 centimeters and a weight of 1650 kilograms; the aluminum-26 activity indicates a minimum exposure age of 3 million years.*

Carbonaceous chondrites represent a small fraction of all observed meteorite falls (*1*); however, these chondrites are of particular interest because it is suspected that they represent relatively undifferentiated primitive matter. The last recorded fall of a Type-III carbonaceous chondrite was that of the Kainsaz meteorite in the U.S.S.R. in 1937. When sample acquisition of any meteorite is possible very shortly after its fall, a rare opportunity is provided for measurement of the short-lived as well as the long-lived cosmogenic radionuclides. Measurements of the absolute and relative concentrations of radionuclides in meteorites provide information which is basic to the understanding of their extraterrestrial history, their preatmospheric size, and the spatial and temporal variations of the cosmic-ray flux (*2*).

On 8 February 1969, a Type-III carbonaceous chondrite fell in south-central Mexico near the village of Pueblito de Allende, scattering fragments over a large area (*3*). The Allende meteorite, which was estimated to have weighed several tons (*3*), is by far the largest carbonaceous chondrite ever observed; several hundred kilograms have been recovered. Fragments are presently being studied by several groups throughout the world. The results should provide detailed information on the radiation exposure of the meteorite and on numerous other processes in which it has been involved. Samples of the Allende meteorite were obtained by the NASA Manned Spacecraft Center in Houston, Texas, within a few days after the fall, and a qualitative radionuclide analysis was made (*4*). On 21 February 1969, we obtained from R. S. Clarke of the National Museum of Natural History (NMNH) two halves of an individual fragment which had broken apart upon impact with the earth. The concentrations of several cosmogenic and primordial radionuclides were measured by sophisticated gamma-ray spectrometric techniques in