Kiaman Magnetic Interval in the Western United States

Abstract. *Late-Paleozoic red beds in the western United States indicate that Earth's magnetic field was reversed for a period of the order of 50 × 10⁶ years. This finding agrees with similar results from igneous rocks in Australia, indicating that the long period of reversal in the magnetic field was worldwide. The rocks on the two continents appear to be essentially equivalent in time, suggesting early magnetization of the red beds. The time spectrum of reversals is irregular in geologic time, but present evidence suggests reversals characterized by time scales of 10^4 or 10^5, 10^6, and 50×10^6 years. The 50×10^6 year period of steady reversed field is found in the late Paleozoic and is termed the Kiaman magnetic interval.*

Magnetic epochs have been established for the last 4 million years by use of the K-Ar dating technique to confirm the contemporaneity of volcanic rocks showing normal and reversed magnetic orientations (Fig. 1; *1*). The common occurrence of reversely magnetized rocks throughout the geologic column makes it probable that reversals belonging to the time scale of 10^6 years characterize the last 4 million years and many other periods of Earth's history.

Magnetic events or reversals of short duration also have been demonstrated by studies of igneous rocks (*1*) and of marine sedimentary rocks (*2*); they are probably of the order of 10^4 to 10^5 years.

Irving and Parry (*3*), studying Upper Pennsylvanian and Permian rocks from Australia, found that all were reversely magnetized; they called this period the Kiaman magnetic interval, lasting for about 50×10^6 years. Sparse data previously available from Europe and North America did not conflict with the idea that Earth's field was steadily reversed during this period; the only exception is the Upper Tatarian sequence of Russia.

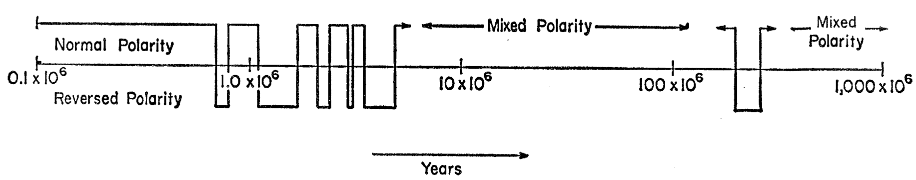

Fig. 1. Time scale of magnetic-field reversals.

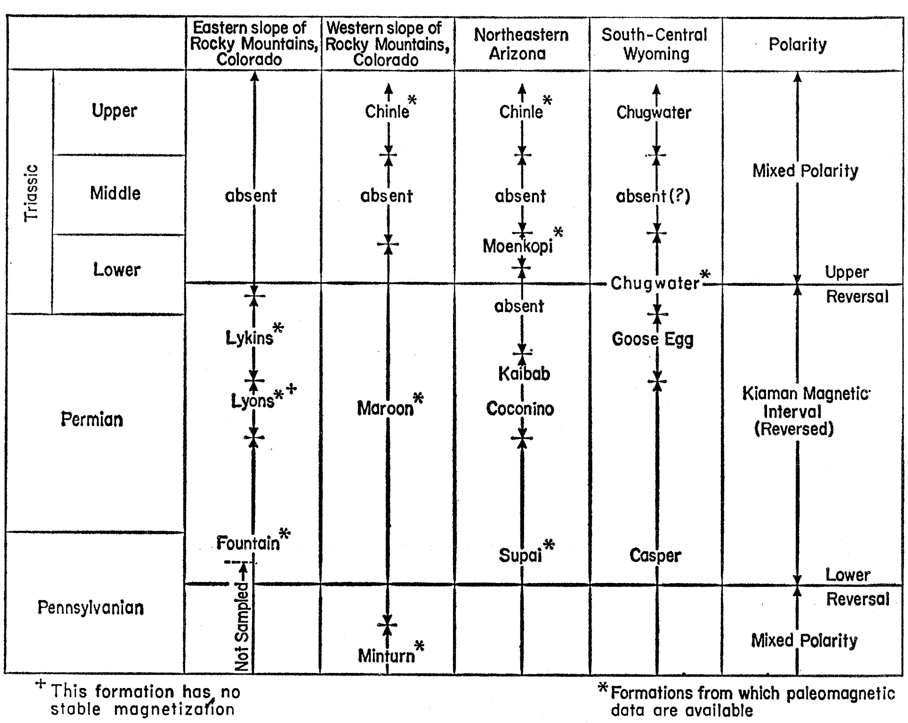

Fig. 2. Correlation chart showing magnetic polarity.

Because further verification is needed to establish the validity of the Kiaman magnetic interval, we have carefully studied rocks in Colorado that include the interval in question. Our results agree with the conclusions based on the Australian data, regarding the dating and duration of the interval and the exceptional polar stability of the interval. The rocks studied are part of an almost-continuous sequence of red-stained, arkosic conglomerates, sandstones, and shales (red beds) extending from Middle Pennsylvanian through the Triassic. Two sets of data, one from the eastern and one from the western slope of the Rocky Mountains, were collected at roughly 30-m stratigraphic intervals. On the eastern slope three formations were sampled—the Fountain, the Lyons, and the Lykins. The Lyons proved to be magnetically unstable, but the Fountain and the Lykins are both uniformly reversely magnetized. On the western slope the Minturn and Maroon formations were sampled; the Minturn and the lower part of the Maroon have rocks of mixed polarities, as does the upper part of the Maroon. However, between these two zones of mixed polarities there is about 1070 m of section that is uniformly reversely magnetized. Thus we find on the eastern slope approximately 610 m, and on the western slope, 1070 m, of sedimentary rocks that appear to reflect the reversed magnetic field postulated for the Kiaman. The age assigned to these two sequences on the basis of fossil evidence (*4*) correlates well with the age assigned to the Australian rocks (*3*). This finding suggests the worldwide nature of the Kiaman magnetic interval. If continuing studies show that it is worldwide, the field was steadily reversed for about 50×10^6 years.

Other red bed formations from the western United States have been studied without recognition of the Kiaman. Following are correlations with the rocks studied from Colorado: The lower part of the Chugwater formation, which by classical geological correlation is regarded as a time-equivalent of the upper Lykins formation, is uniformly reversely magnetized (*5*). The Moenkopi formation of northeastern Arizona and southeastern Utah is a time-equivalent of the very upper part of the Maroon formation of central

Colorado. In both these sequences the rocks show mixed polarities and overlie a thick sequence of rocks that are reversely magnetized (Fig. 2). On the basis of the Australian data and sparse data from Europe (6), the beginning of the Kiaman interval is placed at the base of the Upper Pennsylvanian. On the western slope, the lower reversal is located in rocks of this approximate age. In places, the Fountain formation contains fossils as old as Lower Pennsylvanian, but it is probable that formation was initiated during Upper Pennsylvanian in the area sampled; thinning of the formation in this area supports this interpretation.

It is important to establish the time at which the magnetic moment was acquired by these rocks. Unlike igneous rocks (which have thermoremanent magnetization) or varved clays (which have detrital remanent magnetization), the mechanism, and therefore the time, of magnetization of red beds is poorly understood.

In the western interior of the United States the good correlation between the established stratigraphic relations and the top of the Kiaman division, as determined from available paleomagnetic data, suggests that the magnetization of the beds was acquired near the time of deposition. Further supporting this interpretation is the observation that in the red beds of the western interior of the United States there is a steadily reversed zone which, on the basis of fossil evidence (4), is the approximate age-equivalent of the Kiaman division defined by Australian paleomagnetic data.

Thus we may conclude that the evidence to date suggests that the pattern of polar reversals occurs on three time scales: approximately 10^4 or 10^5, 10^6, and 50×10^6 years. An effort to check the validity of the Kiaman magnetic interval as a worldwide event has demonstrated good correlation between the western interior of the United States and observations based primarily upon Australian paleomagnetic data. Because the Australian data came from igneous rocks dated by radio isotopes, and the data from the western interior of the United States were obtained from red beds dated by fossils, the evidence favors the interpretation that the red beds were magnetized early in the history of the deposits. Finally, the correspondence between paleomagnetic data and classical geological correlations within the western interior suggests that paleomagnetic information may eventually aid stratigraphic correlation.

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Composition of the Ancient North American Crust

Abstract. *Geochemical studies of Wyoming Precambrian graywackes derived from continental crust older than 3.2×10^9 years indicate that their source area was at least as highly differentiated as most younger Precambrian crust. The composition of this early crust (approximately that of calcium-rich granite) is not unlike that of the 2.5 to 3.2×10^9 year old North American crust. Limited geochemical data suggest that the composition of North America may not have changed significantly during the last 3.0 to 3.5×10^9 years.*

Whether or not continents have changed appreciably in composition as a function of geologic time is a major problem in the study of continental evolution. Although geologic and geochemical data indicate that K:Na, Fe^{3+}:Fe^{2+}, and Ca:Mg ratios of sediments (which in turn reflect continent composition) have increased in the last 0.6 to 1×10^9 years (1), the evidence for secular compositional changes prior to this period is less certain.

It appears that the oldest orogenic granite-forming event preserved in the continental crust is about 3.4 to 3.6×10^9 years old (2). Although exposures of such ancient crust have been reported only in northern Europe and southern Africa (2), zircons that may be of this age have been found in younger Precambrian terranes of North America (3, 4). Such relict zircon ages suggest that a 3.4 to 3.6×10^9 year old crust also once existed in North America. Although detailed results of geochemical studies of the European and African terranes are not available, geologic studies indicate that they are composed predominantly of granite, gneiss, and migmatite, with lesser amounts of mafic igneous and metamorphic rock and only minor amounts of sedimentary rock (2); their gross lithology is not unlike that of younger Precambrian shields.

Graywackes that occur as large pendants engulfed in 2.5 to 3.2×10^9 year old granitic batholiths in North America represent rapidly eroded mineral and rock-clast assemblages derived from a source, partially or entirely, older than 3.2×10^9 years. The existence of zircons that may be 3.5×10^9 years in age (4) in the Wyoming-Montana portion of the 2.5 to 3.2×10^9 year old North American crust (Superior Province) suggests the possibility that such graywackes in this area may have been derived from crust as old as 3.5×10^9 years.

Graywackes from a large pendant in the Precambrian core of the southern Wind River Range in Wyoming have been sampled in order to estimate the composition of this ancient crust in this area. Although the graywackes have undergone low-grade metamorphism, as evidenced by their constituent mineral assemblages, it is unlikely that their original composition has been appreciably affected. Especially suggestive of approximately isochemical metamorphism is the fact that the enclosed rock fragments indicate a source-area composition similar to that indicated by the bulk chemical composition of the graywackes (5); the fragments indicate a dominant granitic igneous and metamorphic component in the source area.

Twenty-three graywacke samples have been analyzed for eight major and five trace elements by nondestructive x-ray fluorescence and neutron activation (5). The mean values for each oxide and trace element are accompanied (Table 1) by an estimate of