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Marine Magnetic Anomalies, Oceanic Crust Magnetization, and Geomagnetic Time Variations

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Since the classic paper of Vine and Matthews (Nature, 1963), marine magnetic anomalies are commonly used to date the ocean floor through comparison with the geomagnetic polarity time scale and proper identification of reversal sequences. As a consequence, the classical model of rectangular prisms bearing a normal / reversed magnetization has been dominant in the literature for more than 40 years. Although the model explains major characteristics of the sea-surface magnetic anomalies, it is contradicted by (1) recent advances on the geophysical and petrologic structure of the slow-spreading oceanic crust, and (2) the observation of short-term geomagnetic time variations, both of which are more complex than assumed in the classical model. Marine magnetic anomalies may also provide information on the magnetization of the oceanic crust as well as short-term temporal fluctuations of the geomagnetic field. The "anomalous skewness", a residual phase once the anomalies have been reduced to the pole, has been interpreted either in terms of geomagnetic field variations or crustal structure. The spreading-rate dependence of anomalous skewness rules out the geomagnetic hypothesis and supports a spreading-rate dependent magnetic structure of the oceanic crust, with a basaltic layer accounting for most of the anomalies at fast spreading rates and an increasing contribution of the deeper layers with decreasing spreading rate. The slow cooling of the lower crust and uppermost mantle and serpentinization, a low temperature alteration process which produces magnetite, are the likely cause of this contribution, also required to account for satellite magnetic anomalies over oceanic areas. Moreover, the "hook shape" of some sea-surface anomalies favors a time lag in the magnetization acquisition processes between upper and lower magnetic layers: extrusive basalt acquires a thermoremanent magnetization as soon as emplaced, whereas the underlying peridotite and olivine gabbro cool slowly and pass through serpentinization to bear a significant magnetization. Our analysis of the amplitude of Anomaly 25 shows a sharp threshold at the spreading rate of 30 km/Ma, which corresponds to the transition between oceanic lithosphere built at axial domes and axial valleys. The twice lower amplitudes are in agreement with a much disrupted and altered basaltic layer at slow rates and a significant contribution from the deeper layers. Oceanic lithosphere created at fast and slow spreading rates therefore exhibits contrasted magnetic structures. High resolution magnetic anomaly measurements carried out with deep tows and submersibles show that the magmatic (fast spreading and parts of the slow spreading) crust is a good recorder of short-term geomagnetic time variations, such as short polarity intervals, excursions, or paleointensity variations. Surface and deep-sea magnetic anomalies therefore help to confirm or infirm geomagnetic findings obtained by other means. Many excursions and paleointensity variations within Brunhes and Matuyama periods are confirmed, but the "saw tooth pattern" inferred from sediment cores - a possible candidate to explain the anomalous skewness - is not, which suggests a bias in the sedimentary approach.