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Toward a better understanding of magnetic mineralogy and low-temperature alteration of igneous cores from world oceans

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The ocean crust preserves a record of the direction and intensity of Earth's magnetic field in the past. Understanding the magnetic carriers of oceanic crust is an essential prerequisite for addressing fundamental questions in the variability of the Earth magnetic field in the geologic past and its implications for a broad range of problems in the Earth sciences. Professor Masaru Kono has been a pioneer in applying paleomagnetism and rock magnetism to deep-sea igneous cores and his method on how to dividing inclination groups is still widely cited and used by modern Ocean Drilling Program (ODP)/ Integrate Ocean Drilling Program (IODP) scientists.

Previous rock magnetic investigations of oceanic basement samples have been mainly restricted by single drill holes or dredge collections. In this study, we present new and published data on the paleomagnetic and rock magnetic properties of igneous rock samples recovered during several ODP legs in the Pacific, Atlantic, and the southern Indian oceans. The recovered igneous rocks from these legs are mainly basaltic flows (both submarine and subaerial), diabase sills, and serpentinized peridotites with approximately ages of 140,000 years, 10-12 Ma, 34 Ma, 69 Ma, 100-108 Ma, and 110-121 Ma, which offers an opportunity to investigate magnetic properties and mineral changes attending alteration of basement rocks over a wide range of ages from variable tectonic settings. Our rock magnetic data indicate that the differences in the rock magnetic properties of basaltic rocks are mainly a function of mineralogy and alteration. There is no apparent coincidence between the age of the rocks and the degree of low-temperature alteration, as suggested by the presence of nearly unoxidized titanomagnetite in the Cretaceous aged basalts and by an examination of Curie temperature vs. sample age that does not unambiguously show a positive relationship between the degree of low-temperature oxidation and crust ages.

Titanomagnetite and titanomaghemite are commonly present in igneous rock samples of the Ontong Java Plateau, the Kerguelen Plateau/Broken Ridge, the eastern Equatorial Pacific, the middle Atlantic ridge (Trans-Atlantic Geotraverse area), and the Newfoundland-Iberia rifted margins. For basaltic rock samples, three general groups (A, B, and C, respectively) can be divided in terms of rock magnetic properties. Samples from group A have a single phase of Ti-poor titanomagnetite with Curie temperatures ranging between 480 and 580C and exhibit a strong Verwey transition in the vicinity of 110K. Basalts from this group are most likely good paleomagnetic recorders and probably have preserved original and stable magnetic remanences. Group B is mainly observed in pillow lavas and is characterized by a Curie temperature of 260-280C, which is typical of low-temperature oxidized titanomaghemite or titanium rich titanomagnetite (such as oxidized TM60). The low-temperature curves for group B do not show the Verwey transition. Several fine-grained submarine basalt samples in this group exhibited an apparent partial self-reversing behavior during thermal demagnetization and in a narrow temperature window that corresponds to the titanomaghemite phase determined from thermomagnetic experiments. Group C has more than one Curie temperature, which suggests the presence of multiple magnetic phases. Although the hysteresis ratios for rocks in this group still fall in the PSD region, the cluster is centered toward the multidomain (MD) region. Low temperature curves do not clearly show the Verwey transition. The thermomagnetic signature indicates the inversion of titanomaghemite to a strongly magnetized magnetite, as shown by the irreversible cooling curves. The magnetic signatures of the serpentinized peridotites recovered from both sides of the Newfoundland-Iberia rift appear not in conflict with the notion that conjugate margins will have generally similar crustal structure and evolution history.