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Palaeomagnetic constraints on the evolution of the Atlantis Massif oceanic core complex (Mid-Atlantic Ridge, 30°N)

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Oceanic core complexes expose lower crustal and upper mantle rocks on the seafloor by tectonic unroofing in the footwalls of large-slip detachment faults. They represent a fundamental component of the seafloor spreading system at slow and ultraslow axes. For example, recent analyses suggest that detachment faults may underlie more than 50% of the Mid Atlantic Ridge (MAR) and may take up most of the overall plate divergence at times when magma supply to the ridge system is reduced.

The most extensively studied oceanic core complex is Atlantis Massif, located at 30°N on the MAR. This forms an inside-corner bathymetric high at the intersection of the Atlantis Transform Fault and the MAR. The central dome of the massif exposes the corrugated detachment fault surface and was drilled during IODP Expedition 304/305. This sampled a 1.4 km faulted and complexly layered footwall section dominated by gabbroic lithologies with minor ultramafic rocks. The core (Hole U1309D) reflects the interplay between magmatism and deformation prior to, during, and subsequent to a period of footwall displacement and denudation associated with slip on the detachment fault.

Palaeomagnetic analyses demonstrate that the gabbroic sequences at Atlantis Massif carry highly stable remanent magnetizations that provide valuable information on the evolution of the section. Thermal demagnetization experiments recover high unblocking temperature components of reversed polarity (R1) throughout the gabbroic sequences. In a number of intervals, however, the gabbros exhibit a complex remanence structure with the presence of intermediate temperature normal (N1) and lower temperature reversed (R2) polarity components, suggesting an extended period of remanence acquisition during different polarity intervals. Sharp break-points between different polarity components suggest that they were acquired by a thermal mechanism. There appears to be no correlation between remanence structure and either the igneous stratigraphy or the distribution of alteration in the core. Instead, the remanence data are more consistent with a model in which the lower crustal section acquired magnetizations of different polarity during a protracted cooling history spanning two geomagnetic reversals. Differences in the width of blocking temperature spectra between samples appear to control the number of components present; samples with narrow and high temperature spectra record only R1 components, whereas those with broader blocking temperature spectra record multicomponent (R1-N1 and R1-N1-R2) remanences.

The common occurrence of detachment faults in slow and ultra-slow spreading oceanic crust suggests they accommodate a significant component of plate divergence. However, the sub-surface geometry of oceanic detachment faults remains unclear. Competing models involve either: (a) displacement on planar, low-angle faults with little tectonic rotation; or (b) progressive shallowing by rotation of initially steeply dipping faults as a result of flexural unloading (the "rolling-hinge" model). We resolve this debate using paleomagnetic remanences as a marker for tectonic rotation of the Atlantis Massif footwall. Previous ODP/IODP palaeomagnetic studies have been restricted to analysis of magnetic inclination data, since hard-rock core pieces are azimuthally unoriented and free to rotate in the core barrel. For the first time we have overcome this limitation by independently reorienting core pieces to a true geographic reference frame by correlating structures in individual pieces with those identified from oriented imagery of the borehole wall. This allows reorientation of paleomagnetic data and subsequent tectonic interpretation without the need for a priori assumptions on the azimuth of the rotation axis. Results indicate a 46°±6° counterclockwise rotation of the footwall around a MAR-parallel horizontal axis trending 011°±6°. This provides unequivocal confirmation of the key prediction of flexural, rolling-hinge models for oceanic core complexes, whereby faults initiate at higher dips and rotate to their present day low angle geometries.