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Beyond the standard tilt correction: analysing the paleomagnetism of metamorphic soles

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Structural corrections are an essential part of any paleomagnetic study and are applied by restoring sampled units to a paleohorizontal reference frame via rotation around the line of strike. But how may paleomagnetic data be interpreted in cases where we do not know the attitude of the sampled rocks at the time of remanence acquisition?

This is a scenario encountered when attempting to use magnetizations to determine the tectonic evolution of the metamorphic soles of ophiolites. These may experience significant rotation during their exhumation from peak metamorphic depths and their subsequent emplacement. For example, a recent metamorphic sole exhumation model (van Hinsbergen et al., 2015, doi: 10.1002/2015GC005745) involves flattening of a subducting slab during forearc spreading, implying significant rotation of sole rocks after formation.

Here we test this exhumation mechanism using data from the Mersin ophiolite (Tauride Belt, southern Turkey), a well-exposed Neotethyan suprasubduction zone ophiolite that formed in the Late Cretaceous. The Mersin metamorphic sole rocks (predominantly amphibolites) are inferred to have formed at the top of the down-going plate during subduction. Previous paleomagnetic analysis of non-metamorphosed dykes cutting the sole rocks indicate a 45° clockwise rotation of the sole and dykes after intrusion around a NE-trending, shallowly plunging, ridge-parallel axis (Morris et al., 2017, 10.1016/j.epsl.2017.08.040). Here we show that the host amphibolites carry a statistically different magnetization to that of the dykes they host, providing evidence for an earlier phase of rotation.

Tectonic interpretation of these data in the absence of paleohorizontal markers cannot be achieved using standard paleomagnetic tilt corrections. Instead we adopt a Monte Carlo approach to modelling potential net tectonic rotation parameters and permissible orientations of the foliation in the sole rocks at the time of magnetization and incorporating statistical uncertainties into the analysis, after back-stripping the later rotation of the sole-hosted dykes. Results suggest that the sole acquired its remanence while the metamorphic foliation dipped moderately to the ENE and then underwent an early phase of anticlockwise rotation around an inclined, NW plunging axis. This is consistent with a two-stage rotation model involving an earlier phase of exhumation by slab flattening followed by a later spreading-related rotation around a ridge-parallel axis after accretion of the sole to the base of the ophiolite. These rotations around different inclined axes are consistent with a geodynamic setting similar to the modern Andaman Sea, where spreading in a suprasubduction zone environment occurs obliquely to the subduction direction of the down-going plate.