PALEOMAGNETIC ANALYSIS OF THE METAMORPHIC SOLE ROCKS OF THE MERSIN OPHIOLITE, SOUTHERN TURKEY

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ABSTRACT

The metamorphic soles of ophiolites may experience significant rotation during their exhumation from peak metamorphic depths and their subsequent emplacement. For example, a recent metamorphic sole exhumation model involves flattening of a subducting slab during forearc spreading, implying significant rotation of sole rocks after formation. Here we test this exhumation mechanism using paleomagnetic data from the Mersin ophiolite (Tauride Belt, southern Turkey), a 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. 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 during exhumation. Tectonic interpretation of these data in the absence of paleohorizontal markers cannot be achieved using standard paleomagnetic structural 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, after back-stripping late 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 later spreading-related rotation around a ridge-parallel axis after accretion of the sole to the base of the future ophiolite. These rotations around different inclined axes are also 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.

1. Introduction, Geological Setting and Ophiolite Rotation

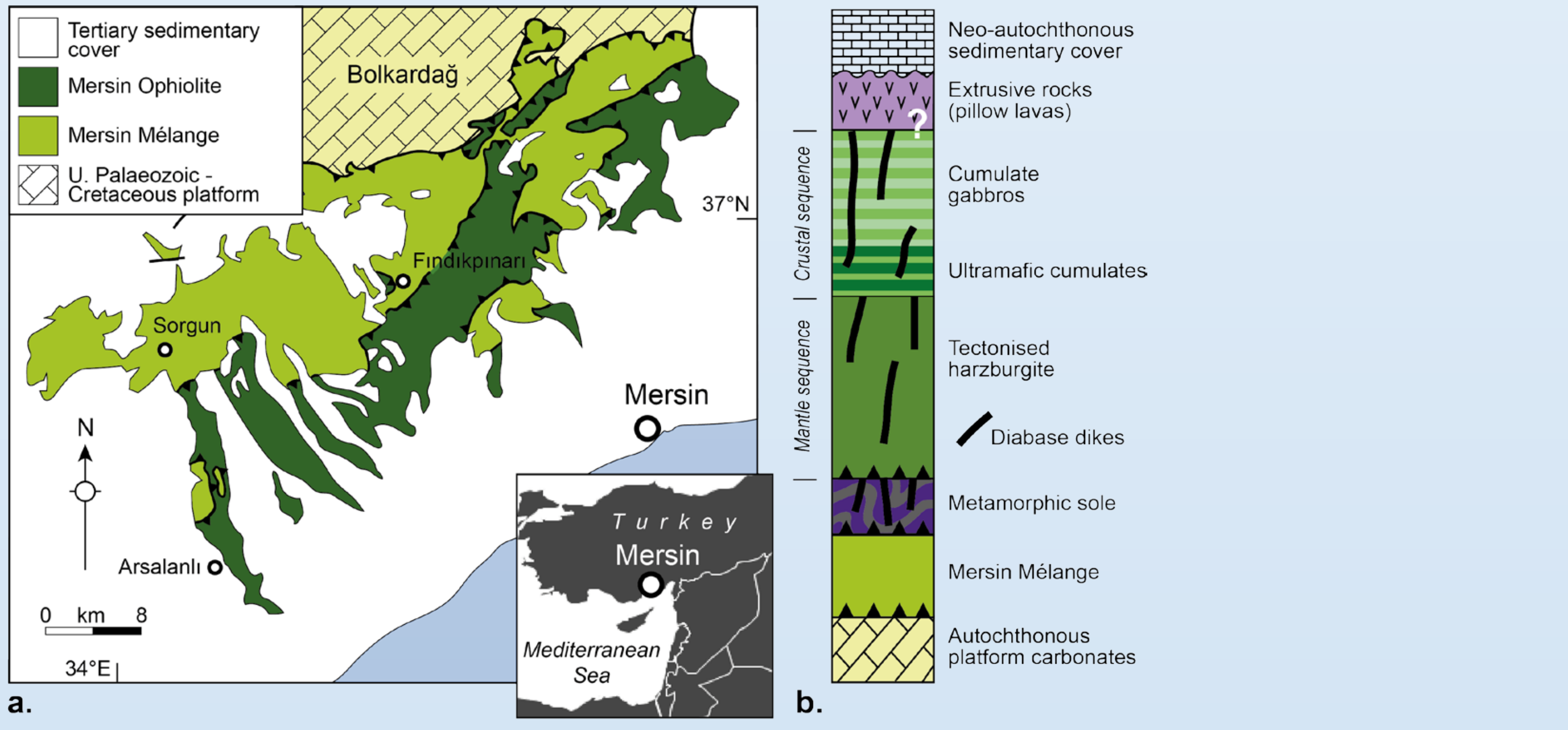

Fig. 1. (a) Simplified geology map (after Tekin *et al.,* 2016) and (b) tectonostratigraphic column (after Parlak *et al.,* 1996) of the Mersin ophiolite

Lower crustal cumulates, dykes cutting cross both mantle and sole rocks of Mersin ophiolite have been studied by using paleomagnetism technique and parameters of the rotations experienced by igneous rocks have been already presented (Morris et al., 2017). It has been revealed that all these units have experienced these rotations around more or less same axis with different amounts. According to that information, new model demonstrating the formation of the ophiolite and metamorphic sole rocks associated with it has been prepared. As it can be seen in the Fig. 3, the metamorphic sole rocks underwent an early phase of rotation just before they welded beneath ophiolite.

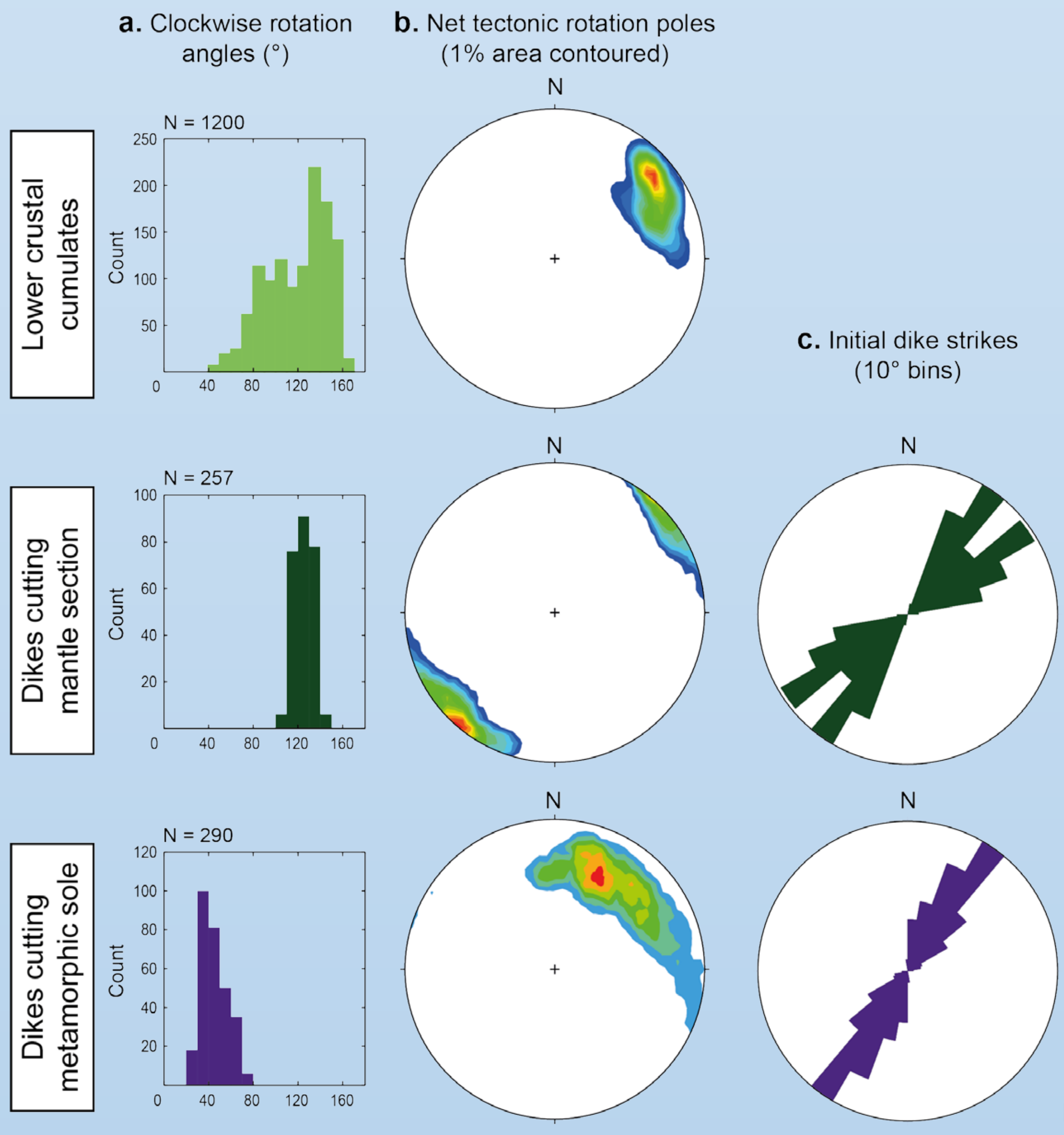

Fig. 2. Results of the net tectonic rotation analysis of paleomagnetic data collected from the Mersin ophiolite (Morris et al., 2017).

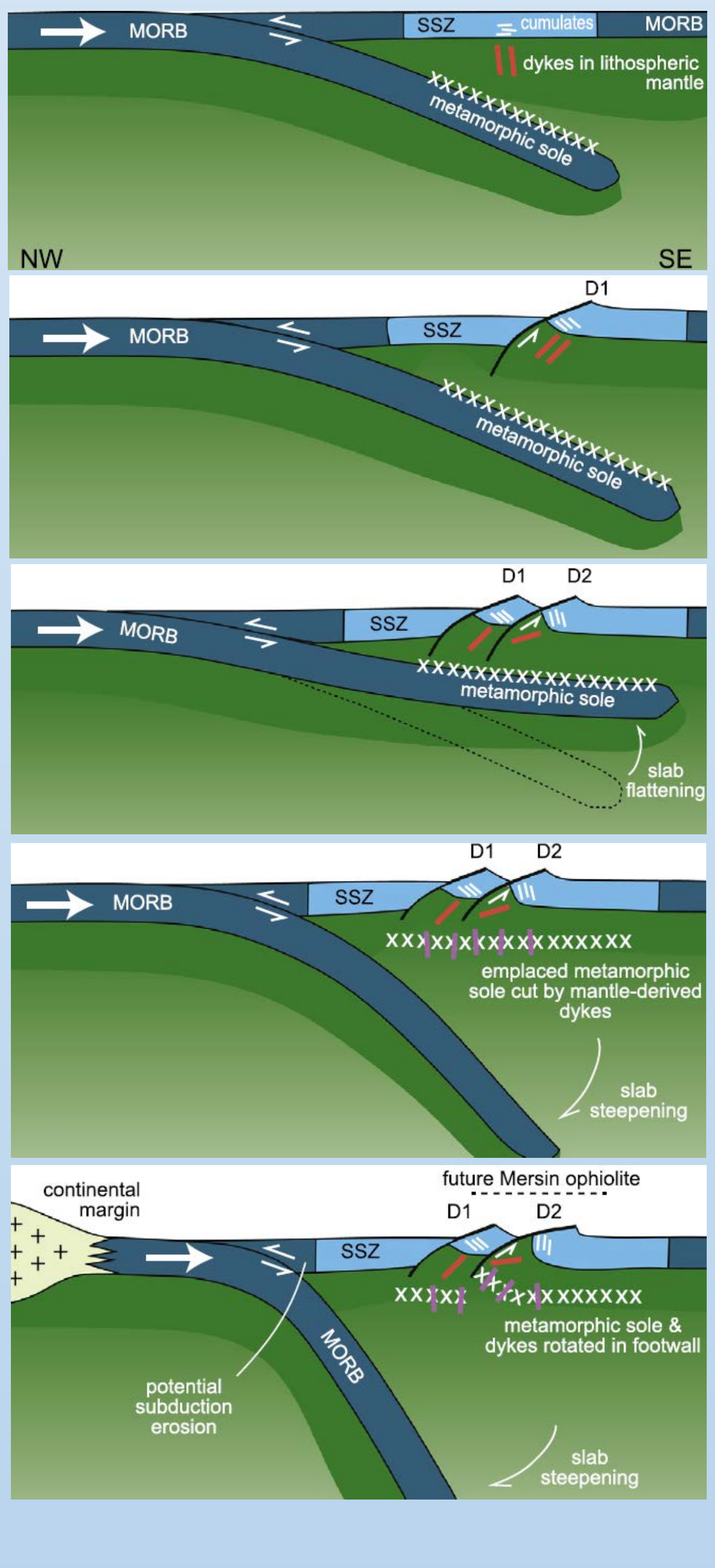

Fig. 3. Conceptual model for rapid and extreme tectonic rotation of a suprasubduction zone ophiolite and its metamorphic sole in a fore-arc environment, based on data in Fig. 2 (Morris et al., 2017) and incorporating metamorphic sole exhumation model of van Hinsbergen et al. (2015).

2. Demagnetization Data

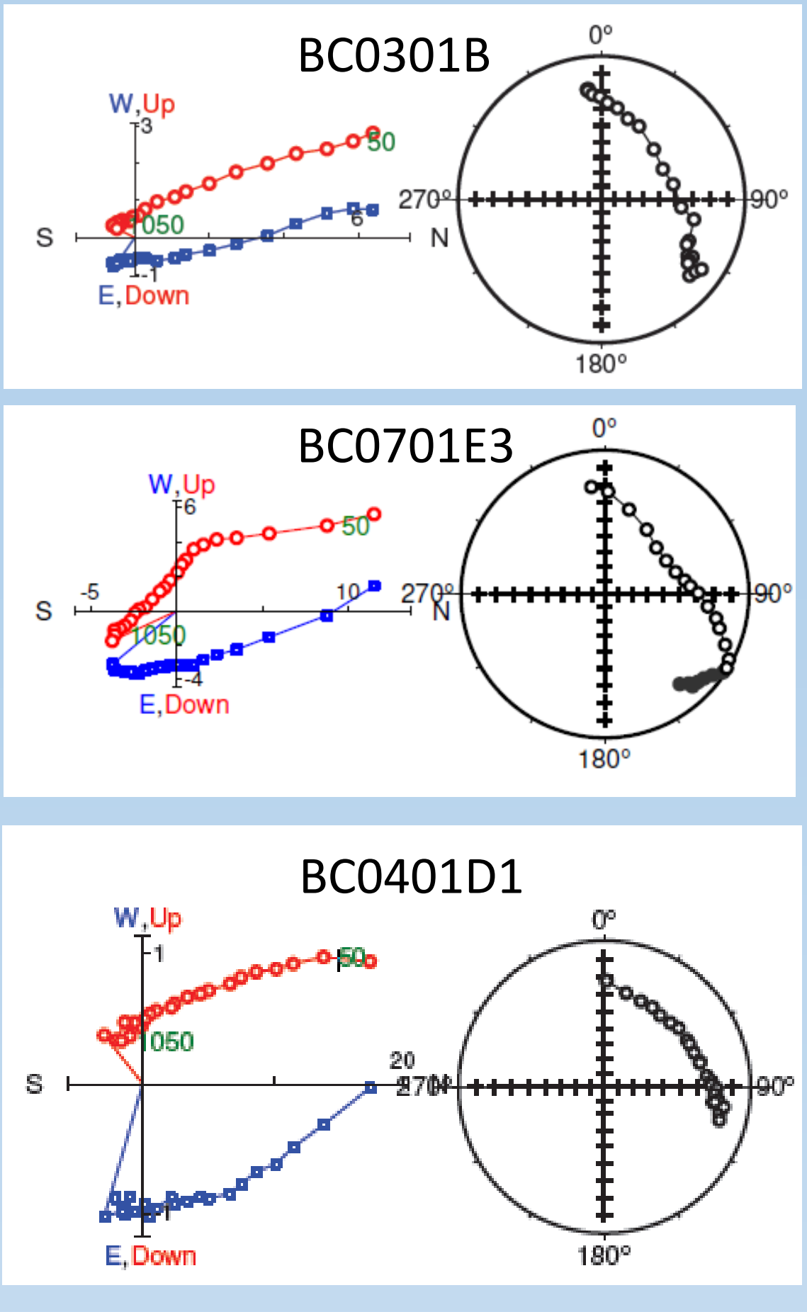

Fig. 4. Some detailed alternating field demagnetization result examples from different rock samples, showing great circle demagnetization paths.

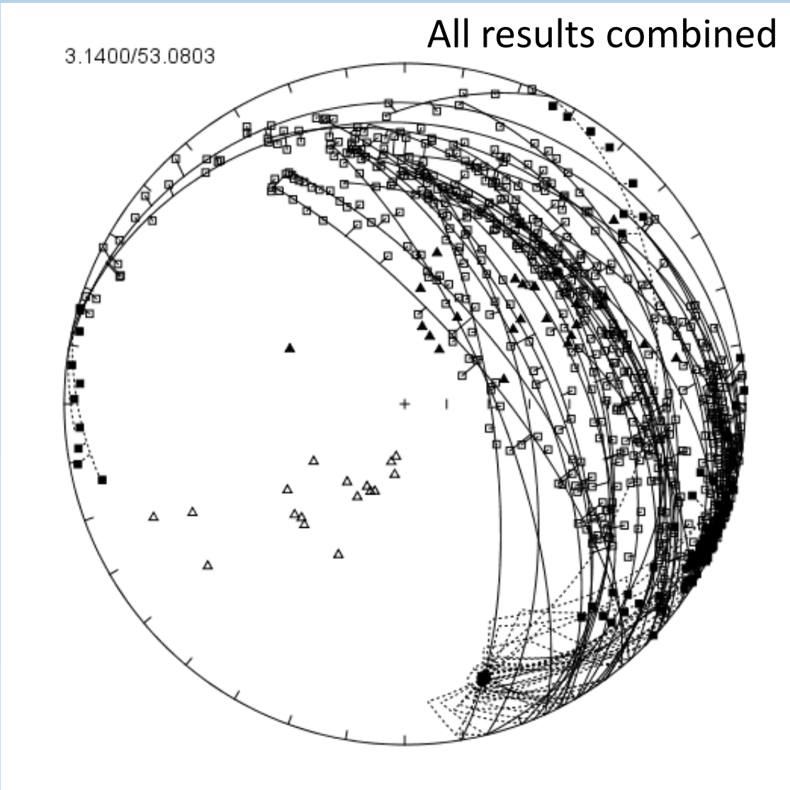

Fig. 5. Demagnetization data from all metamorphic sole samples analysed using the combined great circle and vector end-point method of McFadden and McElhinny (1988). Overall mean direction = 157.3/14.3, α_{95} = 7.5°, interpreted as a reversed magnetization.

The natural remanent magnetization (NRM) of a rock represents the sum of all magnetic components during a rock's history. However, the main aim of palaeomagnetic analyses is to find the earliest component, defined as the characteristic remanent magnetization (ChRM), for geological interpretation. That direction represents the geomagnetic field at the time of acquisition of the magnetization. Therefore, low stability secondary magnetizations (usually carried by the lowest coercivity or blocking temperature grains) needed to be removed. For this purpose, there are two different techniques. One of them is alternating field (AF) demagnetization and the other one is thermal demagnetization. It is quite important to choose the best one for the demagnetization process.

3. Net Tectonic Rotation Analysis – Input Vectors

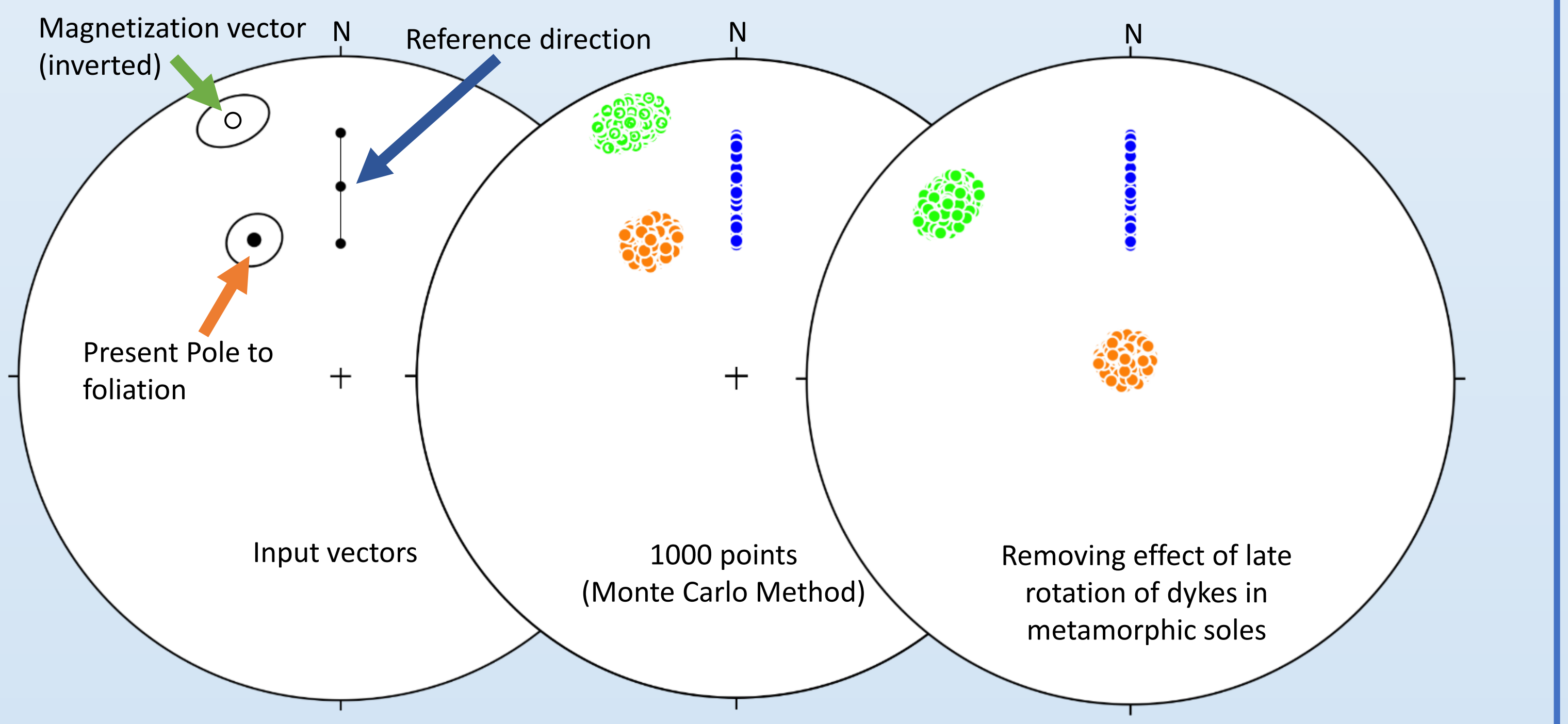

Fig. 6. Left: Input vectors with 95% confidence limits; Middle: distributions of 1000 randomly selected points within the confidence limits of each input vector; Right: same distributions after back-stripping the late rotation of dykes cutting the metamorphic sole. These data are then used to calculate parameters for the earlier rotation phase.

4. Key Assumption – Constancy of β

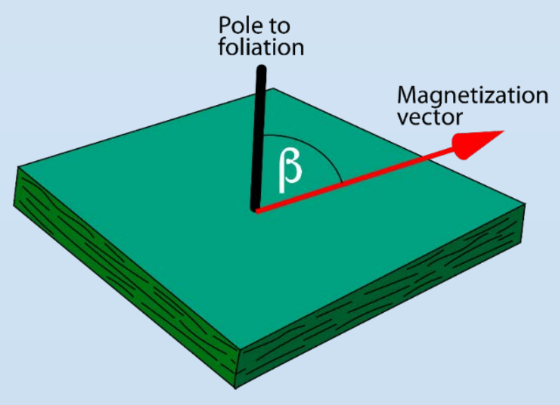

Fig. 7 (left). The net tectonic rotation approach to the analysis of paleomagnetic data is based on the assumption that the angle b between the pole to the structure and the magnetization vector remains constant during rotational deformation.

5. All Potential Net Tectonic Rotation Solutions

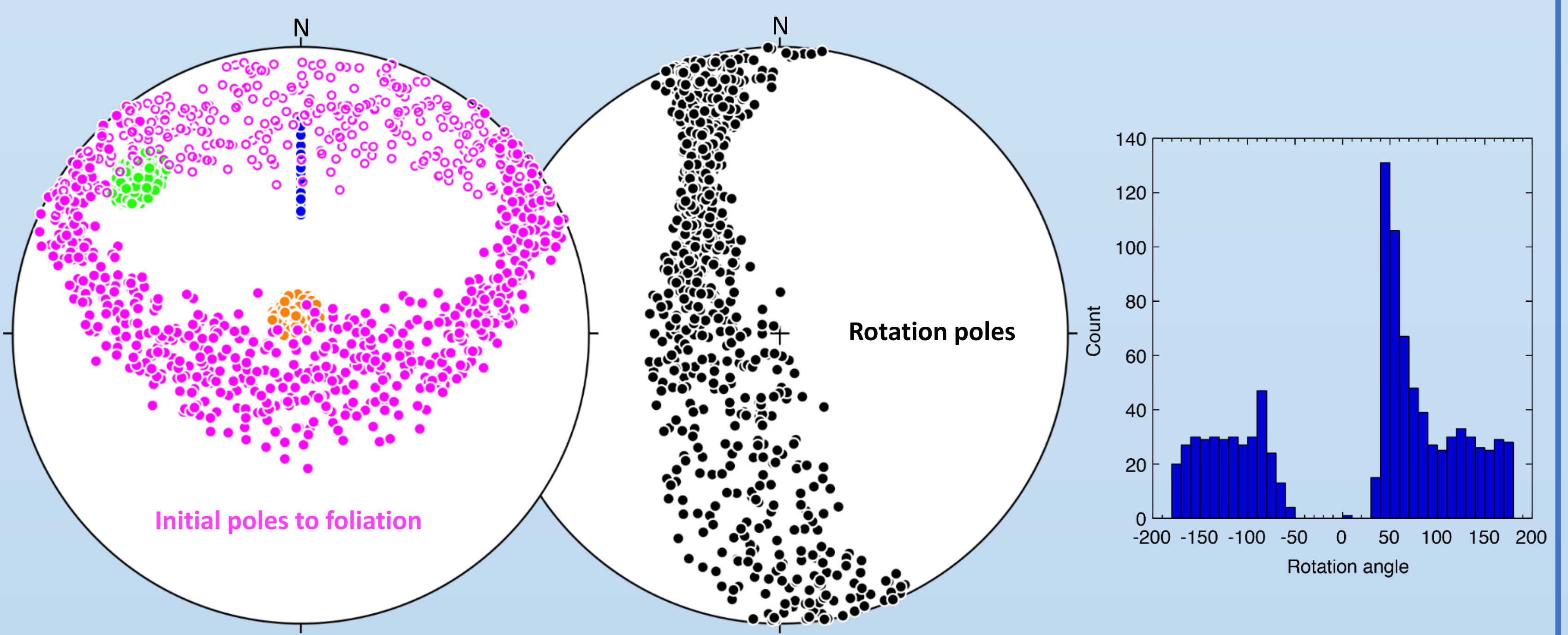

Fig. 8. Left: each combination of a present day pole to foliation and a magnetization vector within the distributions shown in Fig. 6 yields a different value of β. Permissible initial rotation poles are located β degrees from the reference magnetization direction (see Fig. 7). The distribution of 1000 potential initial poles to foliation is therefore calculated by assigning each b angle to one of the estimates of the reference direction and locating the corresponding initial pole β degrees from the assigned reference direction along a random azimuth. Middle: each of the 1000 combinations of magnetization vectors, reference directions and present day and initial poles to rotations yields a single potential rotation axis (located at the intersection of great circle bisectrixes of the structural and magnetization vector pairs). Each point represents a rotation axis capable of restoring the present day structure to its initial orientation and the magnetization vector to the reference direction, yielding (Right) 1000 estimates of rotation angles.

6. Filtering Solutions Using Other Constraints

Not all of these solutions, however, are geologically plausible despite being geometrically possible, and so additional geological constraints need to be used to filter the possible solutions to come up with a set of realistic and acceptable solutions. There are three geological constraints that may be used:

Discard solutions that invert the foliation (i.e. maintain way-up). **Retain** only solutions involving CCW rotation, to be consistent with subduction dipping to east based on one of the recent Regional reconstruction of the Neotethyan system (Maffione et al., 2017). **Discard** solutions involving > 90° rotation

7. Remaining Acceptable Solutions

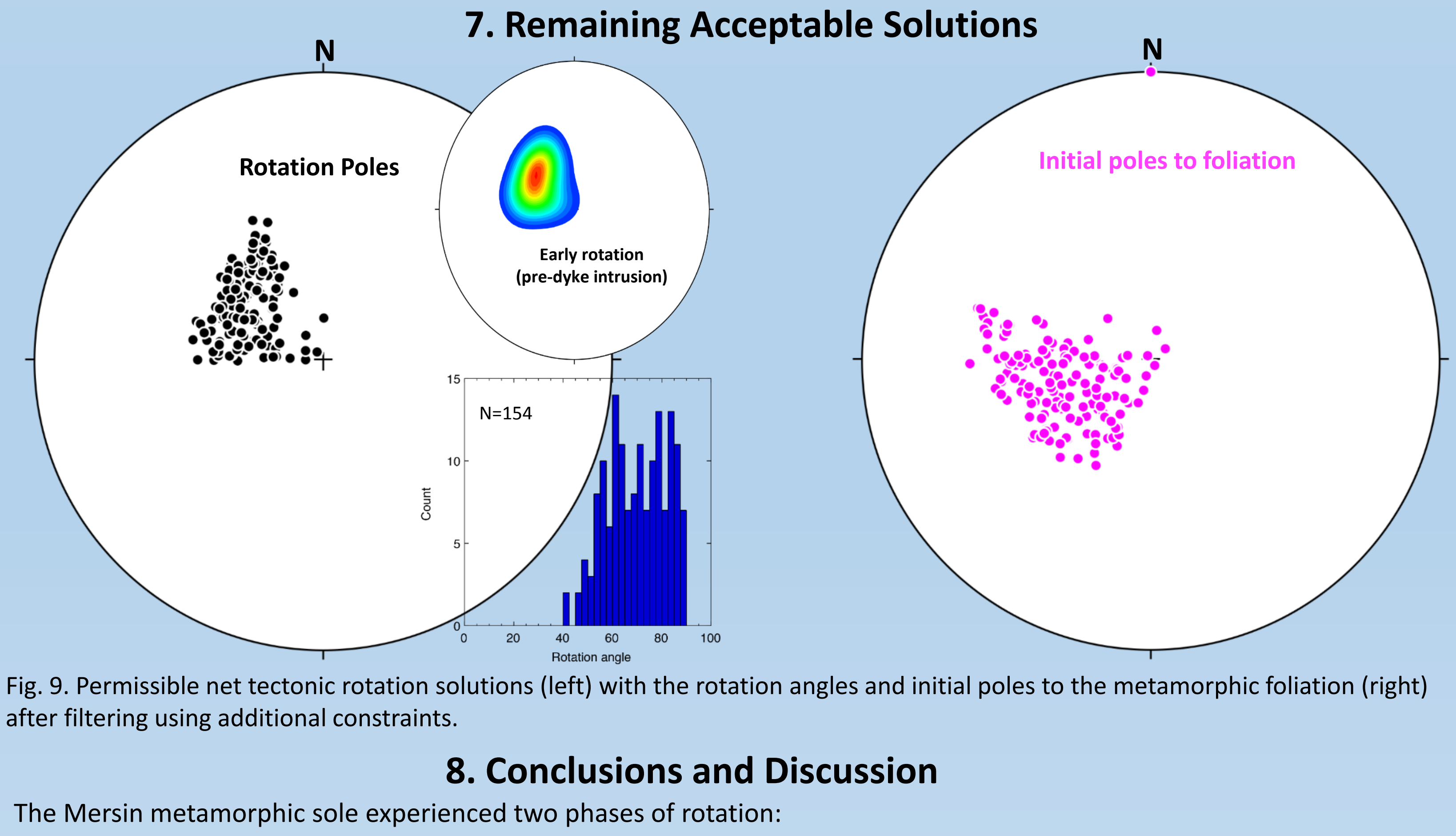

Fig. 9. Permissible net tectonic rotation solutions (left) with the rotation angles and initial poles to the metamorphic foliation (right) after filtering using additional constraints.

8. Conclusions and Discussion

The Mersin metamorphic sole experienced two phases of rotation:

- Early rotation (prior to intrusion of dykes into the sole) around a NW inclined axis, resulting in shallowing of the subducted slab (followed by accretion to base of the overlying plate)
- Late rotation (after dyke intrusion) around a NE ridge-parallel axis during suprasubduction zone detachment-mode spreading

This study represents the first time that paleomagnetism has been applied to sole rocks. This study clearly indicates the potential for net tectonic rotation analysis of remanence data from metamorphic rocks to contribute to understanding their geodynamic evolution. Therefore, sole rocks of other the Neotethyan ophiolites should be studied for further information.

References

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