Unravelling the Remagnetization of the Oman Ophiolite

Louise Koornneef[a], Antony Morris[a], Michelle Harris[a], and Christopher MacLeod[b]

UNIVERSITY OF PLYMOUTH

CARDIFF UNIVERSITY PRIFYSGOL CAERDYD

Abstract:

The Oman ophiolite is a natural laboratory for the study of processes operating above a nascent subduction zone. It formed in the Late Cretaceous by supra-subduction zone spreading and shortly afterwards was emplaced onto the Arabian continental margin. Twelve massifs in the ophiolite expose complete sections of the Neotethyan oceanic lithosphere, including upper mantle peridotites, lower crustal gabbros, and upper crustal sheeted dykes and lava flows.

Previous palaeomagnetic studies have suggested that the southern massifs of the ophiolite were affected by a large-scale remagnetization event during emplacement, that completely replaced original remanences acquired during crustal accretion. In contrast, primary magnetizations are preserved throughout the northern massifs. This study aimed to: (i) apply palaeomagnetic, magnetic fabric and rock magnetic techniques to analyse crustal sections through the southern massifs of the Oman ophiolite to investigate further the extent and nature of this remagnetization event; and (ii) use any primary magnetizations that survived this event to document intraoceanic rotation of the ophiolite prior to emplacement.

Our new data confirms that remagnetization appears to have been pervasive throughout the southern massifs, resulting in presence of shallowly-inclined NNW directions of magnetization at all localities. An important exception is the crustal section exposed in Wadi Abyad (Rustaq massif) where directions of magnetization change systematically through the gabbro-sheeted dyke transition. Demagnetization characteristics are shown to be consistent with acquisition of a chemical remanent overprint that decreased in intensity from the base of the ophiolite upwards. The top of the exposed Wadi Abyad section (in the sheeted dyke complex) appears to preserve original SE-directed remanences that are interpreted as primary seafloor magnetizations. Similar SE primary remanences were also isolated at a control locality in the Salahi massif, outside of the region of remagnetization. Net tectonic rotation analysis at these non-remagnetised sites shows an initial NNE-SSW strike for the supra-subduction zone ridge during spreading, comparable with recently published models for the regional evolution of the ophiolite.

1. Paleomagnetic evidence for remagnetization:

A. Geological setting

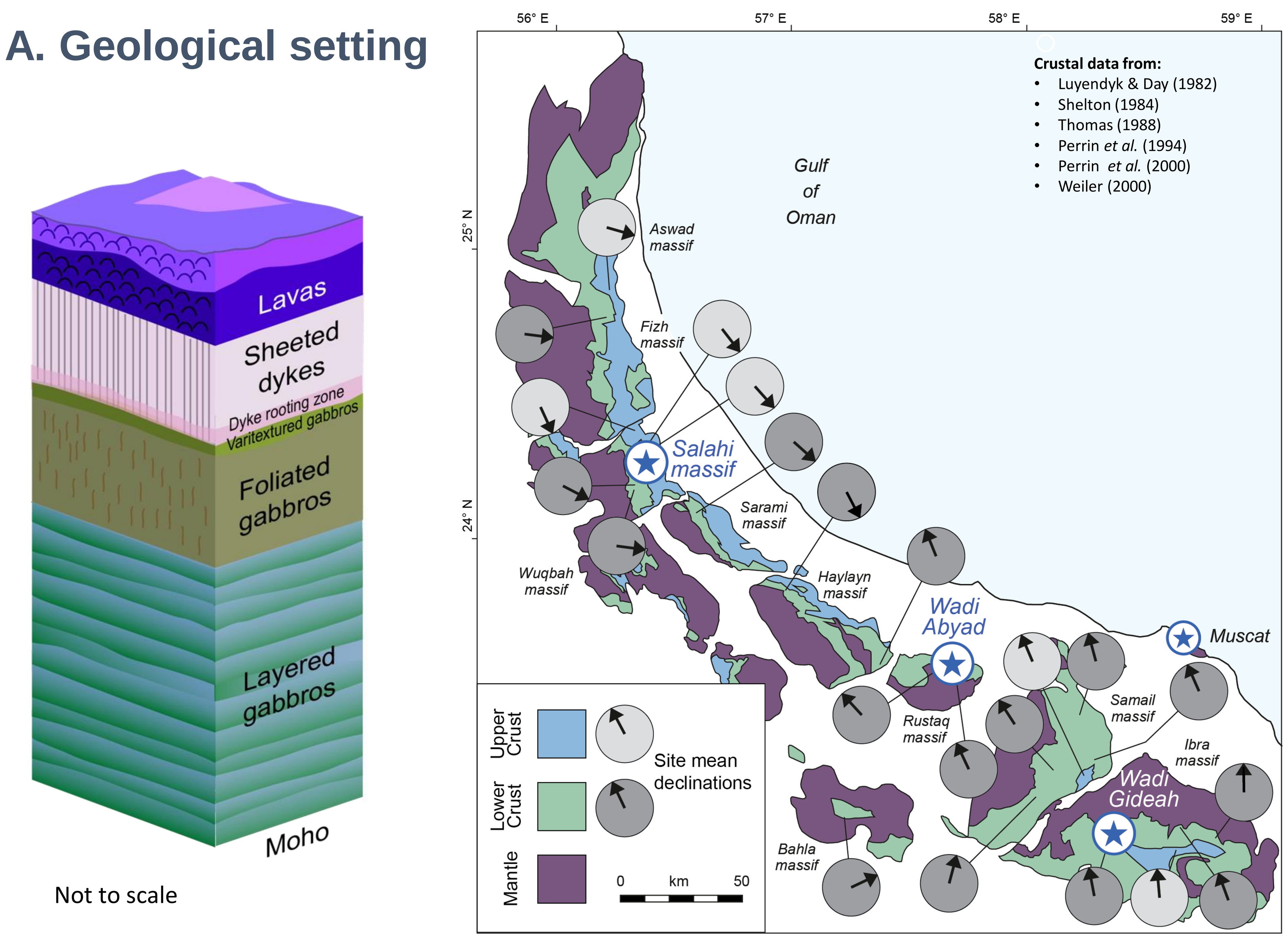
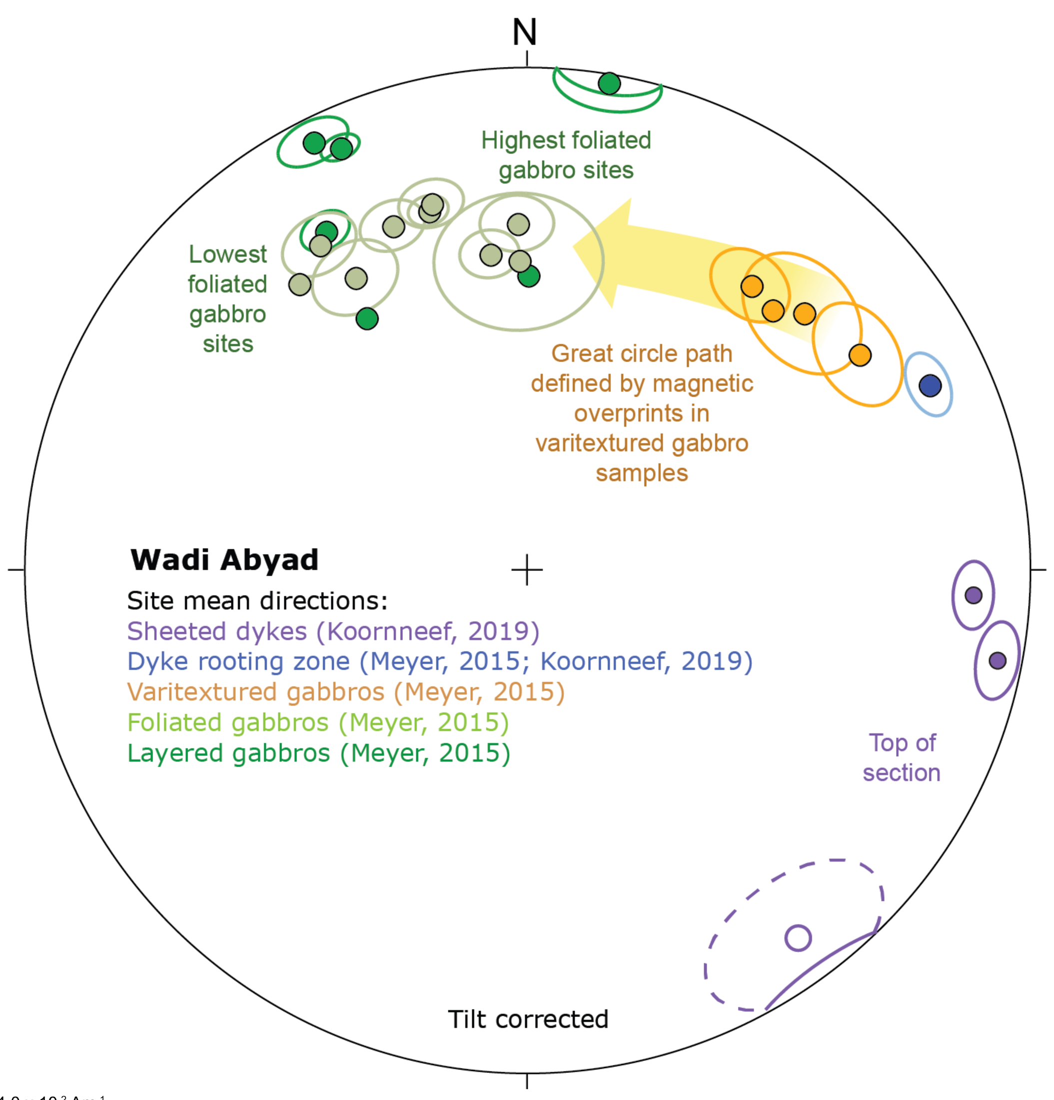
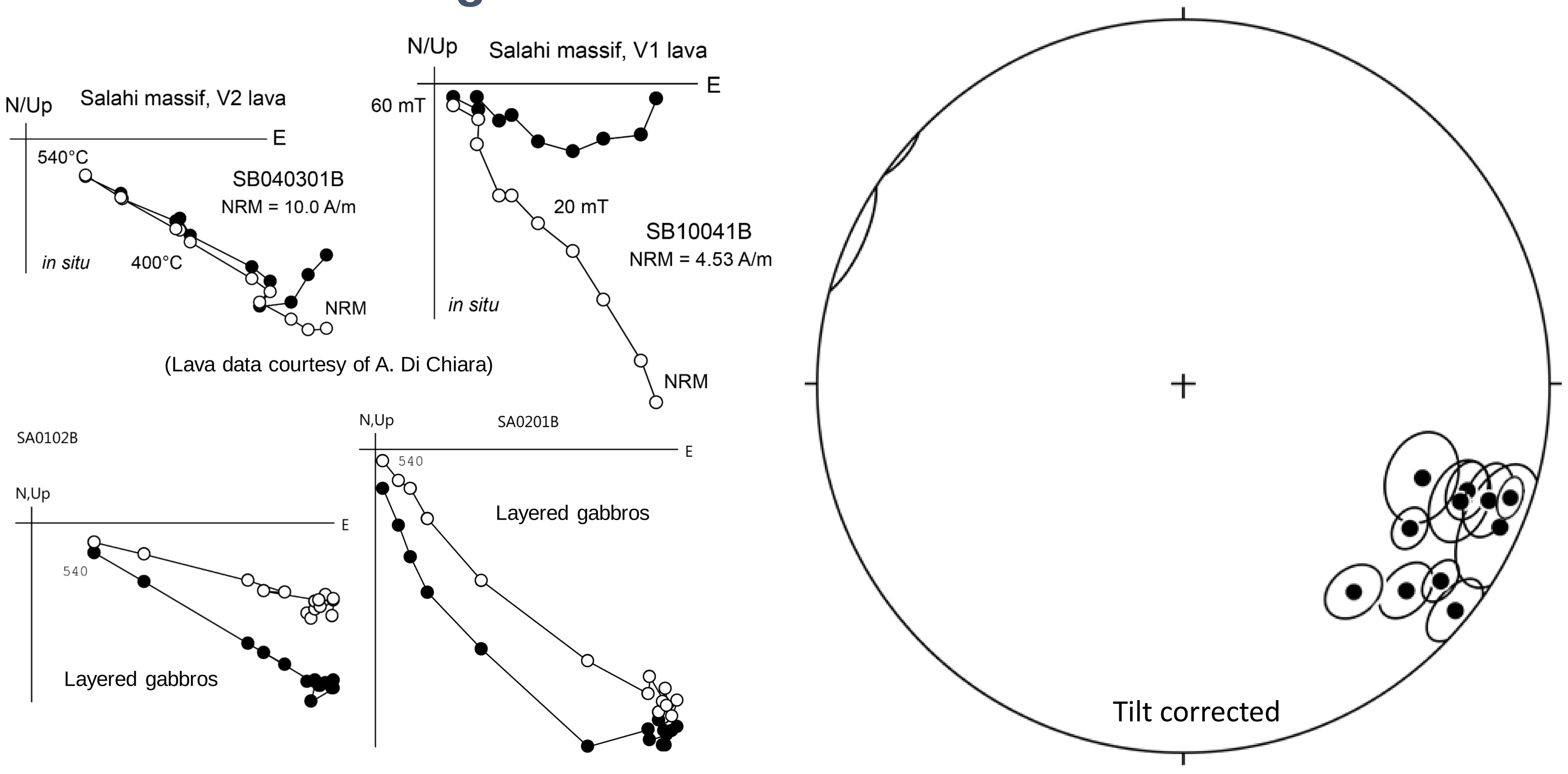


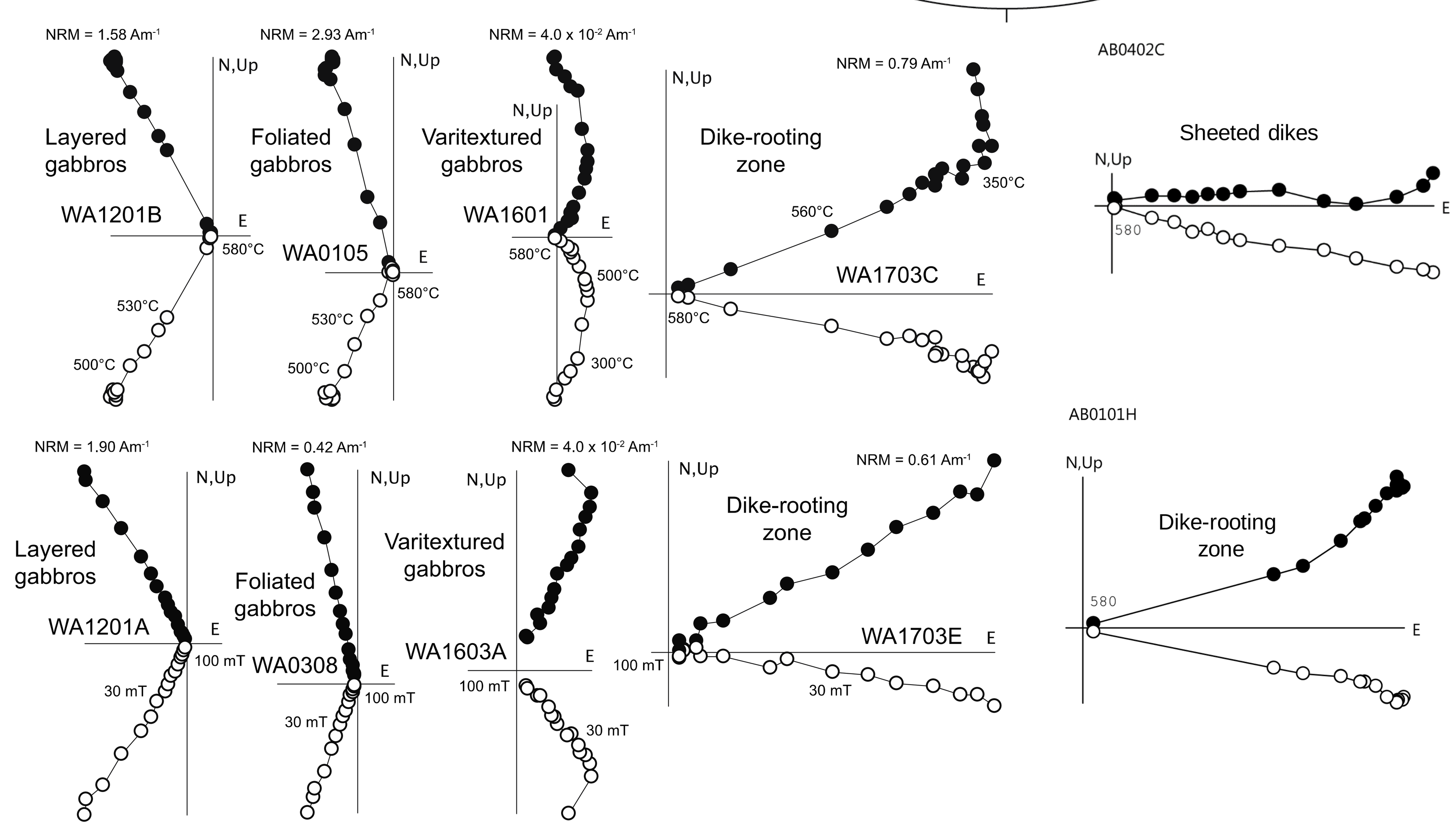
Figure 1. A: Simplified stratigraphic column and geological map of the Oman ophiolite, showing the sampled lithologies and locations (blue stars) of the Salahi massif, Wadi Abyad, and Wadi Gideah. The clock diagrams summarize paleomagnetic declinations obtained from previous studies. **B-D:** Paleomagnetic results from three studied locations. Equal area stereographic projections (tilt corrected) show site-mean magnetization directions and associated α_{95} cones of confidence. Examples of orthogonal Zijderveld plots of thermal and alternating field demagnetization data (tilt corrected). Solid/open circles represent the projection of the remanence vector onto the horizontal/vertical plane, respectively. NRM = natural remanent magnetization. **E:** Equal area stereographic projection of site-level *in situ* magnetic directions from the Samail, Wadi Tayin, Ibra, and Muscat massifs (layered gabbro and peridotites), as well as metabasites of the Saih Hatat continental window (Feinberg et al., 1999). Note that Permian basement metabasites, mantle peridotites and gabbros share a common NW direction of magnetization.



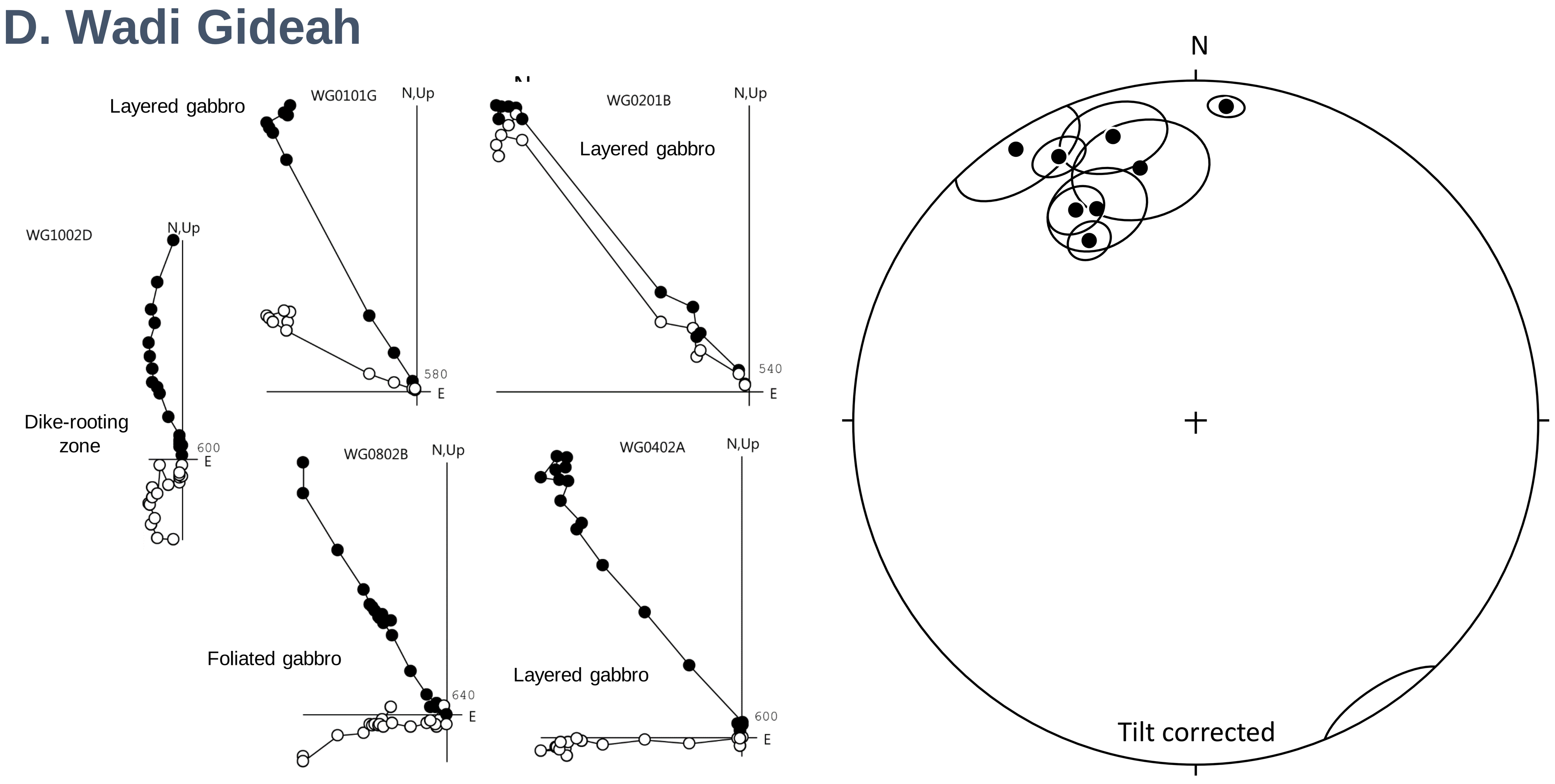
B. Salahi massif: gabbros and lavas



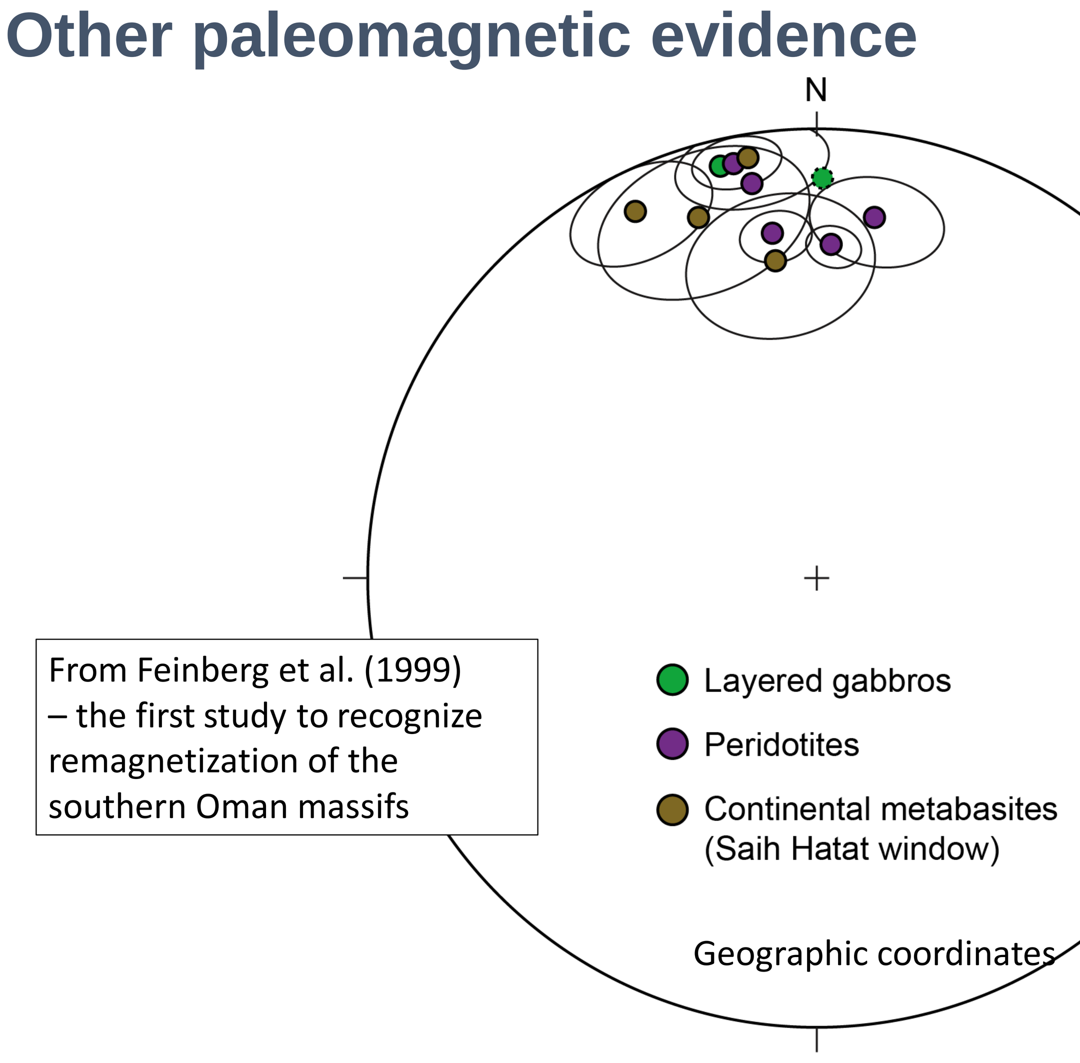
C. Wadi Abyad



D. Wadi Gideah



E. Other paleomagnetic evidence

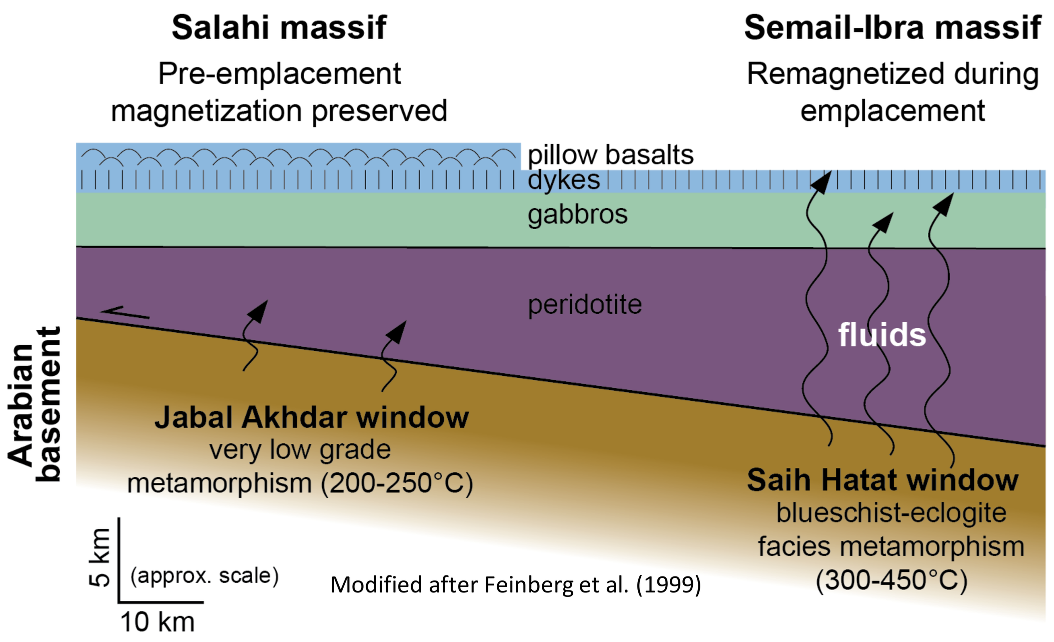


[a]School of Geography, Earth and Environmental Sciences, University of Plymouth, Drake Circus, Plymouth PL4 8AA, UK
[b]School of Earth and Ocean Sciences, Cardiff University, Park Place, Cardiff CF10 3AT, UK

@Magneterrae

louise.koornneef@plymouth.ac.uk

2. Remagnetization model:



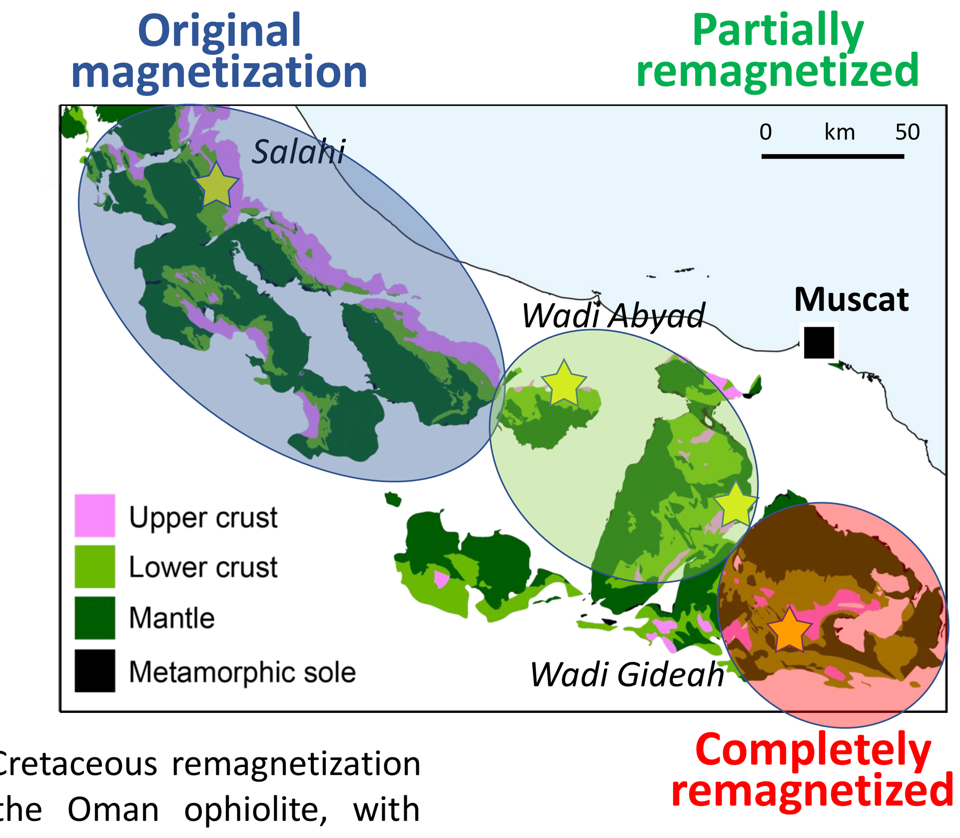


Figure 2. Current model for the Late Cretaceous remagnetization event in the southern massifs of the Oman ophiolite, with retention of original magnetizations in the northern massifs.

3. Origin of magnetization:

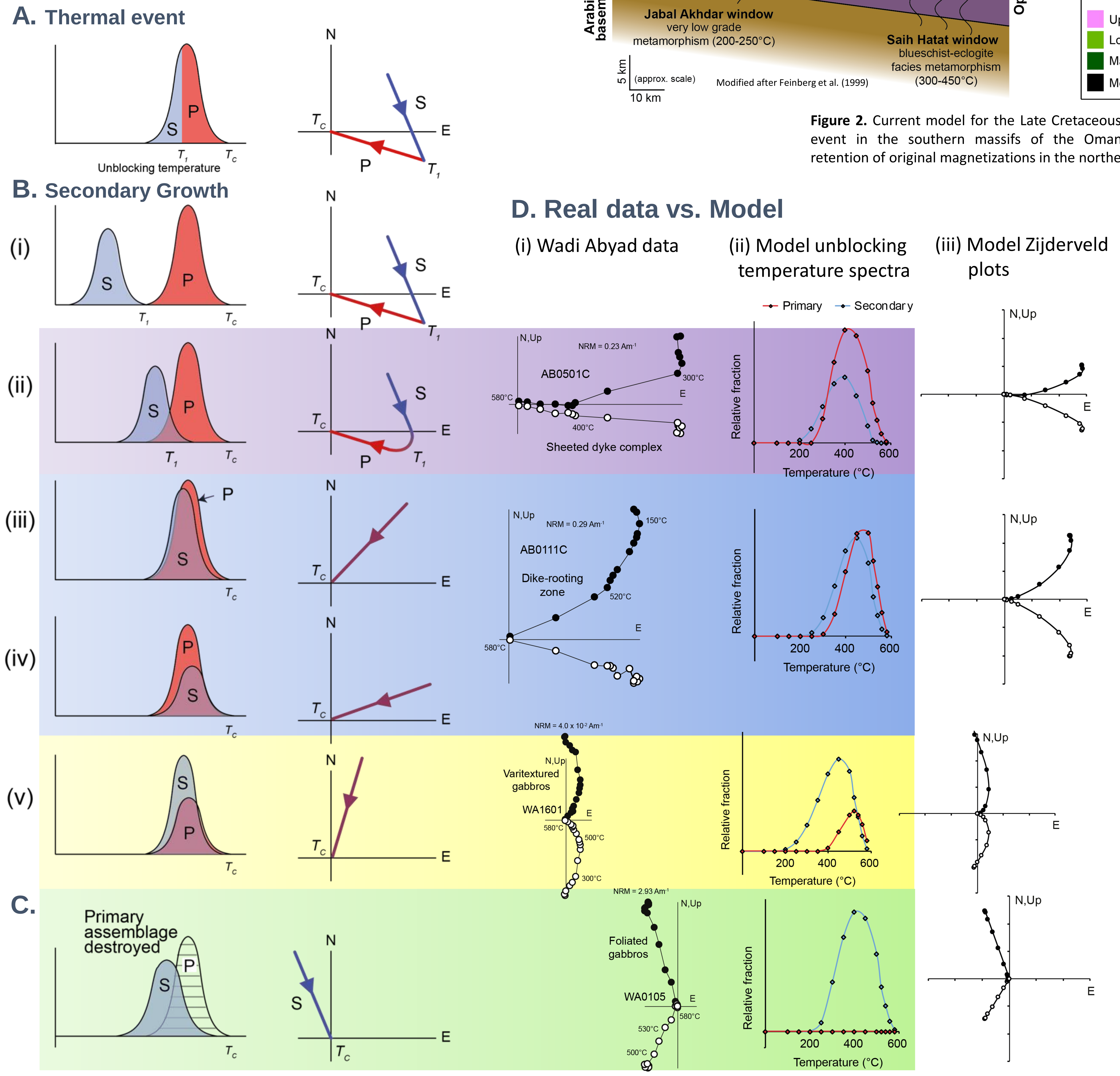


Figure 3. Schematic diagram showing various remagnetization scenarios and their resulting demagnetization paths, predicted for a NNW secondary component (S) and a ESE primary component (P):

A. A purely thermal event affecting a single primary population of ferromagnetic grains, resulting in acquisition of a pTRM overprint with maximum unblocking temperature T_1 and a sharp break point in the demagnetization path at this temperature.

B. Growth of a new assemblage of ferromagnetic grains carrying a secondary chemical remanent magnetization, whose unblocking temperature spectra may be distinct from that of the primary assemblage (i), partially overlap with it (ii), resulting in a curved demagnetization path over the temperature interval of overlap, or (nearly) completely overlap with that of the primary assemblage (iii-v), resulting in a linear demagnetization path with a direction determined by the relative intensity of the component.

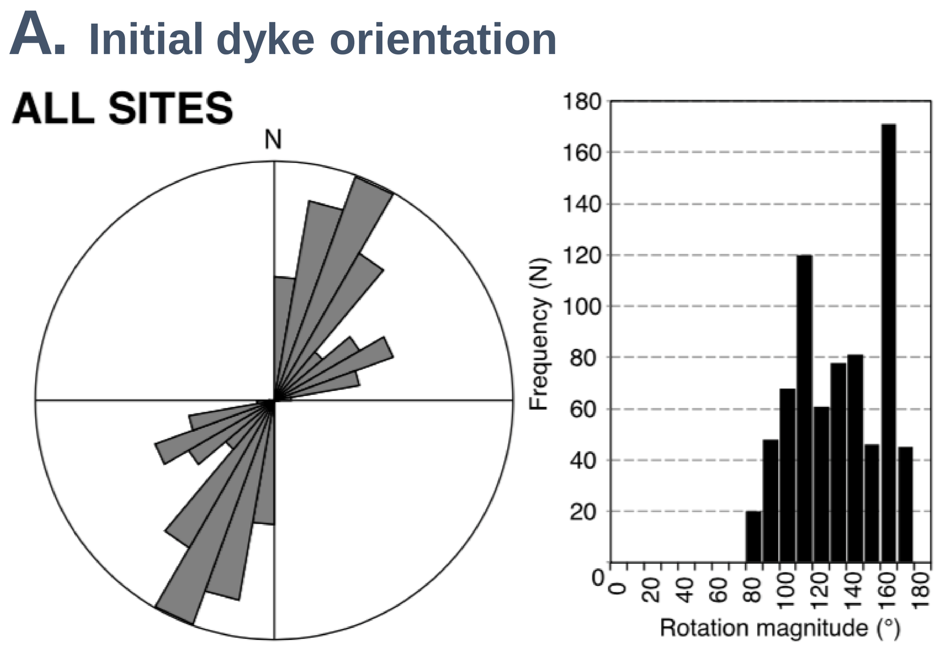
C. Alteration resulting in simultaneous growth of a new ferromagnetic grain assemblage (carrying a CRM) and destruction of the primary grain assemblage, erasing all traces of the original TRM.

D. Results of forward modelling of Zijderveld diagrams seen in Wadi Abyad, corresponding with the schematic diagrams in **B** and **C**. (i) Measured data from various lithologies in Wadi Abyad in stratigraphic order, from top to bottom Sheeted dyke complex, dyke-rooting zone, varitextured gabbros, foliated gabbros. (ii-iii) Model data replicating the measured demagnetization paths in (i) using the same primary and secondary components as in **A-C**. The modelled results show that the demagnetization paths may be explained by varying degrees of overlap of unblocking temperatures of the two components, with upward increase in the relative intensity of the primary component accounting for changes in net remanence characteristics.

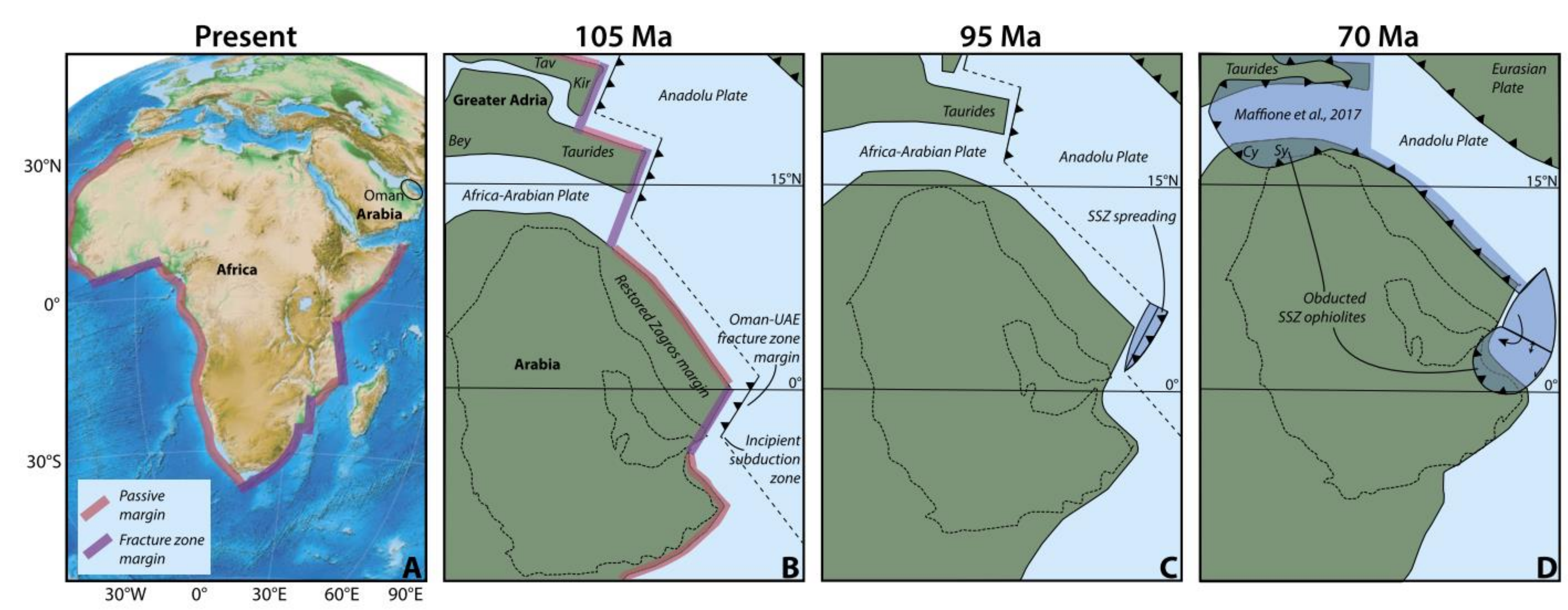
4. Net Tectonic Rotation analysis:

Figure 4. The restored NNE-SSW initial dyke strike of Wadi Abyad dykes after NTR analysis are consistent with a recent reconstruction of the ridge system reported by van Hinsbergen et al. (2019). They indicated:
A. NNE-SSW initial dyke strikes and associated rotation angles for all sites in the sheeted dyke complex across the unremagnetized northern massifs.
B. This resulted in a new tectonic model of subduction initiation along the Arabian margin of Oman.

A. Initial dyke orientation



B. Tectonic model



5.Conclusions:

- Remagnetization in the Oman ophiolite is inferred to result from orogenic fluids related to the emplacement of the ophiolite on to the Arabian continental margin
- Remagnetization happened from the base upwards, involving the acquisition of grain-growth CRM/TCRM that decreased in intensity up-section
- Net tectonic rotation analysis suggest 100-150° CW rotations around sub-vertical axes, restoring the initial dyke strikes to NNE-SSW

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