Evidence for widespread Remagnetizations in South America, case study of the Itararé Group rocks of Brazil

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Summary

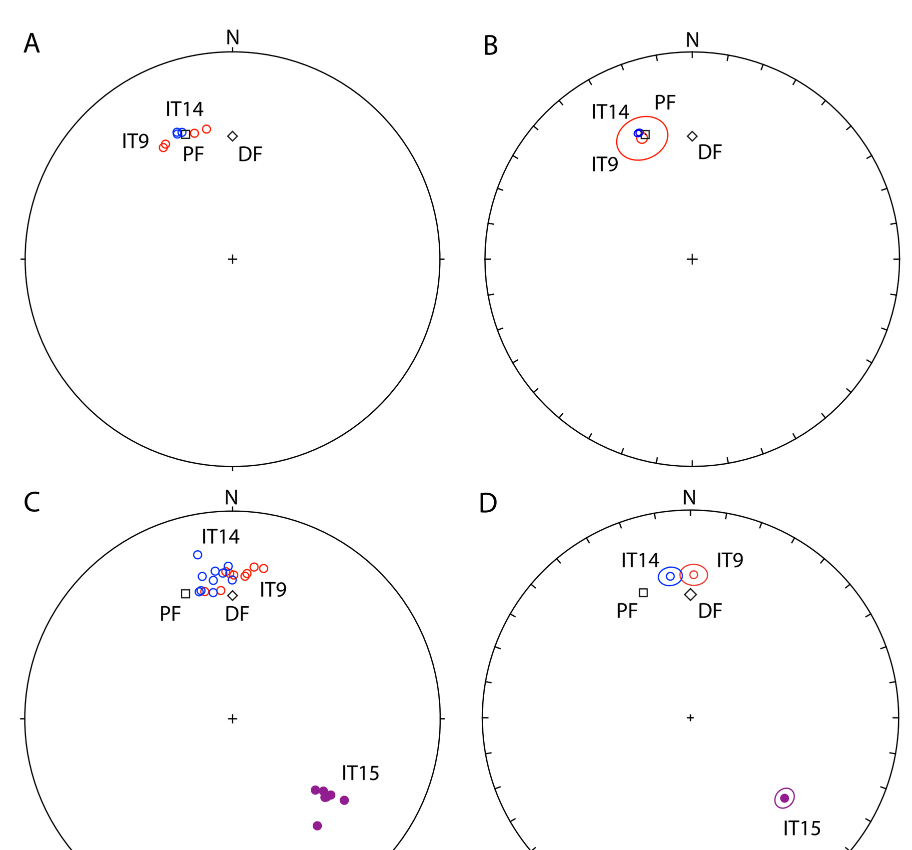
Paleomagnetism of South American Jurassic/Cretaceous rocks has been troubled by elongated distributions of poles which has led to contrasting interpretations. Moreover, many discordant paleomagnetic poles from the Carboniferous to the Triassic have also been recognized and systematically explained by a variety of processes, but this portion of the South American apparent polar wonder path (APWP) still remains problematic.

We have conducted a paleomagnetic study of the sedimentary Permo-Carboniferous Itararé Group rocks and three intruding mafic sills of likely Cretaceous age within the state of São Paulo, Brazil. The site-mean VGP distributions obtained from the sedimentary rocks define elongations that include the VGPs of the mafic intrusions. We interpret these distributions as remagnetization paths toward the directions characteristic of the sills. Careful analysis of the paleomagnetic data of the Itararé sedimentary rocks enables isolation of a primary VGP distribution that is consistent with the reference Carboniferous pole position.

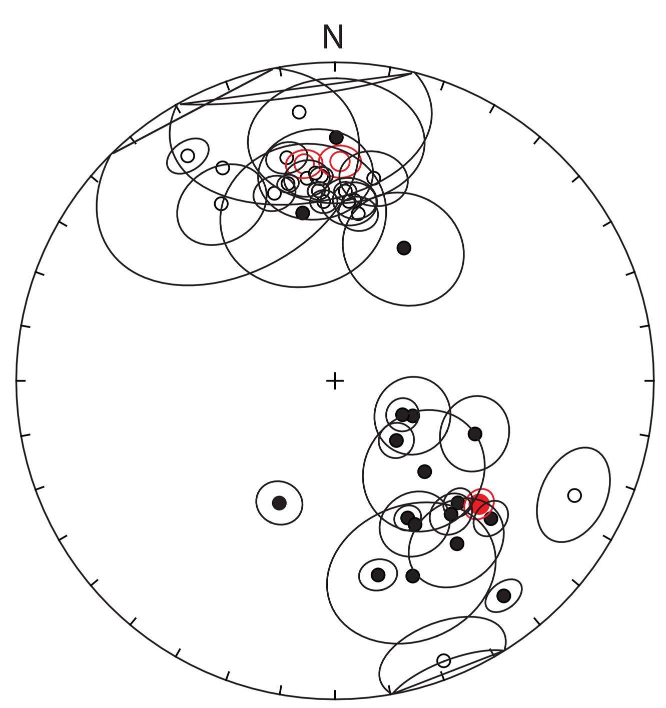
The paleomagnetic directions of the sills are partially overprinted by the present time-averaged and current Earth's magnetic field. Combined rock- and paleomagnetic data suggest that interacting SD grains carry a very recent magnetic overprint that is viscochemical in origin and cannot be fully erased. The dominant distribution of PSD-MD grains carries the high-temperature component, which is either a primary magnetization coincidentally close to the time averaged dipole field direction, or a secondary thermo-viscous magnetization.

Extending our study to other Carboniferous to Triassic South American paleomagnetic records reveals that the majority of these data are elongated, similarly to the Itararé Group rocks. Regardless of the age of the rocks, the elongations systematically intersect at the location of the Late Cretaceous reference pole, and at a long- recognized problematic location ("X") observed in certain Jurassic and Cretaceous rock formations.

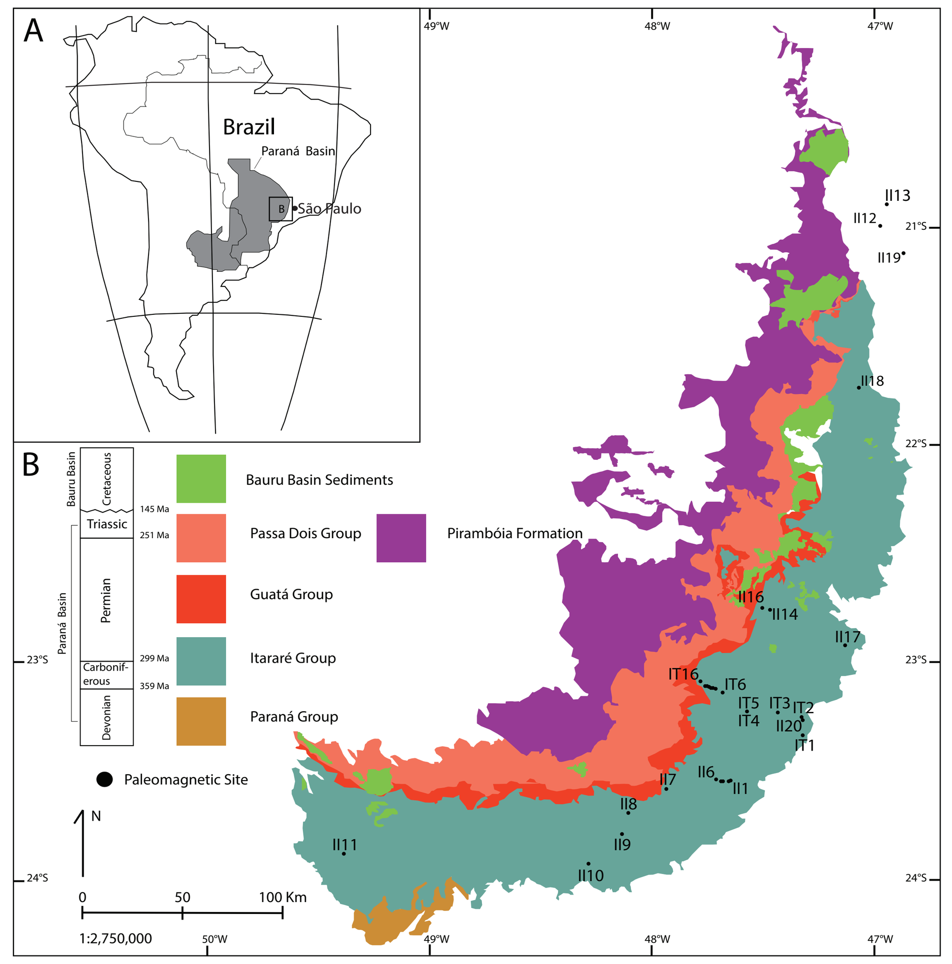
We interpret the elongated VGP distributions to reflect remagnetizations from the primary VGP positions toward Jurassic-Cretaceous and "X" pole locations, which occurred as a result of the widespread magmatic events associated with the opening of the South Atlantic. The extent of the remagnetizations is formation-specific and other rock-formations should be carefully re-evaluated.



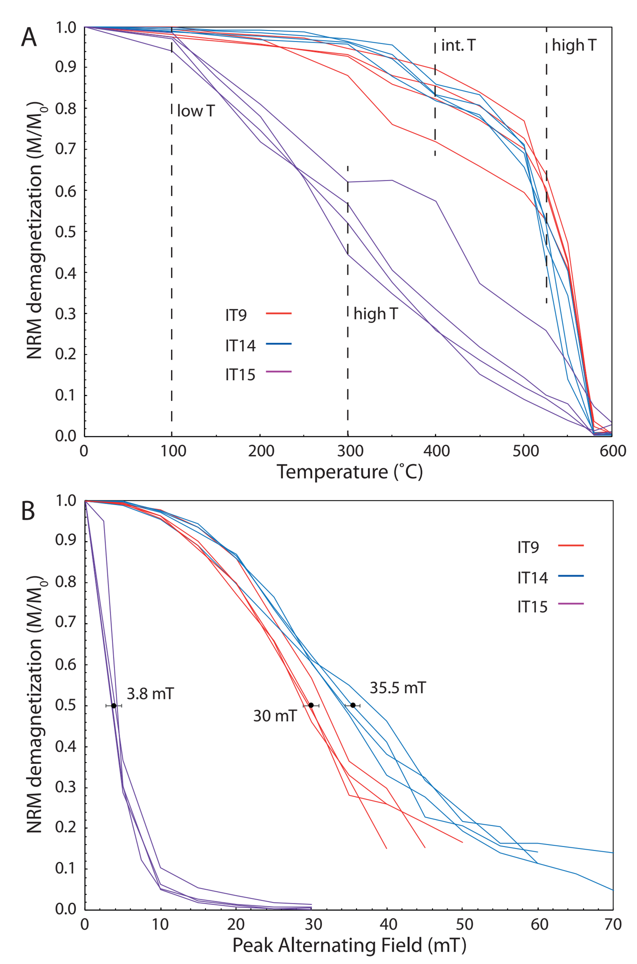
Directions isolated from the mafic sills: (A) intermediate temperature component directions isolated from sills at IT9 (red) and IT14 (blue), the present-day field direction (PF) and the time-averaged dipole field (DF) ; (B) site-mean directions for the intermediate temperature-component; C) high-temperature component directions, site IT15 (purple); (D) site-mean directions for the high temperature-component magnetizations.



Site-mean directions of the Itararé Group rocks plotted on a stereonet: solid (open) symbols are projections on the lower (upper) hemisphere; black and red symbols are for sedimentary and igneous rocks, respectively. Note the clustering of sedimentary rock-derived directions around those derived from the igneous rocks.



Study area: (A) location of the study area within the Paraná Basin; (B) Site locations and outcropping geological formations within the state of Sao Paulo, Brazil. 23 sedimentary sites of subglacial deposits (primarily diamictites, channel sands and siltstones, claystones, rhythmites, red beds) and 3 intruding Cretaceous mafic sills were collected.



(A) Thermal demagnetization of the NRM of the mafic sills, specimens from IT9, IT14, and IT15 are the red, blue and purple curves, respectively; vertical dashed lines indicate the temperature ranges at which the intermediate and high temperature components were isolated; (B) AF demagnetization of the mafic sills; the mean median destructive fields are reported with 1 standard deviation error bars.

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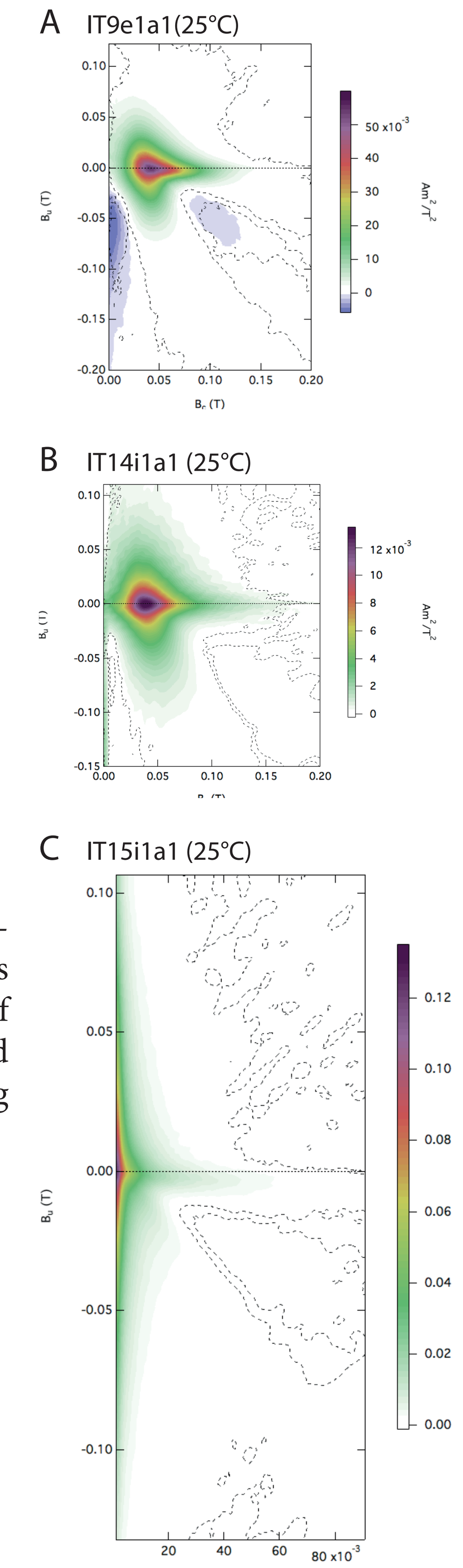
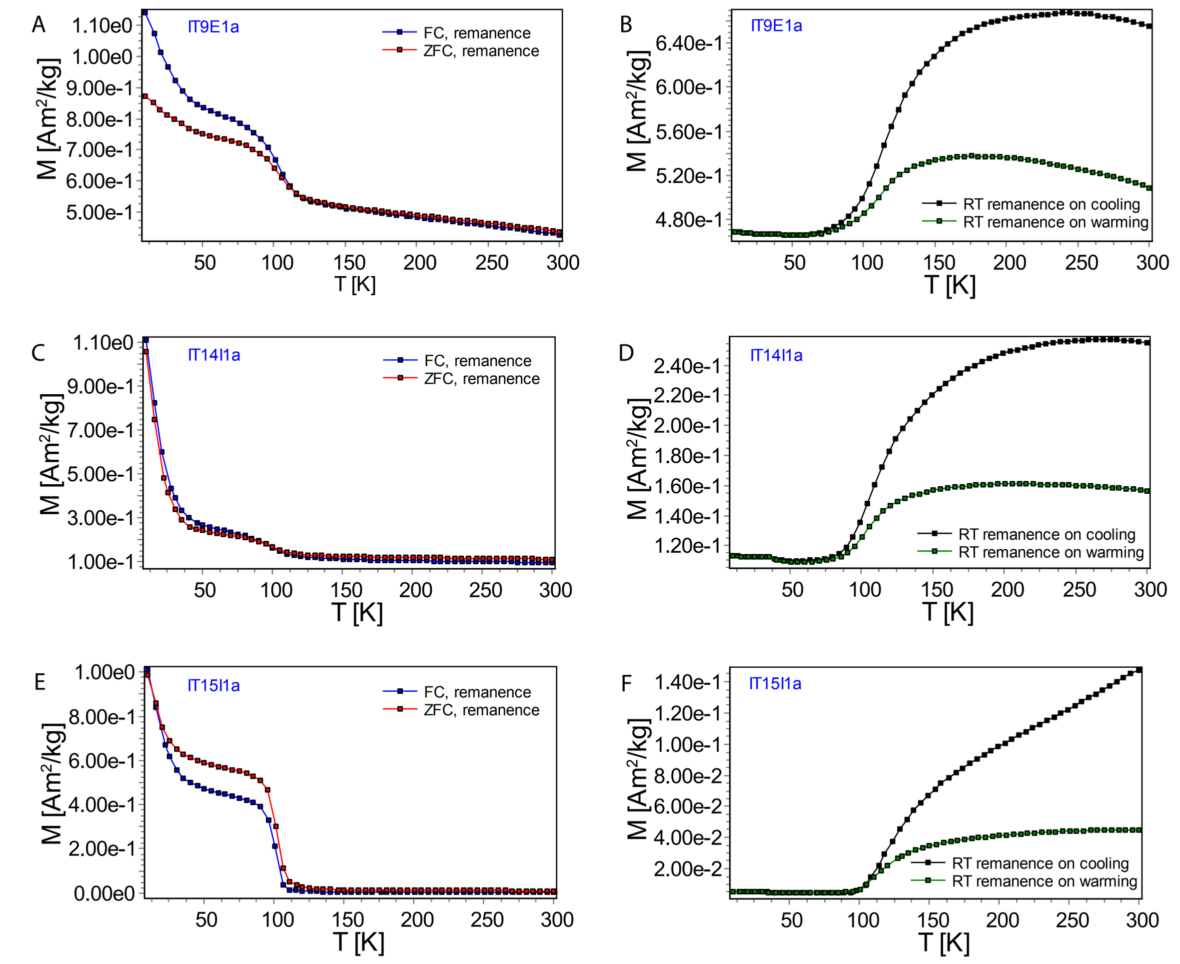
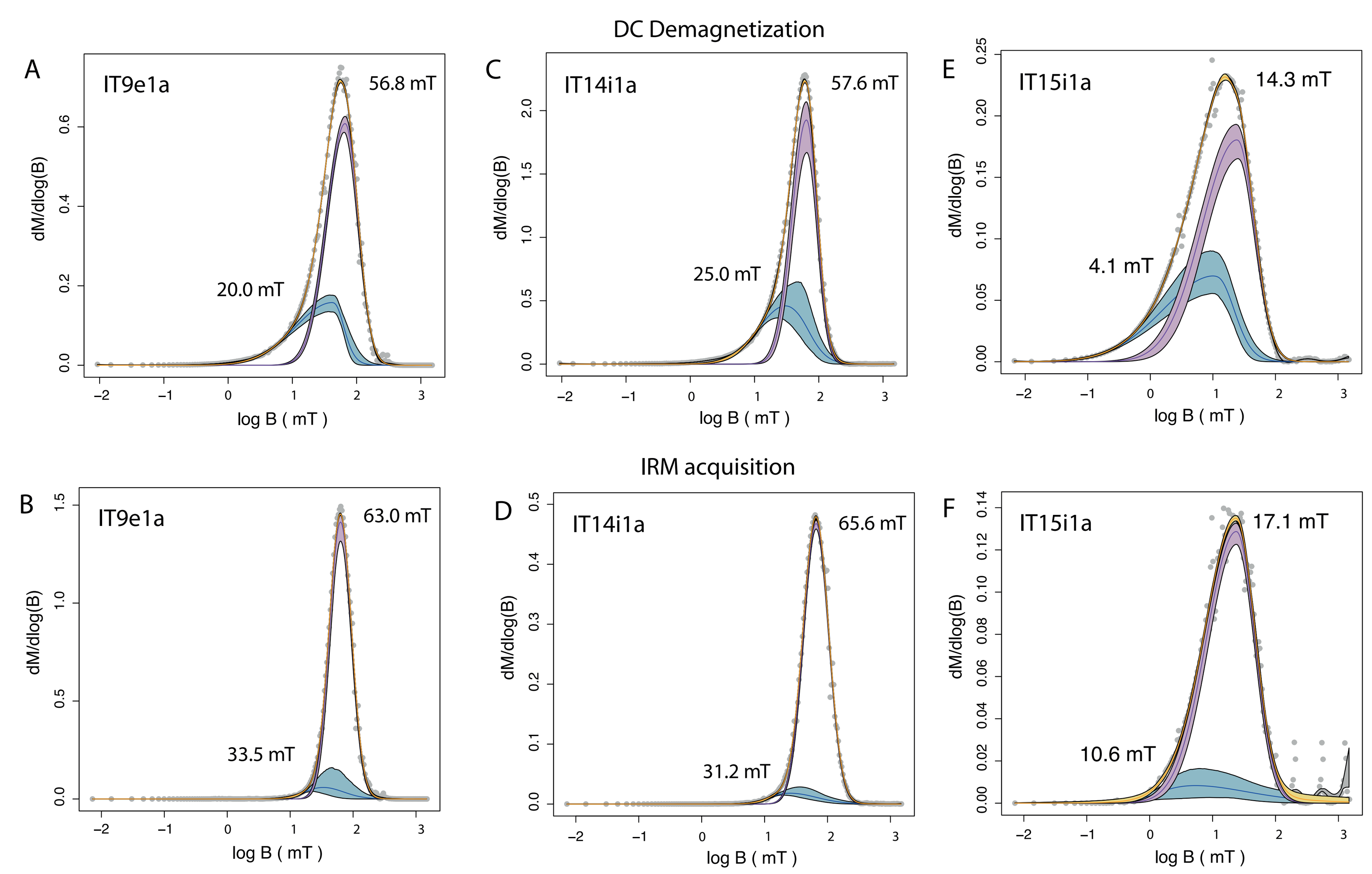


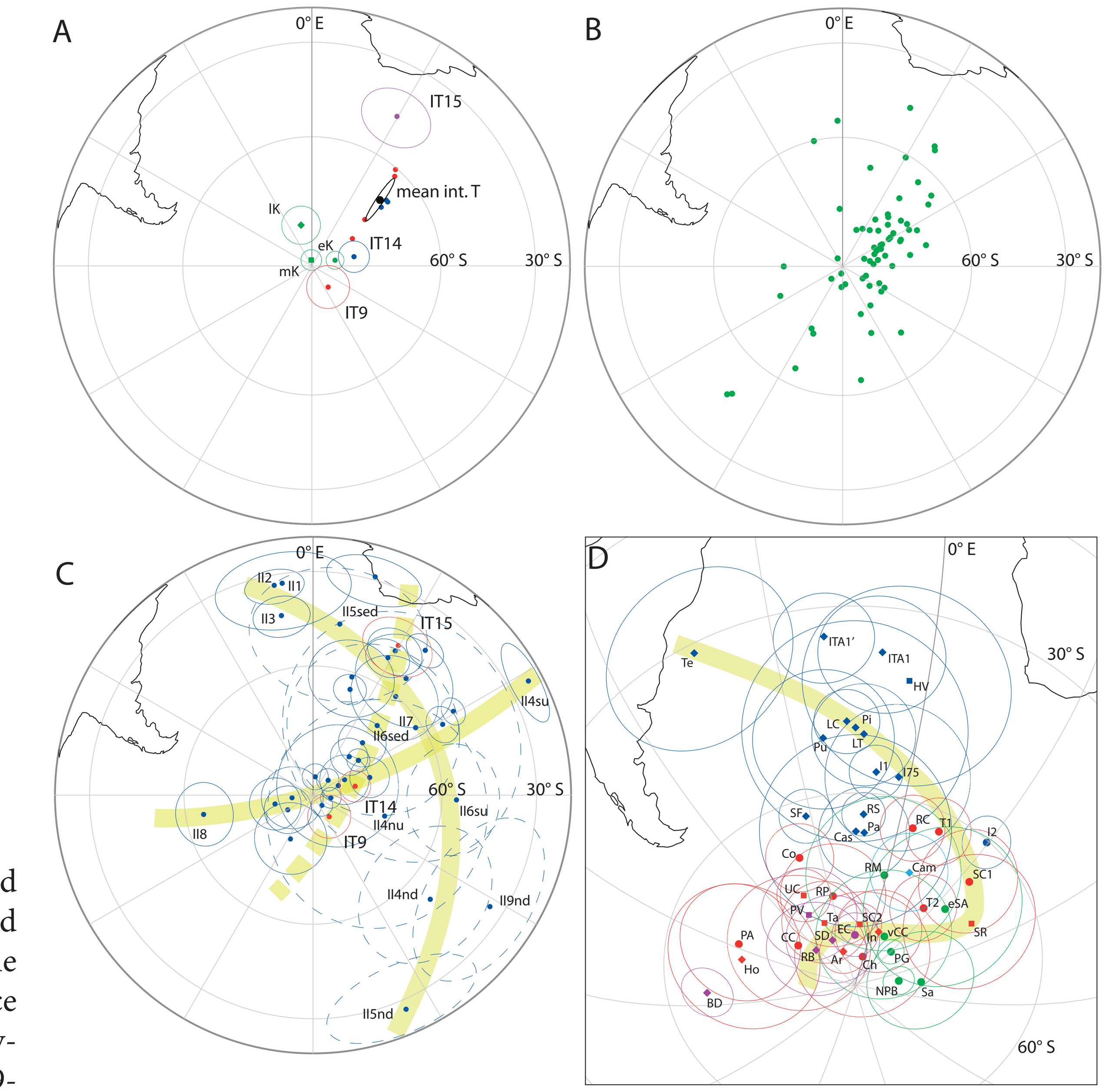
First Order Reversal Curves diagrams: A and B) room temperature diagram for a specimen from the sill at IT9 showing interacting SD distributions (a similar distribution is obtained at 400° C, where the int. component is isolated); C) room temperature FORC for a specimen from IT15, showing a dominant MD distribution with underlying high coercivity "tail".



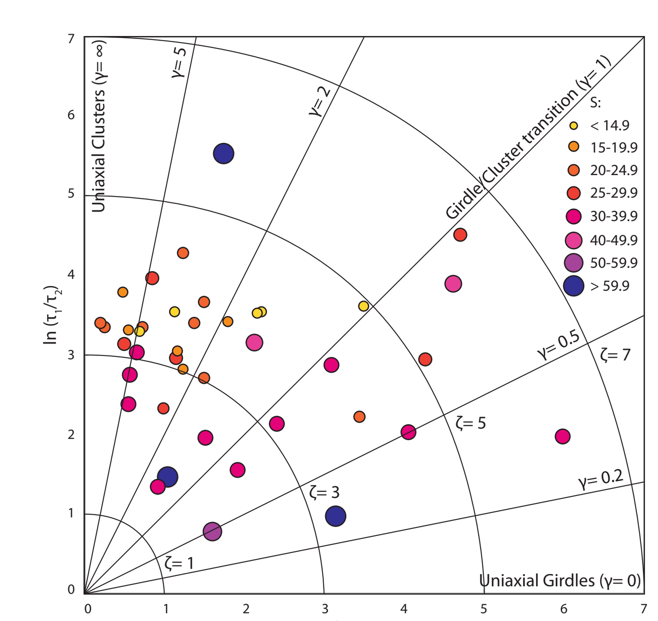
Low temperature magnetic measurements: A, C, E) Field coold (FC)- Zero field cooled (ZFC) remanent curves for specimens of mafic sills at IT9, IT14 and IT15; B, D, F) cooling and warming of a room temperature SIRM for the same specimens. All curves indicate large magnetite grains as dominant remanence carriers, with grain size increasing progressively from IT9 to IT15. Non recovery of the RTSIRM upon T-cycling suggest grain sizes of at least 100 nm (IT9-14) and up to 200 nm (IT15).



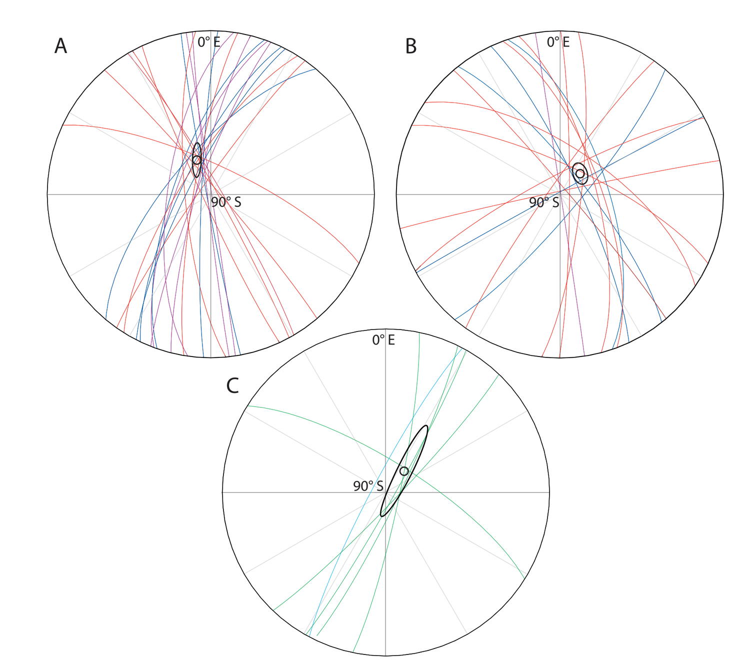
Unmixing of backfield DC demagnetization and IRM acquisition: (A, B) specimen from sill at IT9; (C, D) specimen from sill at IT14; (E, F) specimen from sill at IT15. Note how the coercivity distributions are systematically revealed at lower fields during demagnetization than acquisition, typical of both MD and interacting SD grains. These data, compared to the demagnetization, Zijdervelt diagrams (not shown) and low-T data, imply that the bulk of the paleomagnetic remanence is carried by the MD grain population.



Virtual Geomagnetic Poles (VGPs): (A) VGPs calculated from the high temperature component magnetizations isolated from the mafic sills, and from the mean low temperature component from IT9 and IT14 (indistinguishable from the present field); Reference early, mid- and late Cretaceous paleopoles are in green; (B) Published VGPs from other mafic intrusions and lava flows collected in the same study area; (C) VGPs derived from the sedimentary rocks of the Itararé Group (blue) and from the mafic sills (red). Dashed A_{95}'s indicate VGPs with higher scatter ($A_{95} > 15°$; $k < 10$). Highlighted are the approximate trends of the distributions of VGPs. Dashed-highlight is for the VGPs that follow the distribution of the igneous rocks in (B); (D) Paleopoles from Carboniferous, Permian, Triassic, Jurassic, and Cretaceous South American rock formations (blue, red, purple, light blue and green, respectively). For each geologic period, the circles, squares and diamonds are for early, mid- and late, respectively. Highlighted in yellow is the problematic loop in the classic APWP.



Woodcock (1977) diagram. Shape and strength of the VGP distributions plotted as ln (1/3) vs. ln (2/3), as a function of VGP scatter S. Note how girdled distributions have higher S, as do "stronger" and "weaker" VGP distributions. Likewise, too high clustering could also be considered an artifact of coercive remagnetizations.



Great circle analysis of VGP elongations. In black are the intersections of great circles and bootstrap 95% confidence ellipses. (A) "Late Cretaceous" distribution of Carboniferous through Triassic data; (B) "X" distribution of Carboniferous through Triassic data; (C) "Jurassic-Cretaceous" problematic data distribution of South American igneous rocks, in agreement with (B) which suggests a common remagnetization event.