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Editorial

Thematic issue: Crustal and mantle sources of magnetic anomalies

This thematic issue on “Crustal and mantle sources of magnetic anomalies” originated from the topical session on the same subject at the American Geophysical Union Meeting of Fall 2012 in San Francisco. A brief review of the state of our knowledge on lithospheric sources introduces this thematic issue. The nine contributions in this volume represent recent advances in our understanding of lithospheric magnetic sources and follow three research streams: mantle sources, crustal sources and methods. This editorial concludes with an overview of the importance that the European Space Agency Swarm magnetic satellite mission is anticipated to have for future research on magnetic anomalies.

In 1998, Langel and Hinze considered that the subdiscipline of satellite geomagnetism had reached a plateau in its advancement, with limited new developments. Stimulated by the prospect of the Swarm mission, burgeoning new ideas and methodological advances prelude the revival of satellite geomagnetism. After all, magnetic anomalies constitute one of the primary sources of information for deep lithospheric architecture, both in oceanic and continental domains. The Curie depth, for example, is used to evaluate the thermal state of the crust. While the origin of long wavelength magnetic anomalies has long been debated, magnetizations measured in lower crust rocks appear too weak to account for some of the observed magnetic anomalies. This “missing magnetization” inspired a sustained quest for strongly magnetized lower crust rocks. For others, however, magnetizations measured from rocks are compatible with magnetization computed from magnetic anomalies. The long held paradigm that mantle rocks are too weakly magnetic and too hot to contribute to long wavelength magnetic anomalies (e.g., Wasilewski et al., 1979) no longer seems to apply universally. Indeed, regions of cold, strongly magnetic upper mantle may contribute to magnetic anomalies in oceanic basins, fore arc and cratonic settings.

1. Mantle sources

Ferré et al. present a review of evidence supporting contributions of the uppermost mantle to magnetic anomalies, ranging from modeling of anomalies to experimental petrology. Exceptionally unaltered mantle xenolith collections representing magnetic assemblages present at mantle depth provide key information supporting these new views.

Friedman et al. analyze fresh mantle xenoliths from the Western United States, both on-craton and off-craton. The paleomagnetic results support the inference that the magnetic assemblages formed at mantle depth, although current remanent magnetization was acquired at the earth's surface. The cratonic mantle of the Bearpaw Mountains has been serpentinized at mantle depth and displays induced and remanent magnetizations at least an order of magnitude larger than the off-craton mantle. The authors conclude that, far away from plate boundaries, metasomatic processes can deeply affect the magnetic contribution of the upper mantle to magnetic anomalies.

Martin-Hernandez et al. address the issue of the significance of natural remanent magnetization in mantle xenoliths for the cases of multiple components and single components. Their contribution further examines which component of the remanence would be present at mantle depths. The authors conclude that the contribution of pyrrhotite to natural remanent magnetization would disappear at mantle conditions.

2. Crustal sources

Blakely et al. investigate part of the Cascadia backarc from a gravity and magnetic viewpoint. The detailed analysis of crustal aeromagnetic anomalies provides important constraints on the architecture of this tectonically complex assemblage at depth.

Clark reviews the effects of hydrothermal alteration on magnetic properties and magnetic anomaly signatures within economically important mineralized systems. The author describes the use of magnetic anomalies as a predictive exploration tool for porphyry copper and iron oxide copper–gold deposits. This study also emphasizes the importance of identifying signatures that are appropriate to the local geological setting, rather than simply searching for look-alike signatures, because anomalies ultimately depend on tectonic setting, magma type, composition of host rocks, and many other factors.

Brown et al. analyze the magnetic properties of lower crustal rocks assumed to be responsible for long wavelength magnetic anomalies of $+/-20$ nT in northern Saskatchewan. These 2.6–1.8 Ga terrains, consisting of tonalites, mafic granulites, and granite, intruded by a dike swarm at ~1.9 Ga, display widely ranging magnetic susceptibility and magnetic remanence, carried primarily by magnetite. The majority of specimens have Koenigsberger ratios lower than 1, which limits the contribution of remanence to the observed magnetic anomalies.

3. Methods

Salem et al. focus on the central Red Sea rift, an embryonic ocean characterized by high heat flow. Their study uses the “de-fractal spectral depth method” to estimate top and bottom boundaries of the magnetized layer. The results indicate variable magnetic bottom depths from $\approx$8 to 19 km, closely corresponding to the Moho in the rift area, but shallower than the Moho outside the rift.

Hamza et al. use spectral analysis of data from twelve aeromagnetic surveys of central Brazil to evaluate the magnetic characteristics of the

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lithosphere in this region. Centroid-based spectral magnetic methods are used for the first time in conjunction with the matched filtering spectral modeling method to obtain better source depths. The depth to the bottom of magnetized crust varies from 30 to 40 km, which in the São Francisco craton is greater than the crustal thickness. This means that the uppermost mantle may be ferromagnetic.

4. Swarm

The launch of the three satellite mission SWARM in November 2013 constitutes a major event for the geomagnetic community. It follows high-quality missions such as Magsat, POGO, Oersted and CHAMP, but promises higher resolution by removing the external field and observing magnetic gradients. These characteristics should enable Swarm to investigate how common serpentinized slab remnants and serpentinized fore arc mantle wedges are in subduction settings.

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