Notes on Interpretation of Geophysical Data Over Areas of Mineralization in Afghanistan

By Benjamin J. Drenth

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Introduction

Afghanistan has the potential to contain substantial metallic mineral resources. Although valuable mineral deposits have been identified, much of the country's potential remains unknown. Geophysical surveys, particularly those conducted from airborne platforms, are a well-accepted and cost-effective method for obtaining information on the geological setting of a given area. This report summarizes interpretive findings from various geophysical surveys over selected mineral targets in Afghanistan (fig. 1), highlighting what existing data tell us. These interpretations are mainly qualitative in nature, due to the low resolution of available geophysical data.

Geophysical data and simple interpretations for six different areas and deposit types are noted below:

Aynak: Sedimentary-hosted copper

Zarkashan: Porphyry copper

Kundalan: Porphyry copper

Dusar Shaida: Volcanic-hosted massive sulphide (VMS)

Khanneshin: Carbonatite-hosted rare earth element

Chagai Hills: Porphyry copper

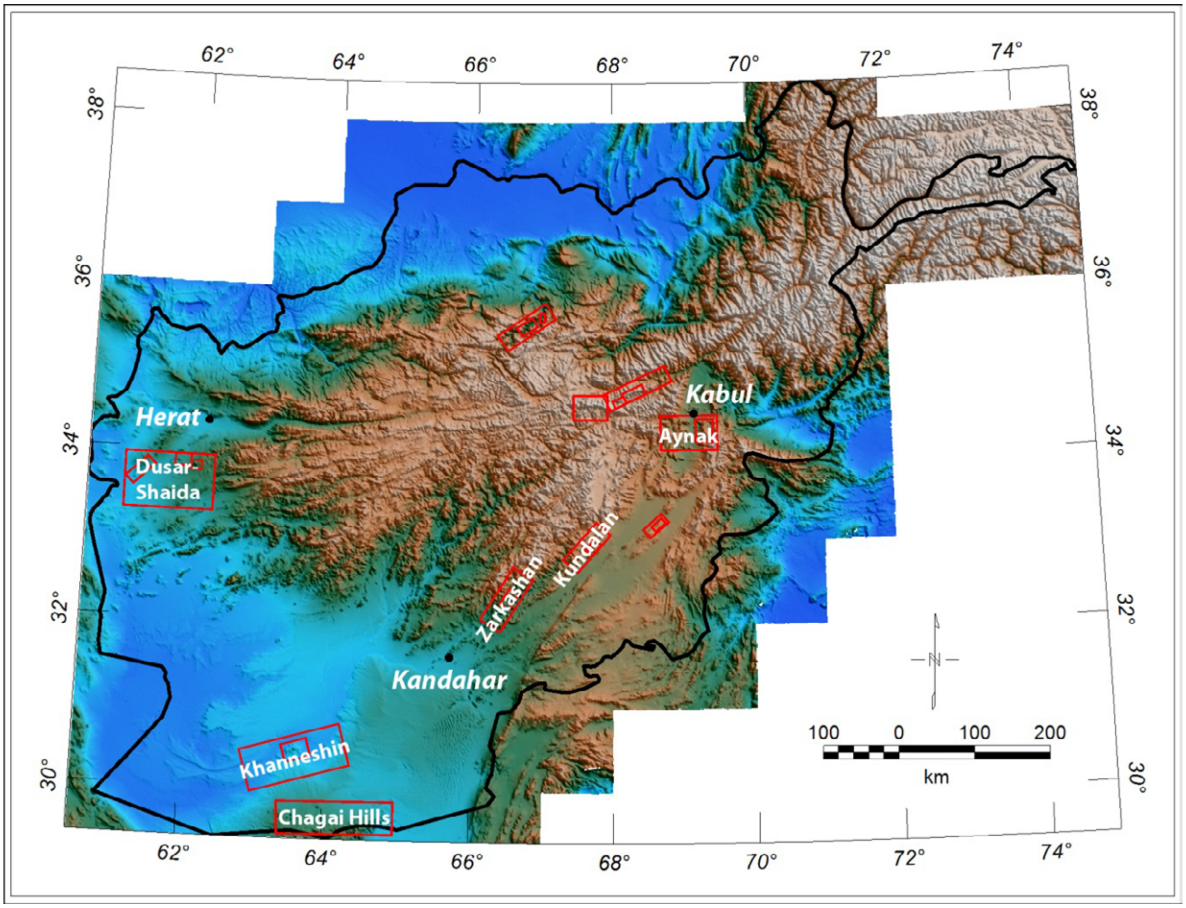

Figure 1. Map of Afghanistan, with areas of interest for mineral exploration outlined in red. Areas covered by geophysical data and discussed in this report are labeled.

Aynak

Existing Data

The only existing aeromagnetic data (fig. 2) available for the Aynak region are those acquired in 2006 and 2008 by the U.S. Geological Survey (USGS) and the Naval Research Laboratory (NRL) (Ashan and others, 2007; Shenwary and others, 2011). Lines were spaced 4 kilometers (km) apart and were flown at an undesirable height of 5 km or more above the ground. Gravity data were also collected but are thought to have little bearing on geology related to mineralization.

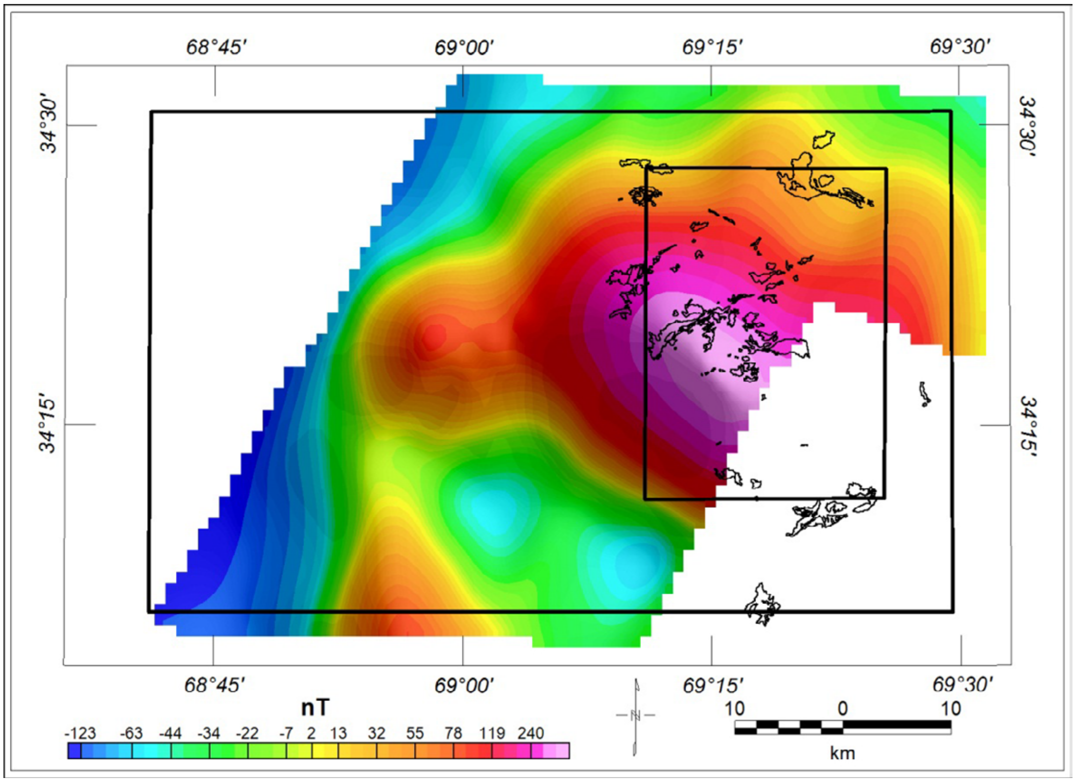

Figure 2. Reduced-to-pole aeromagnetic anomalies over the Aynak region. Black rectangles indicate areas of interest for mineral exploration (inner rectangle is area of greatest interest). Outcropping amphibolites of the Welayati Formation (Bohannon, 2010) shown as irregular polygons.

Interpretation

A broad aeromagnetic high is observed over the Aynak region. Several units that are potentially strongly magnetized, including plutons, crop out in the region (Doebrich and others, 2006; Bohannon, 2010). However, the outcrop pattern of amphibolites of the Neoproterozoic Welayati Formation (Bohannon, 2010) have the greatest spatial correlation with the aeromagnetic high (fig. 2), suggesting that similar or related rocks may be present at depth with a significant volume. Results of ground magnetic surveys in the 1970s by Soviet Union geoscientists suggest that these amphibolites are among the most strongly magnetized rocks in the region (Kleimenev and others, 1974). The Welayati Formation is significant as one of the major stratigraphic units in the area of copper mineralization. The low resolution of the existing aeromagnetic data prevents any detailed mapping of structures and calculation of meaningful depths to magnetic sources.

Zarkashan

Existing Data

The only existing aeromagnetic data (fig. 3) available for the Zarkashan region are those acquired in 2006 and 2008 by the USGS and NRL (Ashan and others, 2007; Shenwary and others, 2011). Lines spaced 4 km apart were flown at an undesirable height of 5 km or more above the ground. Gravity data were also collected but are thought to have little bearing on geology related to mineralization.

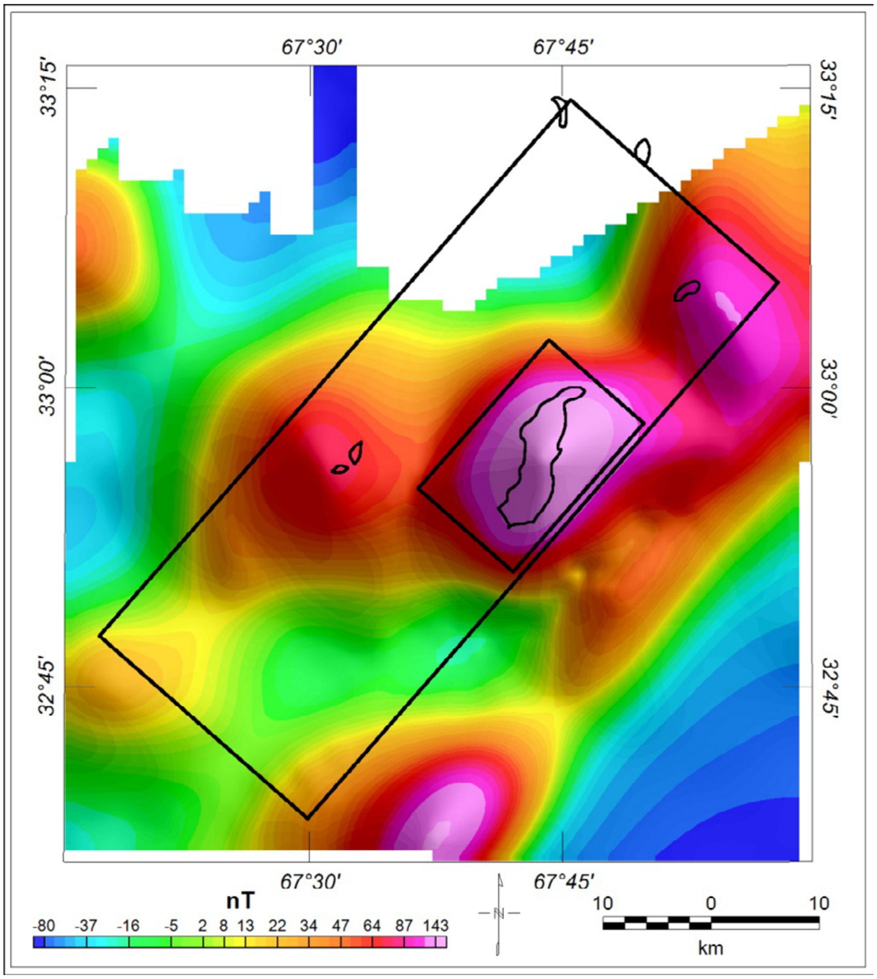

Figure 3. Reduced-to-pole aeromagnetic anomalies over the Zarkashan region. Black rectangles indicate areas of interest for mineral exploration (inner rectangle is area of greatest interest). Outcropping intrusions related to mineralization (Doebrich and others, 2006; Peters and others, 2007) shown as irregular polygons.

Interpretation

Aeromagnetic highs are spatially correlated with outcropping plutons related to porphyry-style mineralization. Soviet Union geoscientists have reported that ground magnetic surveys were useful in detailed mapping of veins, skarns, and other structures (Kleimenev and others, 1974). The low resolution of the existing aeromagnetic data prevents any detailed mapping of structures and calculation of meaningful depths to magnetic sources. However, the horizontal gradient magnitude transformation (Cordell and Grauch, 1985; Grauch and Cordell, 1987; Grauch and others, 2001) of the aeromagnetic anomalies is useful for mapping geologic contacts and faults. Here, the method is helpful for mapping the approximate boundaries of the largest plutons (fig. 4). In this map, ridges of relatively high values indicate locations of magnetization contrasts that represent pluton boundaries.

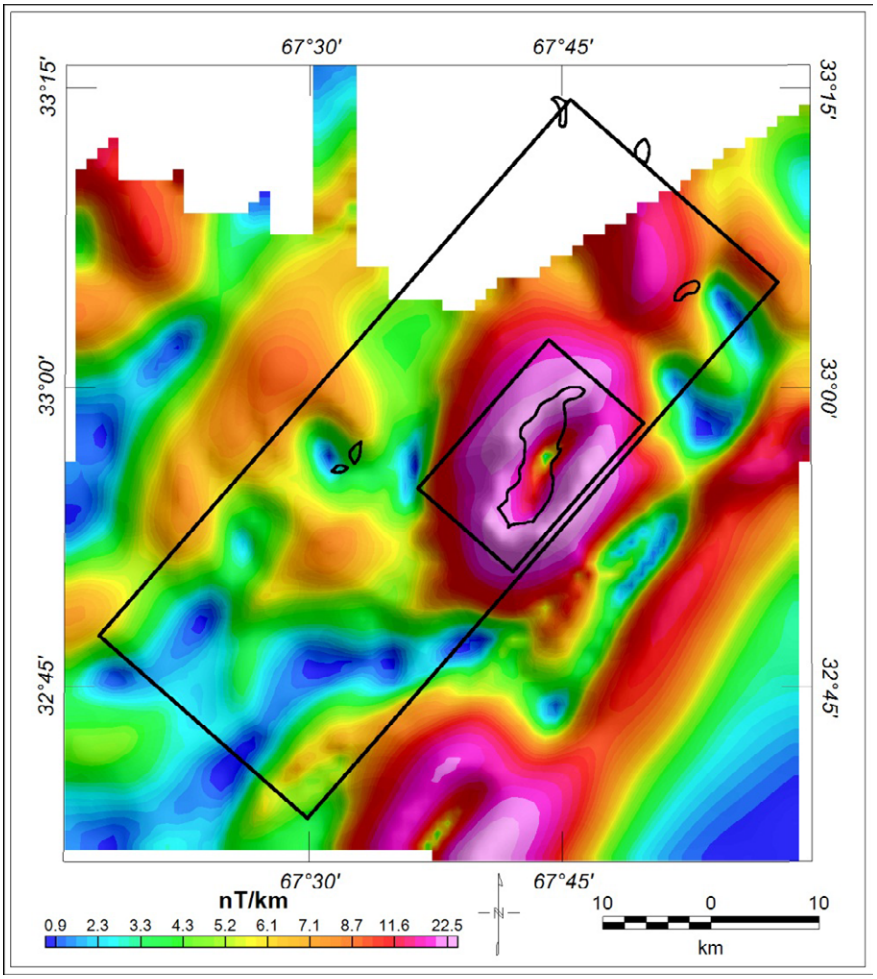

Figure 4. Horizontal gradient magnitude transformation of reduced-to-pole aeromagnetic anomalies over the Zarkashan region. Black rectangles indicate areas of interest for mineral exploration (inner rectangle is area of greatest interest). Outcropping intrusions related to mineralization (Doebrich and others, 2006; Peters and others, 2007) shown as irregular polygons.

Kundalan

Existing Data

The only existing aeromagnetic data (fig. 5) available for the Aynak region are those acquired in 2006 and 2008 by the USGS and NRL (Ashan and others, 2007; Shenwary and others, 2011). Lines were spaced 4 km apart and were flown at an undesirable height of 5 km or more above the ground. Gravity data were also collected but are thought to have little bearing on geology related to mineralization.

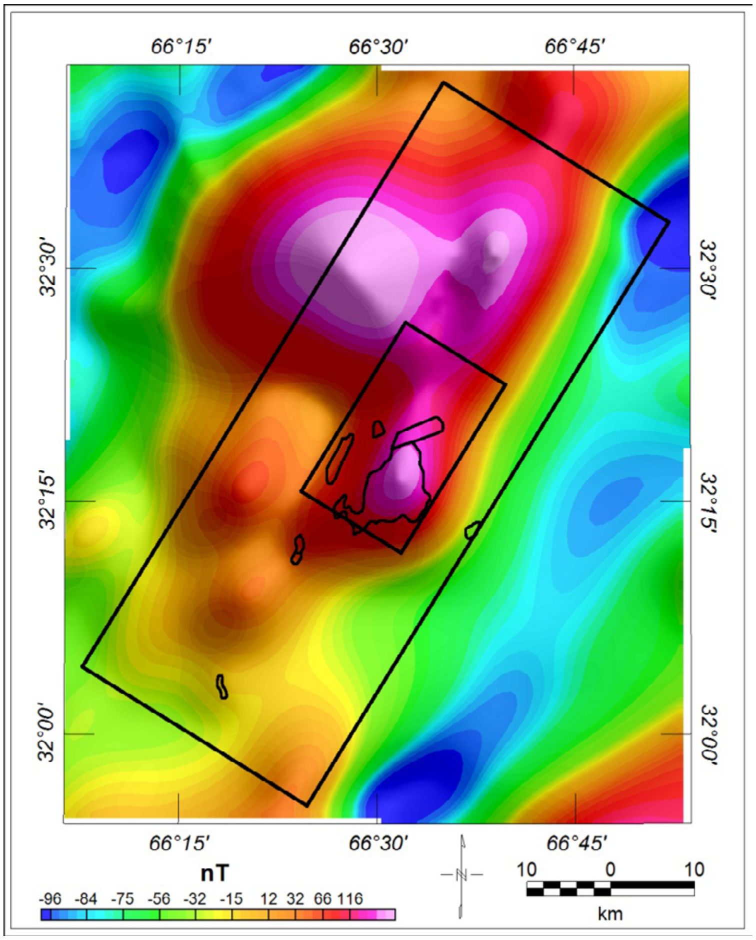

Figure 5. Reduced-to-pole aeromagnetic anomalies over the Kundalan region. Black rectangles indicate areas of interest for mineral exploration (inner rectangle is area of greatest interest). Outcropping intrusions potentially related to mineralization (Doebrich and others, 2006; Peters and others, 2007) shown as irregular polygons.

Interpretation

Aeromagnetic highs are spatially correlated with outcropping plutons related to porphyry-style mineralization. Soviet Union geoscientists have reported that ground magnetic surveys were useful in detailed mapping of veins, skarns, and other structures in the Zarkashan area (Kleimenev and others, 1974), which is geologically analogous to the Kundalan region (Peters and others, 2007). The low resolution of the existing aeromagnetic data prevents any detailed mapping of structures and calculation of meaningful depths to magnetic sources. However, the horizontal gradient magnitude transformation of the aeromagnetic anomalies is useful for mapping the approximate boundaries of the largest plutons (fig. 6). In this map, ridges of relatively high values indicate locations of magnetization contrasts; in this case, pluton boundaries. Other ridges reflect structures such as faults, as well as contacts of other plutons (not related to mineralization) in the region.

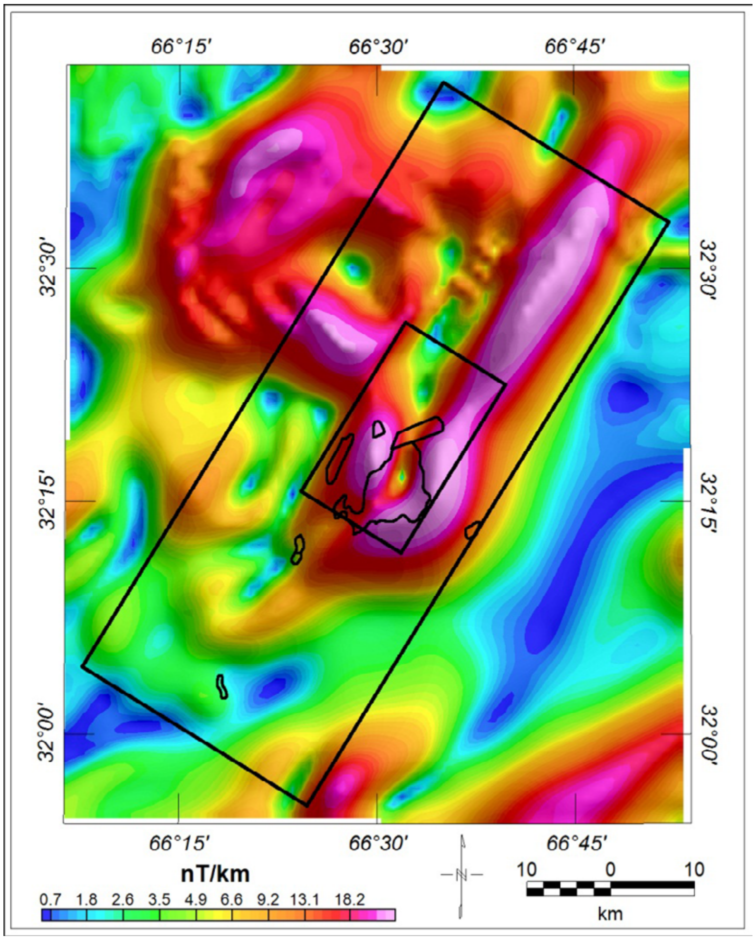

Figure 6. Horizontal gradient magnitude transformation of reduced-to-pole aeromagnetic anomalies over the Kundalan region. Black rectangles indicate areas of interest for mineral exploration (inner rectangle is area of greatest interest). Outcropping intrusions related to mineralization (Doebrich and others, 2006; Peters and others, 2007) shown as irregular polygons.

Dusar-Shaida

Existing Data

The best aeromagnetic dataset (fig. 7) available for the Khanneshin region is that acquired by Soviet Union geoscientists during 1976 (Sweeney and others, 2006). Line spacing was between 1 and 2 km, and ground clearances are thought to have been about 1 km. The lines data acquired in 2006 and 2008 by the USGS and NRL (Ashan and others, 2007; Shenwary and others, 2011) were spaced 4 km apart and are inferior to the Soviet Union dataset because of extreme flying height (5 km or more above the ground). Gravity data were also collected in 2006 and 2008 but are thought to have little bearing on geology related to mineralization.

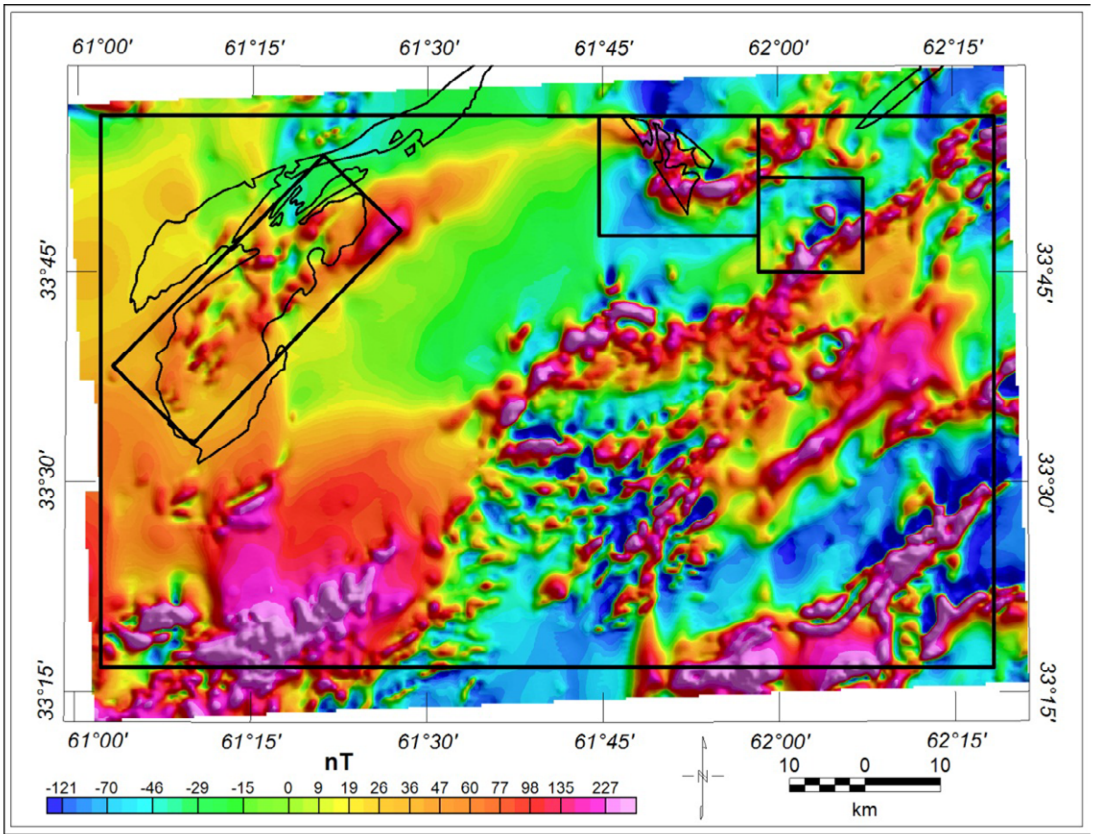

Figure 7. Reduced-to-pole aeromagnetic anomalies over the Dusar-Shaida region. Black rectangles indicate areas of interest for mineral exploration (inner rectangles are areas of greatest interest). Outcropping Mesozoic volcanic rocks related to VMS mineralization shown as irregular polygons (Doebrich and others, 2006; Peters and others, 2007).

Interpretation

Short-wavelength aeromagnetic anomalies are spatially correlated with outcropping Mesozoic volcanic rocks that are suspected to host volcanogenic massive sulphide (VMS) deposits. Alternating highs and lows are observed (fig. 7) as well as a common aeromagnetic pattern over volcanic rocks that likely reflects a mix of both normally and reversely polarized rocks. The low resolution of the existing data prevents more detailed mapping of structures.

Khanneshin

Existing Data

The best aeromagnetic dataset (figs. 8 and 9) available for the Khanneshin region is that acquired by German scientists in 1966 (Bosum and others, 1968; Sweeney and others, 2006). Line spacings varied from 1.25 km to 5 km, and ground clearances were about 1 km. The lines data acquired in 2006 and 2008 by the USGS and NRL (Ashan and others, 2007; Shenwary and others, 2011) were spaced 4 km apart and are inferior to the German dataset because of extreme flying height (5 km or more above the ground). Gravity data were also collected in 2006 and 2008 but are thought to have little bearing on geology related to mineralization.

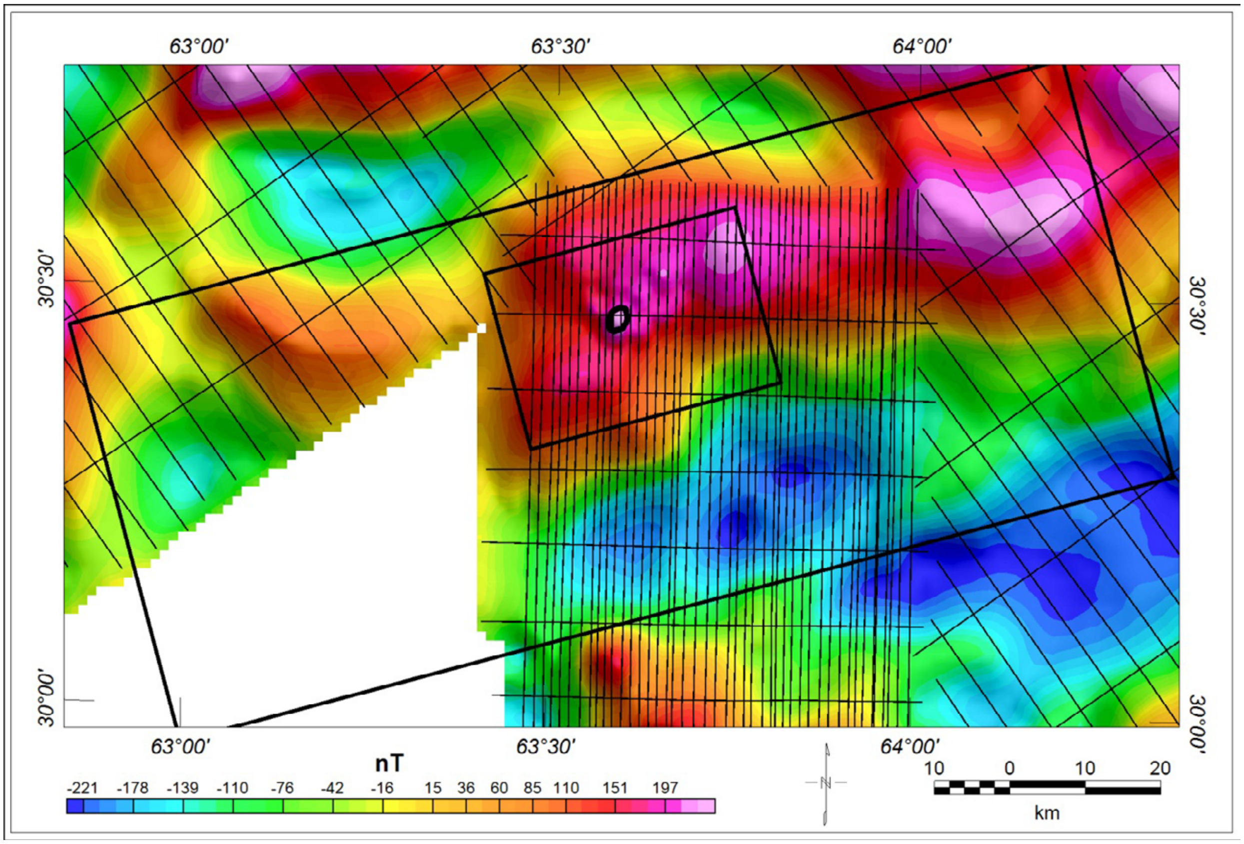

Figure 8. Reduced-to-pole aeromagnetic anomalies over the Khanneshin region. Flight lines shown by light black lines. Black rectangles indicate areas of interest for mineral exploration (inner rectangle is area of greatest interest). Outcropping carbonatite shown by black polygon (about 3 km across).

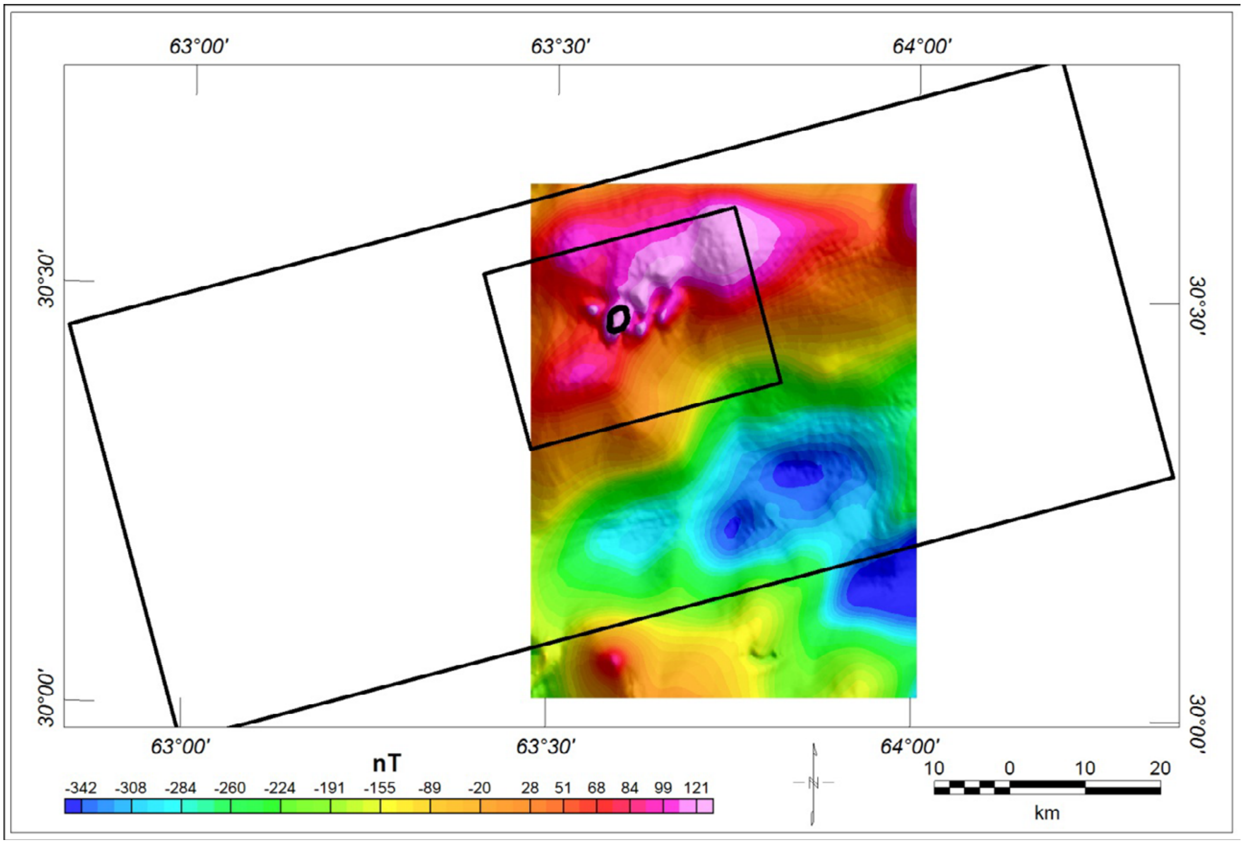

Figure 9. Relatively detailed (1.25 km line spacing, about 1 km above ground) reduced-to-pole aeromagnetic data over the Khanneshin region.

Interpretation

An aeromagnetic high is observed over the outcropping carbonatite (figs. 8 and 9), indicating that those rocks are strongly magnetized. Similar short-wavelength highs nearby (observable on fig. 9) may indicate locations of similar rocks buried in the shallow subsurface. A broad, high-amplitude aeromagnetic high extends along a roughly east-west trend over the Khanneshin region. The source of that anomaly has been interpreted to be strongly magnetized rocks within a Precambrian shield terrane (Bosum and others, 1968), although an intrusion related to the outcropping Quaternary(?) carbonatite is also a possibility. Resolution of the existing data is too low to facilitate detailed mapping of structures.

The minimum depth to magnetic source rocks can be estimated using extended Euler deconvolution (Reid and others, 1990; Mushayandebvu and others, 2001; Phillips, 2002) provided the aeromagnetic data have sufficient resolution (that is, ratio of line spacing to source depth is small). Euler solutions (fig. 10) indicate that most magnetic sources in the Khanneshin region are buried over a kilometer, although the wide-line spacing (1.25 km) means that computed depths less than 2 km are probably unreliable.

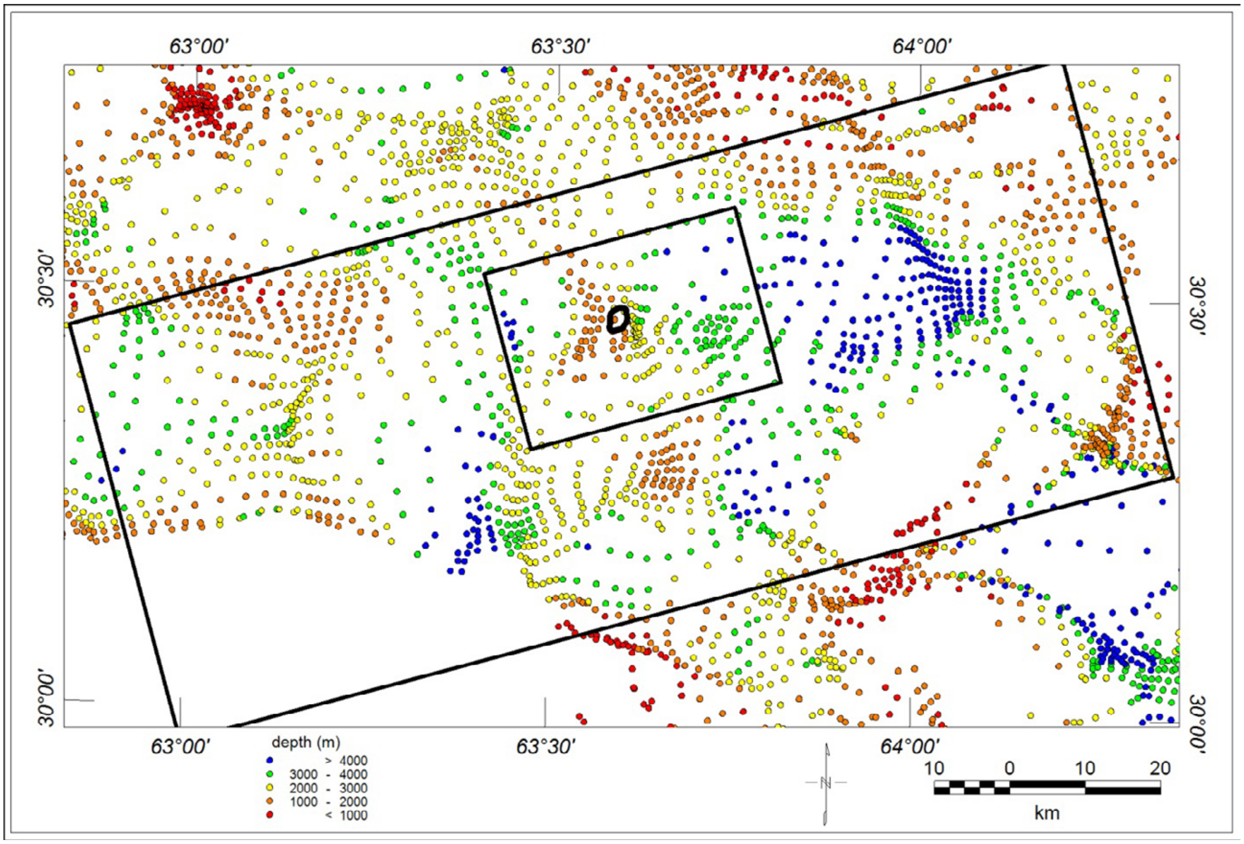

Figure 10. Euler deconvolution solutions, showing minimum depth to magnetic sources over the Khanneshin region.

Chagai Hills

Existing Data

The best existing aeromagnetic dataset available for the Chagai Hills region (fig. 11) is that acquired by German scientists in 1966 (Bosum and others, 1968; Sweeney and others, 2006). Line spacings varied from 1.25 km to 5 km, and ground clearance was about 1 km. The lines data acquired in 2006 and 2008 by the USGS and NRL (Ashan and others, 2007; Shenwary and others, 2011) were spaced 4 km apart and are inferior to the German dataset because of extreme flying height (5 km or more above the ground).

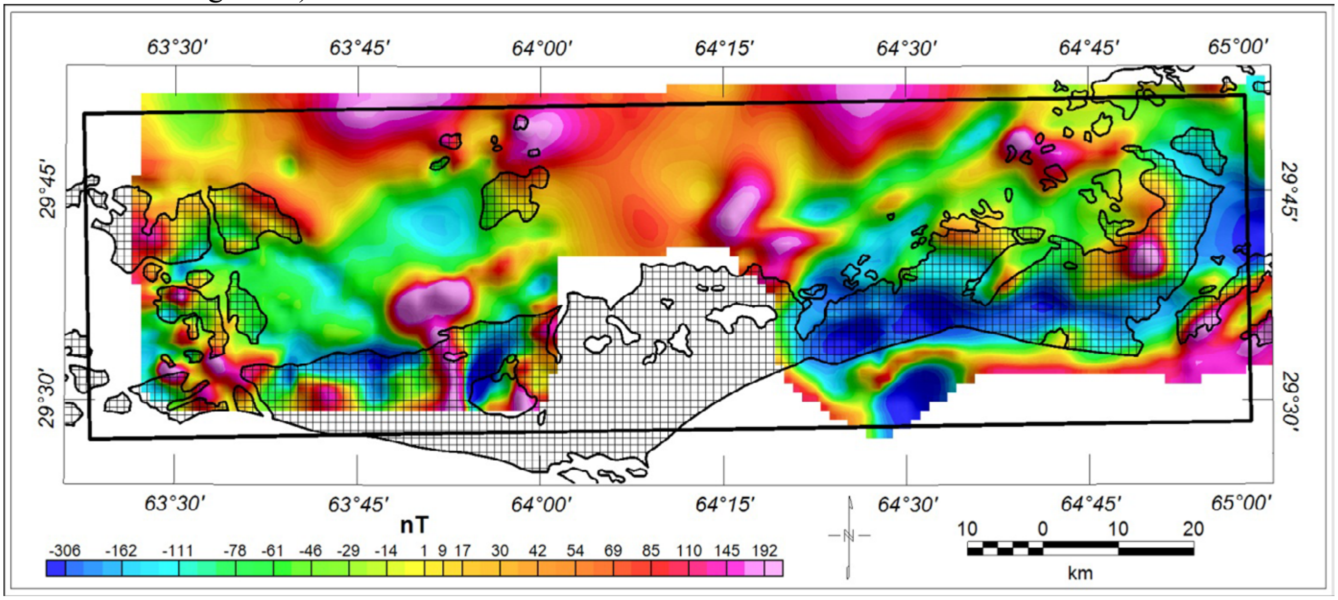

Figure 11. Reduced-to-pole aeromagnetic anomalies over the Chagai Hills region. Black rectangle indicates areas of interest for mineral exploration. Outcropping intrusions potentially related to mineralization (Doebrich and others, 2006) shown as irregular polygons. Outcropping volcanic rocks shown as pattern-filled polygons.

Interpretation

Aeromagnetic anomalies are spatially correlated with some plutons potentially related to mineralization, but in general seem to be better correlated with volcanic rocks that also crop out in the region (Doebrich and others, 2006). The low resolution of the existing aeromagnetic data prevents any detailed mapping of structures. Geologic interpretation of the aeromagnetic data is hampered also by a lack of detailed geologic mapping on the ground.

Conclusions

Existing geophysical datasets provide a useful, yet highly limited, perspective on geophysical signatures of mineral deposits in Afghanistan. The interpretations summarized here would be significantly improved by the collection of high-resolution, low-altitude airborne geophysical surveys.

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