Aeromagnetic Surveys in Afghanistan: An Updated Website for Distribution of Data

Open-File Report 2011–1055

U.S. Department of the Interior
U.S. Geological Survey

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U.S. Geological Survey, Reston, Virginia: 2011

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Suggested citation:
Shenwary, G.S., Kohistany, A.H., Hussain, Sardar, Ashan, Said; Mutty, A.S.; Daud, M.A.; Wussow, M.W., Sweeney, R.E., Phillips, J.D., Lindsay, C.R., Kucks, R.P., Finn, C.A., Drenth, B.A., Anderson, E.D., Abraham, J.D.; Liang, R.T., Jarvis, J.L., Gardner, J.M., Childers, V.A., Ball, D.C., and Brozena, J.M., 2011, Aeromagnetic surveys in Afghanistan—An updated website for distribution of data: U.S. Geological Survey Open-File Report 2011–1055, 8 p.

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Aeromagnetic Surveys in Afghanistan: An Updated Website for Distribution of Data

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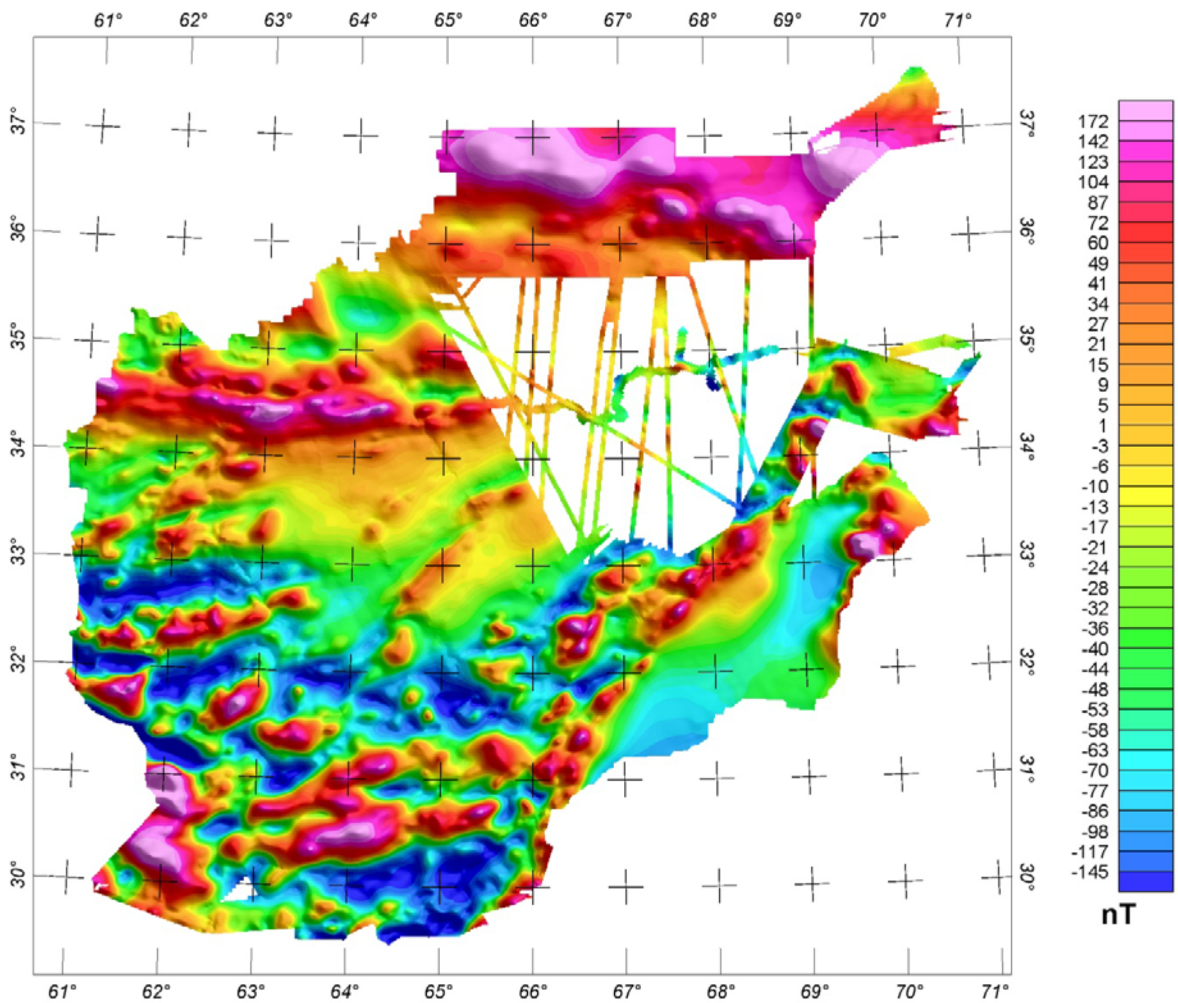
Abstract

Because of its geologic setting, Afghanistan has the potential to contain substantial natural resources. Although valuable mineral deposits and petroleum resources have been identified, much of the country's potential remains unknown. Airborne geophysical surveys are a well accepted and cost effective method for obtaining information about the geological setting of an area without the need to be physically located on the ground. Owing to the current security situation and the large areas of the country that have not been evaluated by geophysical exploration methods, a regional airborne geophysical survey was proposed. Acting upon the request of the Islamic Republic of Afghanistan Ministry of Mines, the U.S. Geological Survey contracted with the Naval Research Laboratory to jointly conduct an airborne geophysical and remote sensing survey of Afghanistan.

Afghanistan Aeromagnetic Survey



The above image was generated from a grid made by merging multiple Afghanistan magnetic anomaly grids. It is a composite of 2006 and 2008 aeromagnetic data described in this report, merged with residual magnetic field data found in U.S. Geological Survey *Open-File Report 2006-1204*, *Open-File Report 2006-1325*, and ground magnetic data described in *Open-File Report 2007-1247*. The data were gridded at 1,000 meter (m) spacing. The simulated elevation of the displayed grid is 5,000 m above terrain. The image is illuminated from the northeast.

Introduction

Because of its geologic setting, Afghanistan has the potential to contain substantial natural resources. Although valuable mineral deposits and petroleum resources have been identified, much of the country's potential remains unknown. Airborne geophysical surveys are a well accepted and cost effective method for obtaining information about the geological setting of an area, and they avoid the need to be physically located on the ground. A regional airborne geophysical survey was proposed owing to the large areas of Afghanistan that have not been evaluated by geophysical exploration methods, and the current poor security situation on the ground. Acting upon the request of the Islamic Republic of Afghanistan Ministry of Mines, the U.S. Geological Survey contracted with the U.S. Naval Research Laboratory to jointly conduct an airborne geophysical and remote sensing survey of Afghanistan. Data collected during this survey provide basic information for mineral and petroleum exploration studies that are important for the economic development of Afghanistan. Additionally, use of these data is broadly applicable in the assessment of water resources and natural hazards, the inventory and planning of civil infrastructure and agricultural resources, and the construction of detailed maps. The U.S. Geological Survey is currently funded by the U.S. Agency of International Development to conduct resource assessments of the country of Afghanistan for mineral, energy, coal, and water resources and for geologic hazards. These geophysical and remote sensing data will be used directly in the resource and hazard assessments. This report serves as an update to *Open-File Report 2007-1247*, presenting all magnetic data collected to date as part of this international and interagency collaboration.

Operations

The U.S. Geological Survey and U.S. Naval Research Laboratory jointly conducted an airborne geophysical and remote sensing survey in Afghanistan during the summers of 2006 and 2008. The Islamic Republic of Afghanistan Ministry of Mines and Industries provided the major funding for this work with additional support from the U.S. Naval Research Laboratory (NRL), U.S. Geological Survey (USGS), U.S. Department of Defense Reconstruction Office (ARO), and the National Geospatial-Intelligence Agency (NGA). Approximately 70 people worked to implement the airborne survey in Afghanistan. Thirteen USGS and NRL civilian scientists conducted the survey with the assistance of 24 scientists from the Afghanistan Geological Survey, the Afghanistan Head Office for Geodesy and Cartography, and the Ministry of Mines and Industries. Twenty-eight military personnel from the NRL Scientific Development Squadron ONE (VXS-1) and two geomagnetic technicians from the Canadian Forces Mapping and Charting Establishment provided critical operational support.

A research-modified Lockheed NP-3D “Orion” aircraft served as the survey instrument platform (fig. 1). The NRL VXS-1 heavyweight P3-B was uniquely configured with a suite of geophysical and remote sensing instruments and specially modified for operation in a combat theater. The geophysical instrumentation employed in this survey included the following:

- Tail-mounted cesium-vapor magnetometer.
- Dual marine gravimeters modified for airborne use.
- True-color, medium-format, photogrammetric digital camera.
- 228-band hyperspectral imaging sensor.
- L-band polarimetric imaging synthetic aperture radar (SAR).

Figure 1. The Naval Research Laboratory NP-3D "Orion" taxiing at Kandahar International Airport, June, 2006.

Figure 2. Kandahar International Airport served as the base of operations for the USGS airborne geophysical and remote sensing survey of Afghanistan. The terminal has seen significant renovations recently and will eventually be ready for civilian use.

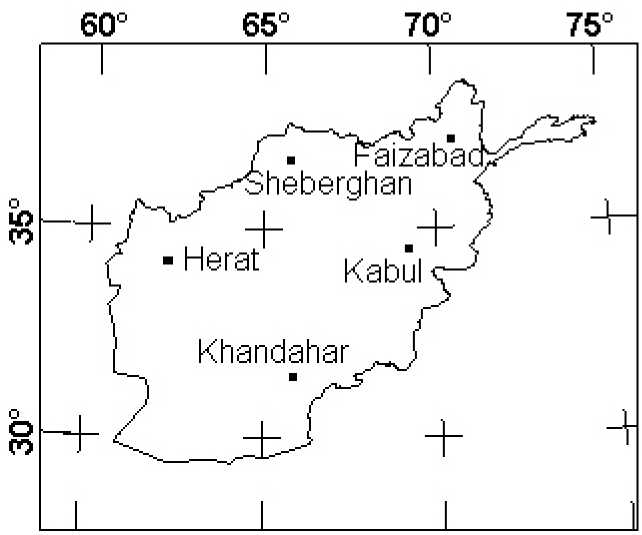
Global positioning system (GPS) and magnetic base stations were established throughout Afghanistan in order to provide correctional data in support of the airborne survey. The NGA established a gravity reference base station at Kandahar International Airport (fig. 2) for use as a gravity datum during the survey. Temporary GPS and magnetic reference stations were positioned in the cities of Kandahar, Kabul, Herat, Sheberghan, and Faizabad. Afghan scientists from the Afghanistan Geological Survey, Afghanistan Head Office for Geodesy and Cartography, and Ministry of Mines and Industries operated many of these stations.

Data Processing Details

Data Processing Details

A typical aeromagnetic survey uses a single base station magnetometer to record the time-varying magnetic fields produced by currents in the earth's upper atmosphere. Because these time-varying fields are unrelated to the geological sources of interest, they are subtracted from the magnetic field measured by the aircraft. For best results, a single base station should be located on the ground near the center of the area to be flown. If the aircraft is too far away from the base station, the time-varying fields measured at the aircraft will differ from those measured at the base station, resulting in increased error. The effective range of a single base station is generally considered to be less than 100 kilometers (km).

Owing to the large area covered by the Afghanistan aeromagnetic survey, a single magnetic base station would not have provided adequate coverage. Instead, five base station magnetometers were in operation during the survey. They were located at Sheberghan, Faizabad, Herat, Kabul, and Khandahar for the 2006 survey, and at Mazar-i-Sahrif, Kabul, and Kandahar for the 2008 survey. In order to correct the airborne magnetic data for time-varying anomalies, a weighted average of data from the five base stations was used to predict the time-varying field at the aircraft.



The first step in constructing the weighted average is to determine the constant magnetic field value at each base station. This constant value is related to the local geology at the base station and is best measured near local midnight, when the currents in the upper atmosphere are least active. For all of the night recordings at the base stations, we determined the magnetic field value at midnight (19:30 universal time (UT)), the average value for one hour near midnight (19:00 to 20:00 UT), and the average value for two hours near midnight (18:30 to 20:30 UT). In general, these three values agreed well at a given base station on a given night. However, we did notice that on certain nights all the midnight values for all base stations were systematically high, and on other nights they were systematically low. This observation meant that it was important that we use the same set of nights to determine the average midnight values for all the base stations.

We used a fixed set of 22 nights for the 2006 survey and 11 nights for the 2008 survey to determine the average midnight field value at each base station. There was little difference in averages based on the measured midnight values at the base station, the one-hour averages about midnight, or the two-hour averages about midnight. The results were the same to within 1 nanotesla (nT). The average midnight value for each base station was subtracted from all magnetic readings at the base station. This operation resulted in corrected values for the time-varying magnetic field at each base station.

The second step in the processing involved removing spikes and noise from the base station readings, some of which were noisier than others. To prevent this noise from propagating into the predicted time-varying field at the aircraft, we applied a three-point non-linear filter to all base station data to remove spikes and noise (using the Geosoft Oasis montaj software nfilt.gx).

The third step in predicting the time-varying magnetic field at any aircraft location was to fit a time-varying surface to the corrected base station data. The surface was defined such that each point on the surface lies on a plane defined by a weighted fit to the five base-station values. We used the inverse distance from the observation point (the aircraft) to each base station as a weighting function.

This choice of surface has several benefits. The surface is continuous; it does not peak over the base stations nor sag away from them. The surface can be evaluated at any point in space, except at the actual base station locations where it is infinite. The predicted value on the surface is weighted most heavily by the nearest base station value.

The above approach for removing the time-varying magnetic field provided a visible improvement over the raw aircraft data. Additional processing was necessary to remove line-leveling noise and elevation variations.

The final diurnally corrected magnetic data had some remaining flight-line noise due to variable flight altitudes and possible compensation issues. All flight and tie lines were thus continued to a nominal altitude of 5,000 m above the terrain. Using Oasis montaj software drape1D.gx, the data were analytically continued to the stated height for compatibility with previously collected data using 10 continuation levels and a low-pass filter factor of 1.0. The data were then tie-line and flight-line leveled, as well as microleveled in some cases, using Oasis montaj to create the final magnetic anomaly grids.

These final magnetic anomaly grids were subsequently merged with the ground magnetic survey data described in Open-File Report 2007-1247 and the residual aeromagnetic field data found in U.S. Geological Survey Open-File Reports 2006-1204 and 2006-1325. All grids were first continued to the nominal elevation of 5,000 m above terrain. Subsequent grid merges were then performed using the Oasis montaj grid-stitching algorithm “gridstch.gx,” with a static shift applied to the ground magnetic survey grid and a static or constant slope shift applied to the data from each of the open-file reports. The slope shift was necessary because of the uncertainty in knowing the accuracy of the main field that had been removed from the earlier survey.

Data Products

All grids are presented in Geosoft binary grid format, and two files describe each of the grids (suffixes .grd and .gi). The database that includes new 2008 data is presented in two formats: Geosoft binary database format and Geosoft ASCII XYZ format. All formats can be converted using the free conversion software offered by Geosoft at *http://www.geosoft.com/*.

- 2008_new_lines.gdb (Database of 2008 aeromagnetic line data)
- 2008_afghan_aeromag_5k.grd (Grid of 2008 aeromagnetic data at 1,000 m grid spacing at 5,000 m above terrain, merged with previous magnetic data products)
- 2008_afghan_rtp.grd (Reduced-to-pole version of the above grid)
- 2008_new_lines.XYZ (ASCII XYZ file of 2008 aeromagnetic line data)
- readme_Afghan_datafiles.pdf (Description of the data products)
- afghan_rtp_new.pdf (Map of the reduced-to-pole total magnetic intensity of Afghanistan)

Projection Specifications

All databases, maps, grids, and xyz files in this report use the following projection specifications:

- Projection = Transverse Mercator
- Central meridian = 66 degrees E
- Base latitude = 34 degrees N
- Scale factor = 0.9996
- Semimajor ellipsoid axis = 6378137 m
- Eccentricity = 0.08181919084
- Horizontal datum = WGS 84
- Ellipsoid = WGS 84

This web site makes the data products mentioned above available to users. To view this directory, click on the link below. To view the README file ("readme_Afghan_datafiles.pdf") describing the aeromagnetic data product files, click on the README line following.

1. **2008_new_lines.gdb**

The new aeromagnetic data presented in this report consist of lines in this Geosoft database. Specific channels in this database are:

longitude – longitude in degrees East.
latitude – latitude in degrees North.
xTM – projected X in meters (Transverse Mercator projection).
yTM – projected Y in meters (Transverse Mercator projection).
Hgt – aircraft elevation in meters.
comp_Tfield – compensated observed magnetic field (in nanoTesla) from aircraft.
Date – date of observation (yyyy/mm/dd).
SecDay – time of observation in seconds of day.
DEM – terrain elevation at (xTM, yTM) in meters.
Diurnal – diurnal correction in nanoTesla.
DGRF – main field calculation for observation (in nanoTesla).
Corr_mag – magnetic observation in nanoTesla corrected for diurnal and DGRF.
Cmag_drape1D_5K – Corr_mag value continued to 5000 m above terrain.

2. 2008_afghan_aeromag_5k.grd

This is a Geosoft binary grid (contained in the files with suffixes .grd and .gi) of the residual magnetic field ("Cmag_drape1D_5K" in above database) after decorrugation and merging with older aeromagnetic datasets. The grid locations are (xTM, yTM) coordinates. The data are gridded at 1,000 m grid spacing. The grid elevation is 5,000 m above terrain.

3. 2008_afghan_rtp.grd

This is a Geosoft binary grid (contained in the files with suffixes .grd and .gi) of the residual magnetic field (2008_afghan_aeromag_5k.grd) after application of a reduction-to-pole transformation. The grid locations are (xTM, yTM) coordinates. The data are gridded at 1,000 m grid spacing. The grid elevation is 5,000 m above terrain.

4. 2008_new_lines.XYZ

ASCII XYZ file of 2008 aeromagnetic line data.

README Afghan datafiles.pdf file describing data in above directory