USGS Projects in Afghanistan

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Afghanistan Airborne Geophysical and Remote Sensing Survey

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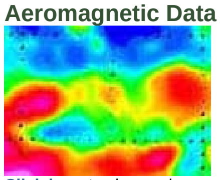
Afghanistan's geologic setting indicates significant natural resource potential. While important mineral deposits and petroleum resources have been identified, much of the country's potential remains unknown. Acting upon the request of the Government of Afghanistan, the U.S. Geological Survey and the Naval Research Laboratory conducted an airborne geophysical and remote sensing survey of Afghanistan. Data collected during this survey will provide basic information for mineral and petroleum exploration studies, which are important for the economic development of Afghanistan. Additionally, use of this 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.

Aerial Imagery

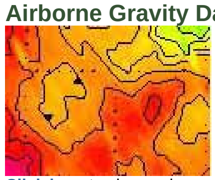
Click here to view and download imagery from the survey staged from the Tile Data Distribution System.

Aeromagnetic Data



Click here to view and download aeromagnetic data through **pubs.usgs.gov**.

Airborne Gravity Data



Click here to view and download airborne gravity data through **pubs.usgs.gov**.

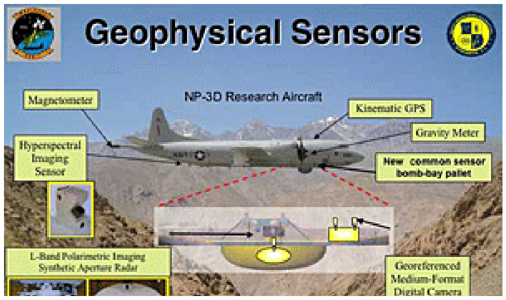
Background

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

The U.S. Geological Survey and U.S. Naval Research Laboratory jointly conducted an airborne geophysical and remote sensing survey in Afghanistan during the summer of 2006. 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), and U.S. Department of Defense Reconstruction Office (ARO). Approximately 70 people were involved with implementing the airborne survey in Afghanistan alone. 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 geomatic technicians from the Canadian Forces Mapping and Charting Establishment were deployed and provided critical operational support.

A research-modified Lockheed NP-3D "Orion" aircraft served as the survey instrument platform (Figure 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 (Figure 2). The geophysical instrumentation employed in this survey included:

- 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)



During the survey the NP-3D "Orion" was stationed at
Kandahar International Airport, about 16 kilometers southeast of Kandahar, Afghanistan (Figure 3). The airport was constructed during the 1960s with financial and technical assistance from the U.S. Agency for International Development (USAID). The airport was severely damaged by Soviet military operations during 1979-89 and again during the early phases of Operation Enduring Freedom in October 2001. The airport has since been renovated and served as a gateway for the 2006 Haj (an important Muslim pilgrimage).

Base stations were established throughout Afghanistan in order to provide correctional data in support of the airborne survey (Figure 4). The National Geospatial-Intelligence Agency (NGA) established a gravity reference base station at Kandahar International Airport for use as a gravity datum during the survey (Figure 5). Temporary Global Positioning System (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 (Figure 6). This equipment provided an excellent opportunity to train Afghan geophysicists in the operation of modern geophysical equipment (Figures 7 and 8).

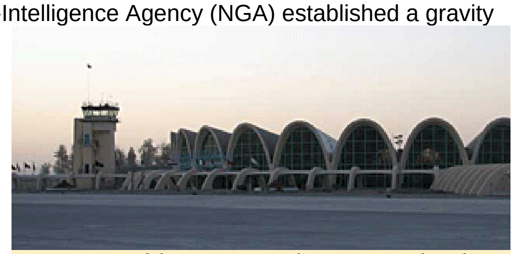


Figure 3. Kandahar International Airport served as the base of operations for the USGS airborne geophysical and remote sensing survey of Afghanistan. The terminal has seen significant renovations recently and will eventually be ready for civilian use.

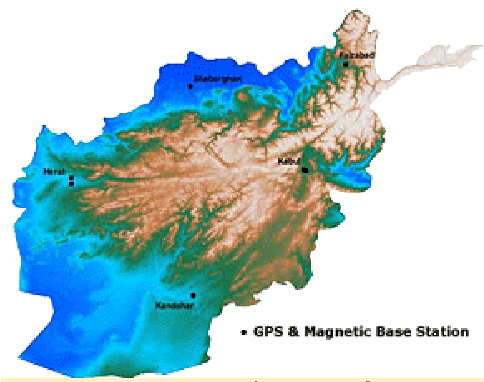


Figure 4. Temporary GPS and magnetic reference stations were positioned in cities throughout Afghanistan.

Figure 5. USGS geophysicist Benjamin Drenth collecting a relative gravity observation adjacent to an absolute gravimeter at Kandahar International Airport.

Figure 6. Global Positioning System (GPS) antenna and magnetometer located in Sheberghan, Afghanistan. This temporary base station was maintained and operated by Afghan scientists from the Northern Afghanistan Oil and Gas Exploration Office (Ministry of Mines and Industries).

Survey Coverage

The airborne geophysical and remote sensing survey of Afghanistan was completed in August 2006. The P-3 "Orion" conducted 37 individual survey flights, logging over 220 hours of flight time during the survey. Approximately 2/3 of the land area of Afghanistan was surveyed (Figure 9). The survey area was limited by flight restrictions imposed by U.S. Central Command (CENTCOM). During the survey 113,000 line kilometers of magnetic data, 72,000 line kilometers of gravity data, and 110,000 line kilometers of SAR data were collected. Additionally, 150,000 square kilometers of hyperspectral imagery and 300,000 square kilometers of stereo true-color photography were collected.

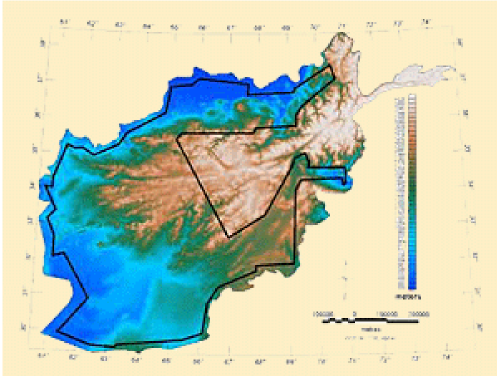


Figure 9. Coverage area of the geophysical and remote sensing survey of Afghanistan. The heavy-black line marks the approximate extent of the survey area. The survey area was limited by flight restrictions imposed by U.S. Central Command (US CENTCOM).

Example Data

Magnetic Aeromagnetic data documents the spatial distribution and relative abundance of magnetic minerals in rocks found at depths shallower than the Curie point isotherm (the depth below the Earth's surface at which temperatures are hot enough that minerals lose their magnetic properties). Because different rock types exhibit varying induced and remanent magnetizations, anomaly maps can be produced from aeromagnetic data. An aeromagnetic anomaly map of Afghanistan will be compiled using data from both this survey and from previous studies. The resulting aeromagnetic anomaly map and associated dataset will provide a basis for geophysical modeling that can be used to infer the shape, depth, and physical properties of the geological features responsible for the anomalies (Figure 10). This information can then be applied to mineral and petroleum exploration, tectonic interpretations, and seismic hazard assessments.

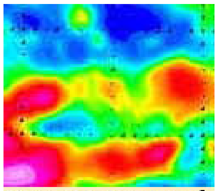


Figure 10. A portion of the aeromagnetic anomaly map produced using preliminary aeromagnetic data from the USGS survey of Afghanistan. Red indicates a positive magnetic anomaly; blue indicates a negative magnetic anomaly.

Gravity

Airborne gravity surveys are used to measure small changes in the Earth's gravity field. These changes are due to density variations between different rock types. Airborne gravity data collected during this study will be used to produce a Bouguer gravity anomaly map of Afghanistan (Figure 11). This map and the associated dataset will provide a basis for geophysical modeling that can be used to delineate the geometry and lateral extent of basins and subsurface structures, which are necessary

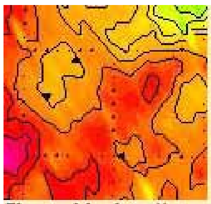


Figure 11. A portion of the Bouguer gravity anomaly map produced using preliminary airborne gravity data from the USGS survey of Afghanistan. Red indicates a positive gravity anomaly; green indicates a negative gravity anomaly.

Figure 12. USGS geophysicist Jared Abraham collecting a relative gravity observation in Bamyan, Afghanistan. One of the alcoves that housed a monumental Buddha sculpture (for 1600 years before destruction by the Taliban in 2001) is visible in the background.

for the assessment of petroleum resources. This information will also be useful to focus future petroleum exploration activities. Gravity data can be used to delineate ore deposits or the structures and trends that may control the location of ore deposits. Additionally, natural hazard assessments often rely on the use of gravity anomalies to detect faults and evaluate their size. Subsequent ground-based gravity surveys of areas of interest will be of much greater accuracy and provide better significantly better anomaly characterization (Figure 12).

Photogrammetry

High-resolution, true-color (Red-Green-Blue), digital imagery was collected over 300,000 square kilometers of Afghanistan (Figure 13). This imagery was collected using a digital sensor system that was completely dependent on airborne GPS-aided inertial navigation systems to identify the location and orientation of each aerial image at the time of exposure (Figure 14). This technology, coupled with image overlap, allows for the production of stereo models and the construction of precise digital elevation models (DEMs) directly from the imagery.

Figure 13. High-resolution, true color, digital imagery of a portion of Kandahar, Afghanistan collected during the USGS survey of Afghanistan.

Figure 14. Dr. John Brozena (NRL) closely monitoring Global Positioning System (GPS) and inertial measurement unit (IMU) data to document and resolve deviation from pre-planned flight paths.

Hyperspectral

Hyperspectral imaging is a remote sensing technique that measures the reflectance spectra of visible and infrared electromagnetic radiation. Patterns of reflectance and absorption across wavelengths can uniquely identify certain materials. Analysis of hyperspectral imagery can be used, for example, for mineral mapping, to detect soil chemical properties, and to identify vegetation species (Figures 15 and 16). More than 150,000 square kilometers of data were acquired using 228 spectral bands between 400 - 1000 nm.

Figure 15. False-colored (RGB) georegistered image

Figure 16. The same image mosaic after application of a chlorophyll mask. Vegetated areas are shown in grayscale, non-vegetated areas are black.

L-Band Synthetic Aperture Radar

Synthetic Aperture Radar (SAR) precisely measures the distance from an antenna to a surface reflection point. Utilization of the reflected signal's amplitude and phase yields a very sensitive measurement of the nature of the reflecting surface. The use of satellite-borne L-Band (1.275 GHz) SAR was previously used in the discovery of buried dry riverbeds in the Sahara Desert of Sudan and Egypt. This study demonstrated the ability of L-band SAR to penetrate up to several meters in dry sandy environments. More than 110,000 line kilometers of L-band SAR data were collected during the USGS survey of Afghanistan. Future processing and analysis of this data may prove fundamental to imaging geomorphic surfaces and the identification of hydrologic features buried beneath the Registan Desert of Kandahar and Helmand Provinces (the Dasht-e-margo - literally "Desert of Death" - was previously inhabited by thousands of pastoralists until a devastating drought decimated their animal herds).

Global Positioning System (GPS)

All geophysical data and imagery collected during this survey was georegistered using post-processed kinematic GPS data that was corrected using data from multiple base stations (Figure 17). Thus, all the data from this survey and derivative products are ideal candidates for use as layers in a Geographic Information System (GIS), and typical image processing software provides mechanisms for merging this data with existing or future data sets.

Acknowledgements

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U.S. Bureau of Land Management
U.S. Department of Defense Afghanistan Reachback Office
U.S. Naval Research Laboratory

Figure 17. Dr. Vicki Childers (NRL) post-processing GPS data using data collected from multiple base stations.

Additional Images