Canada

Carte des Anomalies Magnétiques de l'Amérique du Nord

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Magnetic Anomaly Map of North America

RM

Mapa de la Anomalía Magnética de Norteamérica

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

Booklet to accompany map

Significant data providers

EXPLORACIÓN Y PRODUCCIÓN

Petróleos Mexicanos

U.S. National Oceanic and Atmospheric Administration

Carte des Anomalies Magnétiques de l’Amérique du Nord
Magnetic Anomaly Map of North America
Mapa de la Anomalía Magnética de Norteamérica

Processing, Compilation, and Geologic Mapping Applications of the New Digital Magnetic Anomaly Database and Map of North America

By North American Magnetic Anomaly Group (NAMAG)

Viki Bankey[2]
Alejandro Cuevas[3]
David Daniels[2]
Carol A. Finn[2]
Israel Hernandez[3]
Patricia Hill[2]
Robert Kucks[2]
Warner Miles[1]
Mark Pilkington[1]
Carter Roberts[2]
Walter Roest[1]
Victoria Rystrom[2]
Sarah Shearer[2]
Stephen Snyder[2]
Ronald Sweeney[2]
Julio Velez[3]

Sponsored by

[1]Geological Survey of Canada
[2]United States Geological Survey
[3]Consejo de Recursos Minerales de México

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Introduction

This digital Magnetic Anomaly database and map for the North American continent is the result of a joint effort by the Geological Survey of Canada (GSC), U.S. Geological Survey (USGS), and Consejo de Recursos Minerales of Mexico (CRM). The database and map represent a substantial upgrade from the previous compilation of Magnetic Anomaly data for North America, now over a decade old (Committee for the Magnetic Anomaly Map of North America, 1987). This integrated, readily accessible, modern digital database of magnetic anomaly data will be a powerful tool for further evaluation of the structure, geologic processes, and tectonic evolution of the continent and may also be used to help resolve societal and scientific issues that span national boundaries. The North American magnetic anomaly map derived from the digital database provides a comprehensive magnetic view of continental-scale trends not available in individual data sets, helps link widely separated areas of outcrop, and unifies disparate geologic studies. This booklet outlines the data processing and compilation procedures used to produce the magnetic anomaly database and map that accompany this booklet.

Introduction

L'actualisation de la banque de données numériques et de la carte magnétique de l'Amérique du Nord est le résultat des efforts conjoints de la Commission géologique du Canada (CGC), du U.S. Geological Survey (USGS) et de Consejo de Recusos Minerales de México (CRM). Cette banque de données moderne, intégrée et facile d'accès couvre toute l'Amérique du Nord; elle sera un outil puissant pour faire de nouvelles interprétation des structures, des processus géologiques et de l'évolution tectonique de continent, en outre, on pourra l'utiliser pour résoudre des problèmes sociaux et scientifiques couvrant plusieurs pays. La carte des anomalies magnétiques de l'Amérique du Nord produite à partir de données numériques fournit une vue, à l'échelle continentale, de linéaments non identifiables sur des ensembles séparés de données, elle aide à regrouper des affleurements séparés de roches et à unifier diverses études géologiques. Cette brochures donne un aperçu des techniques de compilation et de traitement utilisés, et des applications géologiques possibles à partir de cette carte magnétique et des données numériques.

Introducción

La actualización de la base de datos digital y el mapa de la anomalía magnética de Norteamérica es el producto de un esfuerzo conjunto entre el Geological Survey of Canadá (GSC), el U.S. Geological Survey (USGS) y el Consejo de Recursos Minerales de México (CRM). Esta base de datos moderna y de fácil acceso que comprende todo Norteamérica constituirá una poderosa herramienta para nuevas evaluaciones de las estructuras, procesos geológicos y evolución tectónica del continente y puede ser usada para ayudar a resolver aspectos sociales y científicos que se extienden mas allá de las fronteras nacionales. El mapa de anomalía magnética de Norteamérica derivado de la base de datos digital proporciona una visión de lineamientos magnéticos a escala continental que no se puede apreciar en los grupos de datos individuales, ayudando a agrupar afloramientos de rocas ampliamente separados y a unificar estudios geológicos. Este folleto describe la compilación y procesamiento utilizado para producir la nueva base de datos digital y el mapa de anomalía magnética de Norteamérica.

3
Magnetic Anomaly Data

Magnetic anomaly data provide a means of "seeing through" nonmagnetic rocks and cover such as vegetation, soil, desert sands, glacial till, man-made features, and water to reveal lithologic variations and structural features such as faults, folds, and dikes. Magnetic anomalies reflect variations in the distribution and type of magnetic minerals—primarily magnetite—in the Earth's crust. Magnetic rocks can be mapped from the surface to great depths, depending on their dimensions, shape, and magnetic properties, and on the character of the local geothermal gradient. In many cases, examination of magnetic anomalies provides the most expeditious and cost-effective means to accurately map geologic features in the third dimension (depth) at a range of scales.

Publicly available airborne and marine magnetic data have been collected in North America primarily by the governments of Canada, the U.S., and Mexico. In the early 1980's, the first magnetic anomaly map was produced for the U.S. (Zietz, 1982). A digitized version of this analog map constitutes most of the data for the conterminous U.S. in the North American magnetic anomaly map compilation (Committee for the Magnetic Anomaly Map of North America, 1987), constructed as part of the Geological Society of America's Decade of North American Geology (DNAG) program. The Canadian component of the DNAG map was based on a 2-km grid (Dods and others, 1987) covering 70 percent of Canada, with the largest data gaps over western Canada and the Arctic Islands. No data over Mexico were published in the DNAG map. Although this first Magnetic Anomaly map was a pioneering effort when it was first constructed in analog form, data resolution is sometimes poorly represented, and the map is often inadequate for addressing current socioeconomic problems requiring modern digital analysis. Moreover, the analog techniques used to assemble the data did not properly reconcile the disparate flight specifications of individual surveys, resulting in substantial inconsistencies that became more obvious after the data had been digitized (Committee for the Magnetic Anomaly Map of North America, 1987; National Research Council, 1993). As a result of these past compilation problems and recent major improvements in data coverage, primarily in Canada and Mexico, an effort to compile a new digital database covering North America was clearly warranted and was one of the key recommendations of the U.S. Magnetic Anomaly Data Set Task Group (1994), who developed the rationale and operational plan for improving this data resource.

Canadian Data

Canada has conducted a systematic aeromagnetic mapping program since 1947 (fig. 1) (Teskey and others, 1993), often on a cost-sharing basis between Federal and Provincial governments. Currently, surveys are contracted out by the GSC and are often jointly funded with industry partners from both the petroleum and mining sectors. Most surveys (70 percent of land coverage) were flown at a line spacing of 0.8 km (fig. 2) and flight height of 0.3 km above the terrain. Detailed mapping at line spacings as small as 0.2 km and regional surveys over sedimentary basins at line spacings as large as 3 km have also been carried out (fig. 2). Approximately 20 percent of the survey data that are part of the new *Magnetic Anomaly Map of North America* were digitally acquired; the remaining surveys were digitized from 1:50,000-scale magnetic contour maps (for example, fig. 3). Data sources also include ship-borne surveys off the Pacific and Atlantic coasts, donated gridded data sets from industry, and U.S. Navy airborne surveys in the Arctic Ocean. Data are maintained in a national aeromagnetic database containing over 12,000,000 km of flight-line data and are available in several formats (see *http://gdcinfo.agg.nrcan.gc.ca*). In the period 1988–1999 after the DNAG compilation, the GSC has flown 57 surveys acquiring 2,300,000 line-km of magnetic data. Coverage of western Canada and the Arctic has improved significantly.

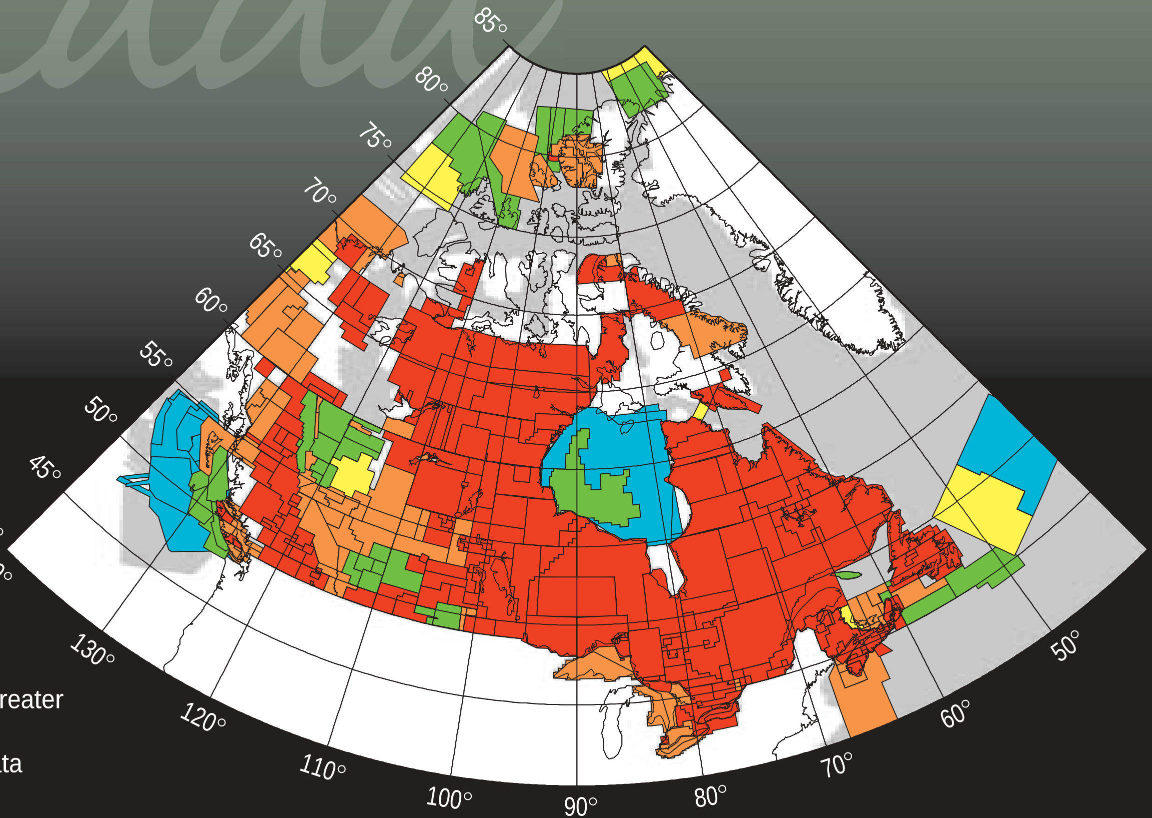
The leveling and merging of aeromagnetic surveys in Canada to produce a country-wide compilation were started in the late 1970’s. A second phase was started in the late 1980’s and has continued, resulting in a regional compilation for most of the Canadian landmass and offshore areas (Teskey and others, 1993). As part of the new North American map, additional data (mostly over the Arctic Islands) were merged with the existing database to produce the most up-to-date coverage of the country.

Procedures and software used to compile the 1-km grid of magnetic data for Canada are detailed on the Geophysical Data Centre website *(http://gdcinfo.agg.nrcan.gc.ca)* and are briefly summarized here. For areas with flight-line data coincident with the existing 2-km national grid (Dods and others, 1987), the difference between the 2-km grid and the gridded flight line was used to determine a first-order correction (either a constant value or a first-order surface). For surveys constituting new coverage, this correction was determined through overlap with surrounding surveys. In both cases, the International Geomagnetic Reference Field (IGRF) for the year and altitude at which the survey was flown was subtracted from the flight-line data. To generate seamless, discontinuity-free boundaries between the surveys, differences between surveys were determined in the overlap region and apportioned over a border zone at the survey boundaries. Merging surveys flown at a constant elevation above topography with surveys flown at a constant altitude was achieved by computationally draping data from the constant-altitude surveys to a surface 305 m above topography using the method of Cordell (1992). Some areas, such as the Yukon Territory, were acquired during periods of high diurnal variations in the Earth’s magnetic field, a hazard of surveying in the auroral zone. To reduce the effects of these secular variations in the Earth’s magnetic field, the survey grids were decorrugated or micro-leveled. This involved a directional filter that reduces anomalies in the flight-line direction. Flight-line data and various grid products can be obtained from the Geophysical Data Centre website *(http://gdcinfo.agg.nrcan.gc.ca)*.


ENERGIE · MINES · RESSOURCES

Figure 1. Beechcraft Queenair B80 aircraft of the Geological Survey of Canada equipped with a twin magnetometer system (separation 2 m) for measuring the vertical gradient of the magnetic field. Photographed in 1973. *Courtesy Geological Survey of Canada.*

canada



FLIGHT-LINE SPACING

- 1.0 km or less
- 1.1–2.0 km
- 2.1–3.2 km
- 3.3–7.9 km
- 8.0 km or greater
- Gridded data

Figure 3 (above). Example of hand contouring of analog magnetic profile data. *Courtesy Consejo de Recursos Minerales of Mexico.*

Figure 2 (facing page). Index map showing flight-line spacings of magnetic surveys used in the Canadian part of the North American grid.

United States Data

The USGS pioneered the first airborne magnetic survey in 1945 (fig. 4). Subsequently, the USGS has acquired aeromagnetic data (fig. 4) for essentially all of the U.S. in a piecemeal fashion. Surveys were designed for many purposes, so they varied widely in both size of coverage and anomaly resolution (determined primarily from flight height and line spacing) (fig. 5). Data collection methods spanned changes in acquisition techniques, from analog-based before the 1970's (for example, fig. 6) to current digital systems utilizing Global Positioning System (GPS) navigation (for example, fig. 7). After more than 50 years, the USGS's digital and analog archives of aeromagnetic data comprise more than 1,000 surveys consisting of nearly 8,000,000 line-km of data that would cost hundreds of millions of dollars to re-fly today.

For the national compilation that forms part of the North American database, the USGS has constructed a data set containing the original aeromagnetic survey data (in digital form) from surveys, maps, and grids of existing public-domain and, where available, proprietary magnetic data (about 5,800,000 line-km). These data either exist as digitally processed flight-line data (here called digital data) or were derived from analog maps if the flight-line data were not available (called digitized data). In the latter case, the analog maps (for example, fig. 3) were digitized, generally taking points from intersections of flight lines with magnetic contour lines and their maximum and minimum values. Where required, further digitizing was done to augment values along flight lines. Most of the aeromagnetic data were usually corrected during initial processing for the diurnal variations of the magnetic field, lag, heading, and occasional errors in flight-line elevation. These corrections are often not retained in the original digital data files.

staggerwing biplane

Figure 4. *A (pages 9–10).* The U.S. Geological Survey (USGS) pioneered the first airborne magnetic survey in 1945 using this Beechcraft Staggerwing 17 aircraft. Note the magnetometer "bird" suspended below the aircraft. (Two views of the same aircraft.) *B (pages 11–12).* This twin-engine Beechcraft owned by the USGS was used for magnetic surveys throughout the United States in the 1940's and 1950's. *C (pages 13–14).* Two views of a Convair 240 acquired in 1963 by the USGS and used for magnetic surveys over the United States until 1971. Note the "tail stinger," which was retractable and held the magnetometer. *D (pages 15–16).* These DeHavilland Beavers were acquired in the early 1970's by the USGS for use in magnetic surveys, but were used for only a few years. *U.S. Geological Survey photographs.*

beechcraft

convair 240


UNITED STATES GEOLOGICAL SURVEY
N1015G

dehavilland beavers


N2749

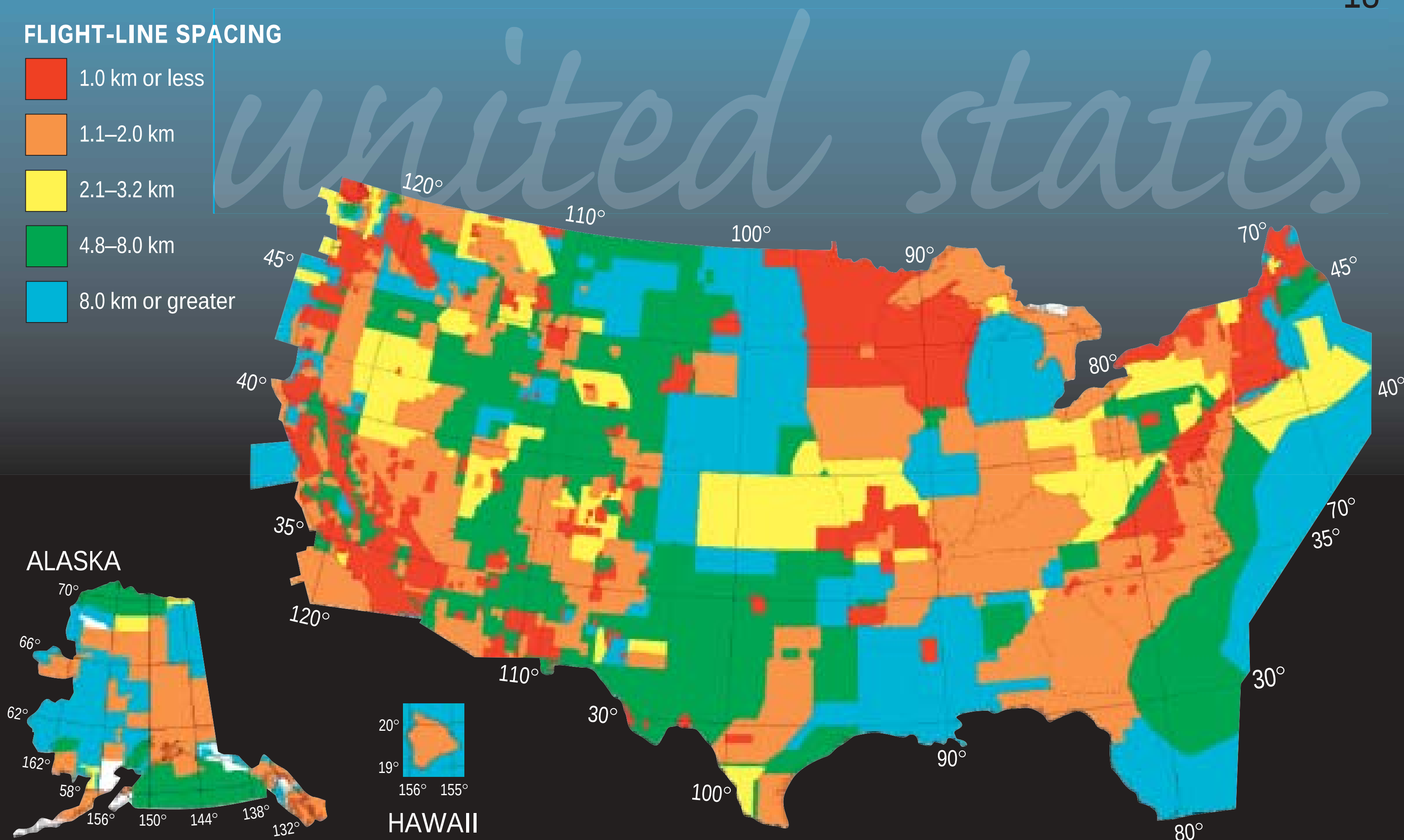
Over the last 16 years, these survey data have been reprocessed, gridded, and merged into regional compilations at U.S. State scales. Many States have been digitally compiled over the last decade (for progress on State compilations, go to *http://crustal.usgs.gov/namad/*). Information on the details of the data processing steps for each State and regional compilation that comprise the U.S. Magnetic Anomaly grid can be found in individual reports (see *http://crustal.cr.usgs.gov/crustal/geophysics/index.html* for list). Surveys covering small areas (< 10 km by 10 km) were generally not included in the State compilations.

Grids were constructed from the original aeromagnetic survey data with a cell size between one-third and one-fifth of the flight-line spacing of the survey using a bi-directional gridding algorithm. For digitized contour line data, the initial grid was constructed using a minimum curvature algorithm with a grid cell size appropriate for the scale of the digitized map. Usually the Definitive Geomagnetic Reference Field (DGRF), in conjunction with the International Geomagnetic Reference Field (IGRF) 1990, was applied for the date of the original survey. However, for some surveys flown before the original IGRF series of main field models were available, Goddard Space Flight Center (December 1966) or any of several variations of Polar Orbiting Geophysical Observatory models were used. The original IGRF1965 model was used often after its availability in 1968. IGRF1975 came out a decade later, followed by IGRF1980. After this, the DGRF suite of models was born out of necessity for creating a uniform standard. Whenever possible, these and other original models were first added back to the survey data, then the appropriate DGRF was removed.

The survey grids were resampled, as necessary, to final cell sizes of 500 and 1,000 m using a minimum curvature algorithm. The original grids were upward or downward continued and converted from level to drape (Cordell, 1992), as necessary, to produce a consistent survey specification of 305 m (1,000 ft) above the terrain. The converted grids were then adjusted by constant values to minimize differences at the boundaries.

These intermediate compilations were stitched together to form a quasi-consistent grid of data for the U.S. with a spacing of 1 km using one of two methods. One method applies a function that “blends” the grids over the area of overlap so that transition from one to the other is smooth without changing the grids beyond the overlap regions. Another method defines a “suture” within the overlapping area of the two grids along which the mismatch in the grid values must be corrected by adjusting the grids on either side of the path, ensuring that the transition from one grid to the other remains smooth, no matter the amplitude and wavelength of the features that the suture path crosses. In general, suture was the method of choice, because it seemed to modify the data mostly in the middle of the overlap zone, and then quickly honor the original data in both grids as one moved away from the suture. But suture also had the drawback of often leaving an artificial anomaly along the suture zone. Whenever this was apparent, and not easily corrected, the grid-knit blend option was used, generally merging the data admirably, but also modifying the data in both grids further from the center of the overlap zone.

Figure 5 (facing page). Index map showing flight-line spacings of magnetic surveys used in the U.S. part of the North American grid.


united states
FLIGHT-LINE SPACING
1.0 km or less
1.1–2.0 km
2.1–3.2 km
4.8–8.0 km
8.0 km or greater
120°
110°
100°
90°
70°
45°
45°
80°
40°
40°
35°
70°
35°
120°
110°
30°
30°
100°
90°
80°
ALASKA
70°
66°
62°
162°
58°
156°
150°
144°
138°
132°
20°
19°
156°
155°
HAWAII

19
Mexican Data

Aeromagnetic surveys in Mexico have been flown by CRM in support of mineral exploration since 1962 (figs. 6, 7, and 8). Prior to 1992, the surveys were flown along north- and northeast-trending flight lines spaced 800–1,000 m apart with flight heights of 120, 300, and 450 m above the terrain (fig. 9). The data were plotted on 1:50,000-scale contour maps (fig. 3) and then digitized by hand, producing about 360,000 line-km of digital data. The points were digitized from intersections of flight lines with magnetic contour lines and their maximum and minimum values. Where required, further editing was done to the line data. The Definitive Geomagnetic Reference Field (DGRF) was subtracted using the digital elevation model and the year and altitude of each survey. Grids were constructed from the database with a cell size one-fifth that of the flight-line spacing, using a minimum curvature algorithm. A first vertical derivative filter was applied to the data to highlight poorly merged areas. These areas were then re-leveled.

Since 1994, the CRM has been systematically flying surveys (fig. 10) over the country's mining exploration areas with Cesium magnetometers positioned by differential GPS (fig. 7) along north-south-trending flight lines spaced 1,000 m apart. The flight height varies from about 300 to 450 m above the terrain. The digital information is corrected for the diurnal variations of the magnetic field, lag, heading, DGRF/IGRF, and tie-line mis-ties. It was then microleveled. The original data from the modern digital surveys, as well as the older analog data, are available (see *http://www.coremisgm.gob.mx*).

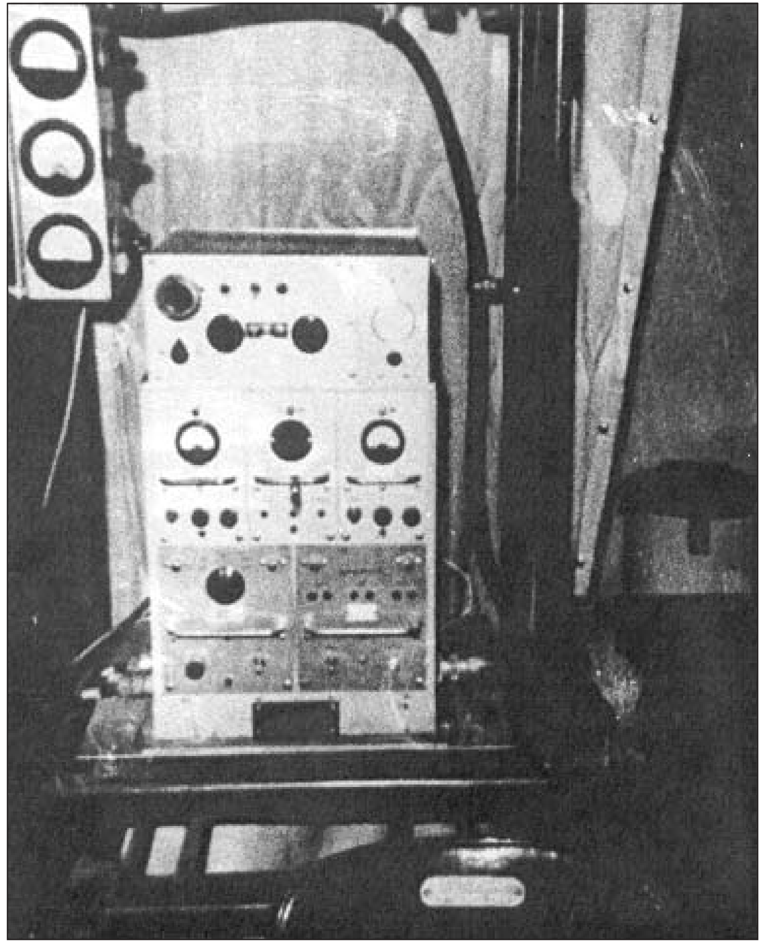


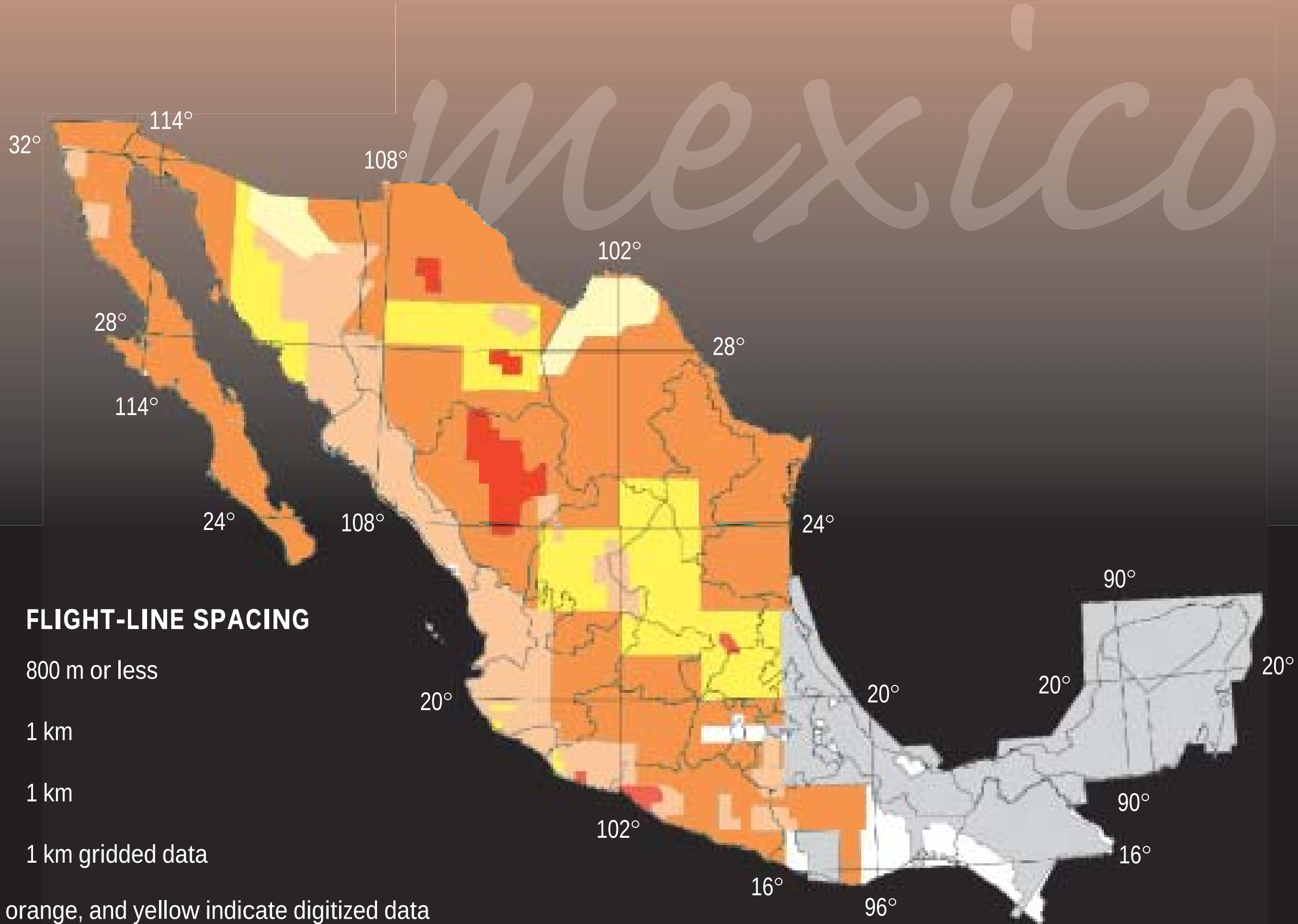
Figure 6 (facing page). Analog-based magnetic data were collected before the 1970's using equipment such as this Gulf Mark III magnetometer. *Courtesy Consejo de Recursos Minerales of Mexico*

Figure 7 (left). Cockpit of modern Britten-Norman Islander aircraft equipped with the latest in digital magnetic data acquisition system and Global Positioning (GPS) navigation. *Courtesy Consejo de Recursos Minerales of Mexico.*


XC-CUJ

twin pioneer

Figure 8 (facing page). The first aircraft used by Consejo de Recursos Minerales of Mexico for magnetic surveys from 1962 to 1974 was this Scottish Aviation Twin Pioneer equipped with a Gulf Mark III magnetometer. See figure 6 for photograph of a Gulf Mark III magnetometer. *Courtesy Consejo de Recursos Minerales of Mexico.*



FLIGHT HEIGHT | **FLIGHT-LINE SPACING**

120 m	800 m or less
300 m	1 km
450 m	1 km
Barometric	1 km gridded data

Lighter shades of red, orange, and yellow indicate digitized data

For the national compilation that is part of the North American database, all of the CRM grids, originally gridded with a cell size one-fifth that of the line spacing, were downward or upward continued to 305 m above ground level and resampled to a 200-m grid. Each grid was adjusted by an appropriate constant to minimize differences at survey boundaries during the process to merge adjacent surveys.

The National Oil Company (PEMEX) provided 19 grids, with 1-km cell size, covering southeast Mexico. The surveys were flown with line spacings ranging from 2 to 6 km and flight heights from 450 to 3,350 m above sea level. These data were reprocessed to account for the IGRF. Each individual grid was converted from a constant (barometric) altitude to a constant elevation above terrain, then a polynomial of first degree was removed before merging all of the individual grids. This final grid (gray areas in fig. 9) was merged with the CRM grid to generate the Mexico magnetic grid.

Figure 9 (facing page). Index map showing flight heights and flight-line spacings of magnetic surveys used in the Mexican part of the North American grid.

Offshore Data

Since the DNAG compilation, the offshore data coverage has significantly improved. These improved data have been incorporated with the aeromagnetic data for this map. The marine data were obtained from the National Geophysical Data Center of the National Oceanic and Atmospheric Administration and span the years 1958 through 1997. Only total magnetic field data were used, to which diurnal corrections, when available, had already been applied. The DGRF was then removed, using the date of the original surveys. These data were then heavily edited, removing obvious erroneous stations and surveys. Gridding was performed to a final cell size of 1 km using a minimum curvature algorithm and a grid radius of 24 km to fill in the many small no-data areas. This final grid was then trimmed, removing those data areas which overlapped the Canada and United States offshore grid areas (figs. 2 and 5). A slight overlap provided a smooth transition when merging with adjacent grids.

Figure 10. This fleet of Britten-Norman Islander aircraft, which is equipped with the latest data acquisition systems, has been used by Consejo de Recursos Minerales of Mexico since 1994. See figure 7 for cockpit view of one of these aircraft. *Courtesy Consejo de Recursos Minerales of Mexico.*

britten-
norman
islander

27
The North America Magnetic Anomaly Grid and Map Products

Products from the North American project include the individual grids from Canada, the U.S., Mexico, the Arctic (Macnab and others, 1995), and marine data. If necessary, each national 1-km grid was reprojected to the DNAG projection (spherical transverse mercator, central meridian of 100° W., base latitude of 0°, a scale factor of 0.926, and Earth radius of 6,371,204 m) (Snyder, 1987; Committee for the Magnetic Anomaly Map of North America, 1987) and merged together, using both blending and suturing approaches to form the North American merged magnetic grid.

Although the North American merged grid represents a significant upgrade to older compilations, the existing patchwork of surveys is inherently unable to accurately represent anomalies with long (greater than about 150 km) wavelengths, particularly in the U.S. and Canada (U.S. Magnetic Anomaly Data Set Task Group, 1994). The lack of information about long-wavelength anomalies is primarily related to datum shifts between merged surveys. These shifts are caused by data acquisition at widely different times and by differences in merging procedures. The artifacts produced by the shifts have wavelengths the size of one or more survey areas and the amplitudes can easily exceed 100 nT. Reliable measurement of long-wavelength anomalies is limited by individual survey sizes, regardless of data quality (for example, it is difficult to definitively measure anomaly wavelengths greater than 100 km when the dimension of the survey area is less than 100 km).

Because wavelengths greater than about 150 km are unreliable in the compilation, applying a high-pass wavelength filter would appear to be a viable solution to remove these unreliable wavelengths. However, removing wavelengths less than 500 km from the merged grid creates artifacts, such as spurious separation of continuous anomalies. Therefore, we removed anomalies with wavelengths greater than 500 km from the merged grid to reduce the effects caused by the erroneous long wavelengths and to maintain continuity of anomalies. The correction was accomplished by transforming the merged grid to the frequency domain, filtering the transformed data with a long-wavelength cutoff at 500 km, and subtracting the long-wavelength data grid from the merged grid. Other methods (for example, Ravat and others, 2002) using equivalent sources based on long-wavelength characterization with satellite and national high-altitude data can also help correct for the shifts.

The 500-km low-pass filtered grid was then color-shaded to form the accompanying map. This filtered grid, the merged grid, the equivalent-source corrected grid (Ravat and others, 2002), and all of the correction grids are available with further processing details, along with the individual national grids and digital survey boundary files from GSC *(http://gdcinfo.agg.nrcan.gc.ca/toc.html)*, USGS *(http://crustal.usgs.gov/namad)*, and CRM *(http://www.coremisgm.gob.mx/inicio.html)* websites. In addition, the ASCII data sets for publicly available aeromagnetic surveys for the U.S. are available online or on disk. Digitized data from analog magnetic maps are published by the USGS (1999); digital data from original magnetic flight-line data will be published in late 2002 (information on this data will be available at *http://crustal.usgs.gov/namad*). Metadata files that provide information about the digital data files for each survey are available at the National Geospatial Data Clearinghouse *(http://130.11.52.184/)*.

Utility of the Compilation

Understanding the regional geology of the continent can provide information useful for a wide variety of applications such as mineral and energy resource assessments, earthquake and landslide hazards, and hydrologic and environmental studies. The size of geologic features that can be resolved with magnetic data depends mostly on the flight-line spacing and elevation above the magnetic sources. Only broad, regional magnetic sources such as batholiths (> 3 km wide) can be resolved with coarsely spaced (> 3 km) surveys, while fine-scale features (< 1 km wide), such as shallow dikes, faults, and folds, can be resolved with closely spaced (< 500 m), low-altitude (< 500 m above terrain) data. Case studies illustrating the utility of various high-resolution surveys (< 800 m line spacing) contained in the upgraded North American Magnetic Anomaly map are available at *http://crustal.cr.usgs.gov/namad*.

29 Future Updates

Low-Altitude Data

The GSC is currently undertaking aeromagnetic surveys in several parts of Canada. Some of this data acquisition fills in gaps in the national coverage, while other detailed surveys will provide higher resolution data over areas previously flown. Even though the present coverage of Canada appears nearly complete, many areas comprise either surveys flown with widely spaced flight lines (as much as 6 km) or data donated as grids for which data quality is difficult to assess.

The current upgraded database of the U.S. still contains major problems due to poor data resolution related to wide flight-line spacing and high flight altitudes (as highlighted by U.S. Magnetic Anomaly Data Set Task Group, 1994). Many existing aeromagnetic surveys in the U.S. are not sufficiently detailed to resolve important geologic features or to merge with higher resolution data from Canada and Mexico. Data collected over a large part of the U.S. do not adequately define three-dimensional sources shallower than several kilometers primarily because of large distances between flight lines. Approximately 90,000 line-km of new data are being collected annually by the USGS. Continued collection of new low-altitude data will be required to produce a more consistent U.S. Magnetic Anomaly map.

For Mexico, CRM will continue flying magnetic surveys to complete the national magnetic database, and they will fly higher resolution surveys for mining resource exploration as well as hazard and environmental assessments.

High-Altitude Data

Although corrections for long-wavelength inaccuracy in the merged magnetic compilation have been made (as described previously), our understanding of the sources of error, particularly in the 150–500 km range, is incomplete. In order to measure anomalies in this wavelength range, consistent magnetic anomaly data must be collected at a high altitude (between 15 and 22 km, with equivalent line-spacing) over North America (National Research Council, 1993; U.S. Magnetic Anomaly Data Task Group, 1994). A high-altitude aeromagnetic data set over North America and adjacent offshore regions would serve two important purposes: one, it would allow the study of long-wavelength magnetic anomalies, which provide insights in the tectonic assemblages and regional physical properties of the crust and upper mantle; two, it would provide a consistent, continental-wide datum that can be used to eliminate the datum shifts and long-wavelength errors in the merged grid. Such an accurate continent-wide datum will improve the continuity of magnetic signatures and, therefore, the validity of the magnetic interpretation that is vital to regional geological mapping.

There are many geologic and geomagnetic applications of a high-altitude aeromagnetic survey, including but not limited to:

- Increased understanding of the global geomagnetic field
- A better reference field for merging aeromagnetic surveys
- A better understanding of core/crust separation
- Improved magnetic charts
- Applications to geology and tectonics
- A better understanding of the continent/ocean transition
- Application to mega-tectonic problems
- A view of the broad characteristics of the Curie-temperature isotherm
- Understanding the nature of crust and mantle magnetization
- Information concerning long-wavelength crustal anomalies
- Mineralogical implications of deep crustal and mantle magnetization
- Social and environmental issues
- Regional controls on mineralization
- Regional aspects of geologic hazards
- Constraints on basin evolution

Acknowledgments

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Selected References

Committee for the Magnetic Anomaly Map of North America, 1987, Magnetic Anomaly map of North America: Geological Society of America Continent-Scale Map–003, scale 1:5,000,000.

Cordell, L.E., 1992, A scattered equivalent-source method for interpolation and gridding of potential-field data in three dimensions: Geophysics, v. 57, p. 629–636.

Dods, S.D., Teskey, D.J., and Hood, P.J., 1987, Magnetic Anomaly Map of Canada: fifth edition, Geological Survey of Canada Map 1255A, scale 1:5,000,000.

Finn, C.A., Pilkington, M., Cuevas, A., and Urrutia, J., 2001a, New digital data base helps to map North America: Eos, Transactions of the American Geophysical Union, v. 82, no. 30, p. 325–330.

Finn, C.A., Pilkington, M.A., Cuevas, A., and Urrutia, J., 2001b, New digital magnetic anomaly database for North America: The Leading Edge, v. 20, p. 870–872.

Macnab, R., Verhoef, J., Roest, W., and Arkani-Hamed, J., 1995, New database documents the magnetic character of the Arctic and North Atlantic: Eos, Transactions of the American Geophysical Union, v. 76, p. 449.

National Research Council, 1993, The National Geomagnetic Initiative Report: National Academy Press, Washington D.C., 246 p.

Ravat, D., Whaler, K.A., Pilkington, M., Sabaka, T., and Purucker, M., 2002, Compatibility of high-altitude aeromagnetic and satellite-altitude magnetic anomalies over Canada: Geophysics, v. 67, p. 546–554.

Snyder, J.P., 1987, Map projections—a working manual: U.S. Geological Survey Professional Paper 1395, 383 p.

Teskey, D.J., Hood, P.J., Morley, L.W., Gibb, R.A., Sawatzky, P., Bower, M., and Ready, E.E., 1993, The aeromagnetic survey program of the Geological Survey of Canada: contribution to regional mapping and mineral exploration: Canadian Journal of Earth Sciences, v. 30, p. 243–260.

U.S. Geological Survey, 1999, Digitized aeromagnetic datasets for the conterminous United States, Hawaii, and Puerto Rico: U.S. Geological Survey Open File Report 99–0557, *http://greenwood.cr.usgs.gov/pub/open-file-reports/ofr-99–0557/html/mag_home.htm*

U.S. Magnetic Anomaly Data Set Task Group, 1994, Rationale and operational plan to upgrade the U.S. Magnetic Anomaly data base: National Academy Press, Washington D.C., 25 p.

Zietz, I., 1982, Composite magnetic anomaly map of the United States; Part A, Conterminous United States: U.S. Geological Survey Geophysical Investigations Map GP–954–A, 59 p., 2 sheets, scale 1:2,500,000.

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