U. S. DEPARTMENT OF THE INTERIOR
U. S. GEOLOGICAL SURVEY

REVISED DIGITAL AEROMAGNETIC DATA FOR AREAS IN AND ADJACENT TO THE NATIONAL PETROLEUM RESERVE AREA (NPRA), NORTH SLOPE, ALASKA

by

V. J. S. Grauch[1] and Esther Castellanos[2]

1995

Open-File Report 95-835

[1]USGS Denver CO 80225 [2]Digimap, Inc., 8151 Pecos St., Denver CO 80221

Abstract

Digital aeromagnetic data for areas covering most of the National Petroleum Reserve Area (NPRA) and adjacent areas are publically available as gridded data from the compilation for the Decade of North American Geology (DNAG). These data were originally digitized from a contour map corresponding to aeromagnetic surveys flown in 1945-1946. However, comparisons of the digital data and the original contour map showed discrepancies that required redigitization of the original map. This report (1) summarizes descriptions of the 1945 and 1946 surveys that are not easily available elsewhere; (2) describes the procedure followed to redigitize the original contour map, grid the data, and remove a geomagnetic reference field; and (3) compares the old and new digital data sets as color figures. The revised digital data and a brief summary of the text of this report (without figures) can be downloaded via 'anonymous ftp' from a USGS system named greenwood.cr.usgs.gov (136.177.48.5). The files are located in a directory named /pub/open-file-reports/ofr-95-0835 and are all in ASCII format.

Introduction

Digital aeromagnetic data for the state of Alaska were compiled by Godson (1984; 1985) and later incorporated into the Decade of North American Geologyc (DNAG) data set for North America (Committee for the Magnetic Anomaly Map of North America (1987; digital data available from National Geophysical Data Center, Boulder, Colorado). The portion of that data set covering most of the National Petroleum Reserve Area (NPRA) and adjacent areas was digitized from the original contour map shown in Woolson and others (1962, plate 3), which was constructed from aeromagnetic surveys flown in 1945-1946 (Figure 1). The contour map was hand-drawn at an interval of 10 nanoTeslas (nT) and published at a scale of 1:1,000,000 in Woolson and others (1962) and redrawn using a 25 nT contour interval for smaller-size publication (approximately 1:1,509,000 scale) in Payne and others (1952). It was recently discovered that maps constructed from the digital data did not satisfactorily match the original contour maps. The problem is not that noticeable in the Alaska nor DNAG compilations because they were prepared at a scale of 1:2,500,000 with contour intervals of 200 nanoTeslas.

The discreprencies between the digital data and the original contour map required redigitization of the original hand-drawn contour map. This also provided the opportunity to correct the data using a more up-to-date geomagnetic reference field. An original contour map at 1:500,000 scale and two obscure reports that document the original aeromagnetic surveys were recovered from USGS files to accomplish these tasks. The two reports (Walton and others, 1954; Keller and Henderson, 1954) were released as Open-File Reports in 1954, but they actually date from 1946 and 1947, respectively. However, neither of these reports are currently available from USGS Open-File Services nor at USGS libraries. Moreover, no later publication describes how the surveys were conducted in adequate detail. For these reasons, descriptions of the data acquisition are summarized below from these two reports. The reports also include some analysis of specific magnetic anomalies that will not be repeated here because the analyses do not reflect current geophysical or geologic knowledge.

Survey Descriptions

The aeromagnetic survey flown in 1945 is reported in detail in Walton and others (1954); both the 1945 survey and the one flown in 1946 are described in Keller and Henderson (1954).

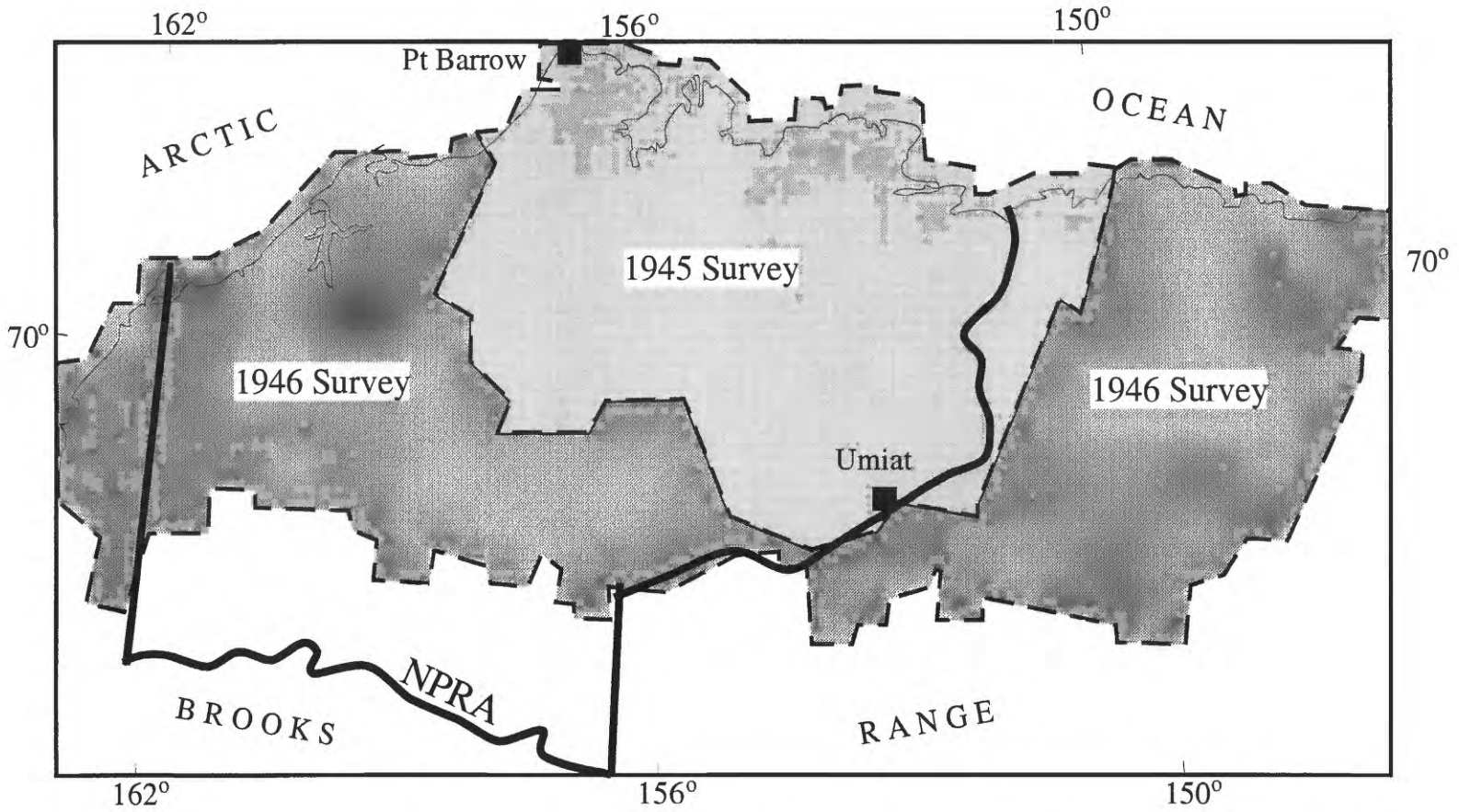

Figure 1.--Index map showing locations of national petroleum Reserve Area (NPRA), North Slope, Alaska, and the 1945 and 1946 aeromagnetic survey areas.

The following paragraphs summarize these reports and the captions placed on the original contour map recovered from USGS files.

In 1945, an aeromagnetic survey over the northern and eastern portions of NPRA, which was then called Naval Petroleum Reserve No. 4, was conducted during the period July 24 through September 14 (Figure 1). In 1946, during the period June 11 to August 4, the survey area was extended primarily to the west and east, but also to the south (Figure 1). Both surveys were flown by the USGS in cooperation with the U.S. Navy along lines trending about N30°E at nominal 1000-foot (305 m) terrain clearance using a PBY-5A fixed-wing airplane. Lines were spaced 2 miles apart for the 1945 survey and 4 miles apart for the 1946 survey.

Lines were flown with the aid of air photos taken in 1943 and followed by sight and compass heading. Vertical positioning was monitored by radar altimeter. Final horizontal positions were determined by marking fiducial points from the air photos onto the magnetometer strip record and the camera strip film. Locations in between the fiducial points were interpolated. Final locations of the lines were transferred to photogrammetric base maps available at 1:200,000-scale for the area flown in1945 and at 1:500,000 scale for the area flown in 1946. Walton and others (1954) note two areas where the 1:200,000-scale base map was inaccurate. One area was along the Arctic coast southward for 10 to 20 miles and the other was a belt about 20 miles wide extending about 100 miles N80°W from the confluence of the Colville and Anaktuvuk Rivers. Keller and Henderson (1954) estimate that inaccuracies in the base map for the 1946 survey may result in 2 to 3 miles of error in the locations of magnetic anomalies.

The plane towed a bird on a 100-foot long cable that contained a self-orienting fluxgate magnetometer (Balsley, 1952). This setup measured total-field intensity with an overall estimated sensivity of well within 2 or 3 nT for the entire NPRA survey. Short-period temporal variations of the magnetic field were monitored using a magnetometer stationed at Point Barrow during the surveys. Flying was halted if magnetic field variations at Point Barrow exceeded an arbitrary limit of 25-30 nT within 15 minutes or less. This resulted in considerable down-time during July 1946, when magnetic disturbances from auroral activity were exteme.

Temporal variations occuring over a period longer than 15 minutes were corrected by adjusting the flight-line data to fit a base-line survey. The base-line survey consisted of seven approximately east-west lines about 20 miles apart with several north-south tie lines. (It took about 15 minutes to fly between base lines, hence the use of 15-minute periods to determine when temporal variations could not be corrected by the base lines and flying should cease.) Each base line was flown across and back in one uninterrupted flight. Magnetic values during the flight were assumed to vary linearly with time and were determined from the difference in values at the point where the flight began and ended. These differences ranged from 10 to 30 nT for 200 miles of flight, which was considered to be very precise for the time. The linear temporal variation was then removed from the base line values in order to isolate the magnetic field variations dependent solely on horizontal distance. The corrected base-line data were then used to adjust the values of the survey flight lines so that values of both lines matched at each intersection. Flight lines and base lines from the perimeters of the 1945 survey were reflown during the 1946 survey in order to tie the two surveys together.

Finally, an arbitrary datum was removed from the data; no attempt was made to remove a geomagnetic regional field. Walton and others (1954) estimated that an approximate value for absolute magnetic intensity at any point could be obtained by adding a value of about 56,000 nT to the residual values.

Revision Procedure

To obtain the revised digital data, magnetic values were digitized from a hand-drawn contour map of the 1945 and 1946 surveys at 1:500,000 scale that was retreived from files at the USGS. This map is the same as is presented at 1:1,000,000 scale in Woolson and others (1962; plate 3) except that it also includes flight line locations and measured maximum and minimum values marked within contour closures. Points were digitized where the flight lines crossed contour lines and at the maximum and minimum points. Flight-line locations can thus be ascertained by plotting the locations of the digitized points. Values were only digitized partway into areas where the map shows dashed contour lines.

The digitized points were edited, then projected from latitude/longitude locations (in decimal degrees, negative for west longitude) into x/y coordinates (kilometers) using an Albers equal area conic map projection, with standard parallels of 55°N and 65°N, central meridian of 159°W, and base latitude 0°. These values were then interpolated onto a regular grid with an interval of 1.6 km (1 mile) using a minimum curvature algorithm (Webring, 1981). To compensate for the arbitrary datum removed from the original contour values, a constant of 56000, as suggested by Walton and others (1954), was added to the residual magnetic values.

The geomagnetic regional field was removed by separately determining the Definitive Geomagnetic Reference Field (DGRF; Langel, 1988) for the two survey areas. First, the corners of a polygon that encloses the area of the 1945 survey were determined and used to separate the grid constructed from all the digitized points into two pieces: a grid of data only from the 1945 survey, and one for the 1946 survey. Values of the DGRF at 355 m elevation for times about midway during the flying times of the surveys were constructed using the computer program of Sweeney (1990): Julian days of 227 (mid-August) and 197 (mid-July) for the 1945 and 1946 surveys, respectively. Grids of the DGRF at these times were removed from the respective survey pieces, then the residual values of the two pieces were combined back into one grid.

Improvement in the Digital Data

Figure 2 shows the 25-nT-interval contour aeromagnetic map taken from Payne and others (1952) reduced to page size for comparison purposes only. Compare the contour map to Figure 3, which is a color shaded-relief image of digital data extracted for NPRA from the compilation for Alaska by Godson (1984; 1985). The original grid had an interval of 2 km, and the data were intended for use at a color interval of 200 nT, whereas the present figure shows the data at an interval of 25 nT and enhances short-wavelength features with the shading. Nevertheless, the match between the digital data shown in Figure 3 compared to the contour map of Figure 2, from which the digital data were derived, is not satisfactory. Some anomalies seem to be missing in the digital data and some of the positive anomalies have artificial negative anomalies surrounding them or concave shapes near the peaks, reminiscent of a caldera at the top of a volcano. These errors could have arisen due to improper digitizing of contour values, digitizing too few points combined with gridding at too fine an interval, or both.

Figure 4 shows an image of the revised digital data, using the same color interval and illumination direction as in Figure 3. The revised data have greater resemblence to the original contour map (Figure 2). Some discrepancies may be due to differences in data interpolation between hand-contouring and the minimum-curvature gridding algorithm.

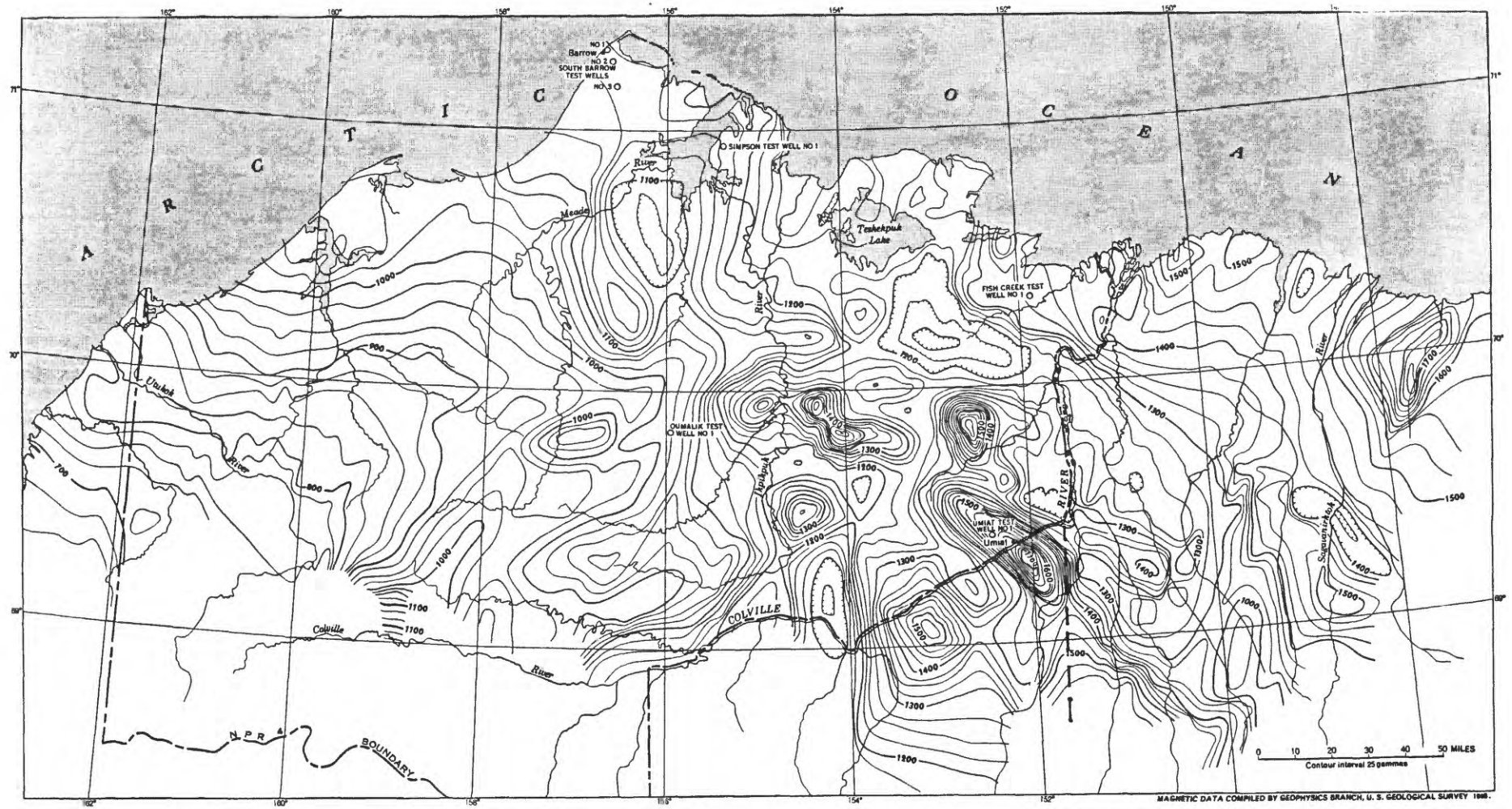

Figure 2.--Contour map of the 1945 and 1946 aeromagnetic data from Payne and others (1952) that was redrawn from the original 10-nT contour map. Note that the area southeast of the Colville River and west of about 151°30'W (heavy dashed line) was noted on the original map (shown on Woolson and others, 1962) as lacking good flight line control.

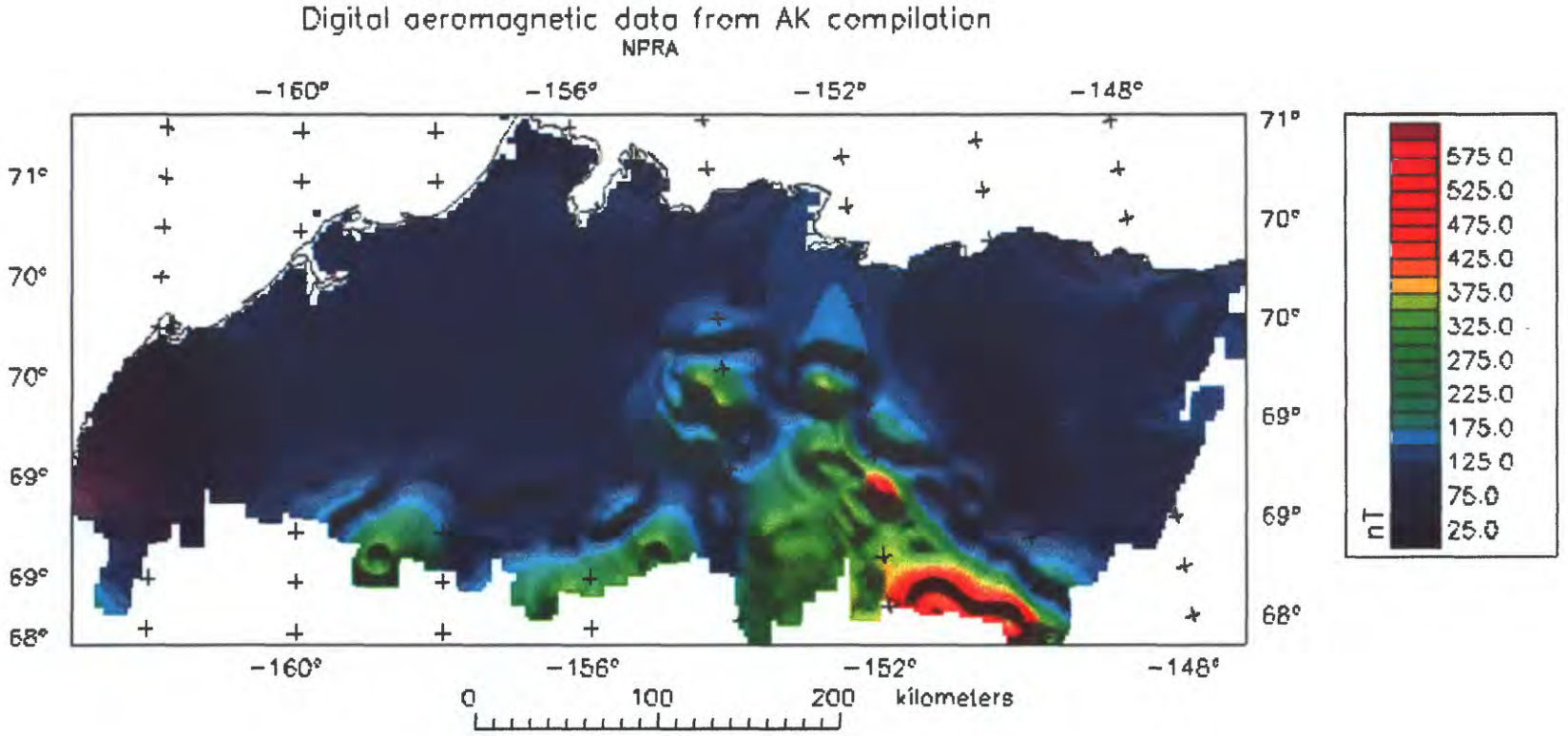

Figure 3.--Color shaded-relief image of digital data extracted from the compilation of Alaska by Godson (1984; 1985), with illumination from the north. These data are also contained in the DNAG North America compilation (Committee for the Magnetic Anomaly Map of North America, 1987). The data were originally intended for use at an interval of 200 nT and scale of 1:2,500,000. Note the discrepancies with the hand-drawn contour map (fig. 2).

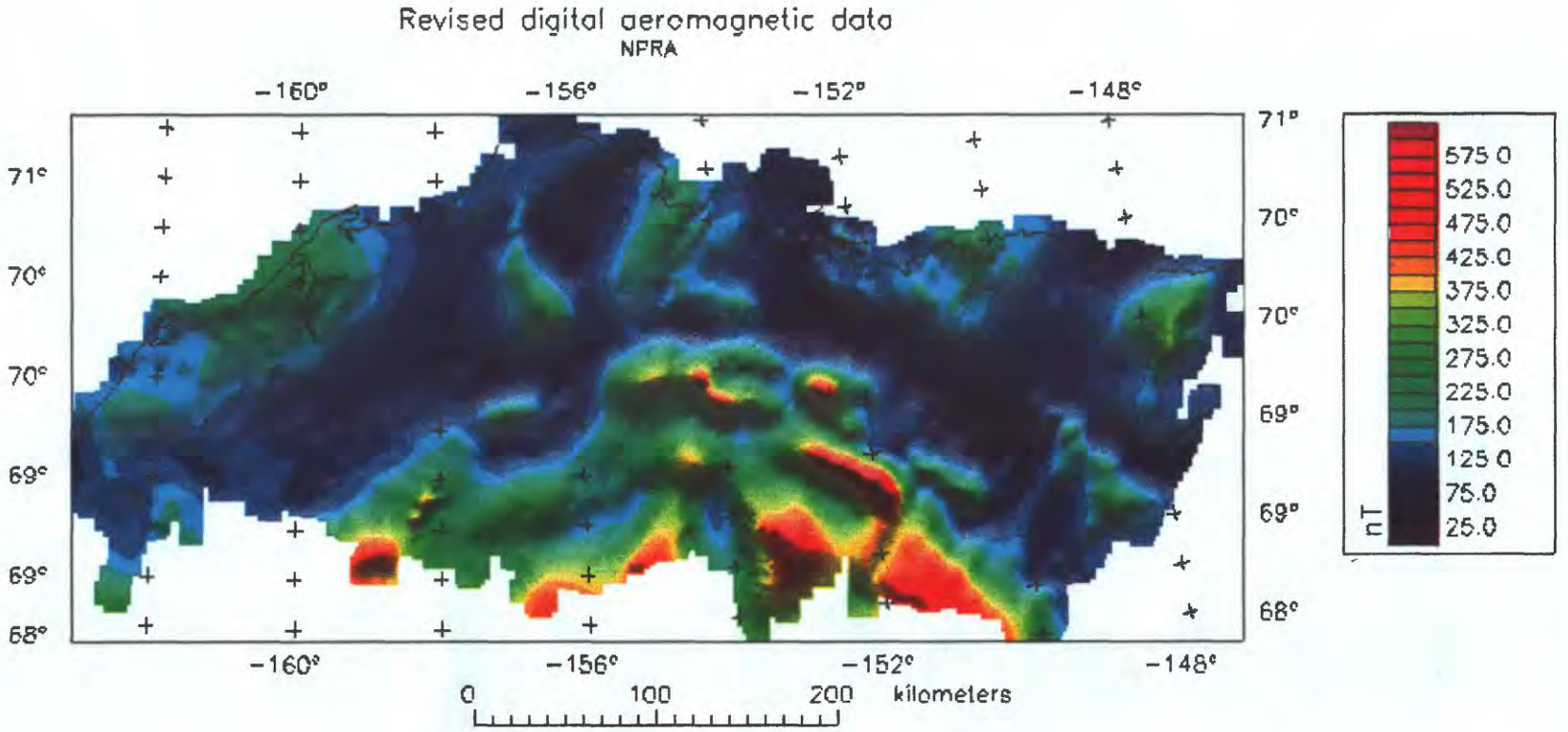

Figure 4.--Color shaded-relief image of revised digital data after redigitization and removal of the DGRF using same interval and illumination as Figure 3. Note the improvement from Figure 3 in comparison to the hand-drawn contour map (fig. 2).

Digital File Descriptions

Table 1 indicates the names of the digital files available for this release, the format of the files, and a brief description of their contents. The data format for grids is explained more thoroughly below.

The revised digital data and a brief summary of the text of this report (without figures) can be downloaded via 'anonymous ftp' from a USGS system named greenwood.cr.usgs.gov (136.177.48.5). The files are located in a directory named /pub/open-file-reports/ofr-95-0835 and are all in ASCII format.

Table 1. File Descriptions

FILE NAME	FILE TYPE	DESCRIPTION
nprapts.asc	ascii x, y, z (3f18.6)	Longitude (degrees), latitude (degrees) and magnetic field value (nT) of digitized points from original contour map of 1945 and 1946 surveys
nprapts.prj	ascii x, y, z (3f18.6)	Projected x (km), y (km), and magnetic field value (nT) of digitized points, projected using Albers equal area conic map projection, with standard parallels of 55°N and 65°N, central meridian of 159°W, and base latitude 0°.
nprapoly.asc	ascii x, y, z (free format)	Projected x, y values of a polygon that encloses the 1945 survey area
nprares.agd	ascii grid*	Gridded values of residual total-field intensity, after removing DGRF separately for 1945 and 1946 surveys, then merging back together
npraold.agd	ascii grid*	Gridded values extracted from the earlier Alaska digital compilation
readme.txt	ascii text	A file containing the text of this report, without figures.

*format described below

Ascii Grid Format Description

The USGS standard grid consists of a header record followed by one record for each row of data. The origin of the grid is the lower left-hand corner. Each row is read from left to right (usually west to east) and rows are read sequentially from bottom to top (usually south to north). Note that parameters xo, dx, yo, and dy must all have the same distance units, usually kilometers for grids using a map projection. Standard grids are binary files, but the two grid files in this release are in an ascii format for ease of transfer. The following describes the parameters contained in the header and data records of the ascii grid files.

A. Header record

```
id -    56 ASCII characters of identification
pgm -  8 ASCII characters of creation program identification
  (2 words)
ncol - number of columns of data (integer, 1 word) in each
  row
nrow - number of rows of data (integer, 1 word)
nz -    number of words per data element (integer, 1 word).
  In this case nz is always 1.
xo -  position coordinate of first (leftmost) column of data
  (real, 1 word)
dx -  equal spacing interval between columns (real, 1 word).
yo -  position coordinate of first (bottom) row of data
  (real, 1 word)
dy -   equal spacing interval between rows (real, 1 word).
```

B. Data record. Each data record contains one row of real data. The first word should contain the row coordinate, but in most programs this coordinate value is ignored. Record length is (ncol*nz)+1 words. To flag grid points where there are no data, the values are set to a large number, usually greater than or equal to 1.e+38. These values are called "dvals".

FORTRAN code to access the ASCII grids and put them into binary format is listed below. The binary write statements in this program can be modified to output the grid in any format.

```
c
c     ASCII2SF  -ascii to binary standard grid
c
c Note:  the maxcol parameter can be changed to reflect the
c maximum no. of grid columns allowed
c
      parameter (maxcol=10000)
      character*50 infile,outfile
      character*56 id,pgm*8
      dimension data(maxcol)
      write(6, 800)
800   format(' 80 column ascii to standard binary grid',/
     1 'Name of ascii input grid?')
      read (5,100)infile
 100  format(a50)
      write(6,801)
801   format(' Name of binary output grid')
      read(5,100)outfile
c
      open(10,file=infile,form='formatted',status='old')
      open(11,file=outfile,form='unformatted',status='unknown')
c
      read(10,110,err=1301,end=1302)id,pgm,ncol,nrow
  110 format(a56,a8,2i8)
```

```
      read(10,120,err=1301,end=1302)nz,xo,dx,yo,dy
  120 format(i2,4e18.8)
      write(11)id,pgm,ncol,nrow,nz,xo,dx,yo,dy
      write(6,130)id,pgm,ncol,nrow,nz,xo,dx,yo,dy
  130 format(1x,a56,a8,/,1x,'ncol=',i8,' nrow=',i8,' nz='
     1,i3,' xo=',e16.8,' dx=',e16.8,/,1x,'yo=',e16.8,'
     2 dy=',e16.8)
c
      do 10 irow=1,nrow
      do 20 j=1,ncol+1,5
   20 if (inarow(data(j)).ne.0) go to 1303
   10 call outbrow(ncol+1,data)
      write(6,803)
803   format(' All done')
      close(10)
      close(11)
      stop
c
c     error exits
c
 1301 write(6,804)
804   format(' Error reading header information')
      stop
c
 1302 write(6,805)
805   format(' End of file while reading header information')
      stop
c
 1303 write(6,806),irow
806   format(' Error while reading row',i5,' of input grid')
      stop
      end
c
c     INAROW - INput Ascii ROW
c
      integer function inarow(data)
      dimension data(5)
      read(10,100,err=99,end=99)data
  100 format(5e16.9)
      inarow=0
      return
c
   99 inarow=-1
      return
      end
c
c     OUTBROW - OUTput Binary ROW
c
      subroutine outbrow(idim,data)
      dimension data(idim)
```

```
write(11) data
return
end
```

References Cited

Balsley, J. R., 1952, Aeromagnetic Surveying, **in** Landsberg, H. E., Ed., Advances in Geophysics vol. 1: Academic Press, New York, N.Y., p. 313-350.

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.

Godson, R. H., compiler, 1984, Composite magnetic anomaly map of the United States, Part B--Alaska and Hawaii: U. S. Geological Survey Geophysical Investigations Map GP-954B, scale 1:2,500,000.

Godson, R. H., 1985, Preparation of magnetic anomaly maps of Alaska and Hawaii, **in** Hinze, W. J., ed., The utility of regional gravity and magnetic anomaly maps: Society of Exploration Geophysicists, Tulsa, Oklahoma, p. 25-32.

Keller, Fred, Jr., and Henderson, John, Jr., 1954, Aeromagnetic survey of Naval Petroleum Reserve No. 4 and adjacent areas: U. S. Geological Survey Open-File Report 54-144, 1 plate, 20 p.

Langel, R. A., 1988, International Geomagnetic Reference Field revision 1987: Eos, Transactions, American Geophysical Union, v. 69, no. 17, p. 557-558.

Payne, T. G. and others, 1952, Geology of the Arctic slope of Alaska: U. S. Geological Survey Oil and Gas Investigations Map OM-126, scale variable.

Sweeney, R. E., 1990, IGRFGRID: A program for creation of a total magnetic field grid representing the Earth's main magnetic field: U. S. Geological Survey Open-File Report 90-45, 39 p.

Walton, M. S., Jr., Rossman, D. L., Hill, M. E., and Balsley, J. R., Jr., 1954, Magnetic survey of part of Naval Petroleum Reserve No. 4 by airborne magnetometer: U. S. Geological Survey Open-File Report 54-327, 20 p.

Webring, Michael, 1981, MINC: A gridding program based on minimum curvature: U. S. Geological Survey Open-File Report 81-1224, 41 p.

Woolson, J. R. and others, 1962, Seismic and gravity surveys of Naval Petroleum Reserve No. 4 and adjoining areas, Alaska: U. S. Geological Survey Professional Paper 304-A, 19 plates, 25 p.