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Residual Total Field Magnetic Anomaly Map of NOARL's Magnetic Observatory

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ABSTRACT

The purpose of this survey is to create an accurate residual magnetic contour map of the Magnetic Observatory area at Stennis Space Center. Measurements were completed covering the observatory grounds. A map of the magnetic residuals is presented.

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RESIDUAL TOTAL FIELD MAGNETIC ANOMALY MAP OF NOARL'S MAGNETIC OBSERVATORY

HISTORY

Conducting magnetic measurements of the natural earth magnetic field variations with state-of-the-art superconducting quantum interference device (SQUID) gradiometers/magnetometers must be done in a magnetically quiet environment. To provide this ideal environment, the Naval Oceanographic and Atmospheric Research Laboratory (NOARL) constructed a magnetic observatory at an isolated location at Stennis Space Center, MS.

Both the isolated location of the building and its wooden superstructure contribute to the magnetically quiet environment necessary to conduct these magnetic measurements. Additional phenomena, such as telluric potentials and magnetotelluric sounding have also been investigated at the observatory site. These measurements are conducted to support the Navy's mapping, charting, and geodesy program in basic research.

The facility also supports other research programs. Some of the programs include: airborne electromagnetic bathymetry measurements, global magnetic modeling, antisubmarine warfare, and Magnetic Anomaly Detection (MAD) (Smits and Barker, 1986).

The U.S. Geological Survey (USGS) Global Seismology and Geomagnetism Division in a joint effort with the Navy has installed recording equipment at the NOARL Magnetic Observatory (NMO) establishing it as the 13th station in their network. NOARL's observatory is conveniently located to fill a gap in the world data network for this portion of the U.S. Figure A indicates the location of current magnetic observatories and magnetic variation stations for North and Central America.

NMO contributes magnetic field data from two types of magnetometers: a ring core fluxgate magnetometer (maintained by NOARL), which is part of the Geoelectric/Geomagnetic Variability (GEO/GEO) project, and a proton precession scalar magnetometer (maintained by the USGS). Data from the two magnetometers is accessed by the USGS data recording system. The USGS handles all reformatting of the data recorded by the system, and the data storage at the World Data Center A in Boulder, Colorado.

The observatory equipment at NMO is designed to operate with minimal maintenance. Maintenance consist of periodic system status checks by NOARL personnel and regular accessing at least 3 times a week by USGS personnel via a telephone modem system (Avera et al., 1986).

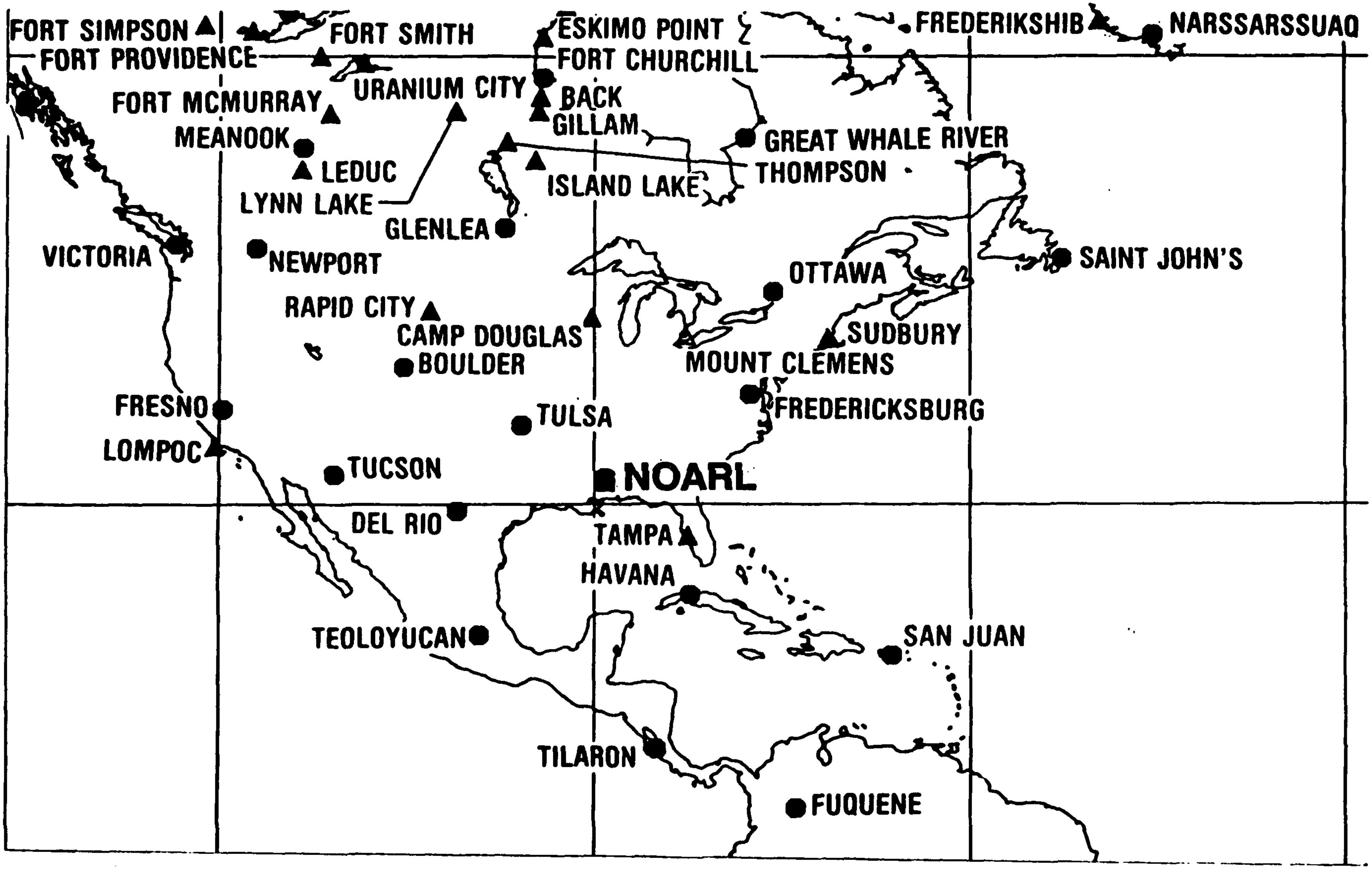

Figure A. Map of all Magnetic Observatories in operation for North and Central America.

INSTRUMENTATION

The instrument used in this survey is the GSM-10. The GSM-10 is a portable Overhauser proton precession magnetometer with a built in microprocessor and memory, enabling complete field data storage and retrieval. Other capabilities include automatic diurnal corrections, printouts of corrected or raw data, and easy interfacing with other data processing systems. Development and manufacturing of the GSM-10 is by GEM Systems, Inc. of Ontario, Canada.

The GSM-10 has a basic resolution of 0.1γ. Operations of the GSM-10 used for magnetic field measurements are listed below:

A. Polarization: An R.F. current is passed through the sensor creating polarization of a proton-rich fluid in the sensor.

B. Deflection: A short pulse (35 μsec) deflects the proton magnetization into the plane of precession.

C. Pause: The pause allows the transients to die off, leaving a slowly decaying proton precession signal above the noise level.

D. Frequency Measurement: The average period of the precession frequency is measured, and then converted into a magnetic field value.

Specifications:

Resolution: 0.1γ.
Accuracy: 0.2γ over operating range.
Range: 20,000 to 100,000γ 70 overlapping steps automatic tuning, requiring initial setup.
Gradient tolerance: up to 5000 γ/meter.
Operating modes:
- Base Station: 7,330 reading (14,770 or 22,220 reading optional).
- Mobile Unit: 2,710 reading (5,350 or 8,060 reading optional).

Instrument Description:

The sensor is a dual coil type designed to reduce noise and improve gradient tolerance. The coils are electrostatically shielded and contain a proton-rich fluid in a pyrex bottle—R.F. resonator. The sensor is connected to the control electronics by a flexible coaxial cable, and attaches to a long staff. The staff is made of a strong aluminum tubing in four sections. This construction allows for a selection of sensor elevations above ground during surveys. A battery pack of 12 V 2.6 Ah lead acid batteries provide sufficient power for more than a full day of surveying under the worst conditions.

The Overhauser Effect:

In contrast to a standard proton magnetometer sensor where only proton-rich fluid is required to produce the precession signal, the Overhauser Effect sensor must also have a free radical added to the liquid. The free radical ensures presence of free unbound electrons that couple with protons producing a two-spin system. A strong R.F. magnetic field is used to disturb the electron-proton coupling. The Overhauser Effect offers a more powerful method of proton polarization than standard DC polarization units. That is, stronger signals are achieved from smaller sensors and with less power.

The ACI-18 Interface converts the raw data acquired by the GSM-10 into ASCII for processing (GSM-10, 1987). Data acquisition and processing needs to be highly mobile therefore the data processing program was written in Turbo Basic for any IBM compatible PC. For the purpose of this project the data processing will be completed on a Zenith personal computer (Z-248). The program listed in Appendix A was used to process the data acquired, and the results were used to produce the magnetic anomaly map of the observatory.

PROCEDURE

The procedure for making a magnetic anomaly map is to first create a base map of the area by the Pace and Compass method. The Pace and Compass method requires first establishing a standard pace distance. Next it is necessary to select the location of the base station and the interval spacing for the measurement stations. A line and station number are assigned to each station to identify the station location. All ferromagnetic objects must be removed from personnel (i.e., jewelry) before measurements begin. According to the GSM-10 operating manual, these objects may impair the quality of measurements or in drastic cases even destroy the proton precession signal by creating excessive gradients.

The data are analyzed to remove Diurnal Variations of the geomagnetic field. The GSM-10 will calculate an exact diurnal correction only if a second instrument of the exact type is used, consequently the diurnal variations will be computed using an approximation method on the Z-248 computer. After making the diurnal corrections the data are posted on the base map and contoured.

DIURNAL VARIATION

The Diurnal Variation is the daily magnetic variation in the earth's magnetic field. To correct for this change it is necessary to measure the amount of field variation at the base station during the survey. Base station measurements were made at the beginning and end of each line. Station measurements along the line are time tagged by the GSM-10. From the time tags, the base measurements can be interpolated to correspond to the time of each station measurement for making the diurnal corrections to the station measurements. Measurement corrections were

$$M_{corrt} = M_{st} - M_{bt}$$

M_{corrt} is the corrected residual magnetic field measurement of time, M_{st} is the station measurement, and M_{bt} is the interpolated base station value for time t.

$$M_{bt} = [M_{bt(i+1)} - M_{bt(i)}/t_{(i+1)} - t_{(i)}](t - t_{(i)}) + M_{bt(i)}$$

where $t_{(i+1)} > t > t_i$.

RESULTS

The map was made in two phases. The first phase was to map the immediate area around the observatory buildings with a detailed survey, and the second phase was mapping the outer lying area with a more regional survey. Both phases followed the same procedure with only slight variation in the second phase. Initially a base station and the lines to be measured were chosen. The base station is located 12 m bearing 48° northwest (with respect to Magnetic North) from the corner of the patio and building 2437. Magnetic North has a declination of approximately 3° east of true north at this location. The base station was chosen at this location because this area was thought to have a low magnetic gradient and to be easily accessed. In the first phase there are nine lines, four running parallel to building 2437 (L6, L7, L2, L8) and four running perpendicular to building 2437 (L4, L1, L5, L9), the ninth line is in the direction of Magnetic North (L3). Figure B indicates the line locations on the map with respect to the buildings. The total area surveyed in the first phase is 516.75 m^2. In the second phase 15 lines were added giving a total of 23 lines for the survey. The lines in the second phase were chosen to ensure an even distribution of data surrounding the Magnetic Observatory. Marking the outside parameter of the survey area are lines LR5, LR3, LR9, LR7, LR8, LR11, and LR5. Lines LR4, LR10, LR6, LR1, LR2, and LR15 radiate out to the parameter along convenient path or trails. Several additional lines were added to fill in the sparse places (LR12, LR13, and LR14). The total area including the first and second phase is 5394.0 m^2 with each station measurement 3 m apart.

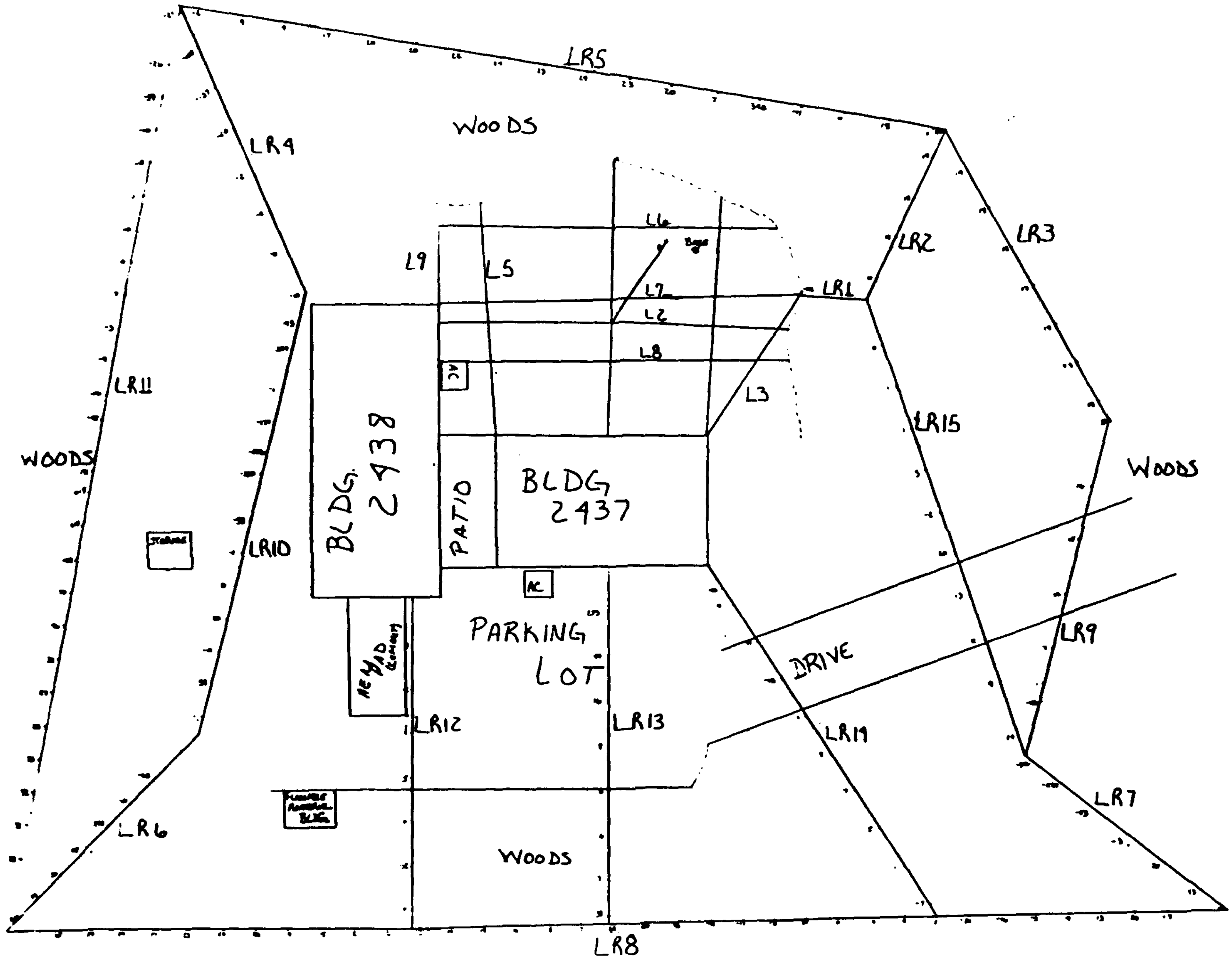

Figure B. Line locations used in survey.

From the Residual Total Field Magnetic Anomaly Map shown in figure C the primary trend of the residual magnetic field is in a north-south direction. Anomalies located near the building are most likely a result of the electricity flowing through the buildings and the metal from air conditioners or other peripheral structures. The survey was conducted during normal working hours with the electricity in the buildings left on. However, the air conditioners were turned off during the measurements.

Power lines running parallel to line LR4 connecting the NMO to the main power supply can be correlated to a strong anomaly located along this line. Likewise, an anomaly located on the center of line LR11 is associated with a pump and air conditioning unit located immediately behind the storage shed. The anomaly extending over lines LR10 and LR11 located beside building 2438 is produced by the building and surroundings power lines. Line LR6 and the bottom of line LR12 show a bulls-eye that are also related to man-made surface features. The bulls-eye on line LR12 and LR6 are related to the flammable material building, although this building is made primarily of nonmagnetic materials including an aluminum door and roof. The presence of buildings and other man-made structures clearly affect the magnetic field indicating that these structures are not totally nonmagnetic. The metal air conditioner used to cool building 2437 located on the south side of the building in the parking lot produces a major high on the map as might be expected. Another large anomaly located in the southeast corner of the map on line LR7 and extending to the drive can be related to the instrument trailer located beside line LR7 made of steel sheet metal over a steel beam frame. There are two anomalies on the map that do not have obvious man-made structures to affect the field. These two anomalies are located in the middle of line LR8 and the right-hand corner of line LR5. They are most likely associated with some type of buried objects from previous human occupation of the area. The strongest anomaly on the map is in the yard area behind the buildings. It is most clearly observed cutting across line L5, and is most likely resulting from the three transformers located on a power pole positioned directly above this line.

In summary, the map indicates an overall regional north-south trend in the direction of the residual magnetic field. Buildings and other man-made structures can be related to the majority of perturbations in the regional trend. Effects from these structures can be observed out to as much as 17 m from the buildings. Only two anomalies on the map are identified that do not have a direct relationship with existing man-made structures.

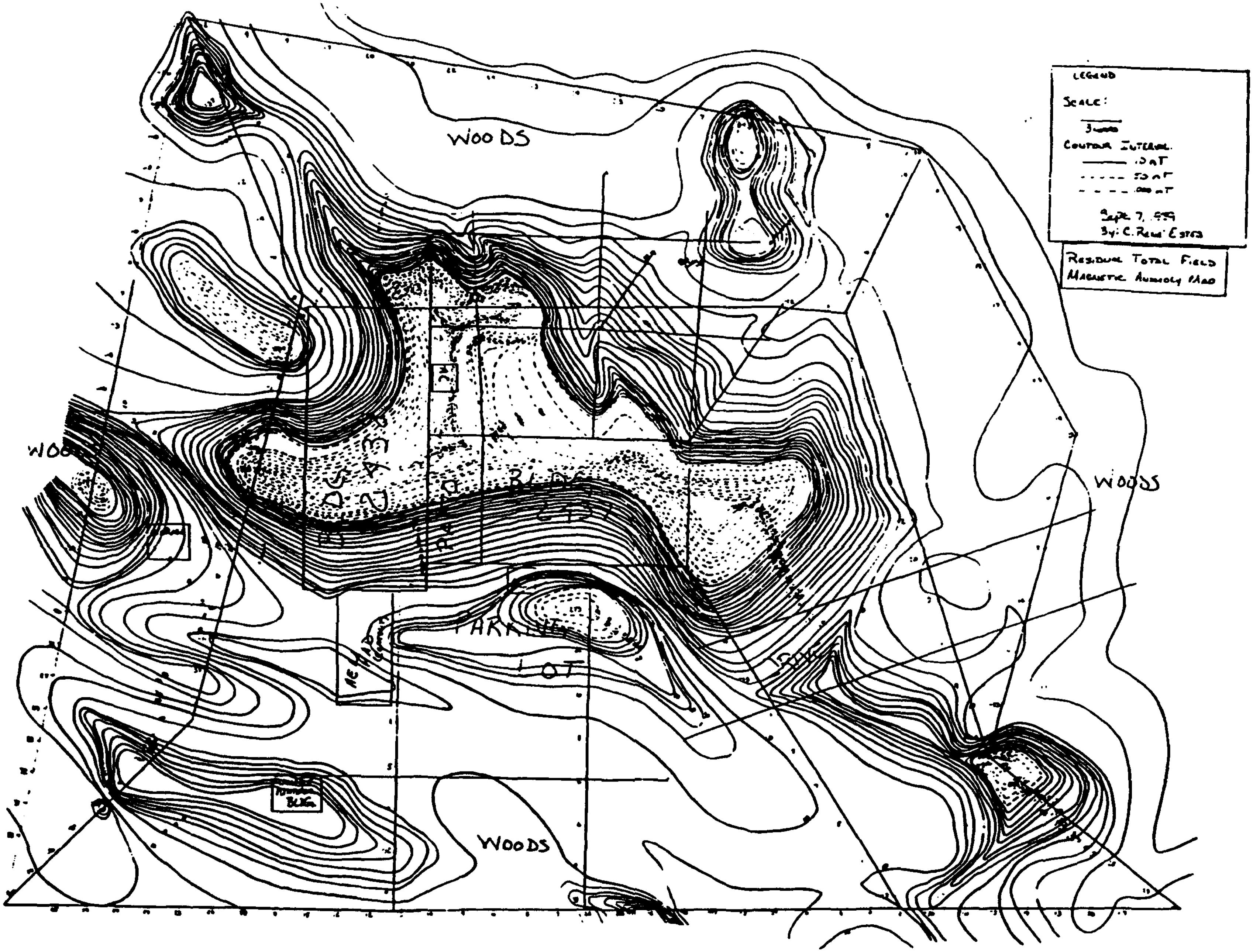

Figure C. Residual total field magnetic anomaly map.

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Smits, K. and F. Slade Barker (1986). The NORDA Review, March 31, 1976 - March 31, 1986. Naval Ocean Research and Development Activity, Stennis Space Center, MS.

Avera, William E., K. Smits, Edward C. Mozely, and G. Daniel Hickman (1986). Geoelectric/Geomagnetic Research at the NORDA Magnetic Observatory. Naval Ocean Research and Development Activity, Stennis Space Center, MS, NORDA Report 167.

GSM-10 Overhauser Magnetometer Instruction Manual (1987). GEM System, Inc.

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REM       APPENDIX  A:  Data Processing Program

***********************GSMTST.BAS******************************
REM VERSION 1.0 6/22/89
REM THE PURPOSE OF THIS PROGRAM IS TO TRANSFER DATA AQUIRED FROM
REM MAGNETOMETERS CAPABLE OF STORING DATA AND PROCESSING
REM BY THE DIURNAL CORRECTION METHOD.
REM
REM THIS PROGRAM AUTOMATICALY PRINTS OUT FORMATTED DATA.
REM IQ = MAX STATION DATA VALUES READ IN. I IS DECREASED BY 1
REM (CON'T) TO TAKE OFF THE EXTRA PASS THROUGH THE DATA SECTION
REM (CON'T) WHEN THE LINE INPUT READS THE END OF FILE.
REM I COUNTS FOR PERIPHERIAL STATIONS
REM J COUNTS FOR BASE STATION
REM BSL = BASE LINE VALUE
REM HH = HOURS
REM MM = MINUTES
REM SS = SECONDS
REM
REM ***************BASE STATION***************
REM BSTATION(J) = BASE STATION NUMBER
REM BLIN(J) = BASE STATION LINE NUMBER
REM BTIM(J) = BASE STATION TIME IN HRS, MIN, AND SECONDS
REM BT(J) = BASE STATION TIME IN SECONDS
REM BDAT(J) = BASE STATION VALUE
REM
REM ************PERPHERIAL STATION*************
REM STATION(I) = STATION NUMBER
REM LIN(I) = LINE NUMBER ON STATION
REM TIM(I) = STATION TIME IN HRS, MIN, AND SECONDS
REM ST(I) = STATION TIME IN SECONDS
REM DAT(I) = STATION VALUE
REM X = DIURNAL CORRECTION
REM RESD(I) = RESIDUAL
REM +++++++++++++++++++++++++NOTE+++++++++++++++++++++++++++++++
REM DON'T FORGET TO DELETE HEADER FROM RAW DATA FILE RECIEVED
REM    FROM GSM-10.
REM +++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
REM
REM
OPTION BASE 1
  DIM STATION$(250), LIN$(250), TIM$(250)
  DIM BSTATION$(250), BLIN$(250), BTIM$(250)
  DIM DAT(250), BDAT(250), ST(250), BT(250)
  DIM RESD(250)
REM
  INPUT "FILENAME ",FLN$
  OPEN FLN$ FOR INPUT AS #1
REM READ HEADER INFO FROM FILE
  LINE INPUT #1, STV$
  LINE INPUT #1, STV$
  LINE INPUT #1, STV$
REM
 LPRINT "STATION        LINE          TIME          DATA      "
```

```
 I = 0
 J = 0
REM
REM READ DATA FROM FILE
 WHILE NOT EOF(1)
  LINE INPUT #1, STV$
  TSTN$ = MID$(STV$,15,1)
   IF TSTN$ <> "N" THEN
REM READ STATION DATA INTO ARRAYS
     I = I + 1
     NUM$ = MID$(STV$,10,6)
     STATION$(I) = NUM$
     NUM$ = MID$(STV$,4,4)
     LIN$(I) = NUM$
     NUM$ = MID$(STV$,27,6)
     TIM$(I) = NUM$
     NUM$ = MID$(TIM$(I),1,2)
     HH = VAL(NUM$)
     NUM$ = MID$(TIM$(I),3,2)
     MM = VAL(NUM$)
     NUM$ = MID$(TIM$(I),5,2)
     SS = VAL(NUM$)
REM CONVERTS TIME INTO SECONDS
     ST(I) = SS + (60.0 * (MM + (60.0 * HH)))
     NUM$ = MID$(STV$,35,6)
     DAT(I) = VAL(NUM$)
     LPRINT STATION$(I),LIN$(I),TIM$(I),DAT(I)
     LPRINT "ST(", I, ")= ",ST(I)
   ELSE
REM READ BASE STATION DATA INTO ARRAYS
     J = J + 1
     NUM$ = MID$(STV$,10,6)
     BSTATION$(J) = NUM$
     NUM$ = MID$(STV$,3,5)
     BLIN$(J) = NUM$
     NUM$ = MID$(STV$,27,6)
     BTIM$(J) = NUM$
     NUM$ = MID$(BTIM$(J),1,2)
     HH = VAL(NUM$)
     NUM$ = MID$(BTIM$(J),3,2)
     MM = VAL(NUM$)
     NUM$ = MID$(BTIM$(J),5,2)
     SS = VAL(NUM$)
REM CONVERTS TIME INTO SECONDS
     BT(J) = SS + (60.0 * (MM + (60.0 * HH)))
     NUM$ = MID$(STV$,35,6)
     BDAT(J) = VAL(NUM$)
     LPRINT " "
     LPRINT BSTATION$(J),BLIN$(J),BTIM$(J),BDAT(J)
     LPRINT "BT(", J, ")=", BT(J)
     LPRINT " "
  END IF
 WEND
REM
```

```
 IQ = I
 LPRINT " "
 LPRINT " "
 INPUT "BASELINE ", BSL
 I = 1
 J = 1
 STNUM = 0
        LINCHK = VAL(LIN$(I))
REM COMPUTE RESIDUAL FROM DATA ASSUMES LINEAR DRIFT BETWEEN
REM BASE STATION READINGS.
 FOR I = 1 TO IQ
REM
  INCRK:
   IF (ST(I) < BT(J + 1)) THEN
        LINVAL = VAL(LIN$(I))
    IF (LINCHK <> LINVAL) THEN
        STNUM = 0
        LINCHK = LINVAL
    END IF
      SLOPE = (BDAT(J + 1) - BDAT(J))/(BT(J + 1) - BT(J))
      BDELTA = SLOPE * (ST(I) - BT(J))
      X = BDELTA + BDAT(J)
      RESD(I) = DAT(I) -  (X - BSL)
      STNUM = STNUM + 1
   ELSE
     IF (ST(I) > BT(J + 1)) THEN
     LPRINT "NEW BASE STATION TIME !!!", BT(J + 1)
     LPRINT " "
     LPRINT " "
   J = J + 1
    END IF
      GOTO INCRK
   END IF
REM
   LPRINT "STATION #", STNUM
   LPRINT "LINE #", LIN$(I)
   LPRINT "STATIONTIME   BASETIME    DIURNAL CORRECT"
   LPRINT ST(I), BT(J), CLNG(X)
   LPRINT "STATION DATA  BASEDATA"
   LPRINT DAT(I), BDAT(J)
   LPRINT "STIME +1      BTIME +1"
   LPRINT ST(I + 1), BT(J + 1)
   LPRINT "SDATA +1      BDATA +1"
   LPRINT DAT(I + 1), BDAT(J + 1)
   LPRINT "RESD(",I,")= ", CLNG(RESD(I))
   LPRINT " "
NEXT I
CLOSE #1
END
```

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