UNITED STATES GEOLOGICAL SURVEY
ALASKA AEROMAGNETIC SURVEY
EXPLANATORY TEXT OF THE OPERATIONAL REPORT
Bettles, Alaska
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INTRODUCTION

The following report describes the aeromagnetic survey conducted by Excel Geophysics Inc. (Excel) for the United States Geological Survey (USGS). The survey area was located northwest of Bettles, Alaska in the Brooks Range. The project area covered the Howard Pass and the East half of the Misheguk Mountain quadrangles. The survey was conducted from June 10th 2008, to August 29th 2008, with a total of 9,661.3 miles (15,548.4 km) flown during this project. Figure 1 shows the survey location.

Figure 1: Survey Location - Howard Pass and East Half of Misheguk Mountain

SAFETY

Each crewmember held current safety certifications in Emergency First Aid, H_2S awareness, and WHMIS. An emergency response plan, containing contact numbers and emergency procedures, was distributed and explained to all field staff. Safety meetings were held by the field staff on a regular basis to identify any potential safety hazards.

Excel ensured that each member of the crew was equipped with appropriate outdoor wear and first-aid kit. The survey aircraft was maintained on a regular basis and was equipped with a satellite phone, first-aid supplies, fire extinguishers, and emergency beacons. No injuries, accidents or incidents occurred during the course of the survey.

AEROMAGNETIC SURVEY PROCEDURES

This aeromagnetic survey was based in Bettles, Alaska. The survey area was located about 300 km northwest of Bettles, in the Brooks Range. The magnetic base stations were set up at the Ivotuk airstrip less than 10 km east of the project area. The following table outlines the main parameters of the aeromagnetic survey.

Table 1. Aeromagnetic Survey Parameters

General Survey Location	Northwest of Bettles Alaska Latitude: 68°N to 69°N Longitude: 156.0°W to 160.5°W
Survey Duration	June 10 to August 29, 2008
Flight Line Spacing	1 mile (1,600 m) North - South
Tie Line Spacing	5 miles (8 km) East - West
Total Line miles flown	9,661.3 miles (15,548.4 km)
Flying Height	1000 ft (304 m) Drape Above Ground
Base Magnetometer Location	Ivotuk Airstrip 68.48°N, 155.73°W
Type of Aircraft	Navajo PA – 31-310 (C-FFRY) Provided by Aries Aviation

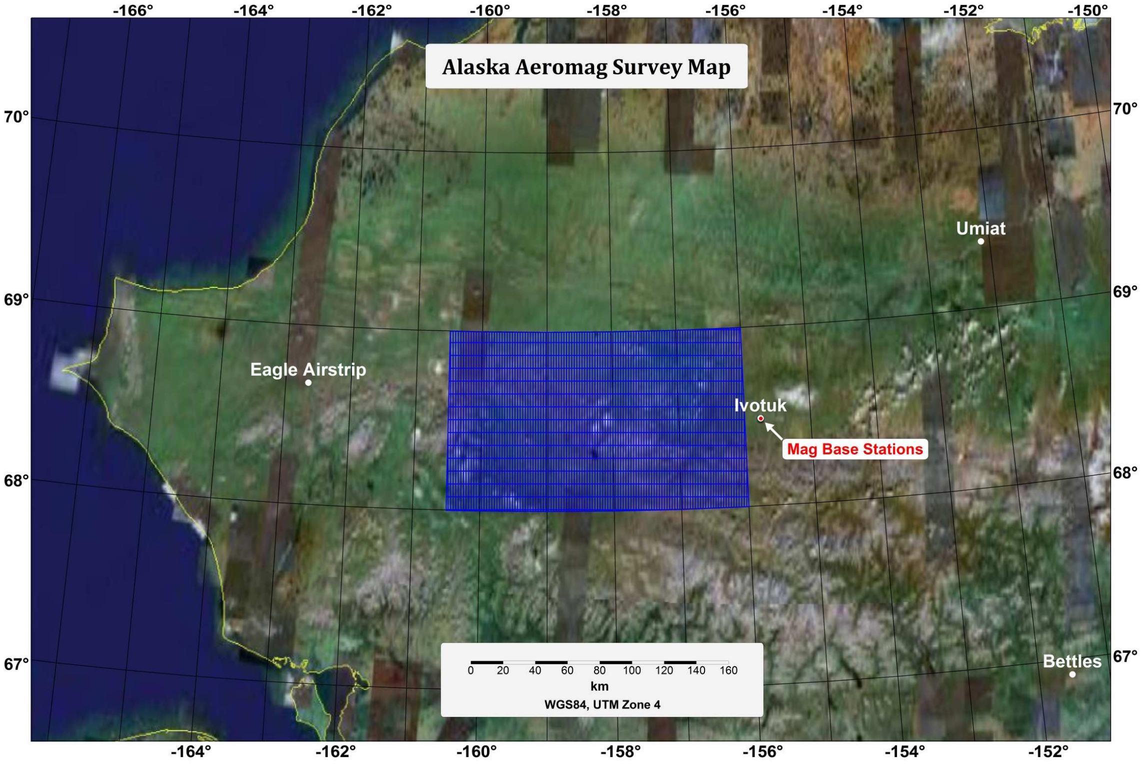

Figure 2: Survey Layout and Base Station Location Map

FLIGHT LOGS

The aircraft was flown from Springbank, Alberta to Bettles, Alaska on June 11th and June 12th 2008. An initial safety flight was conducted where the pilot identified any possible obstacles and evaluated the terrain for possible safety hazards. As well, a FOM flight and a calibration flight for the radar and barometric altimeters were performed prior to data collection. Production flights began on June 14th.

The weather conditions in Alaska during our survey caused significant delays and severely impacted production rates. The final day of data acquisition was August 24th, 2008. The flight logs are shown in Appendix B indicating flight lines, production times, and other relevant information.

INSTRUMENT CALIBRATIONS

Magnetometer

Two calibration flights were flown to define the compensation parameters for this project. Analysis of the calibration, results in a figure of merit value of 0.97 nT. The data are shown in Figure 3.

Radar Altimeter

The radar altimeter used is a TRT model ERT-011. This altimeter is setup for analog output, DC voltage, linear from 0 to 5000 ft. The manufacturer's equation was used to convert the voltage reading to the height above ground (shown below). Several test flights over the airport confirmed the manufacturer's calibration, as shown in Figure 4.

$$h = 60.96 \times V_{rad}$$

h – Height Above Ground (m).
V_{rad} - Radar Altimeter Voltage (V).

The output of the radar altimeter is an analog voltage ranging from 0 to 30 volts. This analog voltage is converted to a digital value and recorded by the RMS system. The RMS data recorder is restricted to a maximum voltage of 9.99 Volts which corresponds to a height of about 2000 ft or 610 m above ground. For surveys draped at 1000 ft, the 2000 ft altimeter range is usually adequate. However, for the present survey, several deep valleys were too narrow and sharp sided to be closely tracked by the draped survey, and the analog voltage output of the radar altimeter exceeded the recording limitation of the RMS system.

As soon as the USGS alerted us of this problem, a new external logging device capable of recording 0 - 30V was installed in the plane. The data from this external logging device was used to replace any data which was out of range for the original system. This was an excellent solution to the problem. For 96.6% of the data, the recorded values from the radar altimeter was used. The remaining 3.4% of data, which radar altimeter data was missing for short segments, were scattered throughout the project area. The height above ground for these readings was calculated using the GPS elevation of the plane and the digital elevation model (DEM) for this area. Comparisons of the radar altimeter vs. calculated height indicate this is an excellent solution which integrated seamlessly. The radar altimeter data is shown in the final data listing *Alaska-2008-AeromagData.txt*. The 3.4% of readings using a calculated height are indicated with a value of "99" in the voltage column.

Barometric Altimeter

A calibration flight was performed over the Bettles Airstrip on June 14th to calibrate the barometric altimeter. Figure 5 shows the results of the calibration for the barometric altimeter. The best fit line though the flown elevations and the output voltage determined the equation to calculate the pressure at each station. The average atmospheric pressure during each flight was taken from the data given by the weather station at Ambler, AK. The station elevation for each station was calculated from the following formula.

$$h_m = \frac{\left(288 - 288 \times \left(\frac{P_{stn}}{P_a}\right)^{0.19026}\right)}{0.0065}$$

P_{stn} - *Pressure at Each Station (inHg).*
P_a - *Atmospheric Pressure (inHg).*
h_m - *Station Elevation (m).*
V_{baro} - *Barometric Altimeter Voltage (V).*

$$P_{stn} = 2.9894 \times V_{baro} + 17.389$$

EQUIPMENT USED

Survey Aircraft

The aircraft used for this survey was a PA-31-310 Navajo (registration C-FFRY), twin engine fixed wing aircraft. The turbocharged twin engine (300 HP each) configuration provided a service ceiling of 26,300 ft (15,800 ft on one engine), 1,395 fpm climb (ISA), and 1,750 ft take off distance over a 50 ft obstacle. The aircraft is capable of performing drape flight and has been specifically modified for geophysical survey work to be magnetically "quiet". The aircraft has been equipped with long range fuel tanks (Nyack) for 7 + hours duration, and is configured with a certified tail stinger, equipment rack and survey power modifications. The aircraft is capable of climb and descent gradients of 6.5%. Survey operations were conducted at an aircraft speed of 120 NM/hr (~210 km/hr).

Survey Equipment

The survey aircraft was equipped with the following instrumentation:

- Three *Geometrics G-822A* high-sensitivity cesium magnetometers installed in the tail boom and wingtip pods.
- 3 component *fluxgate magnetometer*.

- *AARC500 compensator and DGR33A Data Acquisition System* from RMS Instruments, including a front-end magnetometer processor with ±0.32 pT resolution and less than ±0.1 pT internal system noise.
- *Novatel GPS receiver* with dual frequency GPS antenna. Uses real-time correction to provide aircraft positioning in real-time.
- *AG-NAV2 navigation equipment* capable of using a 3D preplanned flight path and real time GPS positioning for navigation.
- *Radar altimeter* TRT model ERT-011.
- *Sony DFW-X710* camera featuring a 1/3" CCD that delivers uncompressed, high-resolution, digital color images and features an easy-to-use asynchronous electronic shutter function with an exposure range from 1/100,000 to 17.5 seconds.
- *Setra Model 276 barometric pressure transducer* with a SETRACERAM sensor.

Video

The Sony DFW-X710 video camera was mounted in the center of the plane with a clear view of the ground. Photos were recorded every second and tagged with a GPS position. All video and GPS files are included on the attached DVD.

Navigation System

The onboard GPS unit was a Novatel OEMV GNSS receiver with a dual frequency antenna. The Novatel received CDGPS differential corrections to provide an accuracy of 0.5 m. The onboard navigation system was the AG-NAV2 system which uses the differential GPS data received from the Novatel GPS unit. The Novatel system monitors the GPS satellite signals, calculates corrections, and transmits this corrected “differential” information to the AG-NAV2. Pictures and performance specifications for each of the Novatel and AG-NAV2 units can be seen in Figures 6 to 9.

Ground Magnetometer

Excel set up two remote reading GSM-19 Overhauser magnetometers about 9 km east of the project area at the Ivotuk airstrip to continuously monitor the magnetic field throughout the project. The GSM-19 has a resolution of 0.01 nT and 0.2 nT absolute accuracy over its full temperature range. Synchronization was maintained through GPS time. The base station unit is shown in Figure 10.

The survey area was extremely remote; over 300 km from the nearest town Bettles, AK, where the crew was based. The base stations were designed to operate unmanned in order to have them located close to the project area. The magnetic base station system was setup with batteries attached to a solar panel power source which maintained power for the entire duration of the survey. The systems were set to automatically upload data to the field computers and transmit the data to the Excel office in High River by connecting every six hours to an ftp site via satellite modem. This remote setup allowed data to be sent on a daily basis with no operator on site. The set up of the base magnetometer systems are shown in Figure 11. The base stations were visited by the survey crew periodically to maintain and create data backups. After retrieving the data in the office from the ftp site, the data were examined for magnetic storms and anomalies.

Four neighboring permanent magnetometer stations were monitored in addition to Excel's two base stations setup at Ivotuk. These permanent base stations were operated by the Geophysical Institute at the University of Alaska. The K-Index recorded at CIGO (near Fairbanks, AK) was also monitored to track magnetic activity. Figure 12 shows the location of the Excel base stations relative to the four neighboring sites (Bettles, Fort Yukon, Poker Flat, and CIGO).

A study comparing the Excel base station data to the published data from the Geophysical Institute base magnetometers shows that the data have the same general trends. If the magnetic field is relatively stable, all base stations show low magnetic activity. If there is high magnetic activity and/or storms, all the base stations show the increased activity. The K-Index also peaks during high magnetic activity periods. Figure 13 shows a sample of data collected by the magnetometers along with the K-Index.

The remote magnetic base station systems provide not only magnetic and time readings but data quality measures of which only the highest quality data were used for processing. Minor concerns were noted in some of the base station files where the data quality would drop during the day for brief periods of time (typically less than 15 minutes). Investigations determined that the source of the interference was the solar array inverters. This problem was corrected by disabling the voltage chopper circuit of the battery charger. The voltage chopper operated intermittently only when the batteries were approaching complete charge under full sunlight. Chopping was not applied early in the charge procedures when full solar power was applied to the batteries, and once fully charged, the solar arrays were turned completely off. The chopper related magnetic noise was intermittent and limited in duration. Numerous samples of good magnetic data occurred throughout these limited windows.

If the surrounding permanent magnetometer stations all indicated that the magnetic field was quiet and stable (well within the survey specifications for monotonic and periodic changes), then the diurnals were interpolated during these periods with interference. Otherwise, the noisy intervals were reflown. All interpolated diurnal values are flagged in the data listings. Typically, the interpolation interval was less than one minute. The maximum interpolated interval was 15 minutes. This problem did not affect any data acquired after July 10, 2008.

DATA AQUISITION AND PROCESSING PROCEDURES

Magnetic Data Reduction

Ground magnetometer data were collected at one second intervals during airborne data acquisition in order to monitor magnetic diurnal. Preliminary processing for onsite quality control was performed as each flight was completed. The ground magnetometer data were plotted and checked for evidence of magnetic storms or short term anomalous magnetic activity. Approximately, 25% of the lines were repeated for this survey. Most of these reflights were due to magnetic diurnal activity beyond the survey specifications.

A datum of 57,270 nT was chosen for the survey and was subtracted from the base magnetometer data. The base data were then combined with the airborne magnetometer data using GPS time to synchronize the two data sets. The airborne magnetic data were recorded at an interval of 0.05 seconds (20 Hz). The base station data, which were recorded at an interval of one second, were interpolated to match the airborne sample rate. The airborne magnetometer data were corrected for diurnal variations by subtracting the base magnetometer value corrected for the datum. The ground magnetometer data were filtered using a sixth-order, 45-point Savitzky-Golay low pass smoothing filter before diurnal subtraction to remove data spikes. The raw, filtered and final values for each reading are included in the data listing. The International Geomagnetic Reference Field 2005 was calculated for each reading and removed.

Once the airborne data had been corrected for diurnal and had the IGRF-2005 removed, they were filtered using a sixth-order, 67-point Savitzky-Golay low pass filter. Finally, the airborne data were leveled using a proprietary program. Final micro-leveling techniques were then applied to the data to remove minor residual variations.
The semi-automated magnetic data leveling system used includes:

1. Tabulation of magnetic data at flight line/tie line intersections, along with flight altitude data;
2. Network analysis of intersection data, based on minimizing the root mean square of the differences and closure errors, to obtain suggested leveling adjustments;
3. Manual analysis of computer suggested corrections, based on magnetic gradients at the intersections and the flight altitude differences;
4. Application of leveling corrections; and
5. Revision of leveling corrections using imaging techniques.

The diurnal and leveling corrections for each data reading are included in the data listing.

The total field magnetic data grid was created using a kriging algorithm.

DATA QUALITY

The leveling corrections applied to the dataset were reasonable. The standard deviation of the corrections is 2.85 nT. This agreement in the line intersections indicates high quality navigation and excellent magnetic data quality. Figure 14 shows a histogram of the leveling corrections applied.

The horizontal distances between the flown elevations and the pre-planned line layout were well within the survey specifications for the entire survey. Figure 15 displays a histogram of the difference in vertical distance between the flown elevations and the pre-planned draped survey (actual – planned). The specified vertical difference for this survey was 0 ± 61m. 97.6% of the data is within this specification. For the remaining 2.4% of the data it was neccessary to deviate from the preplanned drape due to significant terrain changes and the rugged nature of the area. Pilots discrecion was used to safely navigate these rugged areas with steep terrain.

SUMMARY

No incidents or accidents occurred on this project. Weather was the major obstacle to overcome throughout this survey. Cloud cover and fog caused significantly more weather days than expected. The crew was stationed in Bettles for almost three months and was grounded for more than 68% of the time due to weather. This completely destroyed the economics of this project. Magnetic storms in comparison posed only minor concerns. The rugged terrain and remote location of the survey were anticipated and were not a factor in production.