GEOLOGY, GEOPHYSICS AND GEOHAZARDS ALONG THE ALASKA HIGHWAY CORRIDOR

A Project of the Alaska Division of Geological & Geophysical Surveys

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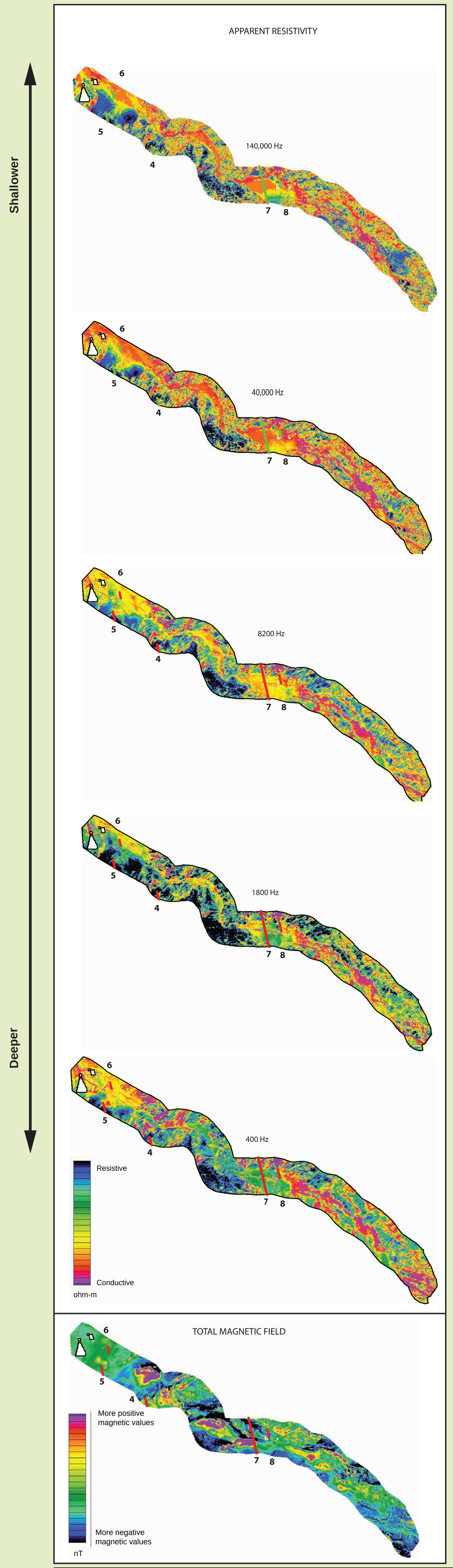

Figure 2: Images of apparent resistivity for each coplanar frequency and total field magnetic data for the entire survey area. The resistivity images are all colored with magenta and purple as most conductive and black and blue as most resistive. Maximum and minimum values (ohm-m) for each frequency differ, as well as color distributions. Most color schemes shown approximate the equal area color scheme, where an equal number of values are shown for each color.

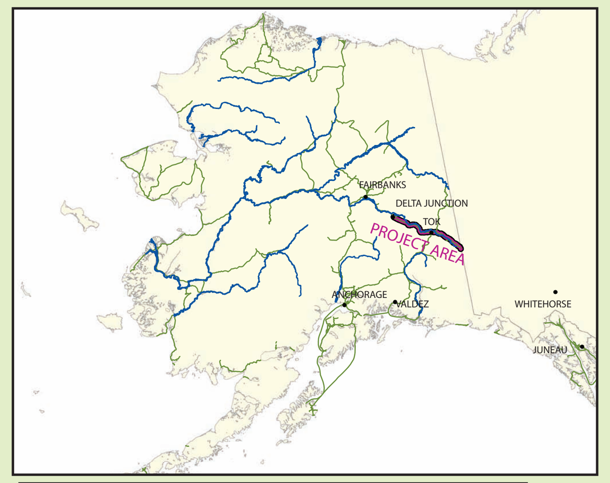

FIGURE 1: Location map showing area covered by geophysical data. Area to be geologically mapped in 2007 is from Delta Junction about halfway to Tok.

Introduction

The Alaska Highway corridor project is a proposed, currently partially funded, multi-year project managed by the Alaska Division of Geological & Geophysical Survey (DGGS) to assess the geologic hazards, mineral potential, and construction materials resources along the major transportation route between Delta Junction and the Canadian border. The project is two-phase. The first phase acquired and released detailed airborne geophysical data designed to see near-surface units. The second phase will follow with detailed geologic mapping of both bedrock and surficial geology. The combination of shallow-level geophysical data and detailed geologic mapping will support the identification and evaluation of geologic hazards and material resources along the transportation corridor. Acquisition of the geophysical data and most of the data release is completed; the geologic mapping and geohazard evaluation part of the project will start in earnest in summer 2007 and is projected to last several years.

DGGS recently acquired and released a helicopter-borne aeromagnetic and electromagnetic survey for a 16-mile (25.7-km) wide, 200-mile (322-km) long transect (over 3,000 square miles, or 7,769 square kilometers) along the Alaska Highway corridor. The electromagnetic data were acquired with Fugro Airborne Surveys' RESOLVE system, which has a configuration designed to acquire information from a wide range of depths, but maximizes information of the near-surface materials such as sand and gravel resources, conductive overburden, and location of potential geologic hazards such as permafrost and near-surface faults. Available geophysical products are listed in general below. Example images for the electromagnetic data and aeromagnetic data are shown to the left.

We are just beginning to interpret the geophysical data. These data are of limited effectiveness unless good geologic mapping is available to guide analysis and interpretation of the geophysics. Because the existing geologic maps are of variable detail and scale, several years of ground-based field studies are needed to produce a comprehensive geologic map of the corridor with unified nomenclature. A higher degree of detail is made possible by the availability of the geophysical data. Geologic work will concentrate on a 12-mile (19.3-km) wide corridor from Delta Junction, Alaska to the Canadian border, mapping bedrock and surficial geology at a scale of 1:63,360. Particular attention will be paid to documenting evidence for active faults in the map area, identifying areas of high permafrost potential, and evaluating surficial deposits for their suitability for use as construction materials. The maps and reports produced from this project are intended to provide basic engineering geologic and resource planning information for future development that might take place in the area, as well as to provide integrated bedrock and surficial geologic mapping along a geologically diverse corridor.

Geophysical Publications

All maps mentioned below and the project report are downloadable for free from our Web site (http://www.dggs.state.ak.us) in Adobe Acrobat format, are available on paper from our office at 3354 College Road, Fairbanks AK 99709 USA, and are also available on one of the DVD publications mentioned below. Maps on paper cost $13 U.S. each plus shipping; 6 maps are needed at a scale of 1:63,360 to cover the survey area. Other contents of the DVD publications are only available through purchasing the publications ($10 U.S. plus shipping).

Available now:

Geophysical Report (GPR) 2006-6: Burns, L.E., Fugro Airborne Surveys, and Stevens Exploration Management Company, 2006, Line, grid, and vector data, and plot files for the airborne geophysical survey of the Alaska Highway corridor, east-central Alaska: Alaska Division of Geological & Geophysical Surveys, 1 DVD.

This DVD includes 1) a database of all the processed geophysical data, 2) gridded data for the aeromagnetic, apparent resistivity, first vertical derivative of the aeromagnetic data, and digital terrain model data, 3) thirty-six 1:63,360-scale maps of the aeromagnetic and 5 coplanar apparent resistivity data in Adobe Acrobat format, and 4) GIS-registered vector files of data contours and flight lines for all the maps included.

Available in the near future:

Geophysical Report (GPR) 2006-7: Burns, L.E., Fugro Airborne Surveys, and Stevens Exploration Management Company, 2006, Title currently undecided, Alaska Division of Geological & Geophysical Surveys, 1 DVD

This DVD should be released shortly and will include 1) 1:63,360-scale maps of the first vertical derivative map of the aeromagnetic data and the coaxial apparent resistivity (3300 Hz), 2) project report and preliminary interpretation, 3) resistivity depth sections (EM profiles; discussed in figures 4-8 and resistivity depth grids, 4) database containing the original data plus the additional data provided by the resistivity depth sections, and 5) stacked profiles of all the data.

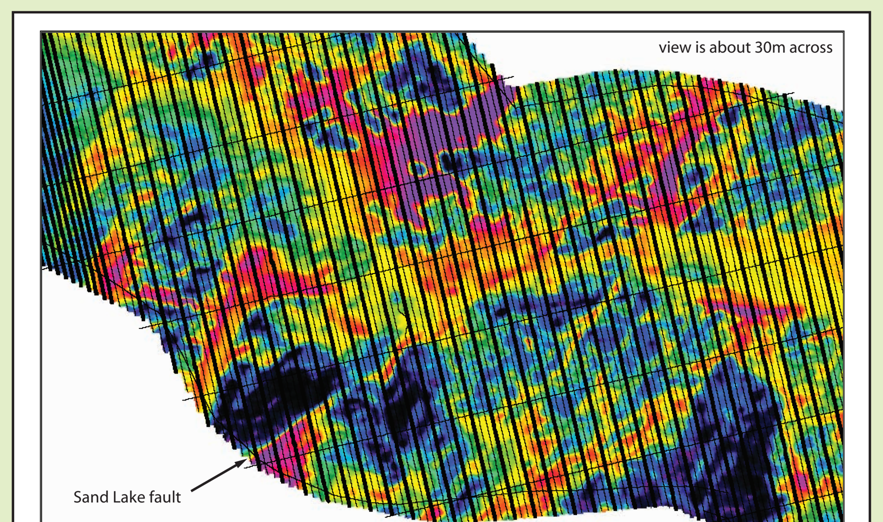

Figure 3: This figure shows a small section of the 8200 Hz coplanar apparent resistivity data around the Sand Lake fault area with traverse, tie, and boundary lines shown in black. Traverse line direction and spacing were N10ºW and ¼ mile (0.4 km) respectively; tie lines were perpendicular to flight lines and were spaced about every 3 miles (5 km). Black and blue represent highly resistive units and magenta and purple represent highly conductive units.

The bold flights lines on Figure 3 represent locations where resistivity depth sections were calculated by Doug Garrie of Fugro Airborne Surveys. Sections based on three different techniques were calculated for every third traverse line (every ¾ of a mile, or 1.2 km) for the entire survey area, except for three areas approximately 5.5 miles (8.8 km) wide where every traverse line was modeled. The three techniques yield the Sengpiel section, the differential resistivity section and the EM1DFM inversion section. Each section was computed for a depth of 100 m and is shown with its topographic profile. The three types of resistivity depth sections will be discussed briefly in Figures 4 through 8. For more information on these profiles, see the project report included with publication ADGGS GPR 2006-7; for Sengpiel profiles see Sengpiel (1988); for differential resistivity profiles see Huang and Fraser (1993); or investigate the applications shown at Fugro Airborne Surveys' Web site (http://www.fugroairbornesurveys.com/service/). The resistivity depth profiles and EM inversion technique can be used to help identify features important to engineering geology, such as permafrost, water table, potential landslide surfaces, paleochannels, and contamination.

Three types of resistivity depth sections:

The Sengpiel and differential resistivity depth sections (examples shown in Figures 4, 5, and 8) each attempt to portray a smoothed approximation of the true resistivity distribution with depth. For these, the calculated depth for each frequency is plotted for each location along the profile. The top resistivity line shown in each of these is the 140,000 Hz. The third type of section, an EM1DFM inversion, produced by Fugro Airborne Surveys for this survey, is shown in Figures 6 and 7. The EM1DFM inversion used a series of thin, fixed layers (25 x 4m) and computed resistivities to fit the EM data. The locations of the sections for the following figures are shown in Figure 2.

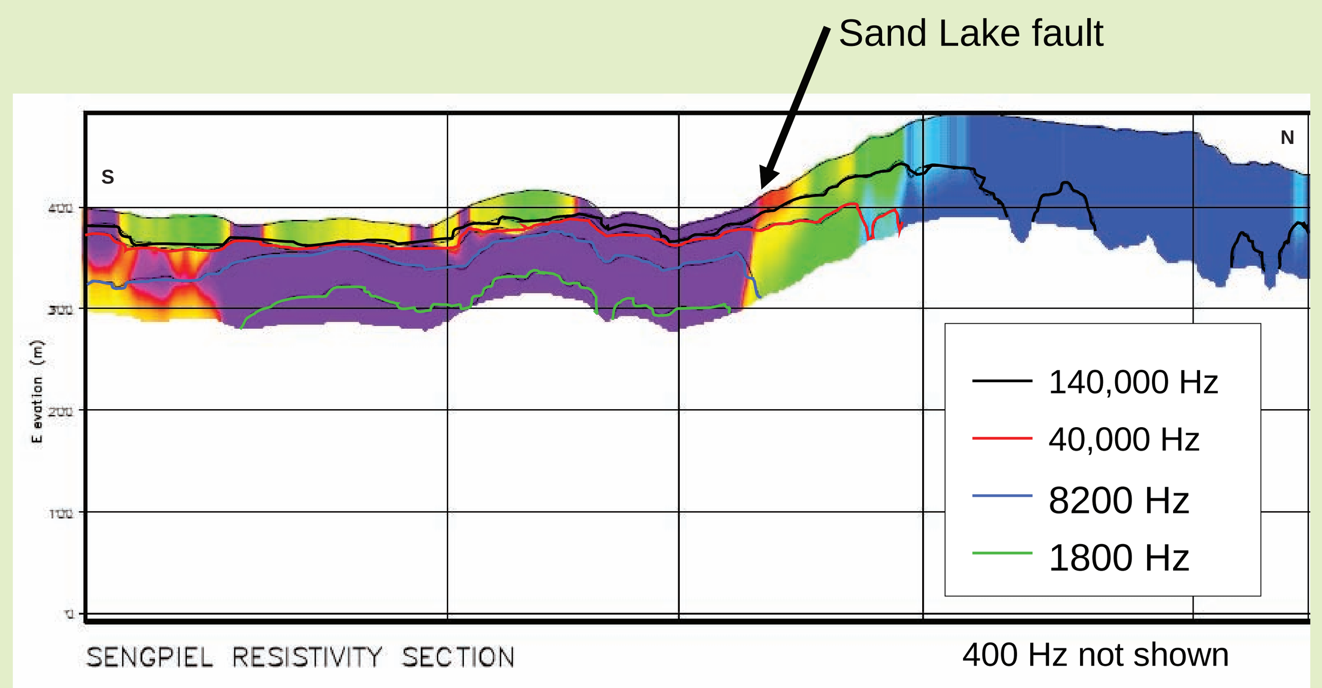

Figure 4: This Sengpiel section illustrates that the depth a frequency is "seeing" is dependent on both the frequency (lower frequency signals see deeper) and the resistivity of the material (signals penetrate deeper in resistive material). Therefore the number of resistivity lines that are visible in the first 100 m varies depending on the resistivity of the material. The Sengpiel sections, where the apparent resistivity for each frequency is plotted at the centroid depth, are the simplest of the three section types. The profile in Figure 4 crosses the Sand Hill fault, a fault made obvious by the juxtaposition of rock types with very different electrical and magnetic properties.

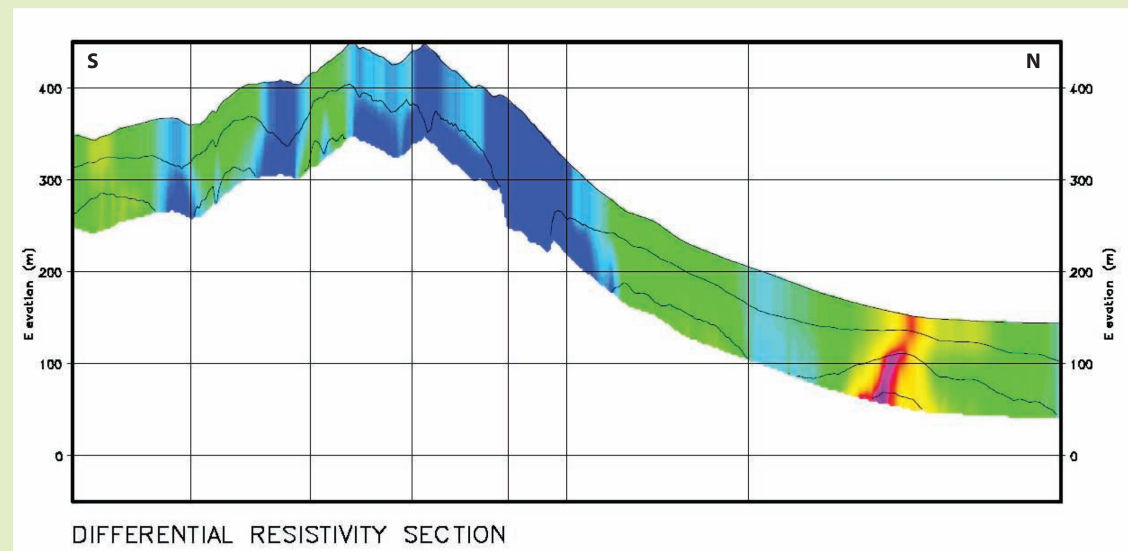

Figure 5: This differential resistivity section shows a steeply dipping conductive zone that is interpreted to represent a fault containing water-saturated clays. Faults may also show up without conductive zones, or the conductivity may vary greatly along their length. Differential resistivity sections, where the differential resistivity is plotted at the differential depth, plot the highest frequency at the computed depth without regard to other frequencies. Because the resistivity values are influenced by the material they traveled through, the differential method then attempts to compensate for by including both the current frequency being calculated and the next higher frequency. For example, the algorithm for computation of the depth and apparent resistivity value for the third highest frequency will include the depth and apparent resistivity value of the second highest frequency. The effect is to modify both the value and the depth at which the third frequency is plotted.

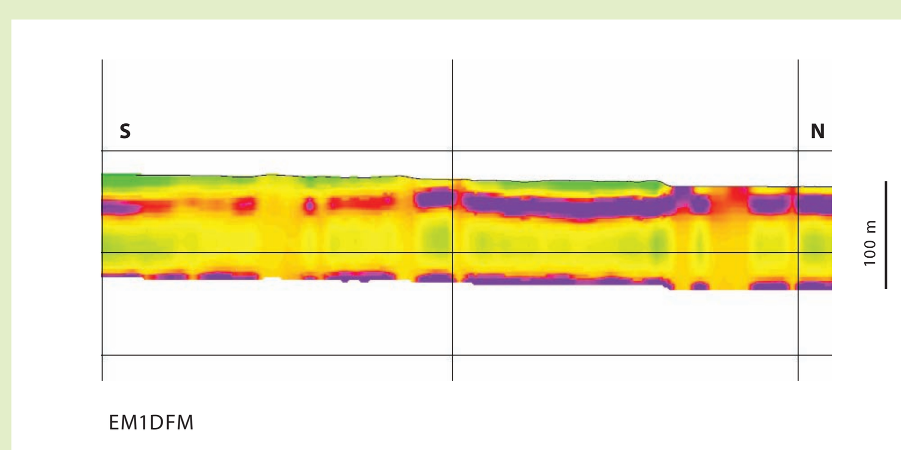

Figure 6: This EM1DFM profile shows a small hill which is probably composed of sand or gravel at the surface. The conductive layer below that probably represents the water table. If there is a fault immediately to the north of this hill, investigation here may provide a good estimate of offset. Any slight change in resistivity along this conductive layer or above it could represent a fault, permafrost, a change in sediment or rock type, or may be a difference within the water table. It is difficult to determine the absolute cause of the signatures without ground follow-up work. This particular profile also shows disruption of the signal where adversely affected by cultural features. The computed resistivities in these areas may be unreliable.

One of the bottom two layers underlying the conductive probable water table in figures 6 and 7, particularly the conductive bottom unit, may be an artefact of the modeling. The resistive layer under the upper conductive (water table?) layer could represent resistive bedrock or a resistive sedimentary layer that holds the water table at the upper depth. There is a slight possibility that the resistive layer is a false layer from the inversion results. Until tested we will not know for sure.

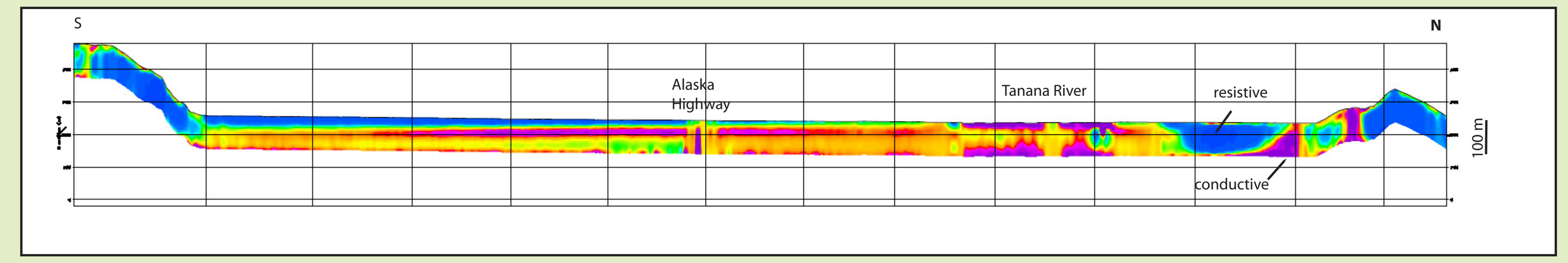

Figure 7: An entire EM1DFM inversion profile is shown in Figure 7. Here the conductive layer interpreted to be the water table dips gently to the south and is fairly continuous. The resistive material in a basin shape on the north is mapped as fine-grained lake deposits (Foster, 1970). The resistive values could possibly be caused just by the material, but more likely represent frozen, probably fine-grained, material. Because the resistivities of sand, gravel, clay, and other materials increase exponentially with temperatures below freezing, high resistivity can indicate that the material is frozen. The high frequency data, which "sees" relatively shallow depths, is thus a good tool to help locate places to investigate for permafrost.

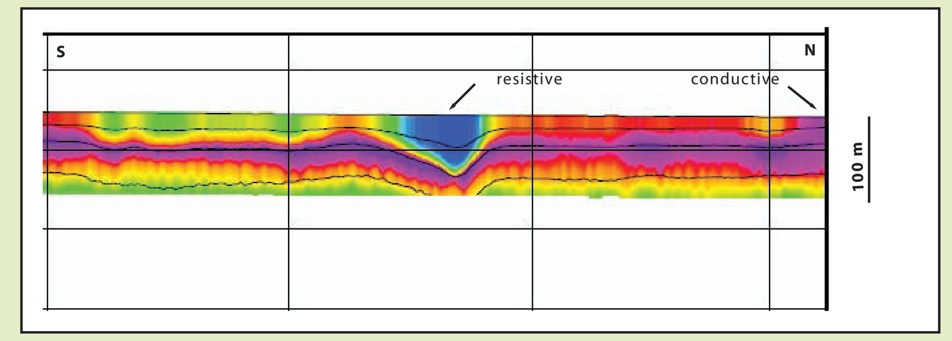

Figure 8: This differential resistivity section shows another area of resistive values similar to that in Figure 7, suggestive of a change in sediment type (possibly lake sediments), and/or frozen ground.

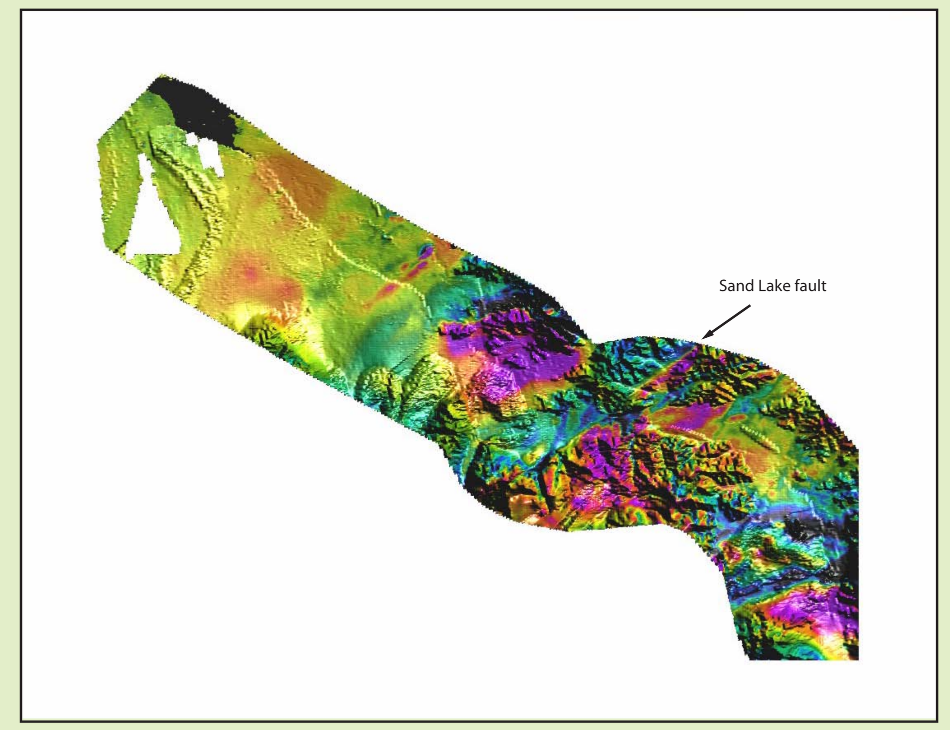

Figure 9: The aeromagnetic values for the western portion of the survey area are shown draped over the digital terrain model (DTM) computed by Fugro Airborne Surveys from the data. High values are represented by purple and magenta; low values by black and dark blue.

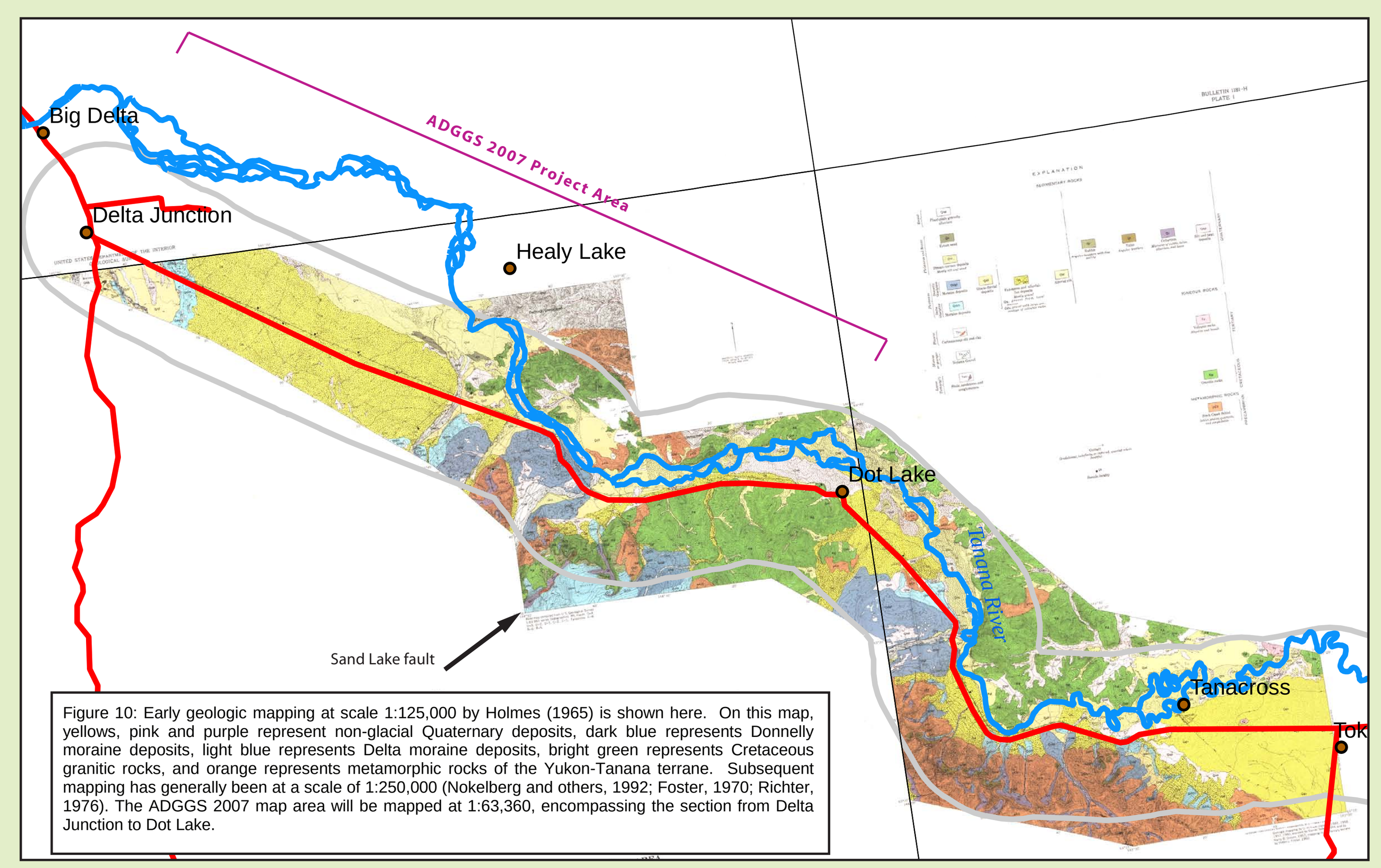

Figure 10: Early geologic mapping at scale 1:125,000 by Holmes (1965) is shown here. On this map, yellows, pink and purple represent non-glacial Quaternary deposits, dark blue represents Donnelly moraine deposits, light blue represents Delta moraine deposits, bright green represents Cretaceous granitic rocks, and orange represents metamorphic rocks of the Yukon-Tanana terrane. Subsequent mapping has generally been at a scale of 1:250,000 (Nokelberg and others, 1992; Foster, 1970; Richter, 1976). The ADGGS 2007 map area will be mapped at 1:63,360, encompassing the section from Delta Junction to Dot Lake.

Acknowledgements

The geophysical data were produced under contract between the State of Alaska, Department of Natural Resources, Division of Geological & Geophysical Surveys (DGGS), and Stevens Exploration Management Corp. Airborne geophysical data for the area were acquired, processed, and modeled by Fugro Airborne Surveys, a subcontractor, in 2005 and 2006. The interpreted faults shown in figure 12 and the resistivity depth sections such as those shown were produced by Doug Garrie of Fugro Airborne Surveys. The Alaska State Legislature provided funding for this project.

Sand Lake fault and other faults

The Sand Lake fault is shown on the geologic map of Nokelberg and others (1992) following a linear through Sand Lake and along Sand Creek north of the Tanana River. South of the Tanana River, Plafker and others show the Horn Mountain-Dry Creek fault, which roughly aligns with the Sand Lake fault, but does not extend across the Tanana River. The recent DGGS geophysical data clearly indicate a linear feature cutting across the full width of the project area (Figures 2, 3, 4 and 9), aligned with the Sand Lake fault of Nokelberg and others (1992). DGGS 2007 mapping will provide documentation of any evidence for the continuation of the Sand Lake fault across the Tanana River, and will look for indications of timing of movement.

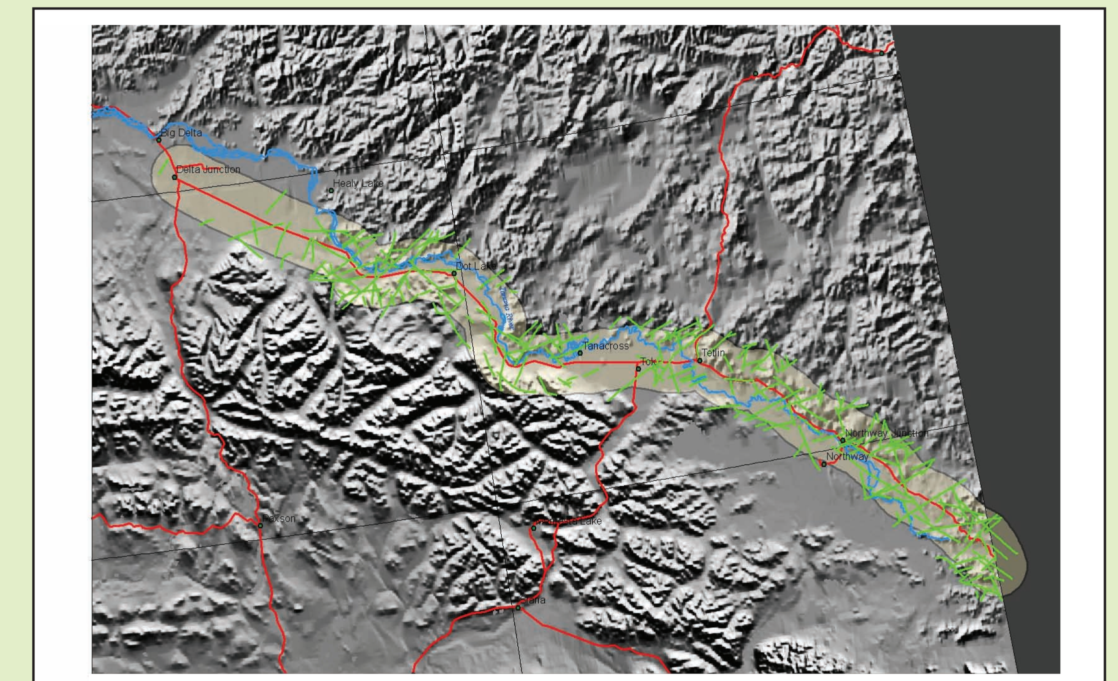

Figure 11: This shaded relief view, with the geologic mapping area in pale yellow, shows linear features interpreted from the geophysical data as potential faults by Fugro Airborne Surveys.

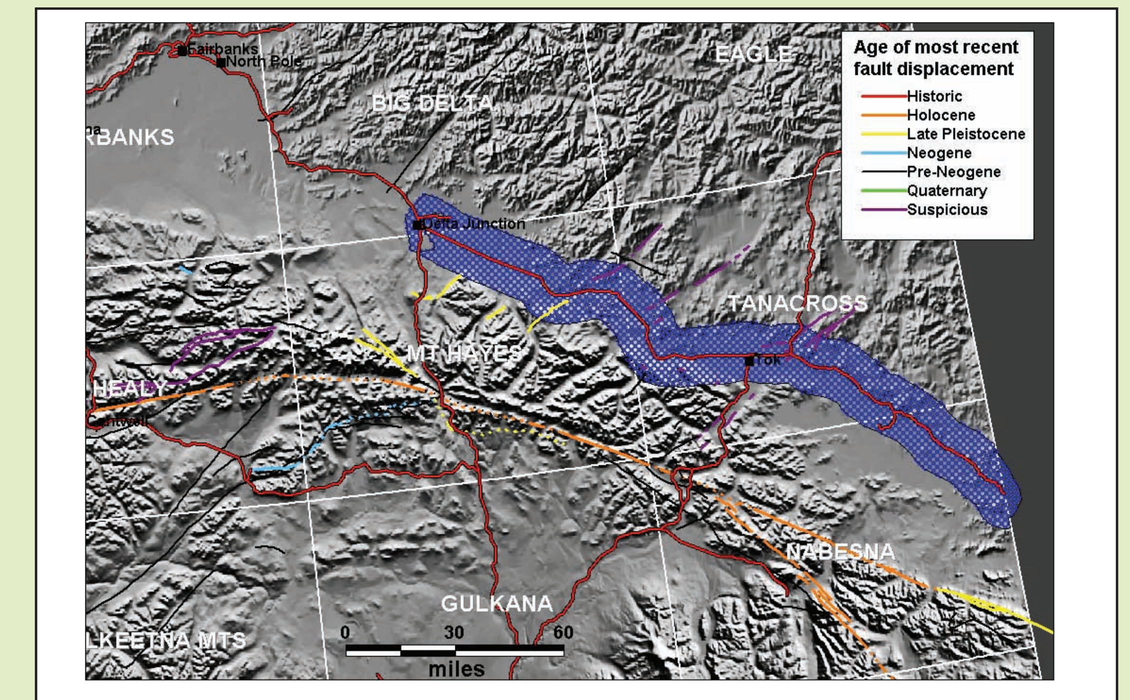

Figure 12: This shaded relief view, with the project area in blue, shows the locations of known faults with movement which has displaced Paleogene or younger features, taken from Plafker and others (1994). The Horn Mountain-Dry Creek fault is shown as having offset "late Quaternary deposits or surfaces (approximately 500,000 to 11,000 years) without younger historic or Holocene record". The purple "suspicious" fault that appears aligned with the Horn Mountain-Dry Creek fault is the Saddle Lineament, which is not in the Sand Lake/Sand Creek valley where the geophysical anomaly runs. If there has been recent movement on the Sand Lake fault, it has not yet been recognized. The engineering importance of establishing timing of motion on any faults crossing the transportation corridor is clear. The combination of detailed geophysical data and geologic mapping should provide a valuable basis for evaluating geohazards in the corridor.

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