STATE OF ALASKA DIVISION OF GEOLOGICAL & GEOPHYSICAL SURVEYS

Alaska GeoSurvey News

http://www.dggs.dnr.state.ak.us

Vol. 10, No. 1, March 2007

Alaska Highway Corridor Geology and Geophysics

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INTRODUCTION

The Alaska Highway, from the Canadian border to Delta Junction, serves as Alaska's most vital land-based transportation link to the rest of North America. The importance of this highway corridor has been highlighted recently in discussions of the proposed natural gas pipeline, as a possible route from Prudhoe Bay to the Lower 48. An extension of the Alaska Railroad through Canada has also been proposed that would probably follow the Alaska Highway corridor at least in part. In order to make informed decisions regarding alignment and design of these or any other proposed developments, a consistent baseline of publicly available geologic data is required. Having a good understanding of the geology allows us to identify associated geohazards along the corridor, such as areas with the highest potential for active faulting, or where permafrost is present, or areas most likely to experience flooding, liquefaction, or landslides. In addition, geologic mapping along the corridor helps us recognize gravel and other material resources needed for construction projects. For this purpose, DGGS has been funded by the Alaska State Legislature to begin a comprehensive geologic investigation of the proposed gas pipeline corridor from Delta Junction to the Canadian border. Completion of the 200-mile-long project will rely on continued funding through 2010.

The first phase of the Alaska Highway corridor study provided detailed airborne magnetic and electromagnetic geophysical data for a 16-mile-wide swath along the corridor from Delta Junction to the Canadian border. DGGS published the geophysical data in May 2006 and will soon release electrical resistivity profiles and additional gridded data produced from some of the profiles.

The electromagnetic frequencies used for the geophysical survey provide more information for shallower features than those flown in previous DGGS geophysical surveys. This enables us to better interpret the properties of materials within the upper 25 meters, for example to predict aggregate sources or the presence of frozen ground.

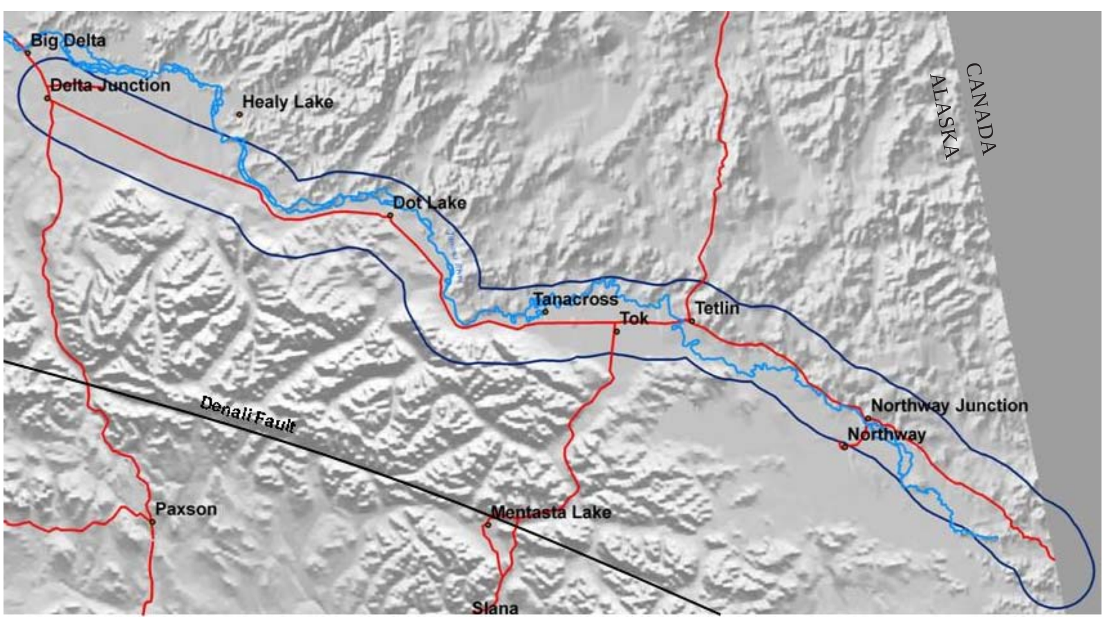

Figure 1. *Location map.*

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(continued on page 2)

The second phase of the Alaska Highway corridor study will provide inch-to-the-mile geologic maps of bedrock and surficial geologic units, based on interpretation of geophysical data and aerial photographs, existing geologic maps, and extensive field observations. The first segment of field mapping, begun in 2006 and to be continued in summer 2007, extends from Delta Junction to Dot Lake, encompassing portions of the Big Delta and Mt. Hayes quadrangles in a 12-mile-wide swath. These data are scheduled to be published by June 2008. Based on this mapping, the study will detail the potential for geohazards and materials resources along the corridor. The bedrock information and related geochemical data that come from this project can also be used to evaluate the potential for mineralization.

GEOLOGIC SETTING

The Tanana River, a major tributary of the Yukon River, roughly parallels the Alaska Highway for much of its length. Major tributaries, including the Gerstle, Johnson, Robertson, Tok, Nabesna, and Chisana rivers, flow generally northward out of the Alaska Range and join the Tanana River. The topography south of the Tanana River valley rises abruptly to peaks of the Alaska Range. Within the map area, elevations rise to more than 7,000 feet above sea level, with rugged, glacially-carved ridges and valleys. Treeline is about 3,000 feet in the study area, allowing good bedrock exposure on the higher ridges. In contrast, north of the Tanana River the hills are lower and forested, rising to just over 3,000 feet above sea level. The heavy vegetation that covers much of the map area creates a challenge for field geologists, and suggests that we will need to rely heavily on geophysical data to help extrapolate ground observations in those areas.

The corridor encompasses three physiographic provinces: the Yukon–Tanana Upland north of the Tanana River, the Tanana–Kuskokwim Lowland along the Tanana River valley, and the Alaska Range south of the Tanana River (Holmes and Foster, 1968). Geologically, however, rocks south of the Tanana River have been mapped as subterranes of the Yukon–Tanana terrane (Nokleberg and others, 1992) extending to the Denali fault, rather than as part of the rest of the Alaska Range. The structural relationship of these rocks, lithologically part of the Upland but topographically part of the Alaska Range, to the rocks of the Upland is not clear. Detailed mapping in the proposed map area will provide the opportunity to better understand this major structural break.

The Yukon–Tanana terrane is bounded on the south by the Denali fault, one of the longest strike-slip fault systems in the world (Harp and others, 2003), and on the north by the Tintina fault zone, a major strike-slip system parallel to the Denali fault. The map area occurs about 25 miles north of the Denali Fault and the coinciding southern boundary of the Yukon–Tanana terrane. Both the Denali and Tintina faults have experienced long-term right lateral strike-slip movement. The physical response of the region between these major fault zones has resulted in a complex structural history including extensive left-lateral movement along northeast-trending faults (Page and others, 1995). To date, few of the anticipated faults have been mapped in the map area.

Bedrock to be mapped in 2007 consists mainly of complexly deformed metamorphic rocks that have been intruded by Mesozoic and Tertiary plutonic rocks (Foster and others, 1992). Early mapping in the Mount Hayes Quadrangle assigned the entire metamorphic rock assemblage to the Birch Creek schist unit, regarded as Precambrian (Holmes, 1965; Holmes and Foster, 1968). Later mapping divided the metamorphic rocks in the map area into three subterranes: Lake George subterrane north of the Tanana River, and Jarvis Creek Glacier and Macomb subterranes south of the river (Nokleberg and others, 1992), based on composition and origin of protoliths, present lithology, structure, and metamorphic history (Foster and others, 1994). More detailed mapping should enable us to break out individual geologic units within the plutonic and metamorphic packages.

Surficial geologic deposits in the 2007 map area include materials deposited by glaciers during at least two Quaternary glacial episodes. The younger Donnelly glaciation most likely took place within late Wisconsin time, during the period of 10 to 30 thousand years ago (Reger and Péwé, 2002). The Delta glaciation occurred prior to the Donnelly, and may even encompass more than one event. Detailed mapping of glacial deposits in the corridor provided through this study should help refine our understanding of the glacial history of this part of Alaska.

GEOPHYSICAL SURVEY

The newly acquired aeromagnetic and electromagnetic (EM) data provide information on magnetic susceptibility and electrical conductivity, respectively, of the material in the area. These complementary physical data can provide invaluable clues as to the areal distribution of rock types, breaks in the subsurface due to faults or contacts between rock or soil types, and the distribution of such features as permafrost, the water table, and shear zones. Pre-fieldwork interpretation of the geophysical data will be used to target areas for investigation during the mapping project.

For survey acquisition and processing, DGGS contracted Stevens Exploration Management Company, who used Fugro Airborne Surveys Corporation as a subcontractor. The survey was flown in 2006. Parallel flight lines were aligned slightly west of north, one-quarter mile apart, for the 200-mile-long corridor. The electromagnetic 'bird', containing the electromagnetic transmitters and receivers as well as the magnetometer in this survey, was towed 100 feet above ground level by helicopter.

The magnetometer is a passive instrument that measures the earth's magnetic field in nanoTeslas (nT). Rocks with high magnetic susceptibilities (measured in SI units) locally attenuate or dampen these magnetic signals, producing the relative highs and lows. Iron-rich magnetic minerals such as magnetite, ilmenite, and pyrrhotite have the highest magnetic susceptibility. These minerals commonly occur in mafic volcanic rocks, mafic and ultramafic plutonic rocks, and amphibolites, as well as others. Rocks with low to no iron tend to produce little variation in the magnetic signal. These include silicic volcanic and plutonic rocks, many quartz–mica schists, and most sedimentary rocks. Because the magnetic signal of many rock types overlaps, field checking is needed to make definitive determinations of rock types.

The electromagnetic data provide information about conduction of electromagnetic waves through the sediments and rock types. In general, in the widespread unconsolidated deposits along the Alaska Highway corridor, the finer-grained sediments, such as clays and silts, will be more conductive than peat and sand. Gravel and then bedrock will be markedly less conductive than sand. In bedrock areas, water-saturated clays, graphite, concentrations of some sulfides, and clay alteration of plutonic rocks are generally the most conductive materials. As with the magnetic data, the conductivity of many rock and soil types overlaps and field checking is needed to complete the work.

Each transmitter in the EM system emits primary magnetic fields. When these magnetic fields encounter a conductive unit, an alternating current is formed. This produces a secondary magnetic field, which is read by the appropriate receiver in the bird. The strength of the received signal correlates to the relative electrical conductivity of the materials within the ground below. The different frequencies used for the survey target different depths. Five coplanar (horizontal) electromagnetic coils for this survey ranged between 140,000 and 400 Hz. Because ground penetration correlates inversely with frequency, the 140,000 Hz represents very near surface rocks, but below the active freeze-thaw layer, and the 400 Hz returns signals from deeper rocks. The depth of penetration of an EM signal also depends on the conductivity of the rocks through which the signal is passing; shallower depths are sampled when the material is conductive. The range of frequencies used in this survey yields conductivity (inverse of resistivity) data for a range of depths from about 5 meters as an extreme minimum to a maximum of 150 meters below ground surface.

Using several different methods and algorithms, Fugro Airborne Surveys produced resistivity profiles to 100 meters depth for every third flight line for the entire corridor. These profiles are "pseudo-cross-sections" of the resistivity data and yield further information on faulting, trends of deposits, and depths of suspected permafrost, as well as many other items. The profiles are also available for every flight line in three selected areas. For these three areas, grids were also developed that can be used to create three-dimensional visualizations of the resistivity characteristics of the subsurface materials. DGGS will publish the profiles and grids in the first quarter of 2007 (Burns and others, in progress).

GEOHAZARDS

One of the most crucial, but also most difficult, geohazards to assess is the presence of potentially active faults within the corridor. The Alaska Highway corridor is transected by a number of prominent structural features revealed by the geophysical survey, striking northeastward through the map area. One of the most obvious geophysical anomalies crosses the corridor south of Lake George (fig. 2). However, previous mapping has not recognized a contiguous fault across the corridor (Holmes, 1965; Nokleberg and others, 1992). Even so, "this should not be construed as evidence that this region will not be subjected to severe seismic shaking or to faulting of unconsolidated deposits" (Carter and Galloway, 1978). The neotectonic map of Alaska (Plafker and others, 1994) shows faults active in Late Pleistocene and faults suspected of late Tertiary activity in and near the map area.

In light of the high potential for infrastructure development along the Alaska Highway corridor, understanding the structural geology of the map area and whether it presents a potential hazard is critical. By using interpretation of aerial photographs, geophysical data, and careful examination of land formations in the field, this project will identify if there is evidence for recent movement on any observed faults. To gather more detailed information, where feasible we will transect the trace of suspect faults with a shallow trench. This will expose a profile of the sediments to allow observation of features such as offsets in layering or other disruptions, and possibly result in measurements of direction, distance, and timing of motion of the fault.

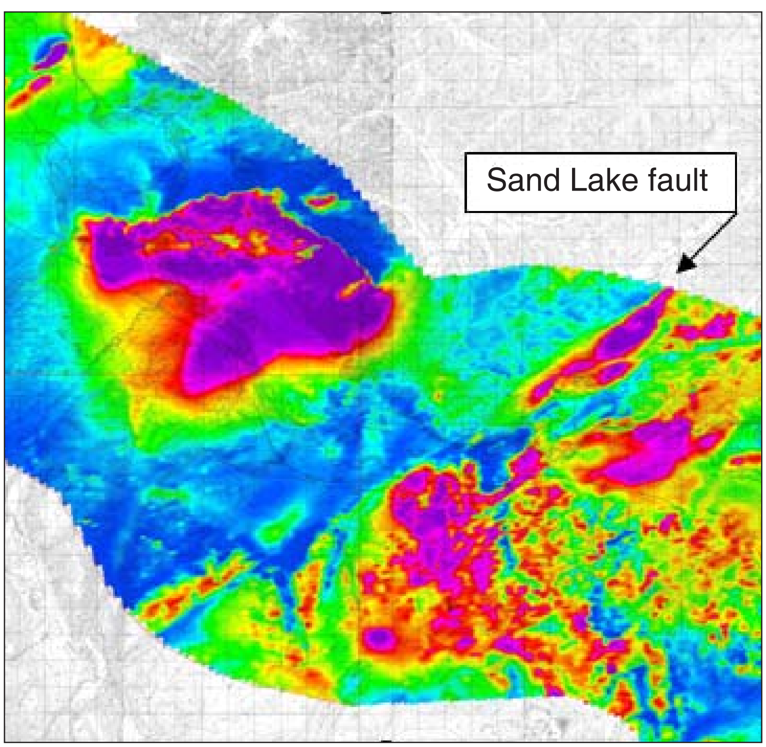

Figure 2. *Airborne total magnetic field survey of a portion of the Mt. Hayes Quadrangle.*

PRODUCTS

Products released to date include the basic geophysical data in map, grid, and database form, listed below in the first reference cited. Each map included in that publication is also available on the DGGS website (http://www.dggs.dnr.state.ak.us/pubs) in Adobe Acrobat (.pdf) format. An additional geophysical publication will contain the interpretive EM profiles and grids as described in this article and several other items. By mid 2008 we will publish 1:63,360-scale bedrock geology maps and surficial geology maps of the segment of the Alaska Highway corridor from Delta Junction to just east of Dot Lake. We will also publish, either as part of those maps or as separate reports, the results of our investigations into geohazards and material resources for that same segment of the corridor. Pending continued funding from the State Legislature, we hope to continue this project to the Canadian border.

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Dear Readers:

Very few geoscientists would dispute the claim that Alaska is a virtual 'candy store' of geology—when compared to other regions of our continent, Alaska certainly has one of the finest 'selections of flavors' to choose from. Besides hosting the largest oil and gas field ever discovered in North America, we are blessed with a multitude of geologic provinces that contain a complex suite of tectonic, sedimentary, metamorphic, mineralized, and magmatic terranes. In addition, the surficial processes that are constantly changing our landscape range from alpine to coastal, and arid-frozen Arctic to coastal rainforest. I cannot think of a geologic discipline that would go wanting for the lack of an exciting problem to decipher, and it could be argued that we have merely scratched the surface.

Your Alaska Division of Geological & Geophysical Surveys is fully engaged in increasing the geologic knowledge of the state and has developed a diverse set of programs to help address myriad geologic issues. New project areas and expansion of existing programs are providing much-needed information that will help explorers, policy makers, and communities make informed decisions in a dynamic world. Recent changes in the global commodity market have catapulted Alaska's vast resource potential into the forefront, and public realization that we live in a complexly interwoven physical and biological environment has fully awakened the debate of human involvement in the earth's natural processes.

These are exciting times.

To address the changing political, economic, and physical environment, the Alaska Geological Survey is in a constant state of metamorphosis. We are expanding our efforts on geohazard analysis across the state to keep pace with increased development activity as well as accelerated natural hazards associated with a warming Arctic. The feature article of this newsletter, by Diana Solie and Laurel Burns, highlights a major project we are undertaking to address geohazards and material sites along the proposed gas pipeline route from Delta Junction to the Canadian Border. This work will dramatically increase our geologic understanding in a poorly mapped area of the state that will likely see a dramatic increase in development activity.

Our energy group has moved into the subsurface with newly acquired data, and broadened its efforts to include a number of poorly understood basins across the state. The minerals group is expanding our airborne geophysical survey coverage and moving our detailed mapping efforts into new areas of mineralization. Our communications group continues to develop our web-served database, which has seen a dramatic increase in data distribution with more than 300,000 maps and reports being downloaded last year alone.

We again encourage you to visit our website (www.dggs.dnr.state.ak.us) or stop by our offices to discuss Alaska's geology and become involved in the cutting-edge work being undertaken at your State Geological Survey. We very much appreciate your input and support.

Sincerely,

Bob Swenson
State Geologist & Acting Director

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IC 56. Using geologic maps, by Athey, J.E., 2007, 2 p. Free.

DGGS NEWSLETTER

NL 2006-2. Alaska GeoSurvey News, by DGGS Staff, 2006, 10 p. Article: A brief overview of Alaska petroleum systems. Free.

RAW DATA FILES

RDF 2006-1. 2006 Bristol Bay, Alaska Peninsula field summary and outcrop sample results from porosity & permeability and mercury injection capillary pressure analyses, by Strauch, A.L., Gillis, R.J., Reifenstuhl, R.R., and Decker, P.L., 2006, 65 p. $7.

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