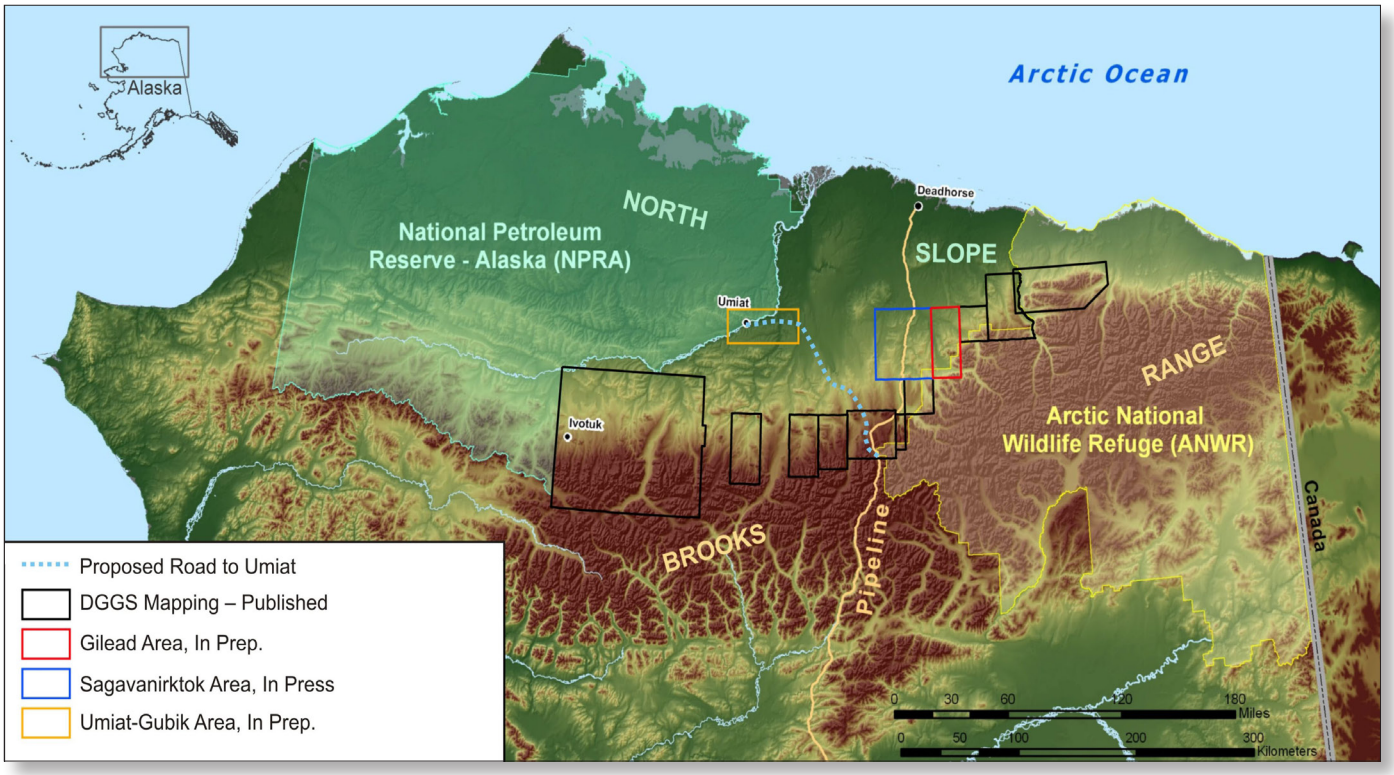
BROOKS RANGE FOOTHILLS AND NORTH SLOPE PROGRAM

Northern Alaska is a world-class petroleum province that includes some of the most prospective onshore regions remaining in North America. Despite this potential, the North Slope remains underexplored relative to other sedimentary basins around the world. New exploration ventures are hampered by the limited amount of published geologic data, much of it reconnaissance in nature. This problem is particularly acute for smaller companies with limited access to proprietary industry data. In an effort to stimulate exploration for hydrocarbons in northern Alaska, the Alaska Division of Geological & Geophysical Surveys (DGGS) developed a program to acquire and publish high-quality geologic data to improve our understanding of regional petroleum systems and entice new exploration investment. The cost of this program is shared by major and independent oil and gas companies. While directed by DGGS, this research effort is a multi-agency collaboration that includes the Alaska Division of Oil & Gas (DOG), the U.S. Geological Survey (USGS), the University of Alaska Fairbanks (UAF), and others.


Cretaceous deltaic sediments along the Colville River--an analogue for potential subsurface reservoirs

DGGS regularly conducts bedrock geologic mapping as an integral component of the Brooks Range Foothills and North Slope mapping program (see map). Our long-range objective is to eventually produce a contiguous series of detailed geologic maps along the entire foothills belt, thereby establishing the regional geologic framework necessary to understand the evolution of the petroleum system. Our work also includes examination of the sedimentology and stratigraphy of key Cretaceous-age reservoir and source-rock intervals, providing new constraints on the depositional history and correlation of units. Over the last several years we have also collaborated closely with DOG to interpret available seismic and well data on the North Slope. The integration of our surface structural and stratigraphic observations with subsurface data has allowed for an improved understanding of basin evolution and regional exploration potential.

Two new 1:63,360-scale geologic maps will be published through DGGS in the upcoming year as well as a collection of papers summarizing recent structural and stratigraphic studies.



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ALASKA DIVISION OF GEOLOGICAL & GEOPHYSICAL SURVEYS
FY14 Project Description

FRAMEWORK GEOLOGY OF PROSPECTIVE NORTH SLOPE SHALE OIL TARGETS

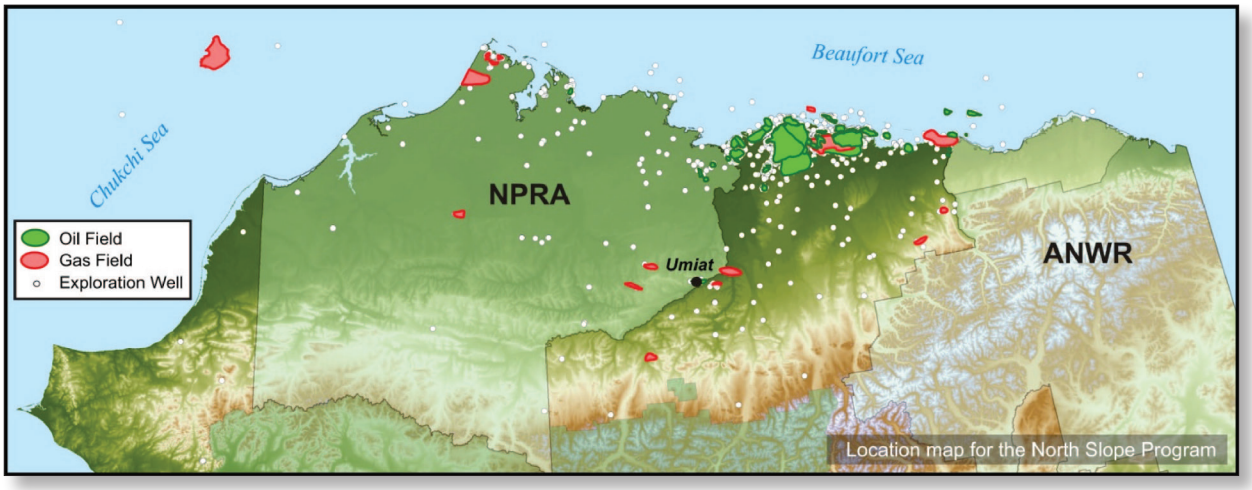
North Slope oil production is in decline as the main conventional fields mature, highlighting the need for new exploration and production (see map). Maturing petroleum basins in the Lower 48 have recently been rejuvenated by the advent of shale oil and shale gas exploration. The North Slope petroleum system includes three excellent organic-rich source rock intervals—a characteristic that is required for the successful creation of shale oil accumulations. Although the play is unproven in Alaska, industry has recently recognized its potential, as indicated by their investment in expansive lease tracts of prospective State-owned acreage south of the producing areas.

The main source rock of interest in northern Alaska is the Upper Triassic Shublik Formation (see photo), an interval known to have generated the oil that migrated into many of the conventional accumulations on the North Slope. The overlying Lower Jurassic Kingak Formation is also recognized as an oil-prone source, particularly the condensed basal part of the unit. Finally, the Cretaceous Hue Shale (see photo) includes significant organic-rich mudstone deposited in distal parts of the Colville foreland basin.

Numerous geologic factors influence the productivity of shale oil systems. Organic geochemical properties, thermal and tectonic history, porosity and permeability characteristics, and mechanical properties (brittleness) can each control whether the resource can be commercially produced. These key characteristics are poorly understood on the North Slope. In order to contribute to an improved understanding of this prospective hydrocarbon play, the Alaska Division of Geological & Geophysical Surveys (DGGS) recently initiated a collaborative study with the University of Alaska Fairbanks and the U.S. Geological Survey to evaluate the geology of targeted shale oil units. This project aims to acquire key subsurface and surface data, including the collection of a diverse suite of samples for laboratory analysis.


Organic rich Cretaceous mudstone and tuff, Hue Creek, eastern Brooks Range

Oil-saturated Triassic lime mudstone, western North Slope



Location map for the North Slope Program

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COOK INLET GEOLOGY AND HYDROCARBON POTENTIAL

The Alaska Division of Geological & Geophysical Surveys (DGGS) has led a multi-agency program of applied geologic research in Cook Inlet basin since 2006 to promote new petroleum exploration investment and support responsible resource and land-use management. The program was developed in response to predicted deliverability shortfalls for Cook Inlet gas supply to south-central Alaska customers and significant declines in oil production in recent decades that pose potential threats to the region's economy. This collaborative effort involving DGGS, the Alaska Division of Oil & Gas (DOG), the University of Alaska Fairbanks, and the U.S. Geological Survey relies heavily on performing detailed field studies to develop a better understanding of the basin's hydrocarbon system.

Historically, Cook Inlet exploration has focused on locating conventional plays in structural traps in younger, shallower Cenozoic rocks. Most of these large, relatively shallow structures have been found and tested, but the older, deeper Mesozoic strata that underlie the basin and contain Cook Inlet basin oil source rocks remain virtually unexplored. One of the challenges facing new exploration of the Mesozoic petroleum system in Cook Inlet is the identification of reservoir rocks capable of hosting oil and gas.

Beginning in 2009, DGGS and DOG initiated field studies of Mesozoic rocks in lower Cook Inlet to improve understanding reservoir type and quality, and geologic and structural controls on Mesozoic depositional systems in the older parts of the basin.

Work in the Kamishak Bay and Iniskin Peninsula areas (figs. 1 and 2) focused on Jurassic- and Cretaceous-age rocks, both of which contained intervals that are oil saturated, indicating that they had sufficient conventional permeability and porosity to pass and retain liquid hydrocarbons in the past. Samples collected at both locations will help to identify the hydrocarbon source rocks and determine whether the sandstone composition or other factors were responsible for their enhanced reservoir quality. Continued stratigraphic and structural studies in the Iniskin Peninsula and Tuxedni Bay areas, including new geologic mapping of the Iniskin Peninsula in summer 2013, focused on how major geologic structures such as the Bruin Bay fault influenced the basin's stratigraphic architecture, which has implications for predicting the distribution of reservoir and reservoir seal lithologies. We are continuing fracture studies of Mesozoic rocks in the Kamishak Bay and Iniskin Peninsula areas to understand the stratigraphic and structural controls on their development and gather baseline data about unconventional fracture porosity and hydrocarbon migration pathways.

This project is funded by the State of Alaska and the U.S. Geological Survey, with contributions from industry. Results of this work have been documented in a series of publications available from the DGGS website (http://www.dggs.alaska.gov), including a recently published edited volume highlighting the significant findings from our 2012 field season (http://www.dggs.alaska.gov/webpubs/dggs/pir/text/pir2013_001.pdf). Additional publications will be released as they become available, beginning in early 2014.

Figure 1. DGGS geologist Trystan Herriott measuring the orientation of a Jurassic sandstone bed on a high bluff overlooking Cook Inlet as part of a geologic mapping project on the Iniskin Peninsula.

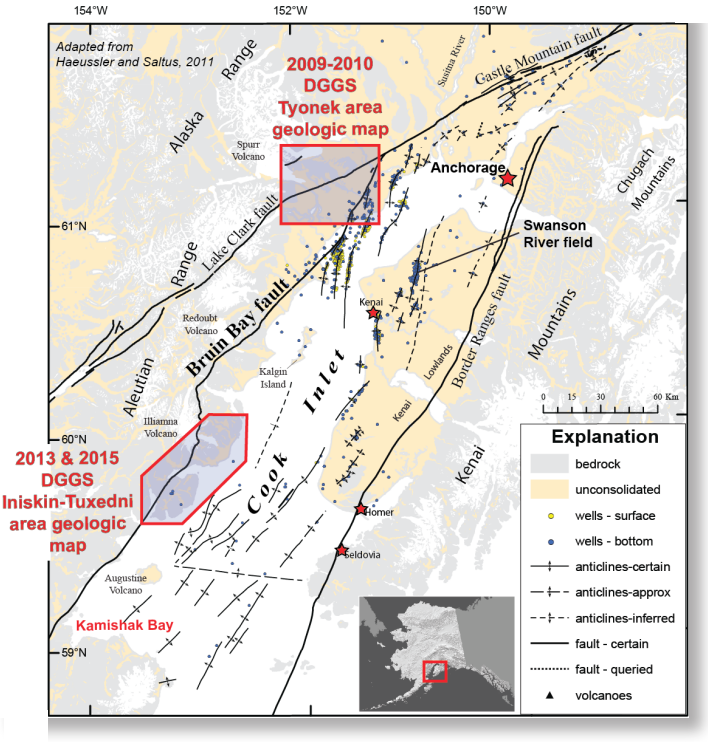

Figure 2. Generalized geologic map of Cook Inlet basin. Modified from Haeussler and Saltus, 2011, U.S. Geological Survey Professional Paper 1776-D.

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ALASKA DIVISION OF GEOLOGICAL & GEOPHYSICAL SURVEYS
FY14 Project Description

GEOLOGIC MAPPING OF THE INISKIN PENINSULA, LOWER COOK INLET

Gas production from Cook Inlet basin has contributed significantly to Alaska's economy by providing inexpensive natural gas for industrial use, electric power generation, home heating fuel, and job creation for south-central Alaska. Rising demand, predicted deliverability shortfalls, and volatility in commodity prices underscore the need for discovery of additional gas reserves in Cook Inlet. Despite the growing need and significant remaining gas potential, Cook Inlet basin remains underexplored. The Division of Geological & Geophysical Surveys (DGGS) is responding by conducting a program in the basin focused on understanding how sediment composition, stratigraphic architecture, and geologic structure control potential conventional and unconventional (tight) reservoir systems (see briefing paper, facing page). This program includes detailed geologic mapping in Cenozoic and Mesozoic stratigraphic intervals where outcrop relations are complex, poorly understood, and important for understanding the potential for gas reservoirs.

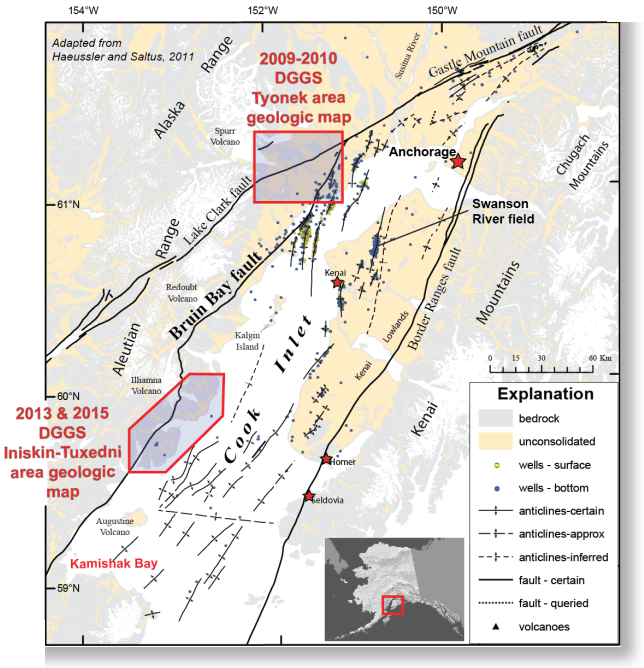

Figure 1. Regional map of the Cook Inlet region, showing the locations of previous and current DGGS geologic mapping projects in the Cook Inlet basin.

During summer 2013 DGGS, with help from the Division of Oil & Gas (DOG), completed 1:63,360-scale geologic mapping of approximately 260 square miles on the Iniskin Peninsula (fig. 1). This work represents the first year of a multi-year project to re-map the stratigraphic and structural relationships of the Mesozoic forearc basin interval from Iniskin Bay northeastward to Red Glacier by 2015. The Iniskin Peninsula area (fig. 2) hosts numerous oil seeps and was the site of some of the earliest oil exploration in Alaska from the early 1900s to the 1950s, but has remained idle since. A more thorough geologic understanding of the region is important because the entire Mesozoic stratigraphy, including the oil source rocks to the Cook Inlet basin, is well exposed in this region, yet reconnaissance work by DGGS in the area since 2009 suggested that the original mapping conducted five to six decades prior is in need of significant revision. Our new mapping is guided by nearly 20 new measured stratigraphic sections, new geochronology, and kinematic structural analysis, some of which will be detailed in a series of short progress reports published in early 2014. The final published product will be a new 1:63,360-scale geologic map encompassing approximately 500 square miles along the northwestern margin of Cook Inlet basin, and an accompanying report. Our mapping has unraveled complex stratigraphic and structural relationships and represents a major step forward in understanding the geologic evolution of the northwestern margin of the basin. Our work in this area will help spur exploration interest and investment in Cook Inlet basin.

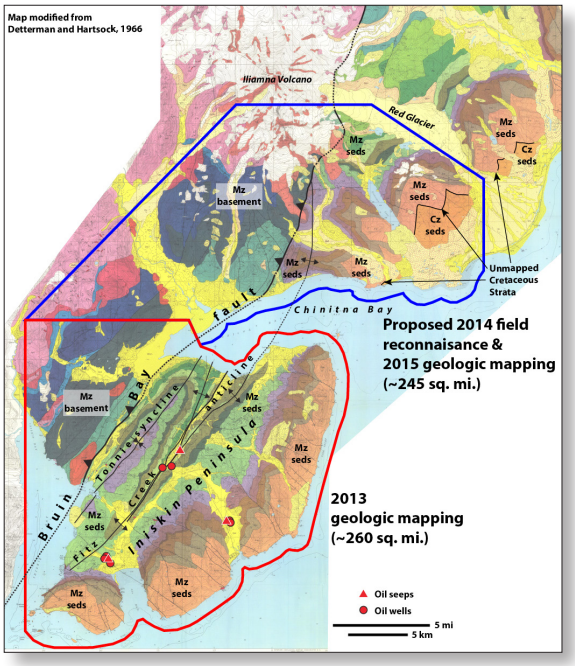

Figure 2. Locations of 2013 geologic mapping (red outline), and proposed geologic reconnaissance and mapping in 2014 and 2015 (blue outline).

Preliminary 2013 mapping was completed with partial funding from the U.S. Geological Survey's STATEMAP program; a preliminary map of the Iniskin Peninsula will be submitted to the USGS in spring 2014. Preliminary results from related stratigraphic and structural studies will be published as DGGS reports starting in early 2014.

Figure 3. DGGS geologist Marwan Wartes conducting field geologic mapping of a stratigraphic contact in Naknek Formation rocks on the Iniskin Peninsula (2013).

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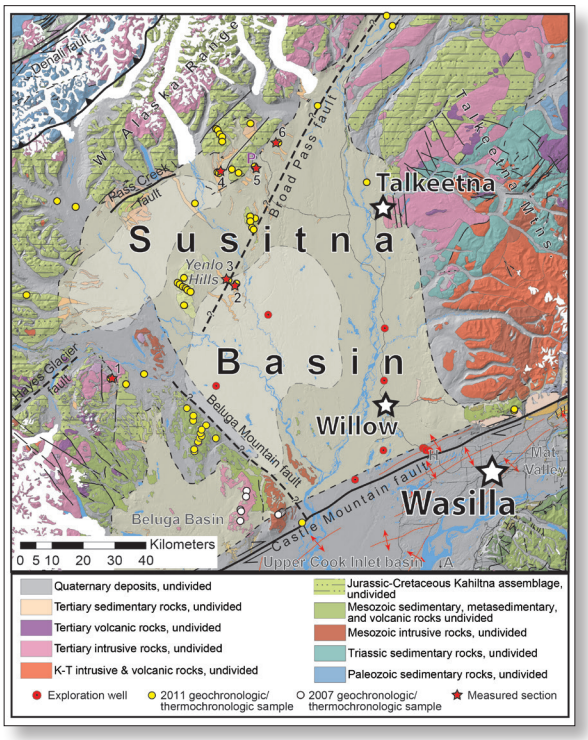
NATURAL GAS POTENTIAL OF THE SUSITNA AND NENANA BASINS



Geologic map of the Susitna basin region, showing sample collection locations and proximity of the potential gas-prospective basin to major population centers such as Wasilla.

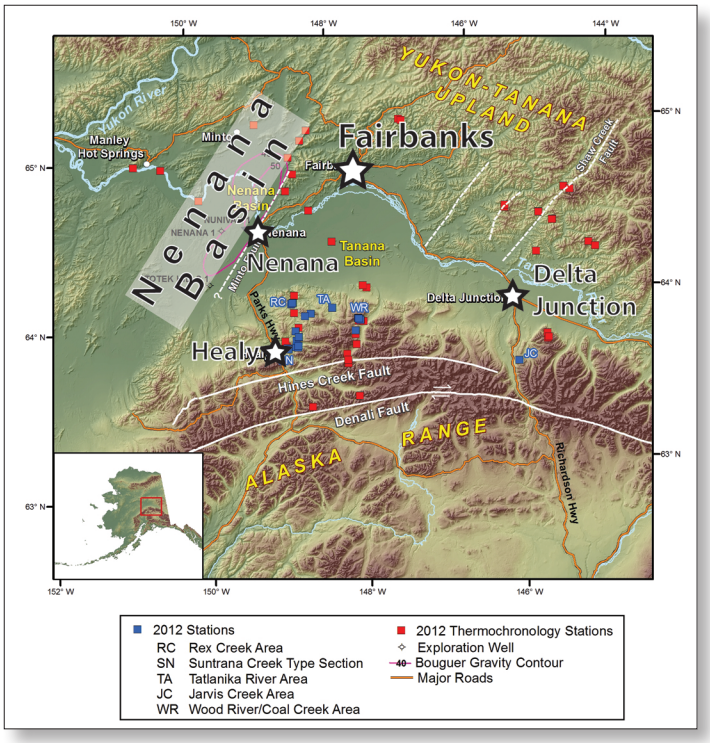
Alaska faces significant future challenges in supplying reliable, affordable domestic energy to a large percentage of the state's population, particularly in rural areas and interior regions. This is because adequate energy sources at reasonable cost have not been identified to serve domestic needs over the next few decades. These challenges can be mitigated by looking for local resources that have the potential to supply more affordable energy for nearby consumption.

The Alaska Division of Geological & Geophysical Surveys (DGGS) in collaboration with the Alaska Division of Oil & Gas (DOG), has responded to these challenges by reviewing publicly available data on sedimentary basins throughout Alaska to identify those whose geology suggests significant natural gas potential (see http://www.dggs.alaska.gov/webpubs/dggs/sr/text/sr066.PDF).

We have identified the Susitna basin in south-central Alaska and the Nenana basin in interior Alaska as having significant gas potential to help meet in-state needs based on geological grounds and proximity to infrastructure (figs. 1 and 2). However, neither of these basins has been adequately explored and little geologic data exist to help attract exploration interest. Basin analysis projects have been initiated in each basin aimed at better understanding the possible presence of functioning petroleum systems. Preliminary fieldwork has been completed in each basin, including progress reports published in 2013 (see http://www.dggs.alaska.gov/webpubs/dggs/pir/text/pir2013_004.pdf and http://www.dggs.alaska.gov/webpubs/dggs/pir/text/pir2013_002.pdf).

The Susitna basin (approximately 5,000 square miles) is thought to host some of the same gas-producing rocks as the neighboring Cook Inlet basin. DGGS and DOG studied and described stratigraphic exposures at several locations in the basin and collected more than 250 samples for various analyses related to evaluating reservoir quality and geologic development of the region. The Nenana basin lacks exposures of potential hydrocarbon-producing rocks at the surface, but the rocks in the subsurface are thought to be correlative to stratigraphy of similar age exposed in the foothills of the Alaska Range directly to the south. Similar to the Susitna basin, DGGS and DOG studied, described, and sampled selected stratigraphic intervals of these rocks at several locations during field studies in 2012. In addition, approximately 50 samples were collected from around the periphery of the Nenana and Tanana basins to develop a better understanding of how and when the basins began to form.

Additional fieldwork is scheduled in the Susitna basin in 2014, as well as compilation of publicly-available well data and additional analyses of well material from the recently drilled Nunivak wells in the Nenana basin.



Geologic map of the Nenana and Tanana basin regions, showing sample collection locations and proximity to Fairbanks and other communities.

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STATE OF ALASKA CONTRIBUTIONS TO THE NATIONAL GEOTHERMAL DATA SYSTEM

The National Geothermal Data System (NGDS) is a U.S. Department of Energy-funded distributed national network of databases and data sites that collectively form a system for the acquisition, management, and maintenance of geothermal and related data (http://www.stategeothermaldata.org/). This national project, involving all 50 states, is organized by the Association of American State Geologists and administered by the Arizona Geological Survey (fig. 1). The goal of the NGDS is to make large quantities of geothermal-relevant geoscience data available to the public and industry by creating a national, sustainable, distributed, and interoperable network of data providers. The state geological surveys develop, collect, serve, and maintain geothermal-relevant data as an integral component of NGDS. The project is digitizing at-risk, legacy geothermal-relevant data and publishing existing digital data by making state databases and directories available to the network.

Much of the risk of geothermal energy development is associated with exploring for, confirming, and characterizing available geothermal resources. The overriding purpose of the NGDS is to help mitigate this risk by serving as a central repository for geothermal and relevant related data, as well as a link to distributed data sources. By helping with the process of assessing and categorizing the nation's geothermal resources, providing strategies and tools for financial risk assessment, and consolidating all geothermal data through a publicly-accessible data system, the NGDS supports research, stimulates public interest, promotes market acceptance and investment, and, in turn, supports the growth of the geothermal industry.

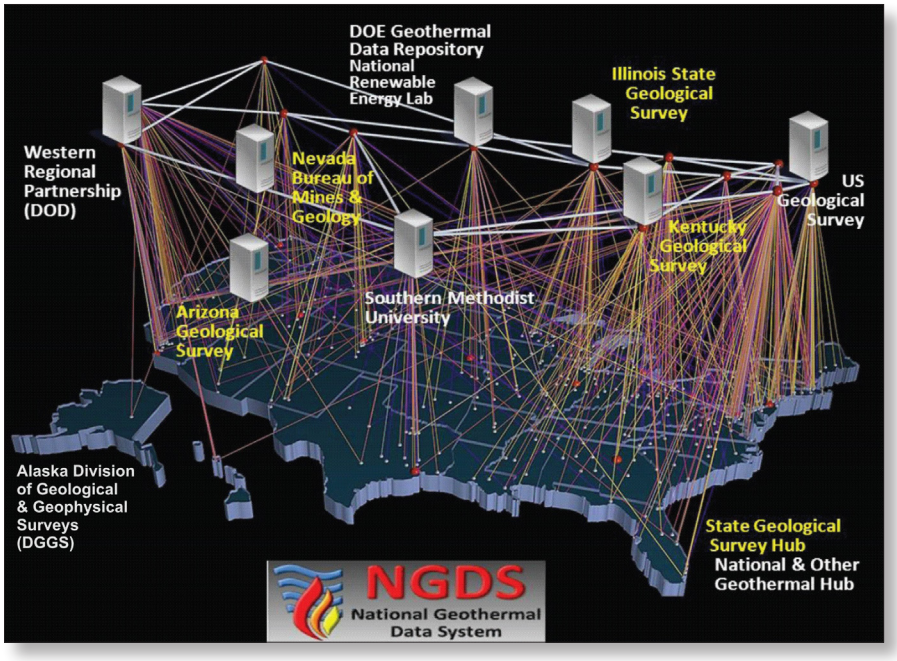

Figure 1. Fifty-state network of geothermal data providers to the NGDS, and the regional hubs (in yellow).

The Alaska Division of Geological & Geophysical Surveys (DGGS) is contributing Alaska geothermal data to the NGDS as part of a three-year national effort called the State Geological Survey Contributions to NGDS Data Development, Collection, and Maintenance. DGGS has submitted feature templates to the NGDS, contributing to the NGDS detailed information on Alaska's geothermal springs (97 sites), aqueous chemistry (815 analyses from 90 sites), Quaternary and younger volcanic vents (395), geothermal wells (122 wells drilled at nine sites), thermal profiles (239 profiles from 70 wells), bottom-hole temperature observations (from 338 oil and gas wells), direct-use applications of geothermal energy (15 sites), earthquake hypocenter data within 5 km of thermal springs (1,974 events), and a geothermal bibliography with 526 references. The project will culminate in the completion of a new ArcGIS-based Geothermal Sites of Alaska map that will incorporate shapefiles of all the related geothermal data sets submitted to the NGDS (fig. 2). This map will be available online for the public by spring of 2014.

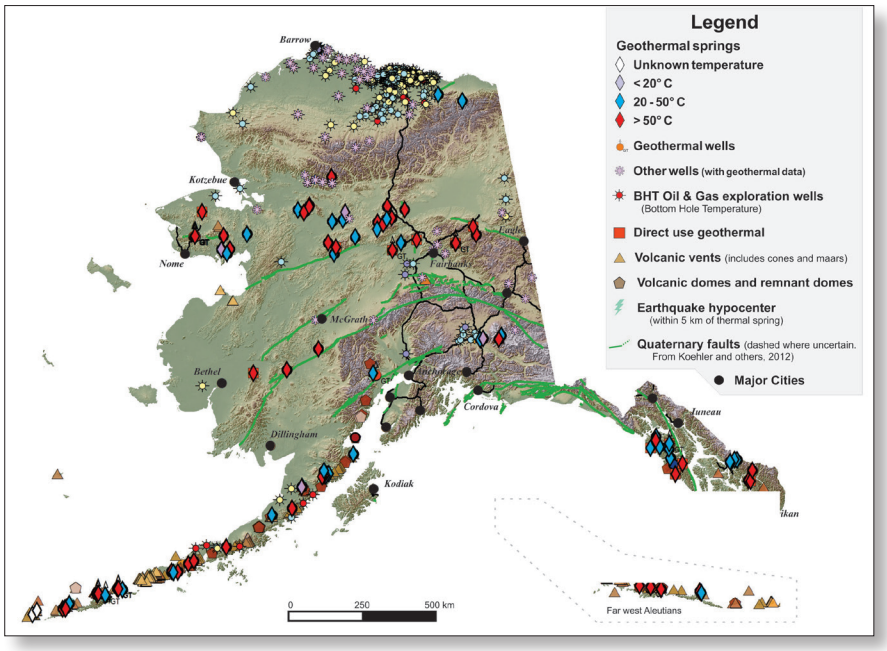

Figure 2. Preliminary draft of the new Geothermal Sites of Alaska map that will be available online in digital format.

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ALASKA COAL DATABASE—NATIONAL COAL RESOURCE DATABASE SYSTEM

The long-term goal of the Alaska Division of Geological & Geophysical Surveys' (DGGS) participation in the U.S. Geological Survey's (USGS) National Coal Resource Database System (NCRDS) cooperative program is to record all known coal occurrences in Alaska and archive the information in a single, readily accessible database available at the USGS website, http://energy.er.usgs.gov/products/databases/USCoal/. The NCRDS program is funded by USGS through a multi-year proposal process with final reporting at the end of each funding period.

Alaska's coal resources make up about half of the United States' coal-resource base and approximately one-sixth of the total world resource base. Total identified Alaska coal resources (all ranks) amount to about 160 billion short tons, yet hypothetical and speculative resources are as high as 5.5 trillion short tons. During the course of gathering information to expand the NCRDS database for Alaska, we recognized the need to collect new coal samples and stratigraphic field data for previously described occurrences. Sometimes a coal occurrence described in literature is poorly located and the description is either inaccurate or inadequate for a proper resource assessment. The most frequent problems we have encountered are unverified coal seams and coal sample locations, suspect coal quality analyses, and insufficient stratigraphic control.

We continue to submit coal samples collected by field crews conducting studies in both the Cook Inlet and North Slope coal provinces, for proximate and ultimate analyses. We focus only on thicker, potentially mineable coal seams that have not been sampled previously. During 2013 we conducted high-pressure gas adsorption analyses on well and outcrop samples from Cook Inlet, North Slope, and Nenana basins (fig. 1). This new data will provide information on the gas holding capacity and carbon sink potential for coal seams in these basins. The project continues to make progress rectifying for accuracy the legacy Alaska NCRDS data sent to DGGS by the USGS team.

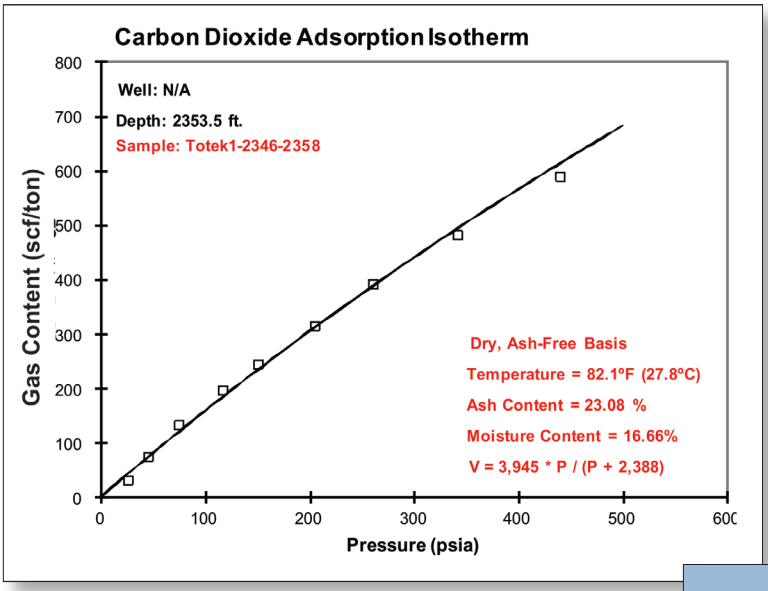

Figure 1. Example of carbon dioxide pressure isotherm from the Totek Hills well, Nenana basin, at a depth of 2,353 ft.

The database for Alaska coal quality and stratigraphic information continues to grow and we are incorporating these data and the appropriate GIS files into the new Coal Resources of Alaska GIS map. This new ArcGIS-based coal resources map of Alaska (fig. 2) meshes well with the NCRDS work by incorporating the coal data into a meaningful and useful format. The map contains compiled geology layers where available, and coal isopachs where calculated and available. We are also incorporating into this map the Alaska abandoned coal-mine inventory data, which has never before been available in a digital format. The new GIS map will allow for calculations of coal resources in areas with sufficient coal-thickness point-source data. This map will be completed at the end of the current 5-year NCRDS project in fall 2015. The final GIS map product will be posted on the DGGS website.

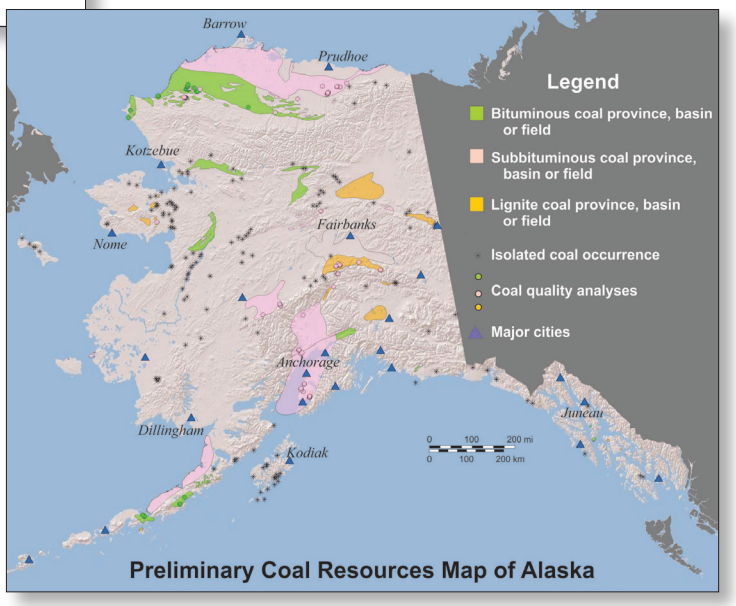

Figure 2. Preliminary draft version of GIS-based Coal Resources of Alaska map that displays coal provinces, basins, coal fields, and isolated coal occurrences and incorporates NCRDS coal quality point source data.

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