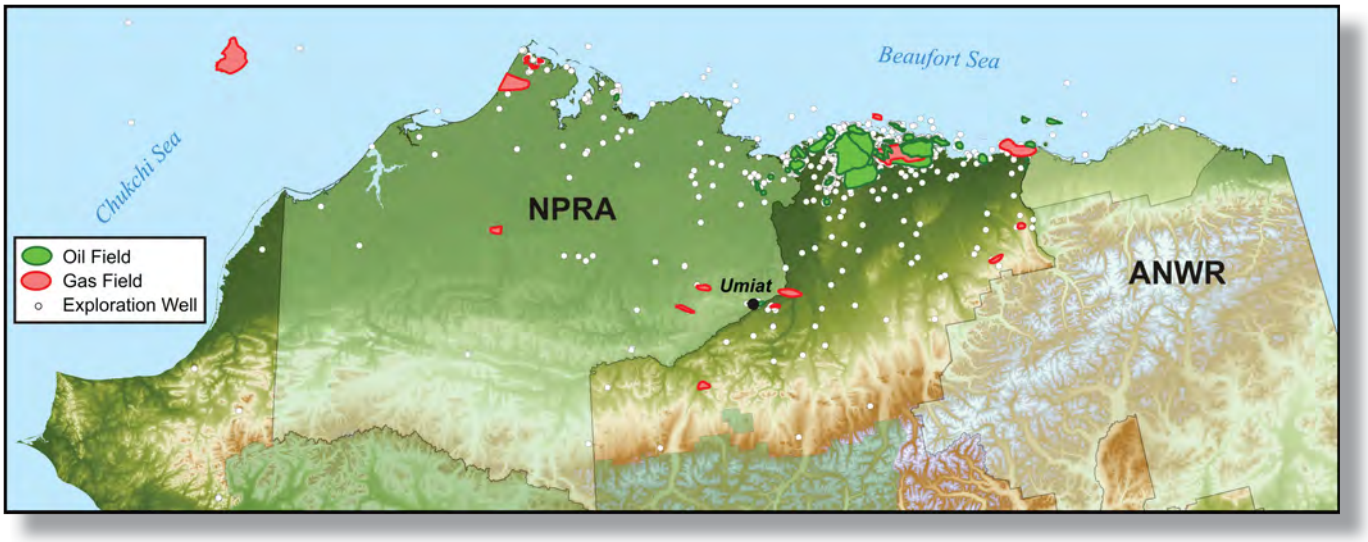
BROOKS RANGE FOOTHILLS & NORTH SLOPE PROGRAM

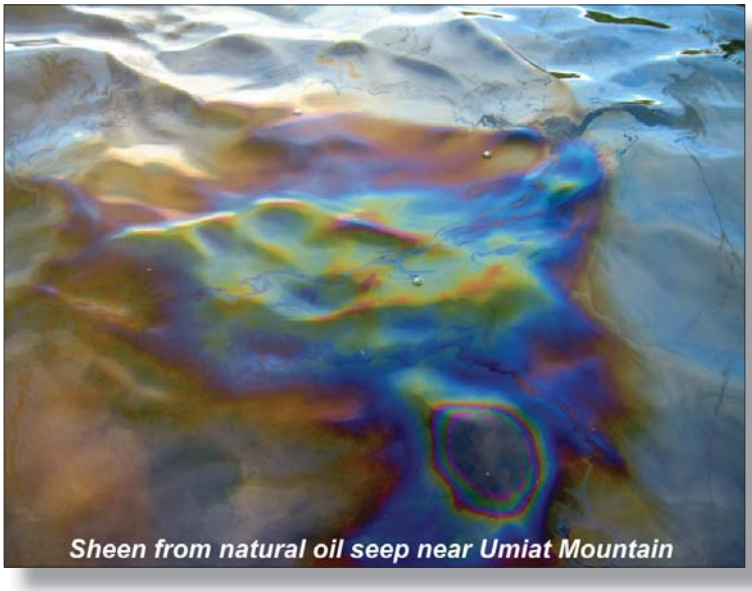
Northern Alaska is a world-class petroleum province that includes some of the most prospective onshore regions remaining in North America. Despite this potential, the North Slope remains underexplored relative to other sedimentary basins around the world. New exploration ventures are hampered by the 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, DGGS developed a program to acquire and publish high-quality geologic data to improve our understanding of regional petroleum systems, entice new exploration investment, and support responsible resource and land-use management. The cost of this program is shared by industry, the State of Alaska, and federal government. While directed by DGGS, this research effort is a multi-agency collaboration that includes the Alaska Division of Oil & Gas (ADOG), the United States Geological Survey (USGS), the University of Alaska, and others.



The limited exploration and development on the central North Slope partly reflects the region's remoteness and lack of infrastructure. To help stimulate industry activity, the State is pursuing the construction of a road to the undeveloped oil and gas fields in the Umiat area (see map). During the 2011 field season, our program conducted detailed geologic mapping and associated studies in the area of the proposed transportation corridor (see p. 31). Our work 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. This type of detailed analysis of outcrop geology leads to improved models for subsurface hydrocarbon accumulation.

Over the past several years we have also collaborated closely with the State Division of Oil and Gas 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.

During 2011, DGGS delivered a number of technical presentations at regional and international petroleum geology conferences, summarizing the results of our recent work relevant to oil and gas exploration in northern Alaska. We also published more than 600 square miles of detailed geologic mapping of prospective State lands on the eastern North Slope, adjacent to ANWR. Additional geologic maps will be published through DGGS in 2012 (see p. 31) as well as a collection of papers summarizing topical structural and stratigraphic studies.


Sheen from natural oil seep near Umiat Mountain

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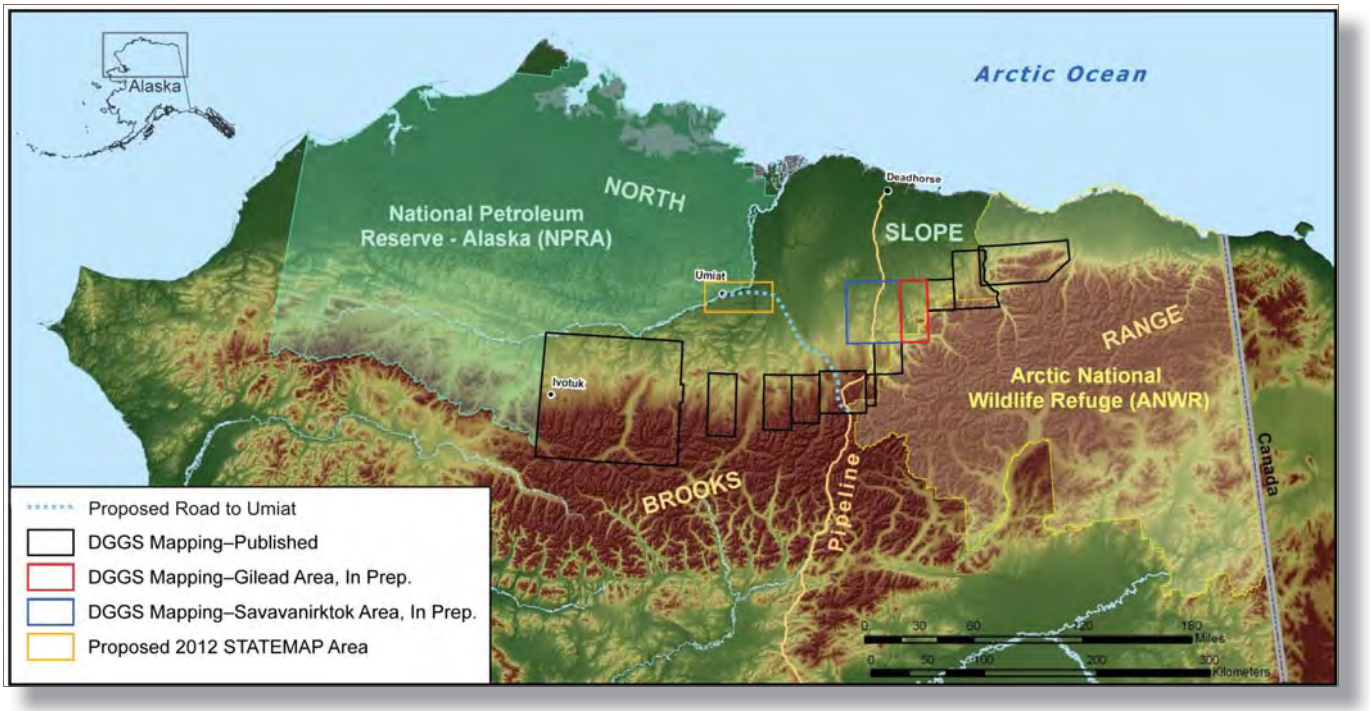
GEOLOGIC MAPPING ON THE NORTH SLOPE

Many regions of the North Slope that are prospective for oil and gas exploration are covered by tundra, thus limiting the collection of geologic data to very costly subsurface methods such as seismic reflection and drilling efforts. However, geologic investigation of related rocks exposed at the surface in the northern foothills of the Brooks Range offers a unique opportunity to study structural and stratigraphic relationships, often resulting in predictive insights into the subsurface petroleum geology elsewhere on the North Slope. The Energy Resources Section of DGGS conducts bedrock geologic mapping as an integral component of the Brooks Range Foothills and North Slope Program (see p. 30). Our long-range objective is to produce a series of contiguous, detailed geologic maps along the entire foothills belt. These maps will establish the regional geologic framework necessary to understand the evolution of the petroleum system needed to support resource management and industry exploration on State lands. In addition, our ongoing work provides critical baseline geologic information that helps constrain the resource potential and long-term supply for the Trans-Alaska Pipeline System and the proposed natural gas pipeline.

During recent summer field campaigns we completed detailed 1:63,360-scale geologic mapping of approximately 1,800 square miles of the eastern North Slope (red and blue box above). We have also conducted preliminary mapping in the Umiat area (yellow box) and propose to conduct additional work in this prospective region during 2012. In collaboration with the Alaska Division of Oil and Gas, we have integrated our surface observations with available subsurface data (seismic and wells) to arrive at a more robust interpretation of the petroleum geology. The new mapping has improved our understanding of fold geometry, which is a key component in evaluating hydrocarbon trapping mechanisms. Detailed stratigraphic observations also enhance our knowledge of how Upper Cretaceous rocks correlate with one another, allowing for improved models explaining the distribution of potential source and reservoir rocks in the subsurface.

This work is supported in part by the federally funded STATEMAP program administered by the U.S. Geological Survey (USGS). The Sagavanirktok River and Gilead Creek map products will be published by mid 2012 as DGGS Reports of Investigation.

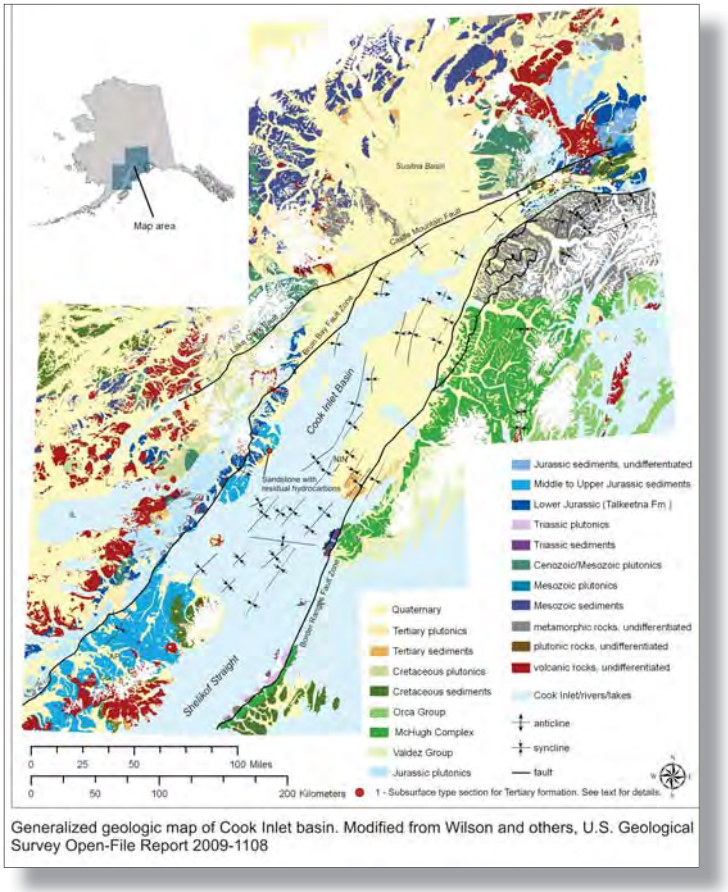


Contact, Sag River map area: Robert J. Gillis, 907-451-5024, robert.gillis@alaska.gov
Contact, Gilead map area: Trystan M. Herriott, 907-451-5011, trystan.herriott@alaska.gov
Contact, Umiat-Gubik map area: Marwan A. Wartes, 907-451-5056, marwan.wartes@alaska.gov

COOK INLET GEOLOGY AND HYDROCARBON POTENTIAL

Increasing demand and predicted deliverability shortfalls for Cook Inlet gas to south-central Alaska customers, combined with significant oil production declines, pose serious threats to the region's economy. The Alaska Division of Geological & Geophysical Surveys (DGGS) is responding to these challenges by leading a multi-year, multi-agency program of applied geologic research to promote new exploration investment and support responsible resource and land-use management. This collaborative effort involves DGGS, the Alaska Division of Oil & Gas (DOG), the University of Alaska Fairbanks, and the U.S. Geological Survey.

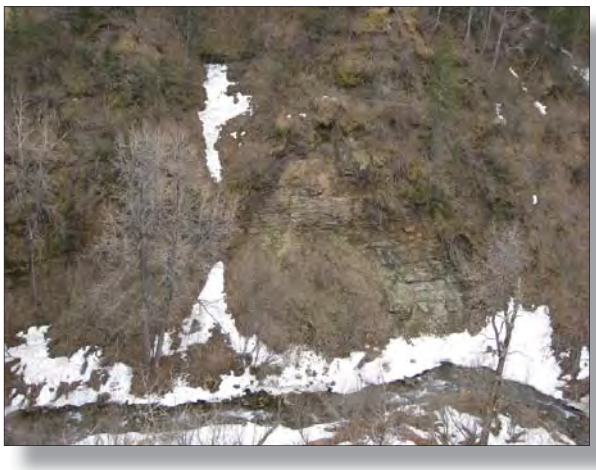
Historically, Cook Inlet exploration has focused on locating large fold structures with four-way closure (analogous to an inverted bowl). Most large structures have been found and tested, and the exploration focus is gradually shifting to subtle stratigraphic traps, reservoirs in formations with low porosity and permeability, and source reservoirs (shale oil and shale gas). Successful exploration for these more elusive reservoirs requires detailed knowledge of potential reservoir geometries, geologic factors controlling them, and geologic controls on reservoir producibility. The initial goal of this program is to improve understanding of reservoir geometries, reservoir quality, their geologic controls, and the structural history of Cook Inlet basin.



Generalized geologic map of Cook Inlet basin. Modified from Wilson and others, U.S. Geological Survey Open-File Report 2009-1108

Generalized geologic map of Cook Inlet basin. Modified from Wilson and others, U.S. Geological Survey Open-File Report 2009-1108.

During 2011, DGGS and DOG continued documenting the geometry of potential reservoir sand bodies in Tertiary- and Mesozoic-age sandstones in the Capps Glacier–Beluga River region west of Anchorage and along the west side of lower Cook Inlet, due west of Anchor Point (see map, right). Work in the former area focused on documenting alluvial fan and gravelly and sandy river deposits along the western basin margin, and basin-bounding structures that deform them. Detailed stratigraphic and structural studies by our group have demonstrated these rocks were deposited during a period of active faulting and volcanic activity, both of which dramatically affected sand body geometries and reservoir quality, and were subsequently subjected to complex folding and faulting. Work in the latter area focused on documenting sand body geometries, reservoir quality, and petroleum-source-rock potential of Middle Jurassic- through Lower Cretaceous-age rocks in coastal exposures. An exposure of sandstone with residual oil, located east of Iliamna Volcano, was sampled for geochemical analysis (see outcrop photograph). Oil extracted from this sample has provided valuable information on petroleum source rocks known to underlie much of the basin. Important additional components of this program include (1) integrated analysis of reservoir potential and quality of Mesozoic sandstones in lower Cook Inlet and Cenozoic sandstones in upper Cook Inlet; (2) a subsurface mapping effort aimed at delineating the distribution of petroleum source rocks relative to thick accumulations of potential reservoir sandstones; (3) structural analysis of basin-bounding faults; (4) analysis of the subsidence and uplift history of upper Cook Inlet basin using publicly available well data; and (5) a detailed bedrock mapping project along the northwestern basin margin (see p. 33).



This project is funded by the State of Alaska and the U.S. Geological Survey, with contributions by Apache Corporation. Results of this work have been documented in a series of publications available from the DGGS website (http://www.dggs.alaska.gov). Additional publications will be released as they become available, including a brief report describing the sandstone with residual hydrocarbons (available early 2012).

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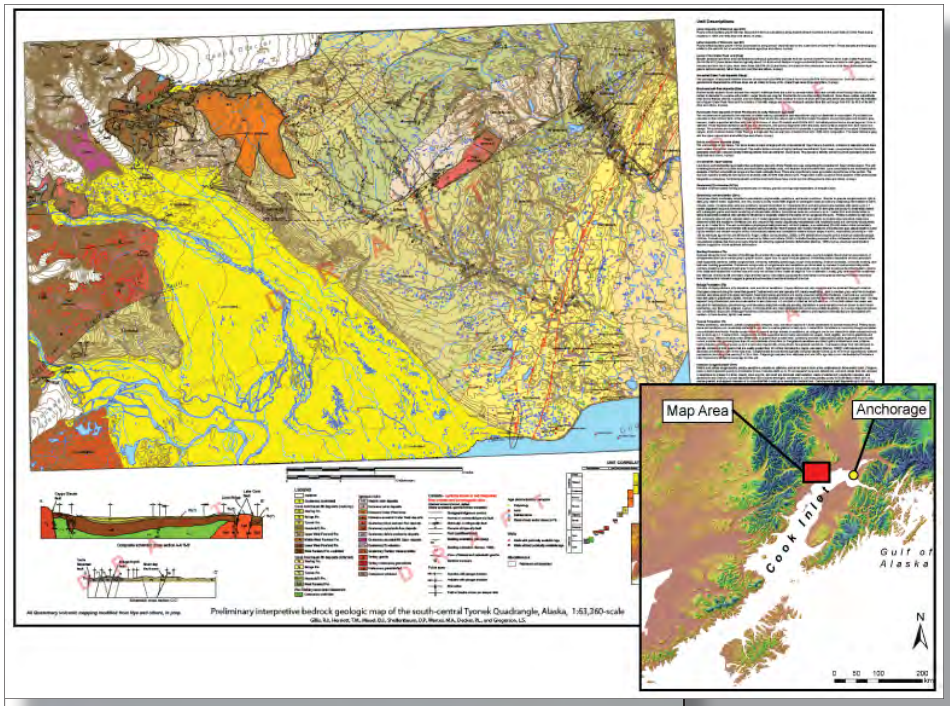
GEOLOGIC MAPPING OF THE TYONEK–CAPPS AREA

Rising residential and commercial heating and power demands, predicted deliverability shortfalls, and volatility in commodity prices underscore the need for discovery of additional gas reserves in Cook Inlet. However, until just recently, new exploration continued to be weak despite the growing need and significant gas potential remaining in the basin. The Division of Geological & Geophysical Surveys (DGGS) is attempting to promote exploration interest by focusing on understanding the potential for stratigraphic traps and gas reservoirs in low porosity and permeability (tight) formations (see p. 32). This program includes detailed geologic mapping of areas where outcrop relations are complex, poorly understood, yet important for understanding the potential for gas reservoirs in stratigraphic traps and tight formations.

During the summers of 2009–2011, DGGS completed 1:63,360-scale geologic mapping of nearly 875 square miles in the Tyonek Quadrangle along the northwestern margin of Cook Inlet basin (see inset geologic map). A more thorough geologic understanding of this area is important because it includes some of the best exposures of Tertiary strata in the basin (see inset photo), some of which serve as reservoirs in the nearby Beluga River, North Cook Inlet, and Granite Point fields. Additionally, the area is transected by several major faults that influenced sedimentation in the greater Cook Inlet basin, including a family of faults that are also responsible for forming some of its structural hydrocarbon traps. Yet available geologic mapping in the area predates modern stratigraphic nomenclature used in the basin and lacks the structural detail necessary to adequately understand the geologic development of the basin margin. Further hindering such understanding is a thin cover of Quaternary deposits that obscure underlying bedrock relationships throughout some of the most prospective onshore regions of the basin. With the aid of publicly and privately held subsurface and airborne geophysical data, our field mapping and stratigraphic work 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. Direct results of our work include (1) the recognition of at least two episodes of deformation along the northwestern basin margin involving different structural styles, (2) the first recognized occurrence of the Hemlock Conglomerate, one of the principal oil reservoirs in the basin, to the northwest of what has long been recognized as the Bruin Bay fault, and (3) that the Bruin Bay fault is not mappable as a through-going fault at the surface in upper Cook Inlet. The Bruin Bay fault thus should be redefined as a mostly pre-Tertiary structure. These insights are novel, well documented concepts that will provide important new information to companies and agencies interested in the hydrocarbon potential of Cook Inlet basin.



Preliminary 2009 and 2010 mapping was completed with partial funding from the U.S. Geological Survey's STATEMAP program and a preliminary map of the project area was submitted to the USGS in spring 2011. A final digital map product and results from related stratigraphic and structural studies will be published as DGGS reports in summer 2012.

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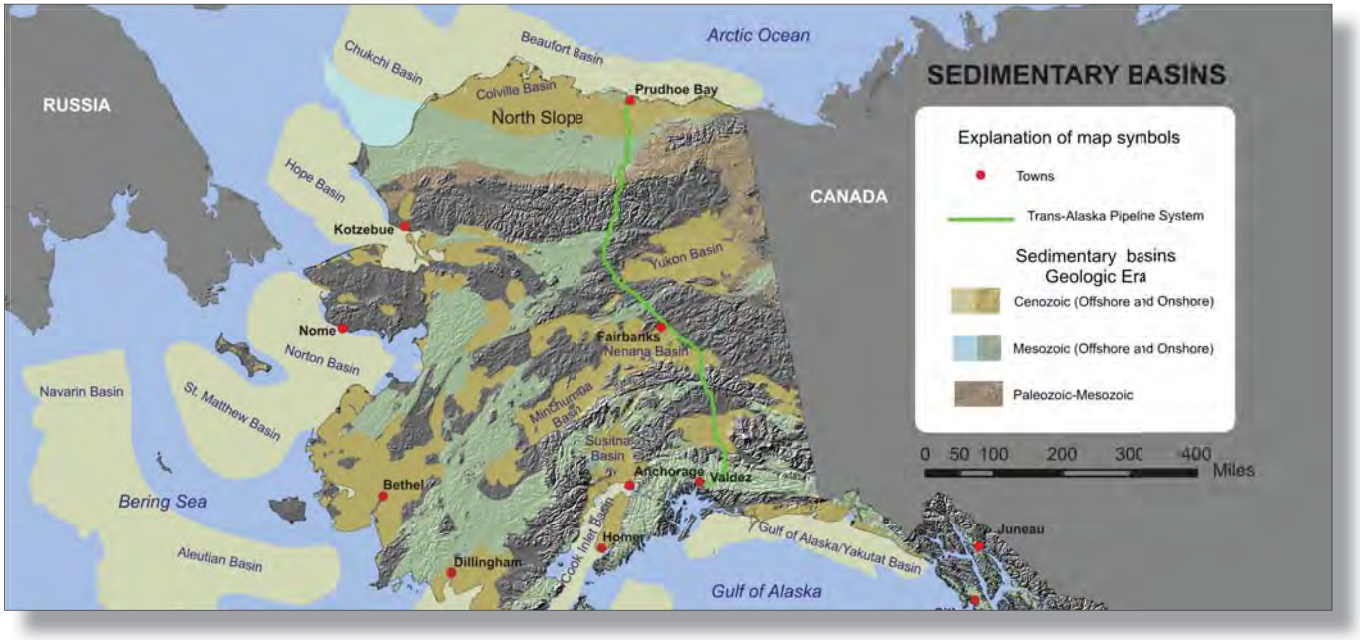
ALASKA DIVISION OF GEOLOGICAL & GEOPHYSICAL SURVEYS
FY12 Project Description

NATURAL GAS POTENTIAL OF THE SUSITNA AND NENANA BASINS

Alaska faces significant domestic energy challenges that threaten the economic well-being of the population and the state's economic future. Simply stated, the state has not identified adequate energy sources to serve domestic needs at reasonable cost over the next few decades. The only way to mitigate these challenges is to look for local sources of energy that have the potential to supply more affordable energy for local 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 basins whose geology suggests significant natural gas potential. The Susitna and Nenana basins have been identified, on geological grounds, as having significant gas potential to help meet in-state needs. Basin analysis projects are underway in each basin aimed at better understanding the possible presence of functioning petroleum systems. This project is being conducted in three phases, with phase I focusing on the Susitna basin, phase II on the Nenana basin, and phase III on finalizing work in both basins and generation of final reports.



In June 2011, DGGS completed ten days of fieldwork in the Susitna basin. Work centered on documenting characteristics of non-marine floodplain mudstones, coals, and river channel deposits of sandstone, as well as documenting the structural evolution of the basin. Floodplain mudstones and coal seams represent potential reservoir seal and gas source rocks, respectively, and sandstones are potential gas reservoirs. These lithologies must be present in the subsurface of the basin in favorable locations relative to one another to allow the accumulation and entrapment of gas. Structural data gathered from the basin margin and intra-basinal uplifts will help define the timing of uplift events. These data will be integrated in a basin model for use in evaluating the possibility of microbial gas in the Susitna basin analogous to producing fields in neighboring Cook Inlet basin to the south.

Planning is underway for 10 days of fieldwork in the Nenana basin in May 2012. Publicly available data are being compiled in ArcGIS for use in designing the field program. The field focus will be to document potential gas source and reservoir rocks and to better understand the basin history as it relates to gas generation, migration, and entrapment in reservoir sand bodies.

This project is funded by the State of Alaska. Results will be documented in a series of publications available from the DGGS website (http://www.dggs.alaska.gov/pubs/) over the next 2–3 years.

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ALASKA DIVISION OF GEOLOGICAL & GEOPHYSICAL SURVEYS
FY12 Project Description

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. The NGDS website is: http://www.geothermaldata.org/. This national project, involving all 50 states, is organized by the Association of American State Geologists and administered by the Arizona Geological Survey (AZGS). The goal of the NGDS is to make large quantities of geothermal-relevant geoscience data available to the public by creating a national, sustainable, distributed, and interoperable network of data providers. The state geological surveys will 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 databases and directories available to the network.

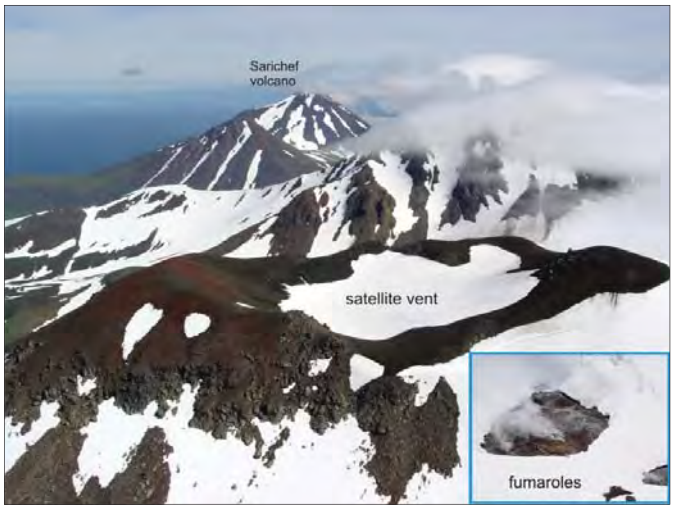
Much of the risk of geothermal energy development is associated with exploring for, confirming and characterizing the available geothermal resources. The overriding purpose of the NGDS is to help mitigate this risk by serving as a central repository for geothermal and relevant related data as well as 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 will support research, stimulate public interest, promote market acceptance and investment, and in turn support the growth of the geothermal industry.

Key components of the NGDS network include:

- Catalog systems for data discovery;
- Service specifications that define interfaces for searching catalogs and accessing resources;
- Shared interchange formats to encode information for transmission (i.e., various XML markup languages);
- Data providers that publish information using standardized services defined by the network; and
- Client applications enabled to utilize information resources provided by the network.

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*. The Arizona Geological Survey has developed a series of geothermal feature templates that includes: Volcanic vents (including vents, fissures, fumaroles, cones, domes, and maars; see photos); thermal hot springs and water chemistry; geothermal well data; active faults and fault features; earthquake hypocenters; developed geothermal systems; and borehole temperature observations. As part of this three-year project that began in 2010, DGGS will compile the available Alaska data for the appropriate AZGS feature templates for input into the NGDS.

Examples of volcanic vents



Young satellite vent on the northeast shoulder of Kliuchef volcano, Atka Island, Aleutians. Sarichef volcano in the distance. Inset, cluster of small fumaroles located on the southern flanks of Kliuchef. Both photos by Game McGimsey, Alaska Volcano Observatory—U.S. Geological Survey.

Lost Jim Cinder Cone, Imuruk Basin, Seward Peninsula. This cinder cone erupted from a Holocene-age volcanic vent. Photo by James Clough, DGGS.

Upon completion of this three-year project in 2013, the compiled Alaska geothermal data along with associated metadata will be placed into the NGDS and available for public and governmental use. A new digital ArcGIS format Geothermal Map of Alaska will be created and made available online.

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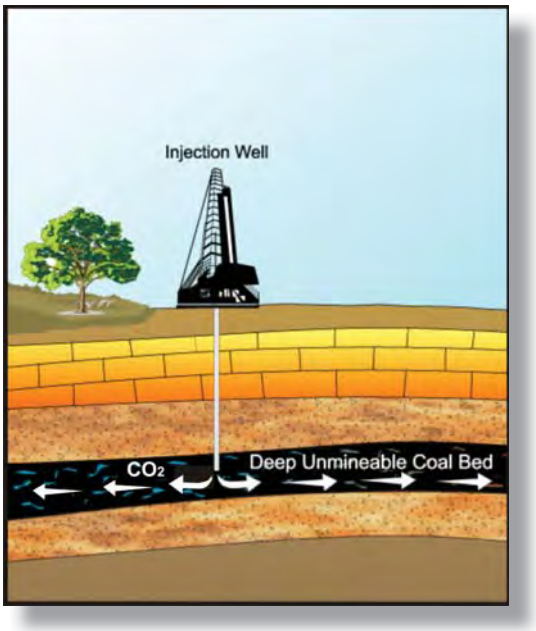
ALASKA COAL DATABASE—NATIONAL COAL RESOURCE DATABASE SYSTEM

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 only 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 current stratigraphic data for previously described occurrences. Sometimes a coal occurrence described in older 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.

Cook Inlet–Capps coal bed, Capps Creek (Tyonek Formation). Similar thick and continuous coal seams that are conventionally unmineable are present in the subsurface. Photo by Bob Gillis, DGGS.

The Cook Inlet basin contains extensive Tertiary-age coal resources, estimated to be up to 1,570 billion short tons, which are mostly within the Tertiary-age Tyonek Formation of the Kenai Group (fig. 1). A large portion of this coal resource is in unmineable coal seams that are either too deep or too thin to be mined economically with conventional surface or underground means, although several areas of the Cook Inlet basin are currently being assessed for *in situ* coal gasification. Many of the subsurface coal seams contain methane adsorbed onto the coal pores and within coal fractures. Because coal has an affinity to preferentially absorb carbon dioxide (CO_2) over methane (CH_4), at CO_2:CH_4 ratios up to 7:1, it may be possible to inject CO_2 into deep, unmineable coal seams and potentially increase production of methane while sequestering carbon dioxide (fig. 2). Extensive infrastructure of roads and pipelines, combined with nearby CO_2 emission sources, makes the Cook Inlet basin prospective for future CO_2 injection into coal seams. Estimates for Cook Inlet CO_2 coal seam storage capacity range from 21 to 43 gigatons, on the basis of comparison to coal basins elsewhere as general analogues. However, actual coal seam CO_2 storage capacity is dependent on a number of factors that include coal rank, porosity, cleating (fractures), and coal quality. No direct measurement of CO_2 adsorption capacity of Alaska coal has been determined in the laboratory. Therefore, estimates of coal seam CO_2 storage capacity are based on comparison to coal basins elsewhere as analogues.



This project will collect coal samples from recent coring of deep unmineable coal seams in the Cook Inlet basin and conduct high-pressure CO_2 gas adsorption testing. These data, combined with coal quality analyses of the same samples, will provide empirical data that can be directly applied to estimating the CO_2 storage potential in the Cook Inlet basin. The final technical report on high-pressure CO_2 gas adsorption and coal quality of core samples will be submitted to the USGS in the fall of 2012.

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