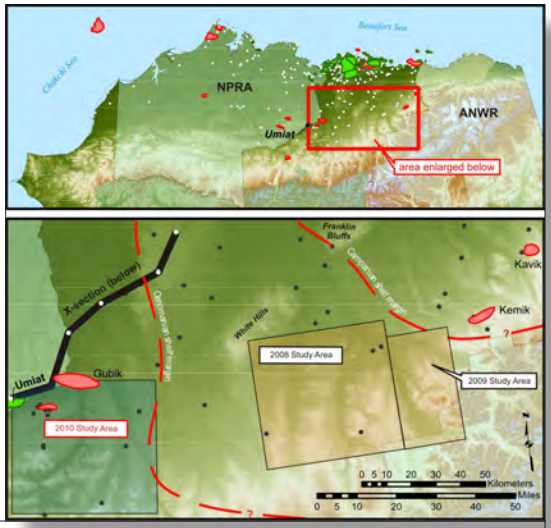
# ALASKA DIVISION OF GEOLOGICAL & GEOPHYSICAL SURVEYS
# FY11 Project Description

## BROOKS RANGE FOOTHILLS & NORTH SLOPE PROGRAM

Alaska's North Slope remains one of the most promising onshore oil and gas provinces in all of North America. The Division of Geological & Geophysical Surveys (DGGS) continues its leadership role in furthering the geologic understanding of this petroleum system, primarily through investigations of rocks exposed in the foothills of the northern Brooks Range. This program was developed in response to the need for high quality, publicly available geologic data to stimulate exploration for hydrocarbons in northern Alaska. 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 United States Geological Survey (USGS), the University of Alaska, and others.

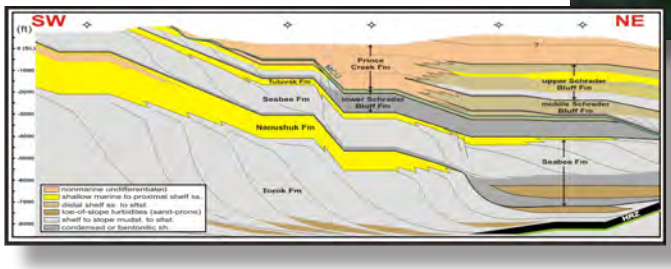
Our work over the last several years has focused on State lands in the central North Slope where we can tie surface geologic observations with the higher density and quality of subsurface data (wells and seismic). During the 2010 field season, the program shifted westward to the Umiat area (fig. 1), a region that has undergone significant exploration activity in recent years. We conducted reconnaissance mapping in anticipation of a multi-year project in the area. In addition we continued our emphasis on key reservoir and source rock intervals, providing new constraints on the depositional history and correlation of units. Our stratigraphic work focused particularly on potential reservoir rocks of the Tuluvak and Schrader Bluff Formations, and included the discovery of an oil-stained interval in the uppermost Seabee Formation. These detailed outcrop observations are being integrated with available subsurface data to arrive at an improved understanding of how this hydrocarbon-rich basin evolved.

During the spring of 2010, we organized a successful two-day DNR Technical Review Meeting in Anchorage to summarize our recent work and share interim results relevant to oil and gas exploration. Much of the work presented at this meeting will be published through DGGS in the upcoming year, including several geologic maps (see p. 35) and a collection of papers summarizing topical structural and stratigraphic studies.




*Location map of northern Alaska and expanded view of state lands of the east-central North Slope. Cross section is simplified from Decker (2007).*


*Oil-stained sandstone of the upper Seabee Formation discovered during 2010 fieldwork along the Anaktuvuk River.*




*Decker, P.L., 2007, Brookian sequence stratigraphic correlations, Umiat Field to Milne Point Field, west-central North Slope, Alaska: Alaska Division of Geological & Geophysical Surveys Preliminary Interpretive Report 2007-2, 19 p., 1 sheet*

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# ALASKA DIVISION OF GEOLOGICAL & GEOPHYSICAL SURVEYS
# FY11 Project Description

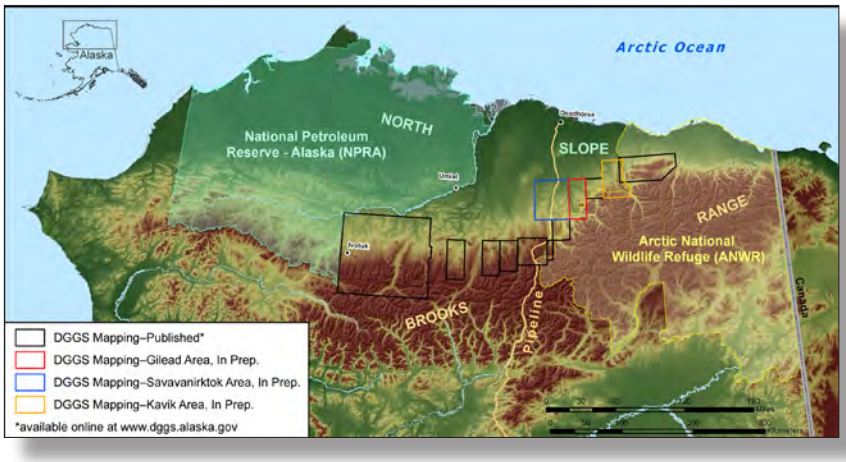
## GEOLOGIC MAPPING IN THE GILEAD CREEK AREA

Petroleum production in northern Alaska has long contributed to the State's economic security and provides many jobs for Alaskans. However, an increasingly diminished throughput in the Trans-Alaska Pipeline System and uncertainty regarding construction of a major natural gas pipeline provide sustained impetus for the Alaska Division of Geological & Geophysical Surveys (DGGS) to continue generating publicly available geologic information. DGGS regularly conducts detailed geologic mapping in the North Slope foothills to improve our understanding of the State's energy resources and promote continued exploration investment by industry. These geologic maps are often consulted by industry in their efforts to determine oil and gas prospectivity, particularly farther north where bedrock exposures are typically obscured by an extensive mantle of Quaternary deposits and tundra.

During summer 2009, we collaborated with the Alaska Division of Oil and Gas and University of Alaska Fairbanks to map ~500 square miles in the Gilead Creek area of the east-central North Slope (see map). This map area lies immediately adjacent to other recent DGGS map projects and furthers one of our program's long-term goals of publishing exceptionally detailed, 1:63,360-scale geologic maps of the entire foothills region.

The Gilead Creek area lies in a unique structural position within the foothills, spanning the transition from thin-skinned deformation of Cretaceous–Tertiary Brookian sediments in the west to higher relief, basement involved structures in the east. This transition exposes at the surface critical stratigraphic relationships that are otherwise only known via subsurface data.

Key observations from our mapping and stratigraphic work include new insights into the mid-Cretaceous Gilead succession, a >850-meter-thick, sand-rich, locally petroliferous package of sediment gravity flow deposits—likely recording basin-axis sedimentation in a toe-of-slope environment—that may have prospective subsurface equivalents to the west (see photo; bed "a" is 3.5 meters thick). Additionally, we recognized two mappable units within the distal Upper Cretaceous Hue Shale that are regionally separated by an intervening tongue of sand-prone Seabee Formation; the latter formation—stratigraphically encased by excellent source-rock facies of the Hue Shale—commonly exhibits a strong hydrocarbon odor.


A digitally drafted geologic map of the Gilead area was prepared during winter 2009–10 and presented to industry, government, and academia participants at the Alaska Department of Natural Resources-led Technical Review Conference in Anchorage (April 2010). We anticipate the final map will be published as a Report of Investigations available through the DGGS website in 2011. This work is funded by the State of Alaska and industry receipts.

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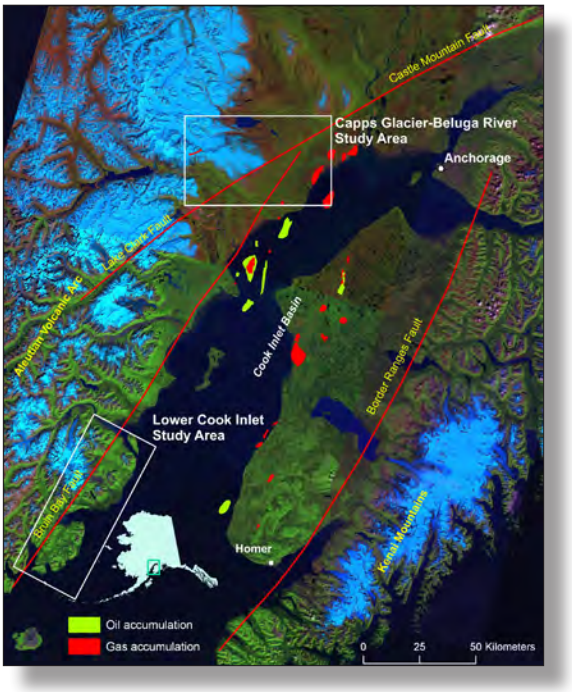
# COOK INLET GEOLOGY AND HYDROCARBON POTENTIAL

Increasing demand and predicted deliverability shortfalls for Cook Inlet gas to south-central Alaska customers pose a serious threat to the region's economy. These factors make it an ideal time to promote new exploration investment in the Cook Inlet region. The Alaska Division of Geological & Geophysical Surveys (DGGS) is responding to this challenge by leading a multi-year, multi-agency program of relevant applied geologic research designed to provide high-quality data to the geologic community and public policy makers. This program is a collaborative effort between DGGS, the Alaska Division of Oil and Gas (DOG), the University of Alaska Fairbanks, and the U.S. Geological Survey.

Historically, Cook Inlet exploration has focused on the search for large fold structures with four-way closure (analogous to an inverted bowl). Now that nearly all large structures have been found and tested, the exploration focus is gradually shifting to subtle stratigraphic traps and reservoirs in low porosity and permeability formations. Successful exploration for these plays requires detailed knowledge of potential reservoir geometries, geologic factors controlling these geometries, and geologic controls on reservoir producibility. The initial goal of this program is to improve understanding of potential reservoir geometries, reservoir quality, and their geologic controls.




During 2010 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 satellite image). Work in the former area focused on documenting alluvial fan and gravelly river deposits along the western basin margin. Detailed stratigraphic and structural studies by our group have demonstrated these rocks were deposited during a period of active faulting and volcanic activity (see inset photo), both of which dramatically affected sand body geometries and reservoir quality. Work in the latter area focused on documenting sand body geometries, reservoir quality, and petroleum source rock potential of Upper Jurassic through Lower Cretaceous age marine rocks in coastal exposures. Oil-stained Cretaceous-age sandstones were sampled for geochemical analysis. Oil extracted from these sandstones will provide valuable information on petroleum source rocks known to underlie much of the basin. Important additional components of this program include bedrock geologic mapping in the Tyonek Quadrangle (see p. 37), a study currently underway to document the subsidence history of upper Cook Inlet, and a subsurface mapping effort aimed at delineating the distribution of petroleum source rocks relative to thick accumulations of potential reservoir sandstones.

This project is funded by the State of Alaska, Apache Corporation, and the U.S. Geological Survey STATEMAP and Energy programs. Results of this work have been documented in a series of publications available from the DGGS website (www.dggs.alaska.gov). Additional publications will be released as they become available.

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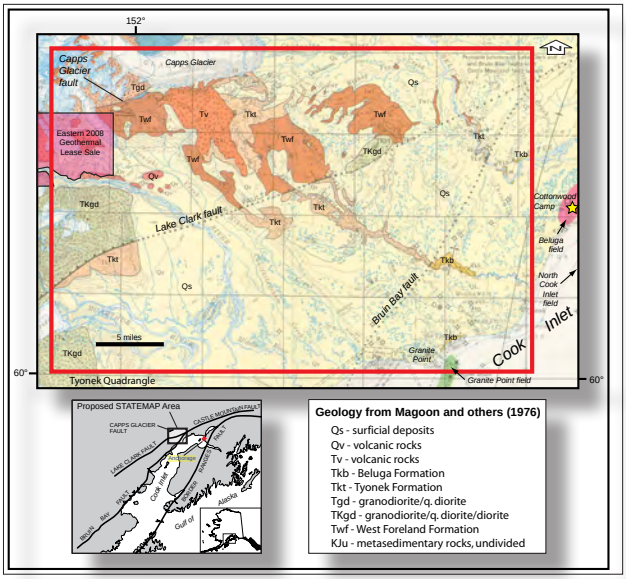
# GEOLOGIC MAPPING IN THE TYONEK–CAPPS GLACIER AREA

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, exploration interest in the basin remains weak. The Division of Geological & Geophysical Surveys (DGGS) is responding by pursuing a program in the basin focused on understanding the potential for stratigraphic traps and gas reservoirs in low porosity and permeability (tight) formations (p. 36). This program includes detailed geologic mapping of areas where outcrop relations are complex, poorly understood, and important for understanding the potential for gas reservoirs in stratigraphic traps and tight formations.




During the summer of 2010, DGGS completed 1:63,360-scale geologic mapping of nearly 475 square miles in the Tyonek Quadrangle, southeast of the Lake Clark fault between Blockade Glacier and Olson Creek (inset map). This work was a continuation of similar mapping performed in 2009 of the region northwest of the Lake Clark fault. The final published product will be a new 1:63,360-scale geologic map encompassing approximately 875 square miles along the northwestern margin of Cook Inlet basin, and an accompanying report. A more thorough geologic understanding of this area is important because it includes some of the best exposures of Tertiary Cook Inlet basin strata (inset picture), some of which serve as reservoirs in the nearby Beluga, North Cook Inlet, and Granite Point fields. Available geologic mapping in the area either predates modern stratigraphic nomenclature used in the basin, or lacks structural details necessary for reconstructing the geologic history of the region. Each is critical for understanding controls on reservoir geometries and quality required to assess the potential for stratigraphic traps and reservoirs in tight formations. 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, including formation of the previously mentioned oil and gas fields. Concurrent with bedrock mapping, new 1:63,360-scale mapping of the surficial geology has led to improved understanding of the glacial history of the region and its sand and gravel resources. Preliminary analysis of shallow-faulting related seismic hazards that represent potential threats to nearby population centers and petroleum production infrastructure has been performed as part of this project as well. Our work in this area will help spur exploration interest and investment in 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 entire project area will be submitted to the USGS in spring 2011. Preliminary results from related stratigraphic and structural studies will be published as DGGS reports by early 2011.

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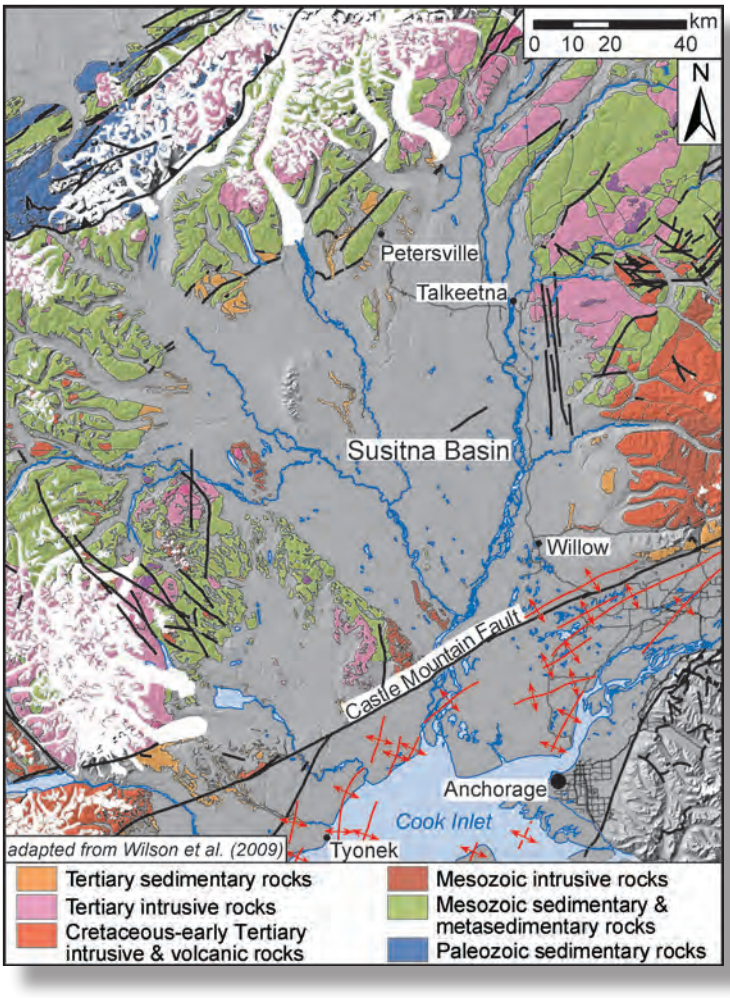
# ALASKA DIVISION OF GEOLOGICAL & GEOPHYSICAL SURVEYS
# FY11 Project Description

## GEOLOGY AND NATURAL GAS POTENTIAL OF THE SUSITNA BASIN

The geology of the Susitna basin suggests it might include producible volumes of natural gas, but a lack of data hinders realistic assessment of this potential resource. The Division of Geological & Geophysical Surveys (DGGS) is responding to this challenge by leading a multi-agency investigation of the natural gas potential (including unconventional gas) of the basin for in-state use. Considering its proximity to the state's most populous region, the Susitna basin project is especially timely as Alaska faces significant energy challenges that threaten the state's economic future. This project, funded by the State of Alaska, will provide relevant geologic data in the public domain to help spur private-sector investment in the basin.

The Susitna basin is poorly understood even though available data suggest it has significant natural gas potential. The basin is bounded by rugged, mountainous topography on the east, west, and north sides and the Castle Mountain fault on the south side (see inset map). The Castle Mountain fault separates the basin from the geologically better known Cook Inlet basin, which includes significant proven oil and gas resources. The Susitna basin includes some of the same coal-bearing rock formations that have supplied large quantities of gas in producing Cook Inlet fields. Outcrops of the coal-bearing Tyonek and Sterling formations are known from widely scattered locations throughout the basin and a few exploration wells have also penetrated these same coal-bearing units. This information suggests the presence of large structures that could have provided the uplift required to facilitate migration of biogenic gas to porous and permeable reservoirs—a mechanism recognized as critical in the formation of Cook Inlet gas accumulations. While these stratigraphic and structural elements are present in the basin, they are so poorly known that realistic evaluation of gas potential is not possible.




DGGS is currently compiling and evaluating available data and planning fieldwork in the basin during the 2011 field season. Fieldwork will focus on developing a better understanding of gas source rocks (coal) and structures that could have resulted in uplift and desorption of gas from coal-bearing strata. Results of this work will be documented in a series of publications available from the DGGS website (www.dggs.alaska.gov).

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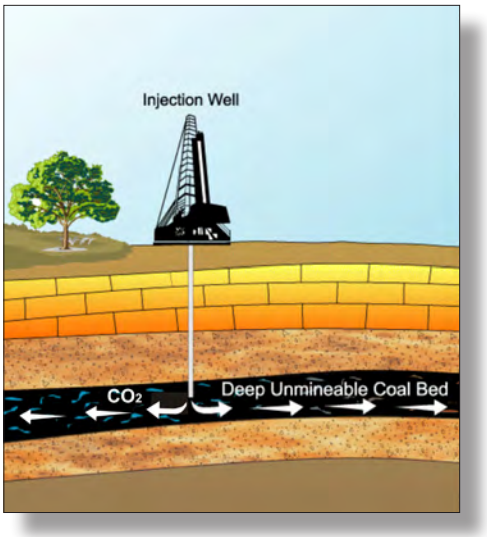
# ALASKA DIVISION OF GEOLOGICAL & GEOPHYSICAL SURVEYS
# FY11 Project Description

## REFINING ESTIMATES FOR ALASKA COAL SEAM CARBON SEQUESTRATION

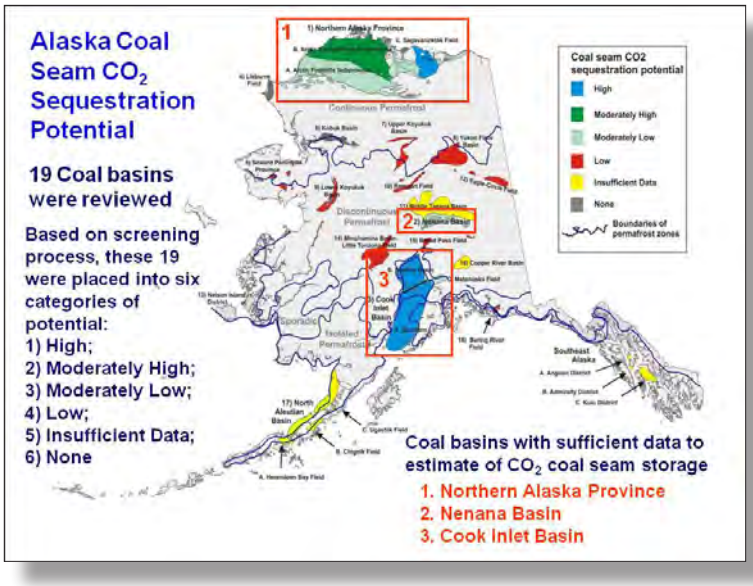



Carbon dioxide ($CO_2$) capture and storage technologies could play a critical role in mitigating the impact of fossil-fuel-based electricity generation on greenhouse gas buildup. Nearly one-third of the carbon emissions in the U.S. come from power plants. Geologic sequestration of $CO_2$ generated from fossil fuel combustion may be a viable method to reduce the amount of greenhouse gas emissions. In the subsurface, coal seams often contain gases such as methane. The gas is held in pores on the surface of the coal and in fractures in the seams. If $CO_2$ is injected into a coal seam it displaces the methane, and can remain stored within the seam, provided the coal is never disturbed. Tests have shown that the adsorption rate for $CO_2$ is approximately twice that of methane. Sequestering $CO_2$ in coal beds has several advantages. For example, $CO_2$ injection can enhance methane production from coal beds.

The West Coast Regional Carbon Sequestration Partnership (WESTCARB) is identifying and validating carbon sequestration opportunities in California, the surrounding states of Arizona, Nevada, Oregon, Washington, Alaska, and the Canada Province of British Columbia. Findings from the first phase of WESTCARB's regional characterization of geologic formations and managed land suitable for long-term $CO_2$ storage (known as 'sinks') indicated a lack of data in many key areas. The Alaska Division of Geological & Geophysical Surveys reviewed and refined the coal estimates for storage of $CO_2$ in deep, unmineable coal seams as the second task under a larger project, Alaska Geologic Carbon Sequestration Potential Estimate: Screening Saline Basins and Refining Coal Estimates, conducted by the Alaska Division of Oil & Gas.

Nineteen Alaska coal basins were reviewed and, through a screening process, were placed into six categories of potential: (1) High; (2) Moderately High; (3) Moderately Low; (4) Low; (5) Insufficient Data; and (6) None. The following main attributes were used in the screening process: • Basin Age, • Depositional Environment, • Structural Setting, • Rank of Coal, • Net Coal Thickness, • Coal Volume, • Coal Quality data, • CBM Data, • Infrastructure, • Type of Permafrost, and • Depth of Permafrost. Three coal basins were determined to have sufficient and reliable subsurface and coal-quality data to make reasonable estimates of $CO_2$ coal seam storage capacity and are in proximity to existing or potential future infrastructure: (1) Northern Alaska Province, (2) Nenana Basin, and (3) Cook Inlet Basin.

Our study indicates that the coal-seam $CO_2$ potential storage capacity of Alaska unmineable coal is about 49 gigatons (Gt), which is about 41 percent less than the preliminary estimated volume of 119 Gt $CO_2$ storage capacity for coal seams. The major difference between our study and the previous study is the result of assessing the presence, extent, and effect of permafrost on permeability of coal seams, and hence its storage capacity. The effective permeability of coal in permafrost is near zero. Therefore, producing methane gas from coal seams in the permafrost zone and storing $CO_2$ in these same seams is unlikely. Storage of $CO_2$ in the North Slope region can only be considered in thick coal seams beneath the base of the permafrost that can extend to depths of more than 660 m. This resulted in our much lower estimate of coal seam $CO_2$ storage capacity of 5.83 Gt than the 98 Gt reported in earlier estimates. Our estimate of 43 Gt $CO_2$ coal seam storage capacity for the Cook Inlet region was about twice the earlier estimate (21 Gt) because our review of available coal resources indicated 1,570 billion short tons of coal present and we used a $CO_2$:CH4 ratio of 7:1 rather than the 1,290 billion short tons of coal and 3:1 $CO_2$:$CH_4$ ratio used in the earlier study.




The final technical report on refinements to coal seam storage of $CO_2$ for Alaska will be submitted to WESTCARB in April 2010.

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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 Web site, 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.

*"Nenana Basin"—Bonnifield project. Aerial view (toward east) of coal-bearing Usibelli Group (likely Healy Creek Formation) in Red Mountain Creek.*

FY2010 was the final year of a five-year NCRDS project to collect new data for the Alaska Peninsula, North Slope, Kenai Peninsula–Cook Inlet, and the Nenana Basin as adjunct to ongoing DGGS projects in these regions. Detailed coal stratigraphic and coal quality studies are rarely conducted as part of these larger projects and the proposed work will augment the non-coal data collection, field activities, and reporting. During 2009, we augmented an ongoing oil-and-gas-related study of Cook Inlet that included coal seams in the Capps Glacier area and completed work on coal samples collected during the 2008 eastern Bonnifield Mining District mapping. Additionally, we received the data analyzed by the USGS laboratory as part of the supplementary NCRDS study examining the chemical nature (major-, minor-, and trace-element and mineralogical composition) of the feed coal, fly ash, and bottom ash at the Fairbanks, Alaska, power plant. Sample localities, coal seam characteristics, coal quality, and point-source data will be placed into the Alaska coal resource portion of the NCRDS, with a final report summarizing these data for release in spring 2011.

*Cook Inlet—Capps coal bed, Capps Creek (Tyonek Formation).*

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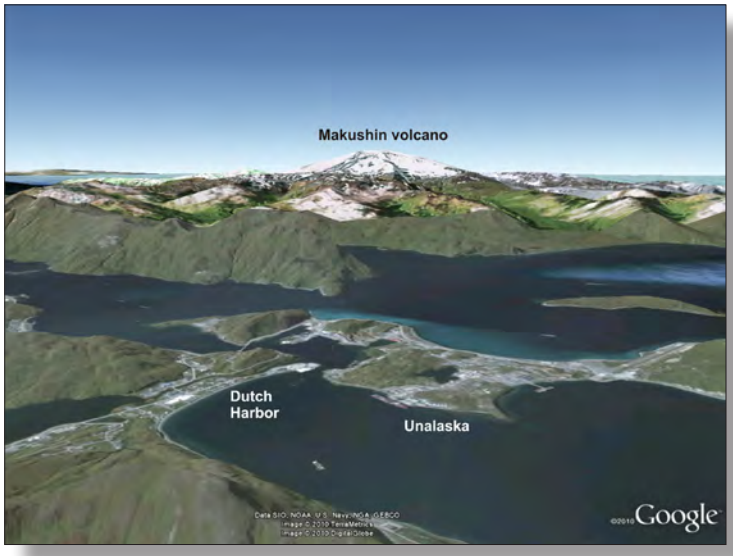
# ALASKA DIVISION OF GEOLOGICAL & GEOPHYSICAL SURVEYS
# FY11 Project Description

## STATE GEOLOGICAL SURVEY 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 address is: www.geothermaldata.org/

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 by 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.

The Alaska Division of Geological & Geophysical Surveys (DGGS) is contributing Alaskan 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 that was proposed through the Association of American State Geologists and is being administered by the Arizona Geological Survey. As part of this three-year project that began in 2010, DGGS will compile available hydrothermal, developed geothermal systems, geothermal well data, and heat flow data for input into the NGDS.




*Google Earth image of Dutch Harbor—Unalaska with active Makushin volcano in the background. View toward the west.*

**Hydrothermal data:** Digital data from 111 thermal springs and wells statewide including location, water chemistry (some sites), flow rate (some sites), and physical site description. The 111 sites are in the geothermal portion of the Alaska Energy Inventory database.

**Developed Geothermal Systems:** Chena Hot Springs (Interior Alaska) generates 400 kw of power from a moderate temperature geothermal ORC power plant and has drilled 18 wells to depths of 1,000 feet. Temperatures recorded are up to 80ºC (176ºF). Data includes water chemistry, permeability, and flow rates.

**Geothermal well data:** The 1980 drilling at Makushin volcano (see photo) yielded 7,585.5 feet of drill core from six exploratory geothermal wells. Associated data include alteration and fluid inclusion studies. Some of these data are in digital format, but most are not. If geothermal energy were successfully developed at Makushin, it could provide electrical power to the nearby towns of Unalaska and Dutch Harbor.

**Heat flow data:** There are 1,400 wells oil and gas wells statewide for which temperature logs are available. These data will be evaluated for temperature profile and formation temperatures. The data set includes bottom hole temperature (BHT) data from 278 oil and gas exploration wells that have previously been collected and corrected, from Alaska's North Slope (252 wells) and other basins (26 wells). An additional 1,800 wells from the Prudhoe Bay area and 974 wells from the Cook Inlet area remain to be compiled, data corrected for time since circulation, BHT determined, and interpreted for heat flow.

By the completion of this three-year project, the compiled Alaska geothermal data along with associated metadata will be placed into the NGDS and available for public and governmental use.

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