ENERGY AND THE ENVIRONMENT—APPLICATION OF GEOSCIENCES TO DECISION-MAKING

PROGRAM AND SHORT PAPERS

Edited by L.M.H. Carter

TENTH V.E. MCKELVEY FORUM ON
MINERAL AND ENERGY RESOURCES, 1995

U.S. GEOLOGICAL SURVEY CIRCULAR 1108

U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY
Gordon P. Eaton, Director

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1995

Free on application to U.S. Geological Survey, Information Services
Box 25286, Federal Center
Denver, CO 80225

Library of Congress No. 91-640066

Organizing Committee for the 1995 McKelvey Forum:

Chair: Dudley D. Rice
Co-chairs: Timothy S. Collett, Thaddeus S. Dyman, and Richard M. Pollastro

Program:
Timothy S. Collett
Robert B. Finkelman
Thomas D. Fouch
Joseph R. Hatch
Melody Holm
Peter J. McCabe
Janet K. Pitman
Dudley D. Rice
Richard B. Wanty

Publicity:
Thaddeus S. Dyman
Karen J. Franczyk
Shirley A. Oscarson

Logistics:
James D. Brewton
George M. Garcia
Vito F. Nuccio
Richard M. Pollastro

Computer support:
James D. Brewton
Raymond C. Obuch

Editorial:
Lorna Carter

Student Participation:
Laurel M. Bybell
Sharon S. Crowley
Thaddeus S. Dyman
Jane R. Eggleston
Robert B. Finkelman
Kathleen K. Krohn
Eleanora I. Robbins
Jane B. Russell
Susan Russell-Robinson
Laure G. Wallace
Susan C. Wells

Tour:
Jane R. Eggleston
Robert B. Finkelman
John R. Keith
Kathleen K. Krohn
Susan Russell-Robinson

The Future of Oil and Gas in Northern Alaska

Kenneth J. Bird, Frances Cole,
David G. Howell, and Leslie B. Magoon,
U.S. Geological Survey, Menlo Park, CA 94025

The North Slope accounts for about 98 percent of Alaska's total oil production or about 1.6 MMBOPD (million barrels of oil per day). This production, along with that from southern Alaska's Cook Inlet fields, makes Alaska the number two oil-producing State, contributing about 25 percent of the Nation's daily oil production. Cumulative North Slope production at year-end 1993 was 9.9 BBO (billion barrels of oil). Natural gas from the North Slope is not marketable for lack of a gas transportation system. Although enormous amounts of gas are produced with North Slope oil (cumulative production is about 20 TCFG, trillion cubic feet of gas), nearly all has been re-injected to maintain reservoir pressure and increase oil recovery. About 2 TCFG has been used locally by the community of Barrow and for power generation in the oil fields. At year-end 1993, North Slope reserves were calculated at 6.1 BBO (99 percent of State total) and 26.3 TCFG (92 percent of State total) (State of Alaska, 1994).

The North Slope is a lightly explored region containing one exploratory well per 270 square miles. Drilling began in the 1940's, when the U.S. Navy explored Naval Petroleum Reserve No. 4 and adjacent areas. This effort resulted in the discovery of several oil and gas fields of insufficient size for commercial development. Five years after the North Slope was opened to private oil exploration, the Prudhoe Bay oil field, North America's largest (12+ BBO ultimate recovery), was discovered in 1968. Regulatory uncertainty and construction of a 48-inch-diameter pipeline stretching 800 miles southward to the Pacific Ocean at Valdez delayed the startup of Prudhoe oil production until 1977. By 1988, North Slope oil production from Prudhoe Bay and three other oil fields peaked at 2 MMBOPD; since then production has declined to the current rate of 1.6 MMBOPD in spite of six more oil fields coming into production (fig. 1). Undiscovered, economically recoverable oil resources, as of 1987, were estimated at 0–26 BBO (mean probability, 8 BBO) for the onshore region and adjacent State waters by the USGS and 0–5 BBO (mean probability, <1 BBO) for the Federal offshore by the Minerals Management Service (Mast and others, 1989).

The North Slope is a high-cost area for oil and gas development because of the hostile environment, the remoteness from markets, and the lack of infrastructure. High costs account for the fact that less than one-third of the known oil and gas fields are producing and that gas is not marketable. They also account for the fact that only fields with high per-well production rates (rates that average two orders of magnitude higher than other U.S. producing regions: thousands vs. tens of BOPD) are currently being produced (Gerhard and others, 1988). When an economic screen is applied to USGS estimates of North Slope undiscovered oil resources, only 60 percent of those resources are considered economically recoverable (Attanasi and others, 1993). For example, the West Sak and Ugnu heavy oil accumulations with 20–40 BBO in-place, located between the Prudhoe Bay and Kuparuk River oil fields, are currently non-economic to produce.

An important factor affecting the future of existing North Slope oil fields and all future oil field development is the continued operation of TAPS (Trans-Alaska Pipeline System). A basic but unanswered question is the minimum throughput rate required for efficient, cost-effective operation. Studies by the U.S. Department of Energy (1991) have assumed a range of 400 to 200 MBOPD (thousands of barrels of oil per day) to illustrate the effects of a shutdown of TAPS. Using reserve and production rate numbers from existing fields, a TAPS shutdown is predicted for year-end 2008 assuming minimum rates of 400 MBOPD, and year-end 2014 assuming minimum rates of 200 MBOPD. Because the time between field discovery or decision-to-develop and first production is about 10 years, new or discovered fields may need to be brought into production by 1998 to assure continued operation of the pipeline.

Major North Slope environmental issues related to oil and gas include the loss of wetlands through gravel mining and placement, disturbance of subsistence hunting and fishing, and disruption of coastal flow patterns or fish migrations by solid-fill causeways. Waste management will become increasingly important as fields mature and field shutdown approaches a reality (Thomas and others, 1993). North Slope operations are already under "zero discharge" regulations whereby all drillcuttings, mud, and other fluids are disposed of by injection into deep reservoirs. Other concerns include the threat of oil spills, disruption of fish and wildlife habitat, and pollution of air and water.

New technological developments applied to North Slope fields have reduced costs, improved oil recovery, and reduced environmental disturbance. More efficient equipment, improved field design, facilities sharing, and industry learning have, in some cases, reduced costs by as much as two-thirds (Harris, 1987). Ultimate oil recovery from the Prudhoe Bay field has increased from 9.6 BBO to about 12 BBO through the use of enhanced oil recovery techniques including waterflooding, miscible gas injection, fracturing, and horizontal drilling. Environmental disturbance has been reduced by siting production wells closer together, resulting in smaller gravel production pads, and by developing offshore fields from onshore sites by extended-reach drilling.

REFERENCES

Attanasi, E.D., Bird, K.J., and Mast, R.F., 1993, Economics and the national oil and gas assessment; The case of onshore northern Alaska: American Association of Petroleum Geologists Bulletin, v. 77, no. 3, p. 491–504.

Gerhard, L.C., Graber, L.A., and Brostuen, E.A., 1988, A look at the status of U.S. petroleum: Oil and Gas Journal, June 20, 1988, p. 73–78.

Harris, M., 1987, Endicott benefits from lessons learned: Alaska Construction and Oil, October 1987, p. 15–16.

Mast, R.F., Dolton, G.L., Crovelli, R.A., Root, D.H., Attanasi, E.D., Martin, P.E., Cooke, L.W., Carpenter, G.B., Pecora, W.C., and Rose, M.B., 1989, Estimates of undiscovered conventional oil and gas resources in the United States—A part of the Nation's energy endowment: U.S. Department of the Interior, 44 p.

Thomas, C.P., Allaire, R.B., Doughty, T.C., Faulder, D.D., Irving, J.S., Jamison, H.C., and White, G.J., 1993, Alaska North Slope national energy strategy initiative—Analysis of five undeveloped fields: U.S. Department of Energy, DOE/ID/01570-T164.

State of Alaska, 1994, Historical and projected oil and gas consumption: Anchorage, Alaska Department of Natural Resources, Division of Oil and Gas, 61 p.

U.S. Department of Energy (DOE), 1991, Alaska oil and gas—Energy wealth or vanishing opportunity?: DOE/ID/01570-H1.

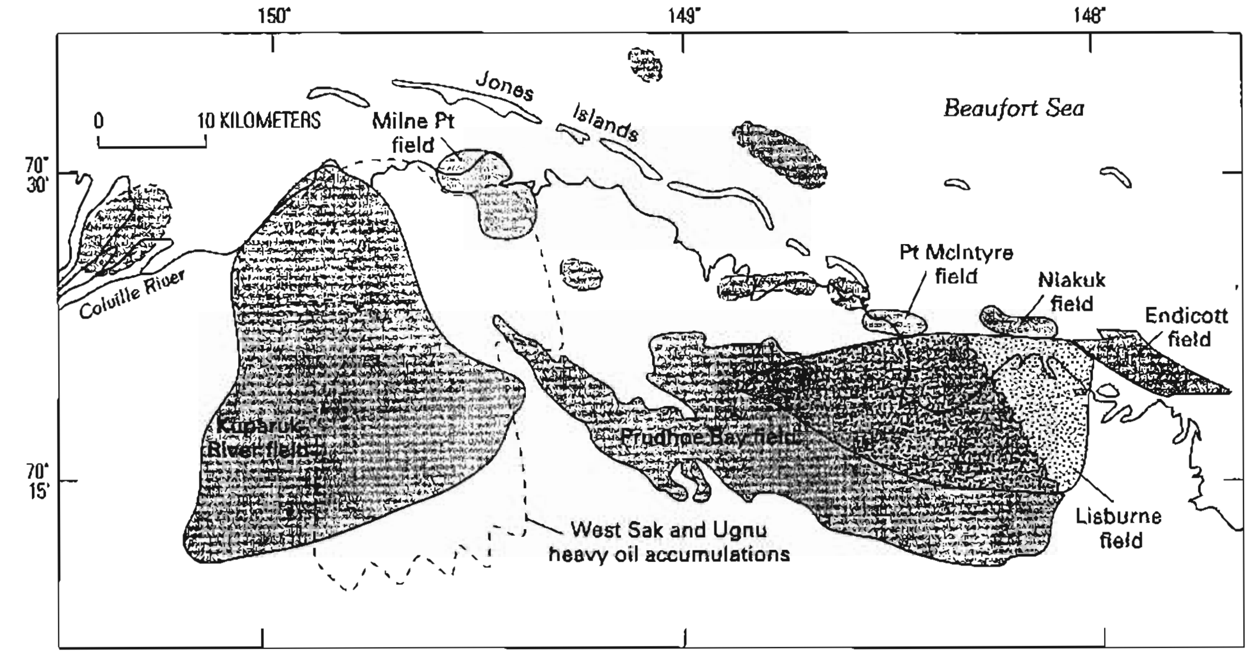

Figure 1 (Bird and others). Oil and gas fields of the greater Prudhoe Bay area, northern Alaska. Patterned dashed outline, nonproductive oil field.

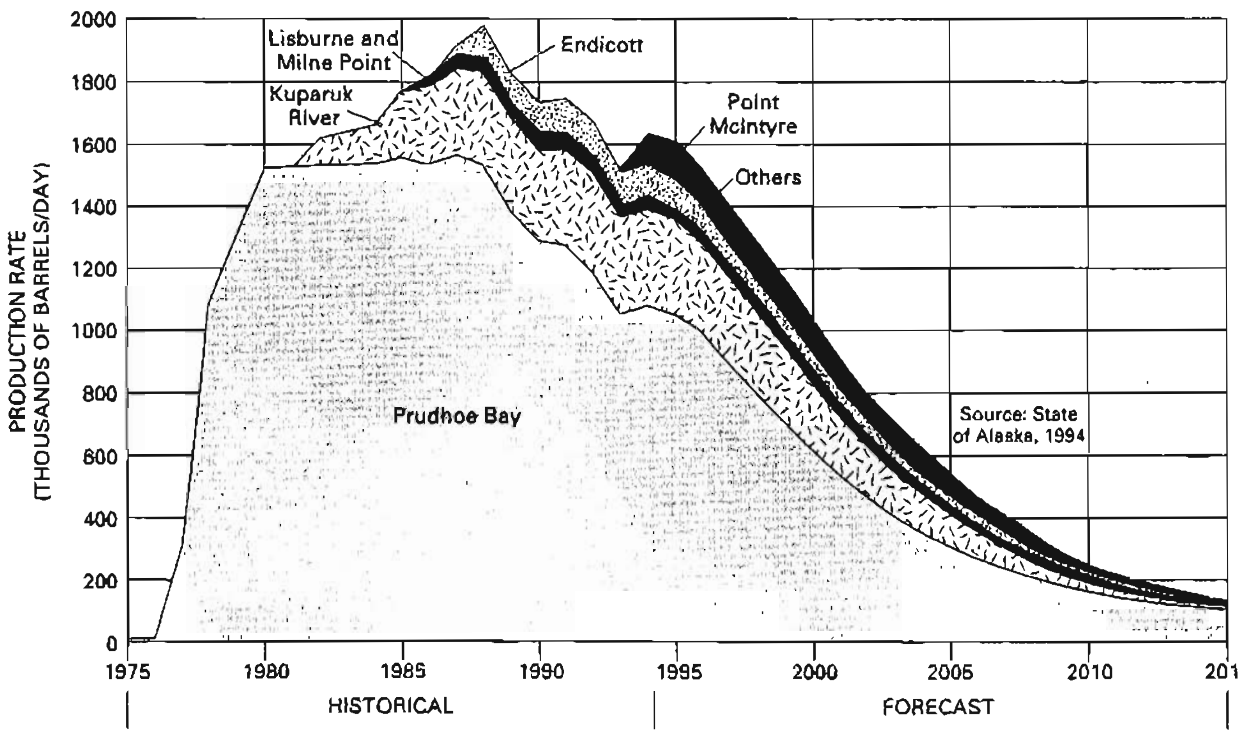

Figure 2 (Bird and others). North Slope oil production.

Oil Spills in Prince William Sound, Alaska

Keith A. Kvenvolden and Paul R. Carlson,
U.S. Geological Survey, Menlo Park, CA 94025

On March 24, 1989, the *Exxon Valdez* supertanker grounded on Bligh Reef in Prince William Sound (fig. 1), spilling ≈11 million gallons of North Slope crude oil. This oil spread quickly from the stricken vessel through the western part of the sound and into the Gulf of Alaska (Galt and others, 1991). Along the southward trajectory of the spill, ≈16 percent of the sandy, gravelly, and rocky shorelines of the sound were coated with oily residues. Cleanup operations and natural processes have now removed much of the oil from the affected shorelines.

As part of a series of studies to determine the geochemical fate of the spilled oil, we have studied the hydrocarbon distribution and carbon isotopic compositions of oil residues collected from beaches throughout the sound starting in 1990. By 1992 we had made two discoveries. First, six samples of weathered oil residues correlated, on the basis of carbon isotopic composition and other geochemical parameters such as hopane and sterane biomarkers and polycyclic aromatic hydrocarbons, with the oil carried by the *Exxon Valdez* supertanker at the time of the spill. The carbon isotopic composition of this spilled oil measured −29.2‰ relative to the PDB standard. Second, two additional samples of residues were chemically and isotopically distinct from the other six samples. Detailed geochemical analyses and comparisons indicated that these non-*Exxon Valdez* residues likely originated from oils from the Monterey Formation (Miocene and Pliocene) of California and are residues of spilled oil products that had previously been shipped by barge to Alaska (Kvenvolden, Hostettler, and others, 1993).

The two samples of non-*Exxon Valdez* residues were collected from Storey Island and Elrington Island, at localities ≈100 km apart near the north and south ends of the sound (fig. 1). The geographic positions and almost identical carbon isotopic values of −23.8 and −23.9‰ suggested that we could expect to find residues of similar carbon isotopic composition on the beaches throughout the sound. This expectation has been realized in that we have now obtained analyses for 48 samples of non-*Exxon Valdez* residues from many places in the sound (fig. 1) that have an average carbon isotopic composition of −23.8±0.1‰. At the same time we have obtained analyses for 18 samples of *Exxon Valdez* residues (fig. 1) that have an average carbon isotopic composition of −29.4±0.2‰. Thus, two distinct populations of oil residues, identified by their carbon isotopic compositions, exist in Prince William Sound.

It is easy to account for the residues with carbon isotopic compositions of −29.3±0.1‰. These residues, collected from beaches impacted by the 1989 oil spill, undoubtedly resulted from that spill. The residues with carbon isotopic compositions of −23.8±0.1‰ are not as easy to explain. The question is how residues which have geochemical signatures indicating oil produced from the Monterey Formation of California can be dispersed throughout Prince Willliam Sound. It is not unexpected to find that California oil products were used in Alaska before Alaska's internal supply of oil was available. Alaska received much of its oil and oil products by barge from southern California. Whittier, in the western part of the sound, and Valdez, at the north end, served as ports for fuel oil and asphalt storage from California for more than 50 years.

The non-*Exxon Valdez* residues could represent early contamination of the sound by numerous small spills of paving and roofing tar, ship discharges, and products spilled from storage facilities. However, the tight range of carbon isotopic values of the non-*Exxon Valdez* residues (–23.8±0.1‰) suggests that these residues not only came from products that originated in California but also came from the same batch of products; that is, these residues, at least most of them, may have resulted from a single event. We believe that the Great Alaska Earthquake, which occurred on Friday, March 27, 1964, could be that event (Kvenvolden, Carlson, and others, 1993). During this quake and subsequent tsunamis, fuel oil and asphalt storage plants in Valdez were destroyed, spilling unknown amounts of oil products into the Port Valdez fjord (fig. 1). A map (Wilson and Tørum, 1972) shows that ≈30 percent of the fjord was covered with asphalt after the quake. There is no record of any asphalt cleanup, and it is likely that the asphalt progressed from the east end of the fjord through Valdez Arm and south into the sound (fig. 1). Asphalt is still present at the site of the storage facilities where the old town of Valdez was located.

Figure 1 shows that non-*Exxon Valdez* residue samples were found on beaches from Valdez south to the lower end of Elrington Island, whereas *Exxon Valdez* residues were found south of Bligh Reef where the supertanker grounded. On several beaches both *Exxon Valdez* and non-*Exxon Valdez* residues were found. Thus the beaches record two oil spills, 25 years apart, in Prince William Sound. Residues from the spill of 1989 correlate with the North Slope crude oil carried by the *Exxon Valdez* supertanker. The postulated spill of 1964 is less certain. Residues of California oil products are without doubt widespread on the beaches of Prince William Sound and apparently are quite refractory, but just how the residues reached the beaches is uncertain. The Great Alaska Earthquake of 1964 offers a possible trigger for a major spill of oil products that passed through the sound, as did the oil from the 1989 spill, leaving a legacy of minor residues on the beaches.

Acknowledgment

The carbon isotopic compositions, which are critical for this study, were provided by C.N. Threlkeld and A. Warden, USGS, Denver, Colorado.

REFERENCES

Galt, J.A., Lehr, W.J., and Payton, D.L., 1991, Fate and transport of the *Exxon Valdez* oil spill: Environmental Science and Technology, v. 25, p. 202–209.

Kvenvolden, K.A., Hostettler, F.D., Rapp, J.B., and Carlson, P.R., 1993, Hydrocarbons in oil residues on beaches of islands of Prince William Sound, Alaska: Marine Pollution Bulletin, v. 16, p. 24–29.

Kvenvolden, K.A., Carlson, P.R., Threlkeld, C.N., and Warden, A., 1993, Possible connection between two Alaskan catastrophes occurring 25 yr apart (1964 and 1989): Geology, v. 21, p. 813–816.

Wilson, B.W., and Tørum, A., 1972, Effects of tsunamis—An engineering study, *in* The Great Alaska Earthquake of 1964: Washington, D.C., Oceanography and Coastal Engineering, National Research Council, National Academy of Sciences, p. 361–523.

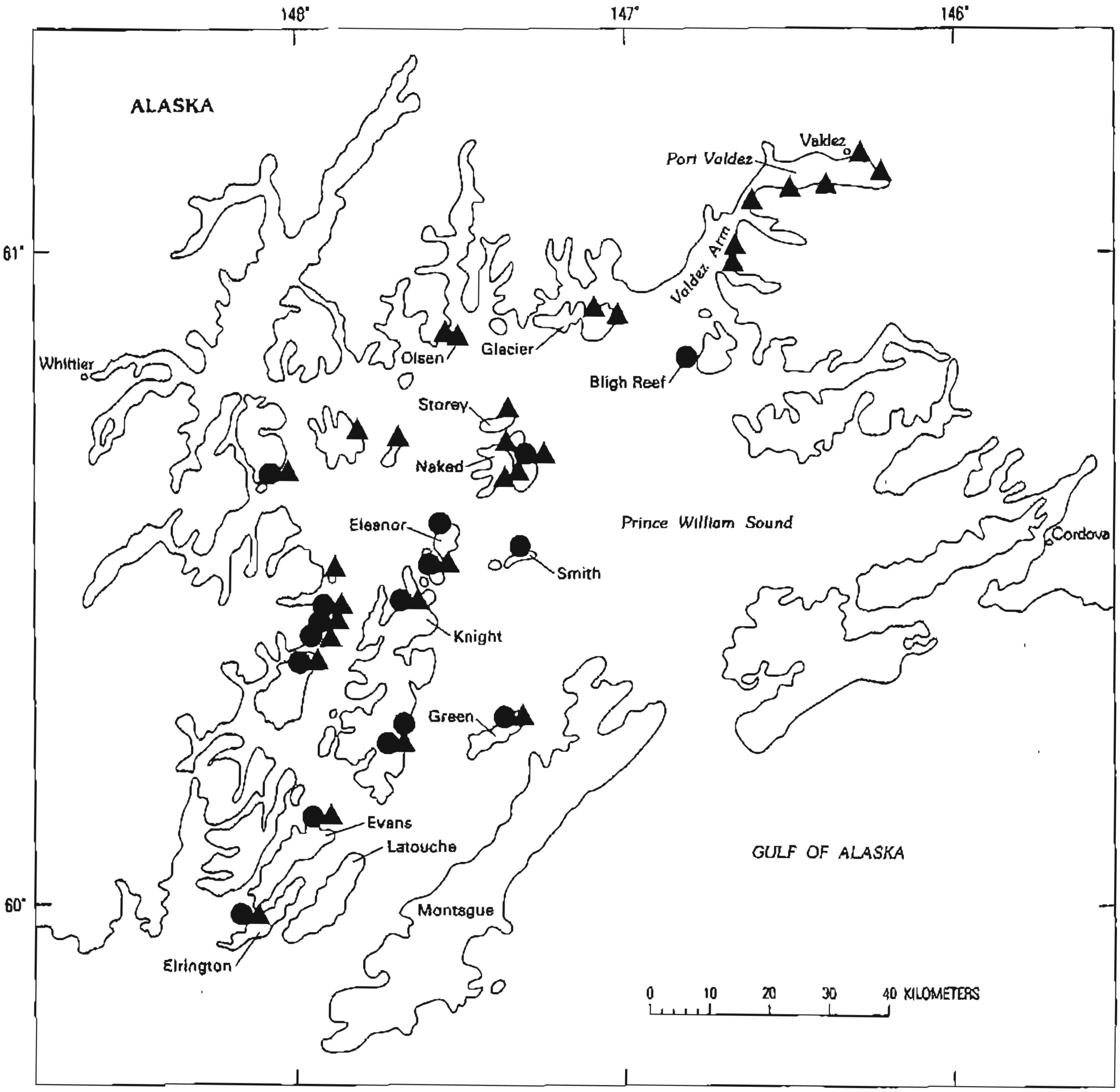

Figure 1 (Kvenvolden and Carlson). Location of oil residue sample sites in Prince William Sound, Alaska. Solid circle, *Exxon Valdez* oil and residue sample site; solid triangle, non-*Exxon Valdez* residue sample site.

Geological and Geophysical Information from the National Petroleum Reserve Alaska on CD-ROM as a Tool in Support of Geoscientific Decision-Making

David J. Taylor and Frederick N. Zihlman,
U.S. Geological Survey, Denver, CO 80225

In light of today's concerns over energy supplies and the impact that exploration for and production of these resources has on the environment, it is critical that explorationists, production companies, and land-use planners have all pertinent geoscientific data at their fingertips. Often the data needed to formulate policy are not available from a single source and are not on media which are easily accessible using today's computer technology. Putting a vast amount of closely related data on a single high-density low-cost medium can be accomplished now, thanks to the development of CD-ROM (Compact Disk–Read Only Memory) data storage technology.

In 1977, jurisdiction of the Naval Petroleum Reserve Alaska (NPRA) was transferred to the U.S. Geological Survey from the U.S. Navy Department, charging the USGS with responsibility for (1) exploring the area for oil and gas and compiling a database for assessing the NPRA's petroleum potential; (2) supplying natural gas to the residents of Barrow, Alaska, and local government facilities; and (3) restoration of areas that were disturbed during construction and petroleum exploration activities into an environmentally acceptable condition. As a result of this charge, the USGS has a large amount of seismic reflection, well-log, geochemical, stratigraphic, biostratigraphic, and well-core data from the NPRA. This region is extremely prospective for future oil and gas development, yet it is in an ecosystem which is highly sensitive to environmental change. The USGS Energy Resource Surveys Program recognizes the importance of the data it holds in this area and is taking steps to ensure that all these data are preserved and made accessible to other government agencies, academia, industry, and the general public, in a cohesive unit on a long-lasting, high-density, easily readable medium in widely acceptable digital formats. These data are now being cataloged and transcribed onto CD-ROM's that are accessible using low-cost IBM-compatible, Apple Macintosh, and UNIX workstations. The idea behind this CD-ROM product is to gather all the data together from different digital and nondigital sources and compile them all onto a single medium as part of the Energy Resource Surveys Program information and technology transfer effort.

As a test of our capability to produce integrated geophysical and geologic data, the Energy Resource Surveys Program has developed a special CD-ROM product containing available geophysical, geologic, borehole, biostratigraphic, and geochemical data pertaining to the Tunalik No. 1 well site, located in the far northwest corner of the NPRA (fig. 1). These data are a relatively complete set of exploration data that would assist exploration, production, and ecosystem managers in creating land-development plans for the area.

This CD-ROM contains digital data in industry standard format, scanned digital images of originally nondigital data in standard graphics format, and software to display the data on IBM-compatible, Apple Macintosh, and UNIX hardware. The digital graphics images can be displayed using low-cost commercially available graphics programs capable of running on the hardware platforms mentioned. The seismic data include final stack data in SEG-Y format, digital shotpoint location data, seismic acquisition parameters, and seismic-processing parameters. The well-log data include digital well-log data, digital images of well core, drilling history reports, depths to selected horizons, digital synthetic seismograms, original logging reports, lithologic reports, original sidewall core descriptions, and original core descriptions. The velocity data include digital depth, interval velocity, and average velocity information from the Tunalik No. 1 well and regional velocity information in digital form. ASCII files containing digital gravity measurements and gravity station locations in latitude and longitude will be included. Biostratigraphic data will include scanned images of the original palynology and foraminifera reports from the Tunalik No. 1 well.

The ultimate goal of this project is to transcribe a majority of our NPRA data onto CD-ROM and then to make these CD-ROM's available to the general public through the National Energy Research Seismic Library

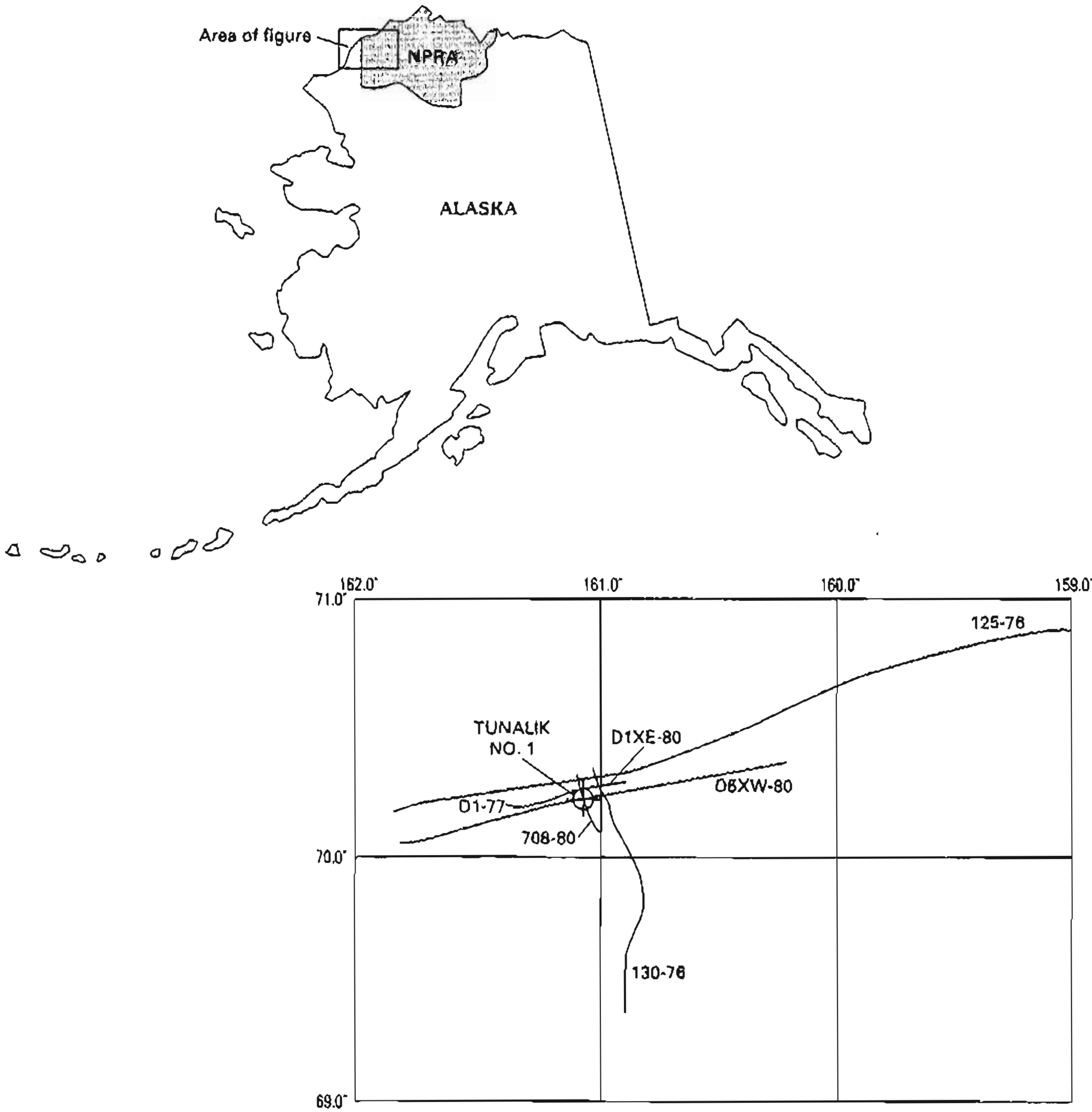

Figure 1 (Taylor and Zihlman). The Tunalik No. 1 well relative to the NPRA boundary, and the location of the surface seismic reflection data. The Tunalik No. 1 well drilled through more than 6,096 meters (20,000 ft) of sedimentary section.

(NERSL). Ultimately, NPRA data along with digital seismic data from other regions will then be available through a number of distribution media, including data on CD-ROM, 9-track and 8-mm magnetic tape, paper hard copy reports, and on-line service that will allow digital information to be downloaded from a USGS server. We expect that making all of our nonproprietary data accessible will take several years to complete, but we will attempt to make subsets of the complete dataset available as soon as cataloging and archiving are accomplished.