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# The Kara Sea: A Soviet Oil Resource for the Turn of the Century

A Research Paper

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March 1988

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# The Kara Sea: A Soviet Oil Resource for the Turn of the Century

A Research Paper

This paper was prepared by [redacted] Office [redacted] OGI [redacted] Office of Soviet Analysis. Comments and queries may be directed to the Chief, [redacted] OGI [redacted]

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# The Kara Sea: A Soviet Oil Resource for the Turn of the Century

**Scope Note**

This Research Paper assesses the petroleum potential of the Kara Sea and describes the methodology used in this assessment and other assessments of virgin exploration areas. Like the Barents Sea, the Kara Sea is an oil frontier that could figure in Soviet oil exploration strategies during the 1990s and into the next century, especially as new discoveries in more hospitable onshore areas become less likely and more expensive

This paper is the last—and by its nature the most speculative—in the OGI series on Soviet Arctic oil frontiers

# The Kara Sea: A Soviet Oil Resource for the Turn of the Century


**Summary**

*Information available as of 31 January 1988 was used in this report.*

The Kara Sea could become one of the major petroleum regions in the USSR early in the next century. We estimate that recoverable oil resources in the Kara Sea amount to 20 billion barrels, roughly double the proved reserves at Alaska's Prudhoe Bay. If developed, these resources could in principle support production of 2 million barrels per day (b/d)—about one-sixth of current Soviet output—for nearly 30 years. Of the remaining oil frontiers in the USSR, only the Barents Sea and perhaps the Caspian region appear to have higher potential.

As oil production in established areas falls and new onshore oil becomes more difficult and expensive to find, the Kara Sea could play an increasingly important role in Moscow's oil strategies. Although the adjacent Barents Sea will clearly remain the primary site of Soviet attempts to tap the oil potential of the Arctic continental shelf, we believe the Kara Sea will be next on the Soviet agenda, lagging activity in the Barents by five to 10 years. Given the environmental harshness of the Kara Sea and limited exploration activity thus far, we see little likelihood that this area will become a significant source of oil until around the turn of the century

Many factors indicate that development of Kara Sea resources will be a slow and difficult process. This region is one of the most severe and remote environments ever considered for drilling, and the Soviets will have to overcome serious financial, technological, and logistic problems to have any chance of success. Drilling activities in the Kara will be more expensive than in any currently producing petroleum region in the USSR and could exceed the costs of US and Canadian operations in the Beaufort Sea. The Soviets will need to acquire Western rigs specially designed to withstand ice forces and temperature stress and will have to develop a support infrastructure more efficient than any they have assembled to date. Down the road, production activities will be inhibited by high cost and by distance from major ports and pipelines

The circumstances that make the Kara Sea a foreboding exploration area to the Soviets also make it an excellent candidate for joint ventures with Western firms. US and Canadian oil companies have been operating in the Beaufort Sea—an area environmentally analogous to the Kara Sea—for more than 20 years and are world leaders in drilling and production in ice-covered waters. Although the competitive position of Scandinavian and

West European companies is excellent for joint ventures in less demanding—but nonetheless harsh—areas such as the Barents Sea, North American firms could be the major competitors for Kara Sea joint ventures if the Soviets open the area for Western cooperation. From the security perspective, the area is not nearly as militarized as the Barents and is so remote that the presence of Westerners would pose little threat to Soviet culture or national interests. Nevertheless, Moscow will be forced to weigh its naval security concerns against its economic need to develop potential Kara Sea oil resources.

Kara and Barents development could mean billions of dollars in trade between the USSR and the West over the next several decades. Even if the Soviets decide to go it alone—allowing no joint ventures and no Western presence—they would still have to spend enormous amounts on Western equipment, control systems, and consulting services. Any effort to restrict such purchases for the Kara Sea would reinforce the Soviet's 10-to-20-year lag behind the West in Arctic offshore expertise. Rather, we believe Moscow may consider some form of joint venture arrangement to speed up the replenishment of its reserve base with Arctic discoveries before the turn of the century. Increased trade would give Moscow more political clout, especially if Soviet Arctic development absorbed a large share of the worldwide oil services and equipment business targeted to harsh environments. Joint ventures, in particular, would give Moscow some important new economic leverage as Western companies sought to protect their equity investment in Soviet oil prospects

Contents

# The Kara Sea: A Soviet Oil Resource for the Turn of the Century

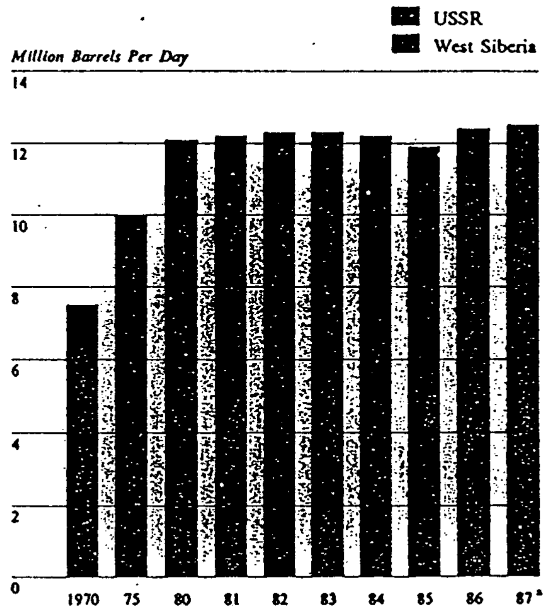
## Background

The USSR is the world's largest oil producer. According to open sources, production amounted to about 12.5 million barrels per day (b/d) in 1987—20 percent of the world's oil output. Oil currently accounts for about one-third of Soviet domestic energy use and about 40 percent of all nonmilitary hard currency trade earnings

Despite the size of the oil industry and the support of a leadership determined to maintain current production levels, the Soviets will be hard pressed to discover enough new oil to hold production up through the 1990s and beyond. Although many factors are at play, the core of the problem lies in producing oil faster than new oil can be discovered. Some signs suggest the Soviets are already in this situation:

- Our analysis indicates that production is declining in 24 of the USSR's 28 oil-producing regions.
- After decades of uninterrupted growth, production has been essentially flat for the last seven years, hovering between roughly 12 and 12.5 million b/d. Such a plateau is typically a precursor to production decline in most world oil industries (figure 1).
- Although production in West Siberia—the backbone of the Soviet oil industry—is increasing slightly, we believe the Soviets have already found the largest fields in this region, and new fields are geologically more complex, smaller, and far more expensive to develop.

Figure 1
Soviet Oil Production, Selected Years




[a] Preliminary

Seemingly aware of this growing problem, Moscow has significantly increased investment allocations for oil exploration during the current Five-Year Plan (1986-90). We believe that, in the near future, the Soviets will continue to devote the lion's share of their exploration budget to onshore areas, notably West Siberia and an area known as the Pre-Caspian Basin. Soviet statements and recent drilling in the Barents Sea, however, suggest that development of the oil potential of the offshore Arctic regions will play an increasingly important role in the Soviet energy strategy for the 1990s and beyond

*Moscow's Other Oil Exploration Priorities*

*With production declining in most of the Soviet Union's established oil regions, Moscow will need to increase efforts in a number of areas to maintain oil production. These will include greater efforts to exploit:*

- Untapped oil. *Getting more oil out of existing reservoirs will require new, expensive, and unfamiliar technologies, probably from the West.*
- Untapped fields. *Substantially increased drilling in existing oil provinces, especially West Siberia, has already been mandated by Moscow.*
- Untapped provinces. *Exploration in frontier regions such as the Arctic offshore could uncover huge new reserves, but the process will be slow and expensive, requiring substantial amounts of Western technology*

*Besides the Arctic offshore regions, Moscow is also devoting more attention to onshore exploration in areas that would have more near-term potential:*

- West Siberia. *After 20 years of production, achieving continued production growth in West Siberia is becoming increasingly difficult and costly. In 1985, Gorbachev indicated that the reserve-to-production ratio had fallen to the industry's nationwide average. As a result, Moscow is stepping up exploration in the region and plans to double the amount of exploratory drilling during 1986-90 from the level achieved during 1981-85. Nonetheless, we believe that the basic trend in oilfield quality—smaller, more complicated, and less productive fields—will continue.*
- The Caspian Region. *We believe the Soviets will devote an increasing amount of exploration resources to the Pre-Caspian Basin. Hopes that this region may be an oil bonanza in the 1990s, however, may be overly optimistic. The geological conditions of the new fields—extreme depth, complicated geology, corrosive fluids—are forcing the Soviets to annually import $100 million of Western drilling and well-completion equipment. Even with this equipment, Soviet drillers are taking one and a half to two years to complete a well, compared with about six months for completion of a comparable well in the United States. Moreover, the Soviets have experienced drilling disasters in the region, including toxic gas leaks, explosions, and loss of life*

**The Arctic Offshore: A Soviet Oil Frontier**

We believe that Moscow will be forced to consider trading off its current low-risk/low-potential exploration drilling in established areas for higher risk/higher potential opportunities in frontier regions. Except for the potentially large oil resources of the Caspian Sea region, we believe the Arctic continental shelf is the USSR's most significant oil frontier. The geology and sheer size of the shelves—two of the world's largest—beneath the Barents and Kara Seas suggest that both regions could be among the largest offshore petroleum provinces in the world. We have already completed a technical assessment of the oil potential of the Barents Sea, indicating the Barents may hold about 30 billion barrels of recoverable oil—placing it in the same league as the North Sea. Favorable geological characteristics also suggest a large oil potential in the adjacent Kara Sea

**The Petroleum Potential of the Kara Sea**

Situated directly north of the prolific West Siberian Basin, the Kara Sea is a tantalizing—and huge—exploration target. Our analysis indicates that it shares several geological characteristics with both the West Siberian Basin—one of the world's largest oil

*Recent Developments in the Barents Sea*

*The Soviets began serious drilling of the Barents in the early 1980s, resulting in an oil discovery on Kolguyev Island that the Soviets have developed with alarming speed, even though its production amounts to only a tiny fraction of the Soviet total. More recently, the Soviets have claimed three gas finds along the northern coast of the Kola Peninsula and a possible discovery in the Pechora River delta. Although the amounts of hydrocarbons involved are not known, our recent geological analysis estimated the oil potential of the Soviet portion of the Barents Sea at around 30 billion barrels, roughly equivalent to currently claimed reserves in Abu Dhabi.[a] An additional 8 billion barrels of potentially recoverable oil may lie in the Disputed Zone, which straddles the competing Norwegian and Soviet boundary claims*

*There are strong indications, then, that the Barents Sea could hold enormous amounts of hydrocarbons. The economic significance of this possibility, however, depends on the discovery of accumulations that are sufficiently large to develop. To date, the presence of oil or gas in such quantities has been proved only on Kolguyev Island. Even though the Soviet press reported that one of the finds off the Kola Peninsula held enough gas to supply all of the northwestern Soviet Union, the chances that the Soviets would develop it are slim given their huge, more accessible onshore gas resource:*

[a] *For a detailed discussion of potential oil resources in the Barents Sea, see DI Research Paper GI 86-10053 (Secret NF NC), July 1986,* The Oil Potential of the Barents Sea: A Future Soviet Bonanza

bearing regions—and the potentially oil-rich Barents Sea. Based on our geological and geochemical analysis of the Kara Sea, we believe it may hold recoverable oil resources of about 20 billion barrels. Although resource estimates in undrilled, little-known basins such as the Kara Sea are subject to considerable uncertainty, we are confident that:

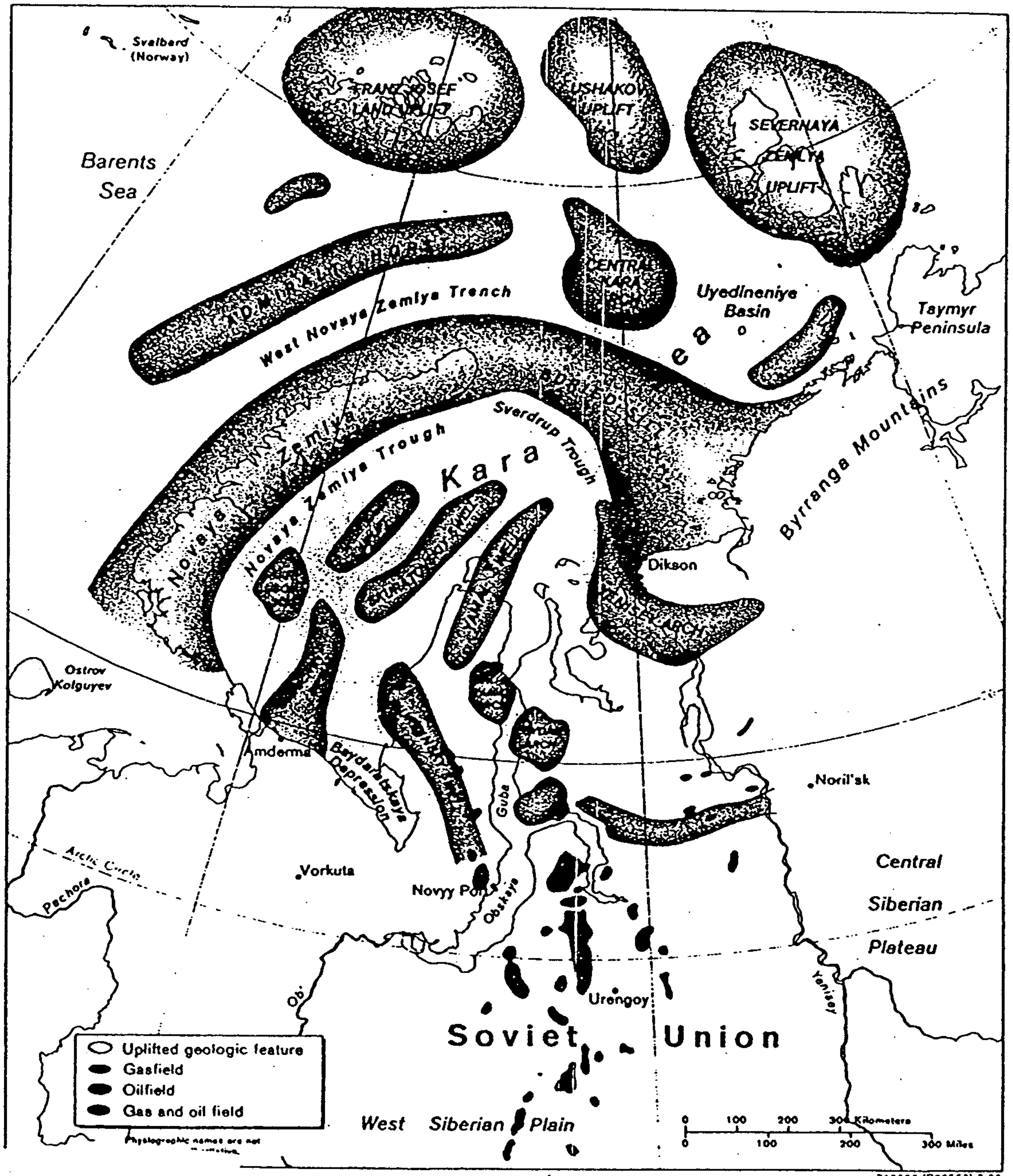
- There is only a small chance that recoverable oil resources in the Kara Sea are as small as proved reserves at Alaska's Prudhoe Bay—10 billion barrels.
- There is an excellent chance that potentially recoverable resources are about 20 billion barrels, roughly equivalent to current proved reserves in Libya.
- There is an outside chance that potentially recoverable oil resources could approach those of the North Sea—30 billion barrels or more

The location of these potential oil resources is almost equally divided between the southern portion of the Kara Sea—roughly east and south of Novaya Zemlya—and the northern portion, which stretches north and west from the Byrranga Coast.[1] Available information is insufficient to further pinpoint prospective oil bearing areas or to estimate the size of potential oilfields within these areas, but numerous oil basins and foldbelts within the Kara Sea continental shelf are likely to contain the necessary stratigraphic and structural characteristics to act as oil reservoirs. Although it is premature to speculate on the exact locations of oil in the Kara, a recent gas discovery on Belyy Island, situated near the center of the Kara Sea, confirms that hydrocarbons are present farther north than was previously thought

Because of the severe environmental conditions in the Kara Sea and its remoteness from established support bases, any effort to develop the Kara will entail enormous investments. Although we do not know what the Soviets consider a minimum field size to warrant development, discoveries in geographically analogous regions, such as the Canadian Beaufort Sea, must hold at least 600 million barrels for development to be economically feasible. Our analysis indicates the Kara Sea contains about 100 billion barrels of oil in place, a resource base large enough to

[1] For the purposes of this study, we have divided the Kara Sea into a southern and northern part by drawing a line from the northern tip of Novaya Zemlya to about the middle of the Taymyr Peninsula. This division reflects both geography and geology: geographically, this is the line south of which there is less than a 50-percent probability of free-floating ice in the summer; geologically, it is roughly contiguous with the Buried Sill, a foldbelt dividing the north and south continental shelves

Geologic Provinces in the Kara Sea



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offer the possibility of several fields of this size.[2] The minimum threshold for development may be somewhat lower in the southernmost portions of the Kara, such as Baydaratskaya Gulf, where very shallow water and relatively mild ice conditions lessen the design requirements of exploration facilities. The threshold may also be less in the farthest northern reaches of the Kara between Franz Josef Land and Severnaya Zemlya. In this area, the permanent icepack provides as firm a foundation as solid ground, making it possible to place drilling rigs above the ice and reducing the requirement for ice-resistant designs and engineering. Because transportation of oil would be very difficult in these regions, however, minimum field size would still be in the 200-to-300-million-barrel range. Fields of this size are considered very large by world standards, but we believe the chances are good that some reservoirs in the Kara are of this size

## Geologic and Geographic Setting

### Geology Is Favorable

The Kara Sea shelf covers parts of two major plates that make up the earth's surface in the northern regions. The northern portion is geologically part of the Barents Sea Plate; the southern portion—contiguous with the prolific West Siberian Basin—consists of a continental shelf that extends from the Siberian Platform. The dividing line between north and south is called the Buried Sill, a geological feature that stretches from the northern end of Novaya Zemlya to the southwestern Taymyr Peninsula (figure 2). The sill is probably an extension of the Ural Mountains and Novaya Zemlya, a dividing line between the Baltic-Barents Plates to the west and the Siberian-Asian Plates to the east

Soviet and Western geological literature indicates that the Kara Sea contains the three major factors necessary for the generation and storage of petroleum—source rocks, traps, and seals:

- We believe that source rocks in the northern Kara are similar in age and type to those in the Barents and that source rocks in the southern Kara are similar to those in the West Siberian Basin.[3]

- Our examination of bathymetric (seafloor) maps and technical literature indicates the presence of numerous large geological provinces that could serve as sites for oil-bearing structures trapping any generated hydrocarbons. In the southern Kara, these geologic provinces generally parallel the Urals-Novaya Zemlya-Buried Sill, trending north-northwest in the southernmost portion and changing to east-west toward the center of the Kara. In the northern Kara, the trend reflects the rest of the Barents Sea Plate, roughly parallel to Novaya Zemlya in the western part, changing to broad and north-south trending in the center and northern part.

- We have little information on the quality of sealing rocks, which are necessary to hold the hydrocarbons in the reservoir. On the basis of Soviet success in the far northern onshore portions of the West Siberian Basin and stratigraphic data from a few points around the Kara, however, we believe that effective seals exist

Although technical information is scarce on the relative timing of rock movements, faulting, and deposition of source materials, we know that the geological provinces have some characteristics that enhance their prospects for storing large amounts of oil. The major arches, uplifts, and basins in the Kara Sea are large, ranging up to several thousand square kilometers ($km^2$) in area, or about the same as provinces in the Barents Sea. Most geological provinces in the Kara have been stable for millions of years, which lowers the possibilities of oil seepage and loss. Some of the provinces in the southern Kara, such as the Yamal Swell and the Nurminskiy Swell, are probable offshore extensions of onshore trends with existing oil and gas production

[2] Oil in place is the amount of oil stored in reservoirs that could later become oilfields. For technical and economic reasons, most of the oil in a reservoir will never be recovered for commercial use

[3] See appendix A for the geochemical methodology used in assessing new oil area:

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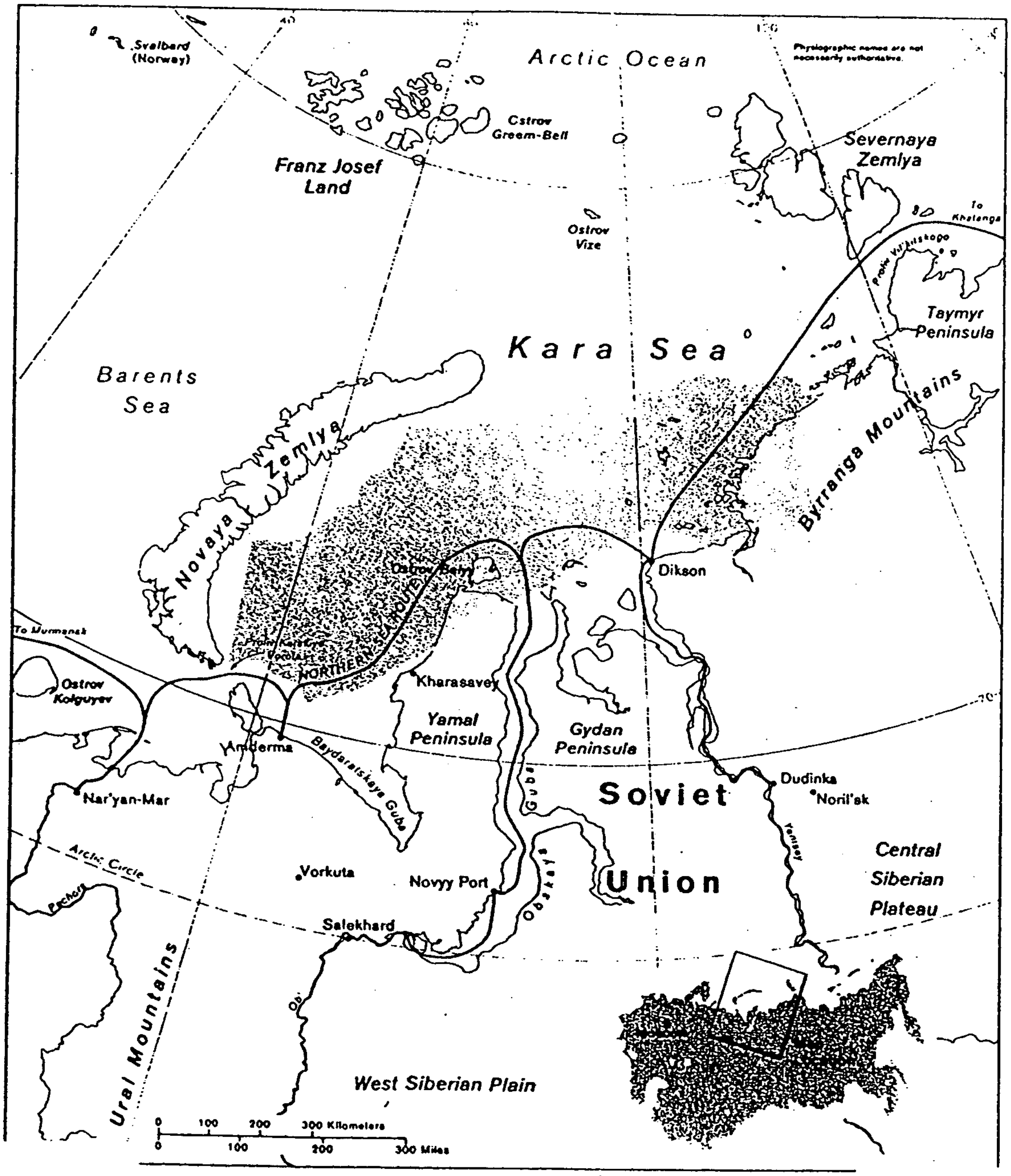
**Figure 3**
**The Kara Sea**



**Environmental Factors: Tough but Possible**

The Kara Sea occupies about 880,000 $km^2$—twice the size of California—lying entirely within the Arctic Circle (figure 3). It is bounded by the Byrranga Mountains on the east, Severnaya Zemlya and Franz Josef Land on the north, Novaya Zemlya on the west, and the northern plains of West Siberia on the south. According to readily available weather data, the sea is completely covered with ice from roughly November through April, and only in the southern portions does pack ice break up for a few months in the late summer and early fall. Temperatures are below freezing for 10 months each year. Average temperatures—not accounting for wind chill—range from 5°C in the southern Kara in summer to −29°C in the north in winter. With low temperatures sometimes approaching −57°C and windspeeds often reaching 40 to 50 knots, the Kara Sea clearly poses severe climatic constraints to human activity.

Although inhospitable, the climate conditions in the Kara Sea do not prohibit petroleum activity.[4] For example, floating ice and severe temperatures are much greater problems in the Kara than in other Arctic offshore petroleum areas, but water depths are well within reach of current drilling technologies, including Soviet technology. Water depths in the Kara average 115 meters overall; by comparison, depths in the adjacent Barents Sea average 220 meters. The deepest water in which oil production has occurred is about 400 meters in Brazil

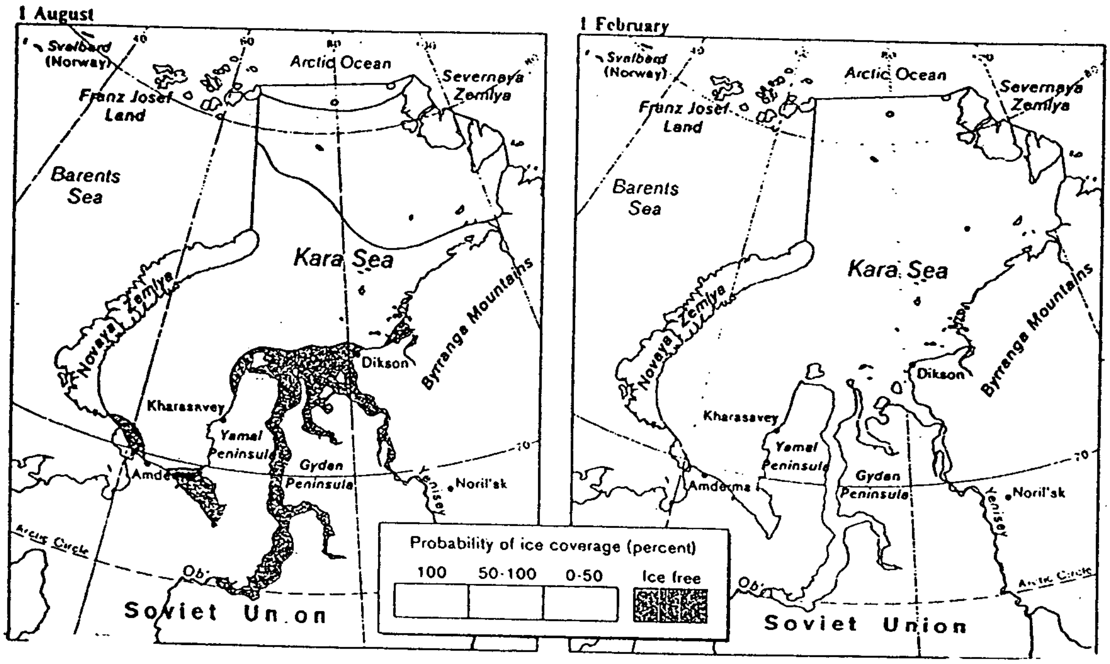
The southernmost Kara Sea is environmentally the most favorable for petroleum development, given its shallow water depths and relative lack of ice during the summer months (figure 4). Water depths within 100 kilometers (km) of the coastline are generally less than 50 meters, well within Western and Soviet drilling capabilities. Furthermore, while the Kara Sea is never completely free of ice, the southernmost coast is generally free of ice from about May to November. But the short drilling window—three to six months—will constrain exploratory drilling. In the southern Barents Sea, where ice is of little concern, it can still take 12 months or more to complete a well; even more time would be required to complete a well in the Kara

Environmental conditions in the northern Kara Sea are much more severe than in the south. Average temperatures rise above freezing for only one month in the summer, and average between −23°C and −34°C in the winter. Winds in excess of 40 knots are frequent, and dangerously high seas occur during the one month when the sea surface is not frozen solid. Perennial pack ice dominates the far northern part of this region, and even in the summer the probability of thick ice is 50 percent or more. Compounding the ice problem is the generally poor visibility, especially during the summer months, which would seriously curb air resupply activities. At Ostrov Vize, for example, visibility is only a few km for 30 percent of the time or more, and for two-thirds of the summer the sea experiences heavy fog. Poor visibility can hinder petroleum activity because ice developments—the breakup of pack ice, moving ice, the formation of pressure ridges—can seriously threaten supply vessels and rigs

Given these harsh conditions and the remoteness of the Kara Sea, we believe the Soviets will have to resolve some serious logistic support problems before significant oil development can be undertaken in the Kara Sea. The most pressing problem is the lack of ports that could serve as supply bases. The closest major port is Murmansk, almost 2,000 km from Dikson. As an analogy, using Murmansk as the base of operations for Kara Sea drilling would be similar to using Quebec as a base of operations for drilling off the southern coast of Greenland. A major port is being built at Kharasavey on the west coast of the Yamal Peninsula to support development of onshore gasfields in the region, but it will not be fully operational until the early 1990s and will be able to support ship activities for only a few months in the summer and fall. Outside of Murmansk and Kharasavey, only two minor ports—Dikson and Amderma—could serve as resupply and petroleum transshipment points. The Northern Sea Route, which follows the Soviet Arctic coast from the Barents Sea to the Pacific Ocean, connects the Kara Sea with other resupply points and oil transshipment and processing facilities. However, it only passes through the southernmost part of the Kara, leaving the north isolated

[4] See appendix B for a guide to Kara Sea developmen

**Sea Ice Conditions in the Kara Sea**




**Outlook for Kara Sea Development**

**In the Early Stages**

Exploration in the Kara Sea is in a very early stage. [redacted] the Soviets have conducted seismic surveys in the region, a necessary first step in an oil exploration program. We believe they will continue conducting geologic surveys to better understand the potential of the Kara but are not yet focusing on where the most prospective areas may lie. We cannot confirm that the Soviets have drilled test wells in the Kara, but [redacted] a drilling rig previously operating in the Barents was moved to the Kara during 1987; its activities have not been verified

The Soviets appear to be at the same stage in the Kara as they were in the Barents about a decade ago. Initial exploration drilling—using Western-type drill ships—did not start in the Barents until 1982. If the same pattern holds in the Kara Sea, a serious drilling program is not likely to be mounted until the early 1990s at the earliest. In this case, we believe any oil production from the Kara Sea would be highly unlikely until sometime after the turn of the century.

In our view, the overall pace of development of the Kara Sea will ultimately depend as much on the amount of oil found there as on the degree of success the Soviets have in finding new oil onshore. The most promising potential onshore area, according to Soviet claims, is the Pre-Caspian Basin. Recent exploration in this area has already resulted in the discovery of several large fields. Most notable among these is the Tengiz field, which the Soviets have stated could become the USSR's third million-barrel-per-day producer. Some statements suggest it may even rival in size West Siberia's supergiant Samotlor field. The Soviet media has claimed that potential oil reserves in the Pre-Caspian Basin could approach those in the Volga-Urals oil province, which has produced 40 billion barrels since the 1930s. Although it is too early to substantiate any figures for the oil potential of the Pre-Caspian Basin, our preliminary analysis suggests that the region may be capable of producing up to 2 million b/d after the turn of the century. If this estimate proves to be reasonably accurate, new oil from the Pre-Caspian Basin may be able to help offset declines in West Siberia and other regions. In this event, Moscow could afford to move somewhat slower on development of the Kara Sea, its large oil potential notwithstanding

In some ways the long-term nature of Kara Sea oil prospects may be a benefit to the Soviets. Kara Sea oil could come onstream just as production from established areas is seriously declining. Although new oil from the Caspian and possibly the Barents would add to the USSR's production base during the 1990s, we doubt that the Soviets would be able to maintain the 1980s level of production into the next century. The long leadtime before any production from the Kara Sea begins also offers Moscow the opportunity to experiment, at a manageable pace, with joint ventures and other business arrangements with the West.

### A Joint Venture Candidate

The Kara Sea is one of the most challenging drilling and producing areas in the world. Drilling and production will require specially designed equipment suited for severe offshore ice conditions, unpredictable subsurface conditions, and temperature stress. In our view, this equipment will have to come from the West, in one form or another, and will require huge financial outlays by Moscow. The shorter drilling seasons in the Kara Sea will necessitate more efficient logistic support than the Soviets have yet demonstrated, covering such items as supply vessels, equipment stocks, fuel, personnel, and port facilities. The Soviets will also need more patience, because leadtimes from exploration to production could be 10 years or more.

For these reasons, we believe joint ventures in the Kara Sea offer an attractive opportunity to the Soviets. The joint venture is a relatively recent topic among international businesses dealing with the USSR, but [redacted] it has quickly become one of the most talked about methods for using Western expertise to extract Soviet resources. The joint venture decree passed by the Soviets in 1987—while ambiguous on some fundamental business points—is generally designed to attract a maximum of foreign capital.[3] This characteristic of joint ventures plays particularly well to Soviet capital-intensive industries such as the petroleum industry. It may be significant that the first US joint venture under the new law involved an entity created by the Soviets and a US company in November 1987 that will upgrade Soviet oil refining capabilities, increasing hard currency exports by as much as $300 million annually. Despite this example, Western firms remain skeptical about joint ventures because the Soviets rarely accommodate some fundamental business requirements regarding profitability, marketing, and management control. Nevertheless, the Soviets appear to be aggressively pursuing joint ventures, and we believe developments during the next decade could produce business terms much more attractive to Western companies, including those interested in exploiting potential oil resources in the Kara Sea

[3] The new law is ambiguous, but the basic characteristic of a joint venture is 51/49 percent Soviet/Western ownership, with hard currency profits to be earned through the enterprise's exports to the West. Based on the few examples so far, the framework of future joint ventures is likely to be case-specific, each one shaped by a combination of the new Soviet joint venture law as well as Western and Soviet business and management interests

The Kara Sea is also a favorable site for joint ventures from the standpoint of Soviet security. It hosts far fewer naval maneuvers than the Barents Sea, and no major military bases are in the area. Although the Soviet Navy is likely to be leary of any joint ventures in the Kara Sea that would require a Western presence, we believe having Westerners in the Kara would trouble the Kremlin far less than their presence in the strategically sensitive Barents. Not allowing Westerners in skilled positions and management would discourage the infusion of foreign technology and expertise, and we believe Moscow would find a way to mollify the military's security concerns while clarifying the terms regulating the presence of Westerners.

Western financial and technical involvement in the Kara Sea could be a boon to the Soviets. The Soviets began large-scale imports of Western equipment about 15 years ago worth hundreds of millions of dollars annually but would need billion-dollar orders for Kara Sea development projects. Canadian firms have provided Arctic technology fairly regularly, as have Finnish firms. West German, Italian, and French firms have also been infrequent but resolute players in the energy area. In the case of the West Siberian Pipeline to Europe, these countries took advantage of US technology-export sanctions to fill in for US firms. Although US companies are at the cutting edge of Arctic petroleum technology, firms in several other countries can deliver some similar technology—most of it derived from US designs and under license from US companies—and are quite ready and willing to do sc [redacted] Finland and Canada are probably in the best position to profit from Soviet Arctic technology purchases, but many other countries could compete, including other Scandinavian countries, West Germany, France, Italy, and Japan

[redacted]

**Implications**

**. . . For the USSR**

We believe the Soviets will continue exploration work in the Kara Sea, but at a very slow pace. With the bulk of future oil exploration budgets earmarked for more hospitable onshore areas and offshore work in the Barents much farther along, comparatively little investment will be left over to devote to the Kara Sea until well into the next decade. At this early stage of exploration, however, only relatively small expenditures would be required. For the next several years, we expect the Soviets to continue conducting scientific surveys to better understand the petroleum potential of the Kara Sea and to identify specific areas with the best prospects. We believe the Soviets could be in a position to begin a test drilling program possibly within the next five years, but the program would probably be on the same scale as the fairly small effort that has been under way in the Barents Sea since 198[illegible]

We see little chance that Moscow will step up exploration in the Kara, even if results in the early exploration stages help confirm that oil is present in the amounts we believe are possible. With some attractive exploration targets onshore, the Soviets may feel they can afford to hold any possible new oil from the Kara in reserve until needed. We believe Moscow would give higher priority to the Kara Sea only in the event that national production begins to worsen dramatically, and if the oil potential of the Pre-Caspian Basin and Barents Sea proves to be much lower than now expected

**. . . For the United States and the West**

Exploration and development of the Kara Sea could translate into potentially billions of dollars of business for Western firms. Although any financial estimates are speculative at this point, even a modest test drilling effort in the Kara Sea would require several hundred million dollars worth of Western equipment, supply and monitoring systems, and design and consulting service

*Gorbachev in Murmansk: NATO Concessions for Soviet Oil?*

*In October 1987 at Murmansk, Gorbachev presented the Nordic countries with a package of proposals that offers substantial economic opportunities for Scandinavia, but coupled with security initiatives distasteful to NATO. Although the goals of Soviet policy in the area are clearly linked to the region's geographic position as NATO's northern flank, Gorbachev framed the proposals around a "pole of peace" concept: although the Arctic regions hold enormous natural resources that could be jointly exploited for the benefit of all nations, regional research and business ventures should be accompanied by at least partial demilitarization of the Arctic*

*The specific proposals covered several topics:*

- Military. *The creation of a Nordic Nuclear-Weapons-Free Zone (NNWFZ) and restrictions on naval and air activity.*
- Economic. *Joint exploitation of Arctic natural resources, and the opening of a permanent Atlantic-to-Pacific Arctic sea route.*
- Scientific/Social. *Cooperation on research of natural resources and Arctic processes, cooperation in environmental management, and interaction of Nordic peoples*

*The Murmansk package ties old political problems to the possibility for new economic and social opportunities. None of the security proposals is new; NNWFZ, for example, was first broached in 1958. The Murmansk speech was politically shrewd nonetheless in trying to legitimize a linkage between security and nonsecurity issues by supporting Scandinavian sympathies on environmental and economic concerns. But the linkage of issues clearly presents a problem for Scandinavian leaders as they formulate an official response. They must balance their legitimate economic interests and the political force of their environmentally conscious populations on the one hand, and their concerns about the Soviet military threat on the other. Initial response to the package accordingly ranged from noncommittal to lukewarm. The Finns, who would profit handsomely by increasing their large trade relationship with the USSR, were generally favorable. Norway, cool to Gorbachev's economic and scientific proposals, stated that no decision on any military proposals will be made until it confers with its NATO Allies*

Many Western companies would clearly be interested in supplying the Soviet market. Competition for a slice of the Soviet oil industry business will probably be fierce, and Moscow may have the luxury to pick and choose among many qualified suppliers. Nevertheless, US and Canadian firms are recognized world leaders in the types of technologies needed in the Kara and Barents Seas and can point to facilities already in place in the Alaskan and Canadian Beaufort Seas—an area analogous to the Kara in terms of ice conditions, climate, and distance from support bases. Unlike the Barents Sea, where military sensitivity would probably rule out any direct US involvement, US oil companies would probably be on an equal footing with other Westerners for potential business in the Kara Sea

Although the Kara Sea appears to offer an opportunity for the Soviets to experiment with joint ventures or engage in trade along conventional lines, there is always the possibility that Moscow will decide to go it alone. Using US and Canadian experiences in similar Arctic conditions as a guide and considering the Soviet's lack of expertise in this environment, a solo effort would probably require a development cycle of about 20 years from the first exploration efforts to the production of commercial quantities of oil from the Kara Sea. With adequate Western assistance, we believe leadtimes could be compressed substantially and commercial production could begin as early as the turn of the century

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## Appendix A

## The Geochemical Methodology: A Tool for Assessing New Oil Areas

The Kara Sea Basin is a virgin exploration area, where assessing petroleum potential raises difficult analytical problems. Detailed geological and geophysical data are limited for an area of such size and potential (figure 5). Because of the paucity of geological data from actual drilling, our analysis of the oil and gas potential of the Kara Sea relied on geochemical theory to provide a framework for understanding the limited empirical information available

The primary element of the methodology used was geochemical analysis of source rocks. This analysis yields the likely volume of oil generated by, and expelled from, rocks that have proper geochemical characteristics. Because only a small portion of the hydrocarbons generated by the source rocks will ultimately be recovered for commercial use, several steps are needed to arrive at an estimate of the potential reserves of the basin. A series of calculations is used to determine the likely amount of oil or gas generated by the source rocks that gathers in commercial-sized concentrations. This mechanism is referred to as "trapping," and results in what is commonly recognized as an oilfield. A factor is then applied to the amount of trapped oil or gas, which reflects the best estimate of the quantity that can be extracted economically from the oilfield at the likely time of extraction (figure 6)

The generation, expulsion, migration, and trapping of oil and gas are very inefficient processes. Because of the enormous lengths of time involved—millions or hundreds of millions of years—geological events, such as folding, faulting, fracturing, and erosion, can create conditions in which the majority of any generated hydrocarbons seep to the surface and escape, lost forever for commercial purposes. For example, our geochemical analysis indicates that more than 1.2 trillion barrels of oil have been generated by the source rocks in the Kara Sea; of this amount, we estimate that only about 20 billion barrels can be recovered, or only 1.7 percent of the oil generated (table 1).

**Figure 5**
**Comparable Availability of Information**

● North Sea
● Barents Sea
● Kara Sea

| | Excellent | Good | Fair | Poor |
|---|---|---|---|---|
| Production history | ● | | | ●● |
| Seismic | ● | | ● | ● |
| Well logs | ● | | ● | ● |
| Lithology | ● | ● | ● | |
| Geologic literature | ● | ● | ● | |
| Gravity, geophysical | ● | | ●● | |
| Reservoir data | ● | | ● | ● |
| Source rock data | ● | | ●● | |
| Structure | ● | | ●● | |

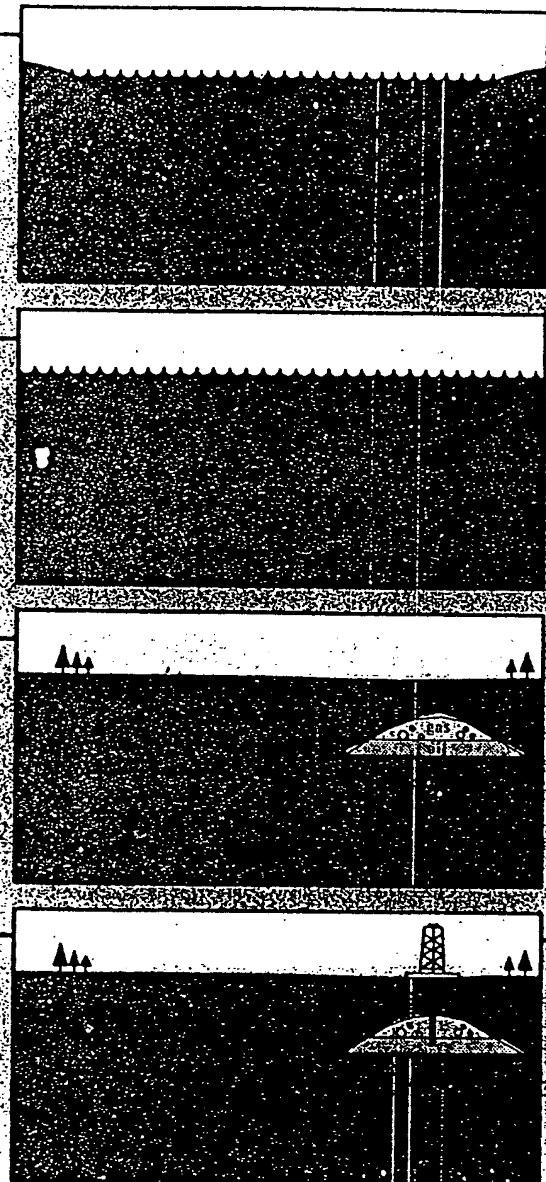
### Source Rock Deposition

Oil is formed by the chemical decomposition of organic matter under the influence of heat. This organic matter is initially deposited along with the sediments that later form rocks, called source rocks. Because of basin subsidence and sea level changes over time, source rock sediments—in fact, sediments of any type—can accumulate over very large areas and in great thicknes

[1] Condensate and gas are not included in this repor

**Figure 6**
**The Geochemical Methodology**

The Geochemical Methodology involves analysis of four stages in the history of oil deposits:



**Source Rock Deposition**
Organic material and sediments are deposited on sea floor.

**Hydrocarbon Generation**
Sediments are buried, and organic matter breaks down under high temperatures.

**Expulsion, Migration, and Trapping**
Hydrocarbons move from source rock to traps sealed by impermeable rock.

**Recovery**
Small portion of original hydrocarbons generated by geochemical process is recovered.

**Geologic Time**
The processes illustrated here take place over time, ranging from millions of years to hundreds of millions of years.

**Table 1**
**Estimated Oil Resources in the Kara Sea**

| | South Kara | Buried Sill | North Kara | Total [a] |
|---|---|---|---|---|
| Weight of mature source rock (*trillion metric tons*) | 118 | 3 | 85 | 206 |
| Weight of organic carbon (*trillion metric tons*) | 3.6 | 0.1 | 2.5 | 6.2 |
| Weight of converted carbon (*billion metric tons*) | 98 | 3 | 69 | 170 |
| Volume of generated oil (*billion barrels*) | 703 | 20 | 495 | 1,218 |
| Volume trapped in reservoirs [b] (*billion barrels*) | 63 | 2 | 35 | 100 |
| Recovery factor (*percent*) | 20 | 20 | 20 | 20 |
| Recoverable oil resources (*billion barrels*) | 12.6 | 0.4 | 7.0 | 19.9 |

[a] Because of rounding, data may not add to the totals shown.
[b] The remaining generated oil is lost for commercial purposes during migration and expulsion.

Source rocks are typically organic-rich black shales or carbonates deposited under shallow marine conditions that undergo chemical re-formation after burial. The presence or absence of oxygen is one of the most importar' factors in this process. If present at the time of deposition, oxygen quickly eliminates the possibility of carbon and hydrogen joining to form hydrocarbons (oil and gas); the oxygen will combine instead with the carbon and hydrogen atoms separately to form carbon dioxide ($CO_2$), carbon monoxide (CO), and water ($H_2O$). For this reason, geochemists look for the occurrence of oxygen-poor environments at the time of deposition, typically large inland seas in which the water is undersaturated with oxygen. Under such conditions, the organic matter is less likely to decompose. Our analysis indicates that significant source rocks were deposited in the Kara Sea, that they were not eroded away by later uplift, and that the Kara Sea experienced oxygen-poor environments in its geologic history.

**North Kara**

In the North Kara, two major source rocks are thought to exist. Upper Devonian shales, deposited about 375 million years ago, are believed to be similar to Devonian rocks in the Barents Sea and the Pechora Basin south of Novaya Zemlya. Upper Jurassic bituminous shales and limestones, deposited about 150 million years ago, are of equal importance. They are believed to have characteristics somewhat similar to the prolific Jurassic rocks of the West Siberian Basin.

A third source rock, from the 95-million-year-old Upper Cretaceous period, is present but is not likely to be an important potential source rock in the North Kara Sea. These rocks did not experience the necessary geochemical environment to produce any hydrocarbons by the thermal process. They may, however, contribute significant amounts of biogenic gas, which is produced by bacteriological, not thermal, decomposition. Biogenic gas is thought by many experts to contribute as much as one-half the total gas reserves of West Siberia. Biogenic gas resources in the North Kara could be significant, but our analysis did not quantify them.

**Buried Sill**

Because it is a structurally uplifted region, the Buried Sill [a] never accumulated the necessary sediments or attained the necessary depths to thermally generate hydrocarbons. In one exception, however, the Upper Jurassic source rocks present in the South Kara lap onto the central portions of the Buried Sill.

[a] The Buried Sill is essentially a subsurface foldbelt or ridge separating partially closed basins. It is probably an extension of the Ural-Novaya Zemlya Foldbelt.

The Buried Sill is much more important from a structural point of view than from a source rock perspective. Because of its proximity to both the North and South Kara shelves and its relatively high elevation within the basins, the Sill is in a good position to trap any generated hydrocarbons, although we do not have detailed information on whether favorable structures exist in this region.

**South Kara**

Two source rock units are present in the South Kara. Our analysis suggests that most of the Upper Jurassic source rocks underwent an appropriate geochemical history. This source rock probably has characteristics very similar to related onshore source rocks that are believed to produce most of the oil in the prolific West Siberian Basin. In addition, the Cretaceous-age source rocks in the West Siberian Basin are believed to extend offshore into the South Kara. They are rich in organic carbon, but the types of organic carbon are not as prone to produce oil as those in the Jurassic. Moreover, the Cretaceous source rocks underwent appropriate geochemical processes only in a small portion of the South Kara region. Therefore, like the Cretaceous source rocks in the North Kara, these rocks are likely to contribute significant quantities of biogenic gas rather than thermally generated hydrocarbons

## Hydrocarbon Generation—The Geothermal History

The transformation of buried organic matter into hydrocarbons is at the core of our analysis. This process is extremely complex, but in virgin areas such as the Kara Sea, we believe analysis of the generation process is the most reliable methodology for making resource assessments. Although technical data on specific structures and rock strata are limited, enough geological information exists to make reasonable estimates of geochemical factors and to estimate past geoenvironments

Once organic matter is deposited and buried, two factors affect the transformation into hydrocarbons: temperature and time

**Temperature**

The complex molecular chains that make up organisms—consisting primarily of hydrogen, carbon, and oxygen, but including many other elements—are broken down, or "cracked," when subjected to heat. This process yields hydrocarbons, simpler molecules containing only hydrogen and carbon, as well as several byproducts, such as sulfurous gases. Our analysis estimated the temperature of the source rocks on the basis of the depth of the rocks and temperature profiles in their vicinity. Depth of the rocks was determined from limited geological information from several locations in the Kara Sea. The temperature profiles were based on heat-flow measurements at the same sites.

**Time**

Once a sufficient temperature is reached, organic hydrocarbons begin forming, but the process does not occur instantaneously. As a general rule, high temperatures for a short time have an effect similar to low temperatures for a long time. In either case, an enormous length of time is involved in successfully forming any significant quantity of hydrocarbons. Depending on the temperature and the type of organic material, the required time can range from millions of years to hundreds of millions of years. For example, some of the most significant source rocks of the world—in West Siberia, the Middle East, the North Sea, the Gulf of Mexico—are of Jurassic age, roughly 150 to 200 million years old.

Time is also critical after hydrocarbons are formed. If the generated hydrocarbons are not expelled from the source rock into surrounding rock layers, the heat will continue to crack the molecules until only gas and carbon residue remain. Therefore, given the temperature of the source rocks, a narrow range of time exposures exists for the optimal formation of each particular type of hydrocarbon (oil, condensate, gas).

### The Time-Temperature Index Methodology

To summarize the critical relationship between time and temperature in the formation of hydrocarbons, we used a methodology based on the Time-Temperature Index (TTI), a methodology proposed by Russian scientists and developed by US geochemists in the 1970s. The TTI formula combines geologic temperature and time into a single indicator, ranges of which are necessary for the generation of specific kinds of hydrocarbons. This indicator was then plotted on maps of the Kara Sea to identify specific areas whose geologic history is consistent with the generation of oil or gas. Combining these areas with estimates of source rock thickness and density, we estimated the quantity of potential source rock present

Only a small fraction of this source rock is organic material. This percentage is arrived at by examining the likely environments of deposition and by drawing analogies with present environments, giving an estimated percentage of deposited material that is organic in nature. This organic material—called Total Organic Carbon (TOC)—is stored in the sediments as they are buried to greater depth and can range from 0 to 15 percent or more of the rock weight. We judged likely TOC values in the Kara Sea source rocks at below 5 percent

Only some of the organic material deposited with sediments, and later buried, has the biochemical characteristics necessary to become hydrocarbons upon heating and aging. Therefore, of the total carbon-based organic material that is in the thermally mature range, only a small percentage is of the type that can produce oil or gas. This percentage is estimated by examining the environment at the time of deposition and the likely types of organic material deposited in such an environment. In the Kara Sea source rocks, less than 3 percent of the TOC was judged to be of sufficient quality to generate oil or gas

## Expulsion, Migration, and Trapping

Expulsion, migration, and trapping are poorly understood processes, but experts generally agree that they are very inefficient. As a result, only a small percentage of the oil generated in the source rock will ever be recovered for commercial use, but estimates of this percentage vary considerably. On the high end, a few researchers believe as much as 20 percent or more of the generated oil is trapped in structures, at least in certain basins where few fractures and faults exist that could serve as conduits for hydrocarbon seepage and loss. But most experts believe that, in an average basin, no more than a small percentage of the generated oil will ever be recovered. Because of this large uncertainty, we made conservative assumptions that tended to limit the chance of overestimating actual recoverable resources

### Expulsion

Clays and associated organic materials are deposited on the seafloor in a water-rich matrix. As the sediment is progressively buried—carrying its organic material to the greater depths needed to generate hydrocarbons—water is squeezed out[a] and the clay layer loses considerable volume. Most researchers agree that as much as 90 percent of the total compaction of the sediments occurs in the first few thousand meters of burial as the result of water loss. This process is similar to squeezing a sponge; little force is required to squeeze most of the water out of a sponge, but a great deal of force—and a strong grip—is necessary to squeeze out the final drops. Since the hydrocarbon generation process does not begin until the sediments have experienced nearly all the compaction they will ever undergo, hydrocarbons must escape the source rock by methods other than compaction itself. This can occur through volume expansion of generated gases and liquids and the natural gravitational tendency for lighter oil and gas to migrate upward under pressure from the heavier water. A considerable percentage of generated hydrocarbons will always remain in the source rock, however, especially if it is a shale, and will never be recovered.

[a] Some of the organic material in the sediment is probably carried away with the water as it is squeezed out. This is another loss in the balance of organic material that could have later been turned into hydrocarbons, but researchers have not yet quantified this loss

**Migration and Trapping**

Once the oils and gases have been expelled from the source rock, they begin migrating laterally and vertically, following the easiest routes. Along the way, some of the fluids are lost. Some fluids are swept along by underground waters in the beds into which they have migrated, where they remain in uncommercial concentrations or are carried to surface springs and dispersed. In some strata, oil may be lost to commercial exploitation because it clings, in the form of a thin film, to the surface of the grains that make up the rock. But most is probably lost through seepage. When the hydrocarbon fluids reach fractures or faults or strata that are not sealed by an impermeable layer, they migrate upward to the surface and seep away. Seeps are quite common and to this day are one of the easiest-to-spot ways of exploring for possible new oil regions:

- Oil seeping into a creek led Colonel Drake to drill the first American oil well in Pennsylvania.
- Numerous seeps—including the La Brea Tar Sands—led to the discovery of the Los Angeles Basin, the richest basin in the world in terms of oil yield per volume of sediments.
- Mexico's Bay of Campeche oilfields were explored only after confirming a fisherman's report of a film of oil on the water

Researchers have had little luck trying to quantify losses during migration. Because of these losses, only a portion of the hydrocarbon fluids will migrate to a point where they can go no farther because of an impermeable bed above and on the sides of the structure. At these locations, the fluids are said to be trapped, and they accumulate in pools that we commonly recognize as reservoirs, or oilfields

Recovery

The percentage of the original oil in place in a reservoir that will be extracted for commercial use is problematic. Ultimate recovery can, in the extreme, be as little as a few percent or more than 90 percent; however, a range of 15 to 50 percent is more common. Even when using state-of-the-art equipment and technology and waterflooding, US operators average only 33 percent. The Soviets claim as much as 45 percent recovery using waterflooding. Because waterflooding is a secondary recovery process, ultimate production from totally natural methods has to be much less. Moreover, we believe the Soviet claims are unrealistic; recovery using waterflooding in the West Siberian fields is probably closer to 20 to 25 percent. In the Kara Sea study, we assumed 20 percent for primary recovery, which we felt was realistic and, in the long run, perhaps conservative

## Appendix B

## The Beaufort Sea: A Guide to Kara Sea Development?

Because of similar ice conditions and the fact that petroleum activity has been under way there for many years, Beaufort Sea development may offer a useful guide to eventual development of the Kara Sea (table 2) [ ] have estimated potentially recoverable oil resources in the Beaufort Sea at about 18 billion barrels—similar to our estimate of the Kara Sea's potential—of which about 2 billion has already been identified with a high level of certainty. But extracting and transporting the oil has proved to be a formidable task, as it will be in the Kara.

The Soviets have little or no experience with the Arctic drilling technologies used by Western operators in the Beaufort and would probably have to rely on Western expertise in some form to make a serious attempt at Kara Sea operations. The necessary technologies are widely available from Western firms, with US and Canadian companies dominating the market. After a decade of learning, the established technologies are no longer particularly complex by Western standards, but they are extremely expensive. Once the technologies are in hand, oilmen operating in the Arctic must tackle three major problems: time, environment, and cost.

**Table 2**
**Comparison of Arctic Environmental Conditions**

| | Beaufort Sea | Kara Sea |
|---|---|---|
| Maximum average water depth (*65 kilometers from shore*) | 200 | 150 |
| Average ice thickness (*meters*) | 2 | 2.4 |
| Duration of ice (*months*) | North | |
| | 11 to 12 | 11 to 12 |
| | South | |
| | 9 to 10 | 9 to 10 |
| Average temperature (February) (*Celsius*) | −29 | −27 |
| Average temperature (August) (*Celsius*) | 4 | 3 |
| Average windspeed (*knots*) | 10 | 11 |

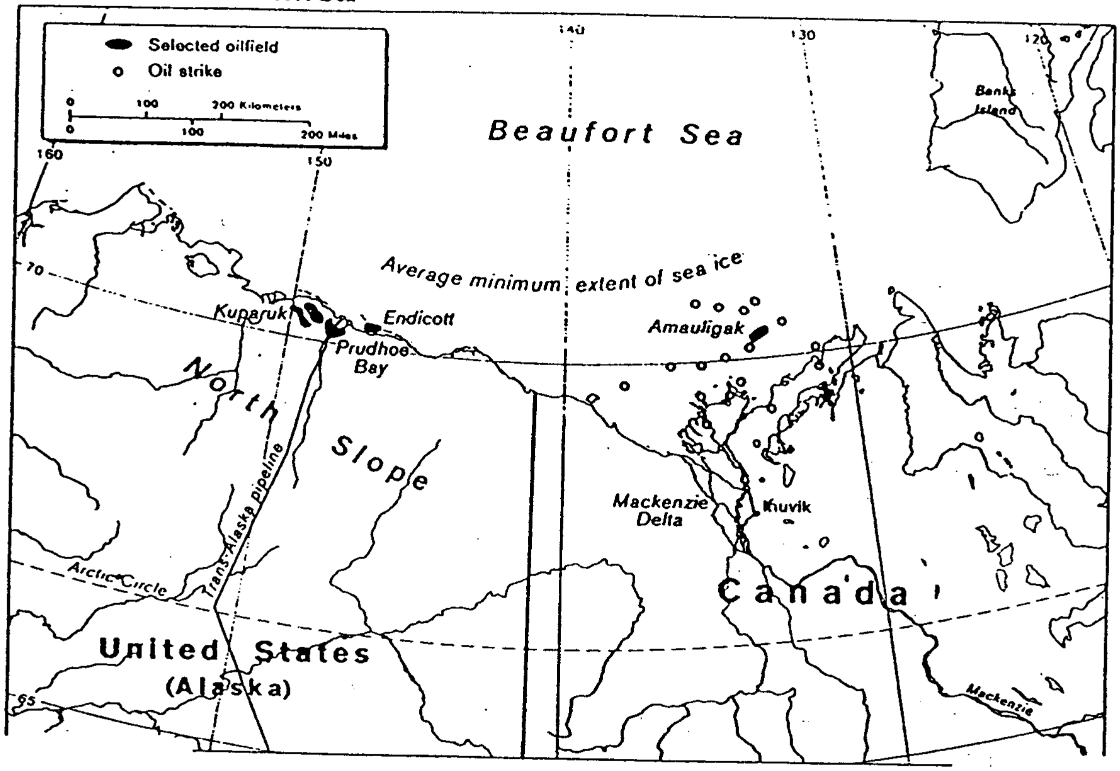
### Long Leadtime

Drilling began in the Beaufort in 1977, 200 kilometers west of Prudhoe Bay, but commercial production was not achieved for 10 years. Production began in November of last year, when Alaska's Endicott field—just offshore from the Prudhoe Bay infrastructure and the Trans-Alaskan pipeline—began producing 40,000 barrels per day from a gravel island connected to land by a gravel causeway. A 10-year leadtime also seems to apply to Canada's largest discovery in the Beaufort (figure 7). The Amauligak field in the Mackenzie Delta—with reserves of at least 600 million barrels—was discovered in 1984, yet will probably come onstream no earlier than 1993. The biggest obstacle to development at Amauligak is posed by the high cost and technical difficulty of constructing an export system.

### Environmental Constraints

All Arctic offshore areas present severe environments in which ice, temperature, and water depth combine to place extreme demands on personnel, equipment design, and facilities operation. Temperatures present an obvious problem in any Arctic area, but the most important factors affecting offshore operations are sea ice and water depth. The Barents Sea benefits from the warming effects of the Gulf Stream current and therefore experiences few ice problems, but most Arctic seas are covered with ice much of the year

Ice and Oil in the Beaufort Sea




Only a few Arctic seas—including the southern portions of the Beaufort and Kara Seas—experience a significant change in ice cover during the year. Drilling and production equipment must be designed to withstand the horizontal forces of moving ice floes—which can exceed the force of a very large earthquake—as well as ice that forms on equipment surfaces and interiors (figure 8 and table 3). In these areas, the forces of winds and currents pile up plates of sea ice upon one another, forming "pressure ridges" of ice rising 6 meters or more above sea level and extending 30 meters below the surface. The design of offshore pipeline systems must accommodate these pressure ridges; pipelines must be buried deep below the seafloor to prevent damage from iceberg scouring and gouging, caused by ice bodies that are pushed by currents to shallow depths and carve deep ruts into the sediments.[5]

### High Costs

In the Beaufort, operators have drilled from artificial gravel islands, which provide a year-round foundation and protect operations from floating ice. But these structures are economic only in relatively shallow depths; at a minimum a gravel island in 6 meters of water costs $100 million to construct, increasing to $500 million or more in 40 meters depth. Where the water is deeper, the only alternative is the use of huge, steel-reinforced gravity structures, consisting of cone-shaped reinforced hulls that rest on the sea bottom and are filled with sand or concrete. Deep-water gravity structures cost as much as $700 million to construct, although units capable of operating in 50 meters may cost only about $250 million.

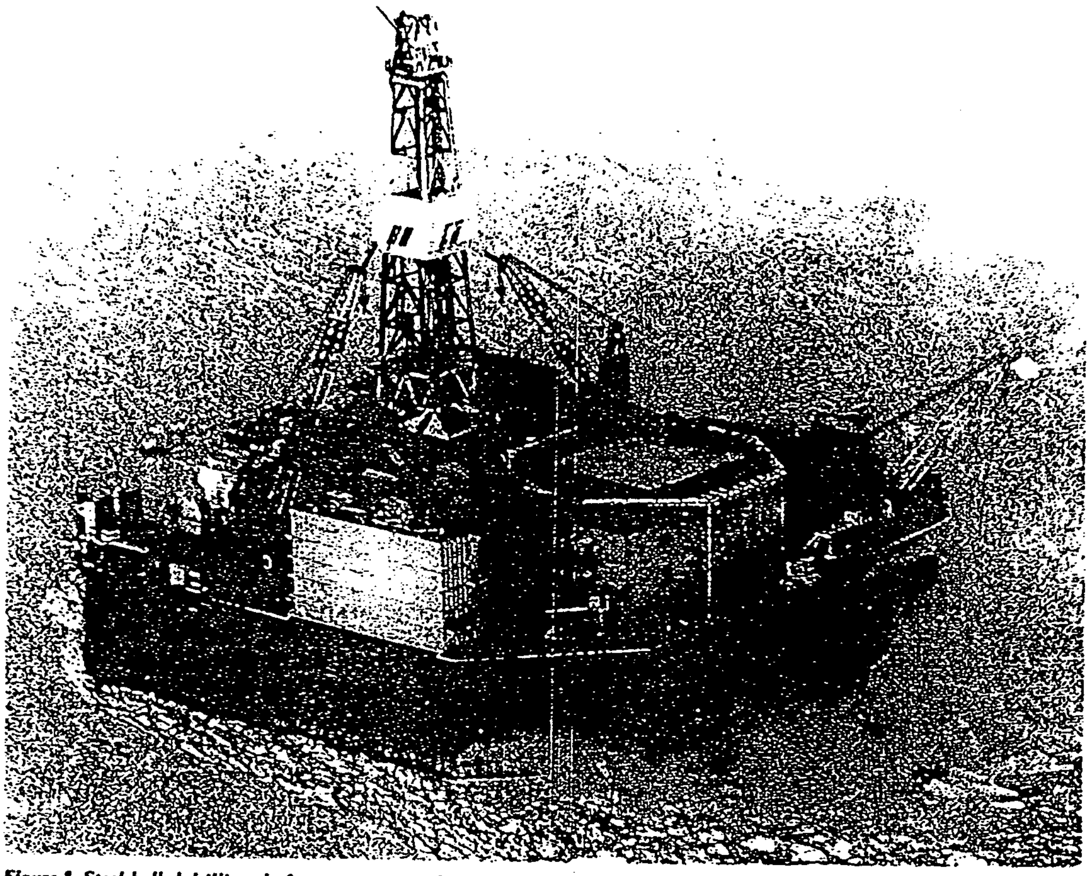


*Figure 8. Steel-hulled drilling platform operating in the Beaufort Sea.*

Operating costs in the Beaufort are extremely high, but transportation costs may be even higher. Moving the oil by surface vessels can be very expensive because of the distance from major offloading ports and the necessity of icebreaker support. Pipelines provide less expensive transportation in the long run, but require huge amounts of capital in the early stages of a region's development. Some experts estimate as much as 70 percent of total development costs in the Beaufort will be earmarked for pipeline and support facilities. Current development plans include options for both tanker shipments to Japan and for a pipeline, at an estimated cost of $3-7 billion, that would extend from Amauligak southward to join the Canadian pipeline system. This pipeline distance is roughly similar to that from the near-shore Kara Sea to the nearest onshore oil pipeline in West Siberia.