THE NORTHERN ENGINEER

volume 10, number 4

10 year index issue

Whatever became of the Polydome?
(and other burning birthday questions)

This magazine has come quite a way from Volume 1, Number 1, with its eight hopeful (and free) pages. With this issue, **TNE** *is ten years old...more or less. One of our birthday questions could honestly be, When is, was, or will be* **TNE***'s tenth birthday? Volume 1, Number 1 appeared in the autumn of 1968, but that volume had five issues and finished with Winter 1969. However, Volume 4 had only two issues, so we're still short one number of the 40 a quarterly should have published by the end of its tenth volume. Well, this is close enough. As you can tell from the cover, we are celebrating the end of Volume 10 with a bow to the past and an index to prove* **TNE** *was there from early in the black gold rush.*

Some old friends have contributed to this party. Gunter Weller first appeared with a paper review in Volume 2, Number 1, an issue on arctic coastal and ocean engineering with W. F. "Willy" Weeks as guest editor; here they bring us into the near future, when oil drilling begins on the Beaufort Sea. Arlon Tussing's first article (Vol. 3, No. 4) earned some outraged hoots, since he was warning Alaskans that easy and inexpensive public land use was coming to an end, and within the decade "each permit, lease or sale will be subject to environmental stipulations." That, some said, was as preposterous as his prediction that oil would increase in cost to $20 a barrel. In this issue he continues in that forward-looking vein, which may or may not be somebody else's jugular. Claus-M. Naske gave us an article on the Alaska Highway (Vol. 8, No. 1), and has been helping us keep our hindsight keen ever since.

All the old friends are here in the index. Preparing that total review of **TNE***'s pages was a monumental chore, an entertaining time trip, and a source of great frustration because it raised so many questions. Whatever did become of the polydome? Now there was an idea with revolutionary possibilities – McLorg, 1(4):3-6. Would polydomes make good shelters for Antarctic camps? And why was there no follow-through on converting thermal differences between arctic seawater and atmosphere into electricity – McKay, 3(4):5-8 – or was there? Hawaii is using a similar ploy in its OTEC project; perhaps Siberia is planning one?*

Yes, the review raised many points of speculation, including one we're glad not to have to answer: Where would **The Northern Engineer** *be without Eb Rice? The index shows how many articles Eb has written, but can't show how much he has contributed. He has certainly been our most popular author, and his* **Building in the North** *is still selling steadily. More than that, he has been our model "northern engineer," one engaged in both research and field work, at home in academia and industry, and willing and able to convey clearly what he has learned – even to non-engineers. This he does with a wry humor that does more than entertain: it acknowledges that the north has ways of making buffoons of us all. Laughter, like mukluks, is a tool for survival here.*

We owe thanks for the magazine's survival through this decade of hurrah and upheaval in the north to many people, more than could possibly be listed here. But we owe the spirit of **TNE** *to Eb Rice, so we cheerfully dedicate this birthday issue to him. We do so with confidence, since even the man who has nearly everything can't have been given too many ten-year indexes for his very own.*

We're looking forward to the next ten years. For applied science and engineering in the north, it should be another interesting decade – and beyond. The challenges that cold regions present to human ingenuity and technology will outlast the supply of oil at Prudhoe Bay. Consider: recent photos of the largest canyon ever discovered show what looks very much like the effect of thawing permafrost on its south-facing wall. The canyon is on Mars.

Happy tomorrow, northern engineers, from **The Northern Engineer**.

THE NORTHERN ENGINEER

Volume 10, Number 4 Winter 1978

TABLE OF CONTENTS

COVER

They were rugged in those days; nevertheless, our cover subject is not sitting down to a stone supper. The 1898 photograph shows O. G. Herning, mining engineer, mine manager, and featured character in the Hatcher Pass article beginning on page 16, posing with ore samples.

Graphics and lettering for our nostalgic anniversary cover were provided by Jim Burton. The photograph is from the O. G. Herning Collection, University of Alaska Archives, Fairbanks.

THE NORTHERN ENGINEER is a quarterly publication of the Geophysical Institute, University of Alaska - Dr. Juan G. Roederer, Director. It focuses on engineering practice and technological developments in cold regions, but in the broadest sense. We will consider articles stemming from the physical, biological and behavioral sciences, also views and comments having a social or political thrust, so long as the viewpoint relates to technical problems of northern habitation, commerce, development or the environment. Contributions from other polar nations are welcome. We are pleased to include book reviews on appropriate subjects, and announcements of forthcoming meetings of interest to northern communities. "Letters to the Editor" will be published if of general interest; these should not exceed 300 words. Subscription rates for *THE NORTHERN ENGINEER* are $10 for one year, $15 for two years, and $35 for five years. Some back issues are available for $2.50 each. Address all correspondence to THE EDITOR, THE NORTHERN ENGINEER, GEOPHYSICAL INSTITUTE, UNIVERSITY OF ALASKA, FAIRBANKS, ALASKA 99701, U.S.A.

by Gunter Weller and Wilford F. Weeks

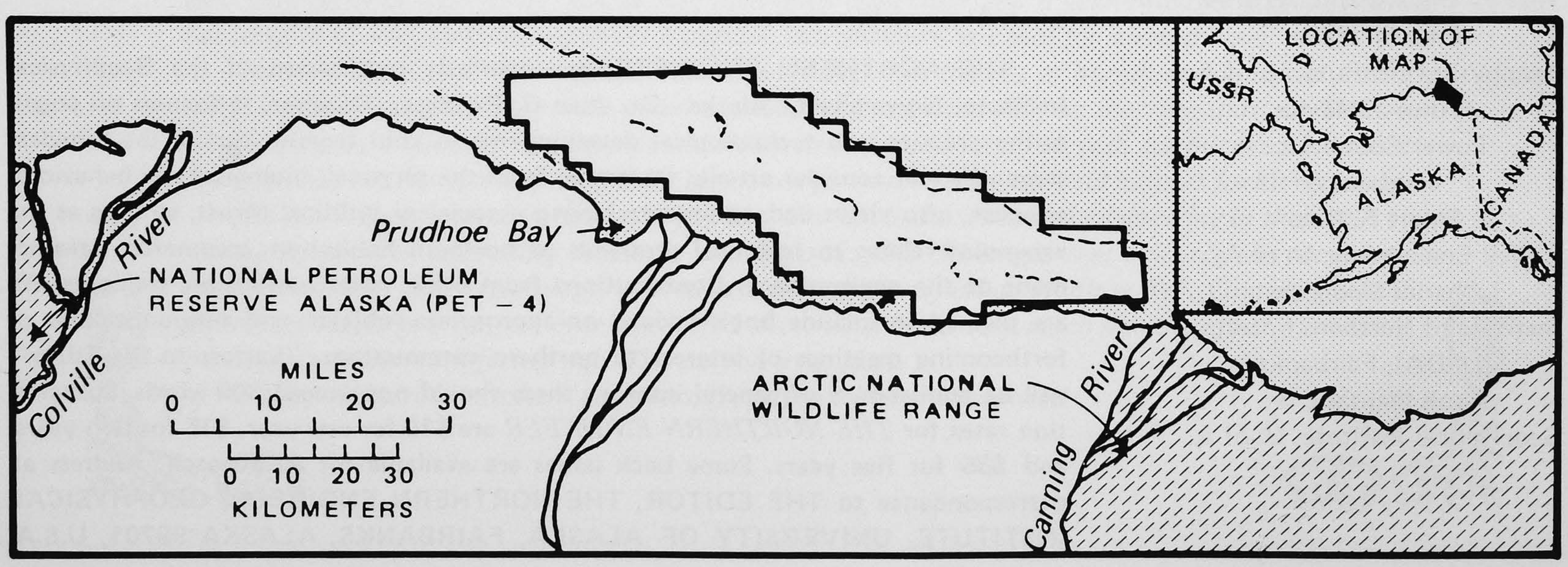
PROBLEMS OF OFFSHORE OIL DRILLING IN THE BEAUFORT SEA

INTRODUCTION

Petroleum exploration and development is proceeding rapidly in the ice-covered waters of the arctic continental shelves. In the Beaufort Sea, Canadian offshore drilling since 1975 has provided strong evidence that the Beaufort Sea portion of the Beaufort-Mackenzie Delta basin has rich and prolific potential. Of the four initial deep wells that have been drilled three are discovery wells (OGJ, 1978). On the Alaskan coast of the Beaufort Sea lies Prudhoe Bay, situated on the largest known petroleum field in North America. Tentative offshore drilling efforts in its vicinity have shown the existence of additional oil and gas reservoirs. In December, 1979, a planned offshore lease sale near Prudhoe Bay is expected to initiate major offshore drilling activities along the Alaskan coast of the Beaufort Sea. A map showing the general location of the proposed lease area is given in Figure 1.

Because of its arctic location, the Beaufort Sea beyond the continental shelf is essentially ice-covered year-round. However, in the waters over the continental shelf, there is usually an ice-free season which may last as long as 2 to 3 months, although during some summers when the winds keep the drift ice pressed against the coast, there may be essentially no ice-free season. The maximum thickness of ice that can form

Figure 1. Proposed Beaufort Sea lease area. (Note chain of barrier islands in the lease area and 20-meter isobath contour shown by the dashed line ---.)



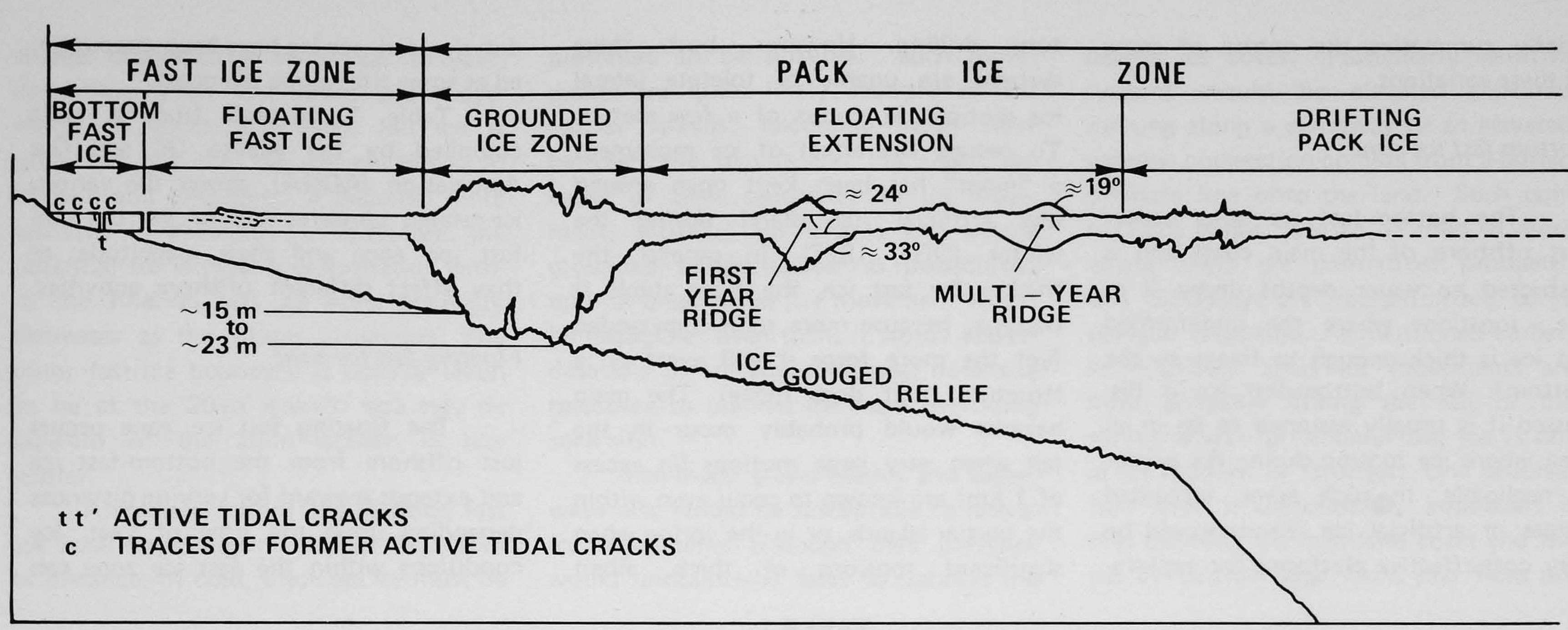


Figure 2. Late winter ice zonation of the Beaufort Sea coast (after Kovacs).

during a winter is just over 2 m. Within the lagoon systems formed between the mainland coast and the barrier islands that characteristically occur along the margins of the Beaufort Sea, the ice cover is "fast" (relatively motionless) during most of the winter. However, appreciable movement can occur in both the fall and spring (freeze-up and break-up) periods even within these lagoons. Seaward of the barrier islands the fast ice extends some distance further offshore with the exact extent varying from year to year and with the time of year. A representative example of late winter ice zonation in the waters over the Alaska Beaufort Sea Shelf is shown in Figure 2. In late winter, the fast ice frequently extends out to the 25-30 m water depth.

Seaward of the fast ice, the pack ice moves in a sporadic, sometimes oscillating or jerking motion, with the general drift being from east to west. During the winter the net movement along the coast is quite small and at times the ice may be motionless for periods of several days. However, movements in excess of 20 km per day are not rare during the summer when the fast ice has melted or moved away from the coast and the pack ice has broken up into individual floes. Although most of the ice in the pack ice zone is first-year ice, "intrusions" of thicker multi-year ice into near-coastal waters are not unusual. Extensive pressure ridge formations are also quite common. At some locations large accumulations of intensely deformed ice survive the summer, and gradually metamorphose into very large, thick masses of low salinity, high strength ice. Also, ice islands (tabular icebergs from the Ellesmere Island ice shelves) are known to drift along the coast of the Beaufort Sea. When large pressure ridges, floebergs (accumulations of highly deformed sea ice), or ice islands ground, they can be pushed gradually along by winds, currents and the surrounding ice pack, gouging grooves several meters deep in the sea floor.

It is within this environment that the proposed offshore oil and gas activities will occur, one that is clearly strikingly different from that encountered during typical offshore operations in more temperate climates. At first thought, it might appear that the environmental hazards along the Beaufort Sea coast are so severe that safe operations are impossible, but such is not the case. For instance, there are tested operational techniques, such as the construction of artificial gravel islands, that can clearly be used safely inside the barrier islands and probably also in the shallower waters seaward of the islands. In water deeper than 13 m (40 ft) ice hazards increase rapidly. Even for there, safe operational schemes can undoubtedly be developed if the hazards that must be surmounted are clearly delineated.

The cost of safe operations may, however, make the development of certain high risk tracts too expensive to exploit profitably now. There is little doubt that in water exceeding 20 m, operations along the edge of the Beaufort Sea can be considered "frontier" in every sense of the word, with ice as the foremost developmental problem, followed by high storm surges and waves carrying massive ice fragments.

ICE AND OTHER ENVIRONMENTAL HAZARDS

Hazards posed by the environment to man's structures and operations in any offshore area may lead to accidents which, in turn, pose threats to the environment. In the Arctic the risks of accidents due to environmental hazards are particularly high and need to be carefully evaluated. A hazard assessment can be completed only when one combines an understanding of the strengths and weaknesses of the technology proposed or in use with knowledge of the environmental constraints that are to be expected at different locations in the field. Sea ice is, of course, the major hazard in the Beaufort Sea that might cause severe disruptions of operations and serious accidents. However, the nature of the ice hazards varies among the different ice zones that occur along the coast and with the type of offshore activity that is proposed. We will now briefly summarize the nature of some of these variations.

Bottom fast ice zone

The bottom-fast ice zone occurs just offshore of the main coast and is restricted to water depths under 2 m (i.e., locations where the undeformed sea ice is thick enough to freeze to the bottom). When bottom-fast ice is discussed it is usually assumed to be in an area where ice motion during the winter is negligible. In such areas, grounded barges or artificial ice islands would be very cost-effective platforms for exploratory drilling. However, both these systems are unable to tolerate lateral ice motions in excess of a few meters. To reduce the effect of ice movement a "moat" has been kept open around one artificial ice island during the winter (OGJ, 1977). In general, the thicker the fast ice, the more stable it becomes because more of it is grounded (yet the more force it will exert on a structure if it does move). The main hazards would probably occur in the fall when very large motions (in excess of 1 km) are known to occur even within the barrier islands, or in the spring when significant motions of thick, albeit deteriorated, sea ice have been encountered at some sites along the coast.

Table 1, adapted from a table compiled by the Alaska Oil and Gas Association (AOGA), shows the various ice-related concerns within the bottom-fast ice zone and their magnitude, as they affect different offshore activities.

Floating fast ice zone

The floating fast ice zone occurs just offshore from the bottom-fast ice and extends seaward for varying distances depending upon the time of year. Ice conditions within the fast ice zone can

TABLE 1

Ice-Related Concerns: Bottom Fast Zone

(Adapted from a table compiled by the Alaska Oil and Gas Association - AOGA)

Activities	Freeze up Movement	Winter Sheet Ice Movement	Breakup Movement, Override	Summer Pack Ice Invasions	First Year Ridges	Multiyear Ice
I. *Transport (Pre and Post Lease)*						
Marine Transport				S		
Ice Surface Transport						
II. *Exploration Drilling*						
Drilling Structure						
Grounded Barges	C	S	C	C		
Ice Islands		S	C			
Gravel Islands		S	S	S		
Barrier Islands			S	S		
III. *Development*						
Drilling Structure						
Grounded Barges w/Gravel Berm		S	S	S		
Gravel Islands		S	S	S		
Barrier Islands			S	S		
Buried Pipelines						
Elevated Pipelines	S	S	S	S		
Causeways		S	S	S		

S = Some Concern, C = Considerable Concern, M = Major Concern

change dramatically from year to year, depending upon the forces and movements to which the weak fall ice is subjected. As the fall ice continues to thicken and strengthen, it becomes more resistant to deformation. Therefore, the potential for extensive deformation within the floating fast ice zone gradually decreases as the winter progresses. The outer fast ice boundary is usually taken to be at the 20-m isobath but may lie seaward of the 20-m isobath in late winter.

Anywhere within the floating fast ice zone large movements, up to 100 m in distance, of cold, thick sea ice must be presumed to be possible. Such movements are quite likely seaward of the barrier islands, becoming much rarer between the islands and the coast. Because of their sensitivity to ice movement, artificial ice islands and simple grounded barges appear as possibilities only in areas where ice movement would be negligible. Even then, it would appear desirable to employ additional defensive measures to prevent ice from overriding such sites.

Man-made gravel islands and causeways also would be susceptible to lateral ice movements although their presence would undoubtedly tend to stabilize the nearby ice cover. Particularly sensitive systems would be elevated pipelines running along a causeway or an elevated pipeline connection coming from a buried offshore line onto the land. Such connections might have to be used in areas where there are permafrost problems, and causeways are not permitted for a sea-land transition. As mentioned earlier, in nearshore areas ice movements are most probable during the fall or the spring when—fortunately—the ice is not at its thickest or strongest. One observation that is undoubtedly important is that between the mainland coast and the barrier islands large multi-year floes are

TABLE 2

Ice-Related Concerns: Floating Fast Zone

(Adapted from a table compiled by the Alaska Oil and Gas Association - AOGA)

Activities	Freeze up Movement	Winter Movement	Breakup Movement, Override	Summer Pack Ice Invasions	First Year Ridges	Multiyear Ice	Ice Gouging
I. *Transport (Pre and Post Lease)*							
Marine Transport				S			
Ice Surface Transport		C			S		
II. *Exploration Drilling*							
Drilling Structure							
Floating Platform	C			M			C
Grounded Barges	C	C	C	C	S	S	C
Ice Islands		C	C		S	S	C
Gravel Islands		S	S	C	S	S	
Cones		S	C	C	S	C	C
Barrier Islands		S	S	C			
III. *Development*							
Drilling Structure							
Gravel Islands		S	S	C	S	S	
Cones		S	C	C	S	C	
Subsea	C	C		M			S
Barrier Islands		S	S	C			
Buried Pipelines							S
Causeways		S	S	C	S	S	

S = Some Concern, C = Considerable Concern, M = Major Concern

rarely found, while outside the barrier islands multi-year floes of appreciable size (up to several hundred meters in diameter) commonly occur within the fast ice. Table 2 shows the ice-related concerns for the floating fast ice zone.

Pack ice and grounded ice zone

The pack ice zone extends seaward of the fast ice zone. The ice in the grounded ice zone and the floating extension of the fast ice shown in Figure I are, for our purposes, considered to be part of the pack ice zone. During early winter the grounded ice zone is formed when the pack ice moves toward the coast, crushing and piling up the thin, newly-formed seasonal ice. The potential for significant lateral ice movements well in excess of a kilometer exists at all times of the year but is particularly high in the early winter. However, as the ice thickens and becomes stronger, the compactness and inertia of the pack ice increase and its susceptibility to deformation decreases.

Any structure contemplated for this ice zone would have to be designed to withstand the forces exerted by continuously moving masses of cold thick first-year ice and by large multi-year floes with embedded pressure ridges. Consideration would also have to be given to the potential forces produced by impacts with thick, massive floebergs and ice islands, as well as the expected recurrence intervals of such impacts. It would appear improbable that an offshore structure could be built to survive the impact of a large ice island. Nevertheless, constructing structures that would be displaced or destroyed as a result of such an impact might still be economically viable if the probability of such an occurrence is sufficiently low and an oil spill could be avoided. However, there is no escaping the fact that in this zone ice/structure interaction problems are severe.

As sea ice moves over the shallower portions of the continental shelves, the keels of the pressure ridges rework the sea floor sediments and modify the bottom topography by impacting, plowing and gouging the bottom. This process presents a serious hazard to wellheads and buried pipelines in the pack ice and fast ice zone. Ice gouge incisions are commonly more than one meter deep within and seaward of the grounded ice zone and less than one meter deep shoreward of the grounded ice zone, although maximum values are much greater. Extreme observed incision depths are 5.5 m in 38 m of water off the Alaskan coast and in excess of 6.5 m in water depths between 40 m and 50 m in the Canadian sector (Lewis, 1977). Table 3 shows the

TABLE 3

Ice-Related Concerns: Pack Ice and Grounded Ridge

(Adapted from a table compiled by the Alaska Oil and Gas Association - AOGA)

	Activities	Winter Ice Movement	Summer Pack Ice Invasions	Multi-Year Floes	Grounded Ridges	Floebergs	Ice Islands	Ice Gouging
I.	*Transport (Pre and Post Lease)*							
	Marine Transport		C					
	Ice Surface Transport	M			M			
II.	*Exploration Drilling*							
	Drilling Structure							
	Floating Platform		M					M
	Cones	S	M	M	C	M	C	M
III.	*Development*							
	Drilling Structure							
	Gravel Islands	S	M	M	C	M	M	
	Cones	S	M	M	C	M	M	
	Tunnels							S
	Subsea	C	M					M
	Buried Pipelines		C					C

S = Some Concern, C = Considerable Concern, M = Major Concern

ice-related concerns for the pack ice and grounded ridge zone.

Ice problems during the open water season

Conventional marine transport, as well as the use of floating drilling vessels, are activities that are essentially restricted to times when sea ice is absent. If the offshore summer pack ice moves into an area, conventional ships may be unable to operate, could sustain hull damage, and might be pushed aground by the ice pack. The operation of floating drilling vessels may therefore be severely curtailed, in that ice motion can force the ship off its station above the drill hole. In any such operation both the wellhead and the BOP (blowout preventer) stack would have to be designed and made ready to disconnect rapidly from the drill string and the vessel be moved off-site if concentrated pack ice moved into the area. Therefore, reliable all-weather ice reconnaissance and ice forecasting are essential to the efficient and safe operation of such systems. Canadian offshore drilling in the Beaufort Sea has been carried out successfully in this manner (Milne, 1978).

Other environmental concerns

Subsea permafrost is yet another bottom hazard; it is a left-over from times when the climate was colder and the sea level lower than at present. This hazard appears to be widely distributed on the Beaufort Sea continental shelf, although detailed knowledge of its distribution and characteristics is still rudimentary. When hot oil starts to flow through pipes from the offshore wells to the shore, permafrost melting may result, producing differential subsidence of the ground and the possibility of pipeline breaks. If the pipes are not placed very deep so that the permafrost can be avoided, the ice gouging problems discussed above become the greatest risk to the pipeline. If the pipeline is elevated above the sea surface, either in gravel causeways or on stilts, forces exerted by moving ice take over as the greatest potential threat to the safety of the pipeline.

Other hazards in the Beaufort Sea include storm surges, which can reach heights of 3 m, low-level seismic activity, the presence of frozen gas hydrates or clathrates and problems associated with the rapid erosion and instability of the coast, river flooding and superstructure icing on ships and drillrigs. There can be little doubt that the risks of accidents are high.

CURRENT DRILLING TECHNOLOGY

Although the hazards posed by ice and other factors to offshore petroleum development in the Beaufort Sea are severe, it is possible to proceed with this development with currently available drilling technology. Figure 3 shows some of the available and proposed drilling methods suitable for the Arctic.

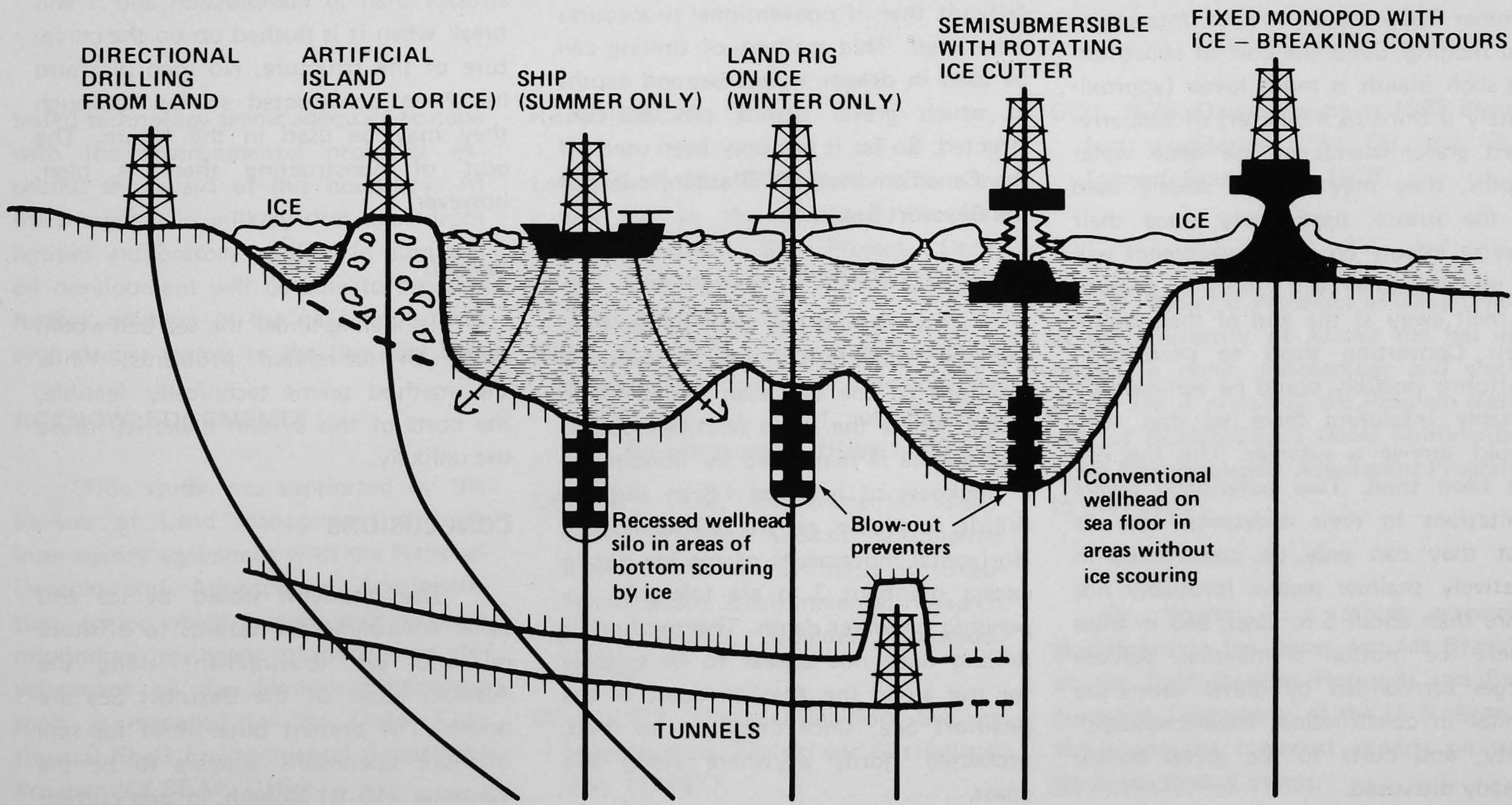
Directional drilling from land

This method is only of limited use, since the distance offshore that can be reached by directional drilling is not great in that the maximum angle subtended between the starting and end points of the drill hole generally cannot exceed 45°.

Artificial islands

To extend the drilling range, artificial islands can be constructed in relatively shallow water from sand,

Figure 3. Methods of drilling in the Arctic.



gravel or silt or a combination of these materials. In the Mackenzie Bay area of the Beaufort Sea more than 16 such islands have been constructed in water depths up to 14 m (43 ft) and an island in 20 meters of water is being built by Imperial Oil Ltd. In the vicinity of Prudhoe Bay similar islands have been constructed in water depths up to 3 m (10 ft). To protect the islands against ice, storm and wave action and override, they must be provided with a high freeboard; also the slopes are usually protected with sandbags or other materials and sacrificial beaches can be added to dampen waves. These artificial fill islands are an efficient, proven method of shallow water exploratory drilling and have the possibility of being converted into production platforms. They are the most likely means of future offshore drilling in the shallow waters of the Beaufort Sea.

Artificial islands can also be constructed of ice. Two such grounded islands have been built so far; one, by Union Oil, in East Harrison Bay (OGJ, 1977), the other by EXXON, north of Prudhoe Bay in about 3 m of water. The EXXON ice island is 400 m in diameter and has more than 7 m (21 ft) of freeboard. It was constructed in the winter of 1978-79 and will be monitored during summer 1979 for ice stresses, movement and melting. Since the cost of constructing such islands is much lower (approximately a third to a quarter) of similarly-sized gravel islands in the same water depths, they may well be widely used in the future, particularly since their adverse effects on the environment will be minimal (they will simply be allowed to melt away at the end of their useful life). Converting them to production platforms possibly could be achieved by suitably insulating them so that they would survive a summer. This has not yet been tried. Two potentially severe limitations to their widespread use are that they can only be constructed in relatively shallow waters (probably not more than about 5 m deep) and in areas where ice motion is minimal. Sunken barges surrounded by gravel berms are similar in construction, hazard susceptibility, and costs to the gravel islands already discussed.

Drilling from ships

Drillships can be used in the Beaufort Sea during the summer and fall only. Drilling during the open water season is, of course, routine. Also, some drilling is possible after sea ice has started to form in the fall, if an ice breaker is available. For instance, Dome Petroleum, though its subsidiary, Canadian Maritime Drilling Company, has drilled several wells from ships in the Mackenzie Delta area of the Beaufort Sea. The drillships have reinforced hulls and are supported by an icebreaker which in the fall keeps the ice broken up around the ships. However, when the ice gets thicker than 60 cm (2 ft), the ships have to stop drilling because of the possibility of being pushed off the site by the ice, even when icebreaker assistance is available. In summer, the greatest threat to the ships is the sudden invasion of the drill area by pack ice. Good ice forecasting is a necessary prerequisite to successful operations, since the ships prefer to have several hours time to disconnect the drill string. They do, however, have a quick disconnect system which allows them to decouple from the hole very rapidly if necessary in order to get out of the way of the invading ice. If the quick disconnect system is used, it makes reoccupying the hole more difficult than if conventional procedures were used. This method of drilling can be used in deeper waters beyond depths in which gravel islands can be constructed. So far it has only been used off the Canadian (not the Alaskan) coast of the Beaufort Sea.

Floating ice platforms

This method has been successfully used by Panarctic Oil, Ltd. in sheltered locations of the Canadian Arctic archipelago where the ice is relatively stable. The sea ice is reinforced by flooding to a thickness of between 4-6 m and the drillrig is placed on the thickened ice. Horizontal movements of the ice not in excess of about 3 m are tolerable, depending on water depth. This method of drilling does not appear to be suitable for use along the Alaskan coast of the Beaufort Sea, since there are no deep, protected fjords anywhere along this coast.

Semisubmersibles with rotating ice cutters

A semisubmersible, which could operate in ice-covered waters by cutting up the ice which moves down on the structure, has been tested with scale models. Although it seems technically feasible to construct such an ice-eating device and provide the necessary power to operate the ice cutter, there are obviously many questions about the reliability, wear and tear and general capability of such systems under the extreme ice conditions in the Beaufort Sea. At present no one has seriously proposed construction of such a system.

Fixed monopod or cone with ice-breaking contours

Monopods have been designed for use by many different oil companies and some are in use. One of them, the Marathon-Union monopod in Cook Inlet, operates in ice-covered waters, although the ice there is quite thin compared to that of the Beaufort Sea. To protect such a structure against ice it can be provided with a curved exterior on which the ice rides up when it is pressed against the drilling rig. The idea behind this is that ice is much weaker under bending stresses than in compression and it will break when it is pushed up on the curvature of the structure. No such platform has been constructed so far, although they may be used in the future. The cost of constructing them is high, however.

Tunnels

Tunneling under the sea bed would avoid all ice-related problems. While the method seems technically feasible, the costs of this system make its future use unlikely.

CONCLUSIONS

The problems posed by ice and other environmental hazards to offshore oil and gas development along the Alaskan coast of the Beaufort Sea are severe. The present outer limit for safe offshore operations appears to be the 13-meter (40 ft) isobath, in that current

tested technology seems adequate to cope with the environmental problems expected shoreward of this boundary. At the present it is unlikely that, apart from limited exploratory drilling in summer, oil development will be able to proceed further offshore in the near future into even deeper waters in the Beaufort Sea.

ACKNOWLEDGEMENTS

This study was supported by the Bureau of Land Management through inter-agency agreement with the National Oceanic and Atmospheric Administration, under which a multi-year program responding to needs of petroleum development of the Alaskan continental shelf is managed by the Outer Continental Shelf Environmental Assessment Program (OCSEAP) Office.

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Finiteness of Petroleum Resources: history and mythology

by Arlon R. Tussing

This paper was originally prepared for the May 1978 Energy Futures Conference sponsored by the California Energy Commission in Sacramento. According to the author, "The conference was polarized into two extreme camps, one advocating the soft technology, anti-growth philosophies of Amory Lovins, E.F. Schumacher, and Wilson Clark, and the other pressing for multi-billion dollar investments in nuclear and other high-technology energy facilities. Despite the sharp discord between the two factions, I was struck by their agreement with the supposedly neutral conference background paper on two propositions: that the age of oil and gas is over, and that government, not the market, must dictate the choice among future energy technologies." Dr. Tussing takes exception to both premises, and to the policies advocated by both the "hard" and "soft" technology camps.

The finiteness of the world's oil and gas resources is an obvious truth, and there seems to be a broad consensus that it is not possible to maintain historic growth rates for petroleum consumption more than a decade or two. Curiously, this consensus is used to support at least two extreme and conflicting strategies regarding technology and economic development. One approach advocates investment in more costly, capital-intensive and centralized sources of energy such as synthetic oil and gas, fission and fusion, and central station solar power; the other urges a shift to "soft" technologies and a deceleration of economic growth toward a "steady state" society. A notion that supports such contradictory policy inferences may not be a truth but a truism, a proposition so general that it is meaningless either as a tool of analysis or a guide to action.

RECURRING GLOOM

The perception of imminent resource exhaustion is not new. In one form or another it has been an element in Western thought since the 18th Century, when population and economic growth were first recognized as long-term trends rather than random fluctuations. And the limits to growth have periodically been a fashionable and intellectually respectable theme since the early 19th Century, when Malthus and Ricardo discovered diminishing returns to land.

Over the last century, geologists and engineers in the United States have predicted an imminent energy crisis every couple of decades, based upon the exhaustion of the dominant fossil fuel of the day, whether it was coal or oil. Most of these forecasts were obviously premature. It is of course possible that the pundits were wrong in the past but that this time the wolf is really here. The end of a finite resource has to come sooner rather than later. Thus, at some level of generalization it is certainly true that depletion of oil and gas resources is an absolute and irreversible phenomenon.

With respect to a given basin in Texas or the United States midcontinent, for example, it is clear that most of the hydrocarbons we customarily call petroleum — crude oil, natural gas, and condensate that flow to the surface under natural or induced fluid drive — have already been produced. More petroleum can be squeezed out of smaller, deeper or less permeable reservoirs, and additional hydrocarbon fluids can be extracted even from "exhausted" formations using solvents, or thermal, chemical and other aids. But these additional quantities can be produced only at sharply increasing costs, and with some degree of confidence we can project the ultimate limits to the oil and gas that can be produced by these means.

The reasonableness of the foregoing logic is obvious for petroleum thus defined, in any one relatively circumscribed portion of the earth's crust. What is not obviously reasonable is to aggregate the volumes of "petroleum" we believe producible by primary and enhanced recovery in each of the earth's potential producing areas, explored or unexplored, and thus to conclude that "the era of cheap fossil fuel" is over.

THE EVASIVE TOTAL

Crude oil, natural gas, and condensate are only a tiny fraction of the known hydrocarbon resources of the United States or the world. Three *individual* deposits in the Western Hemisphere each contain heavy hydrocarbons in volumes (greater than 10^{12} barrels) comparable to the *whole world's* proved, probable and speculative oil reserves as presently estimated. The energy value of the methane in geopressurized aquifers under the United States gulf states alone may be even greater by a factor of tens or hundreds.

Geologists know very little about the total hydrocarbon endowment of the nation or the world, and I have not been able to find a single published estimate of its ultimate volume in total, much less for each class of compound. So long as conventional oil was easy to find, industry never had a good reason to look for many of the most abundant forms of fossil fuels such as tar sands, oil shales and geopressurized methane. Where we do know something about the location or size of such deposits, it is only because they have been discovered by accident or in the search for other minerals. The total amounts of some of these resources are undoubtedly greater than we would ever need as a bridge to inexhaustible energy technologies and greater, perhaps, than our species would ever be able to use during its likely span of existence on the planet.

This line of reasoning is not intended to dismiss the possibility that a growing concentration of CO_2 in the atmosphere or other environmental influences might (or ought to) limit fossil fuel use, but only to suggest that the exhaustion of such minerals *per se* is probably not a limit to energy use over the span in which today's policies and plans have any meaning.

Moreover, the abundance of hydrocarbons in the earth's crust does not assure that the means of using any one of them will be readily at hand when we want it, and it is even less clear that the real costs of primary energy will continue to decline over the rest of this century as it has done over its first eight decades, OPEC notwithstanding. No economist, engineer, or reasonable thinker from any other discipline, relies on faith in the market or in technological progress to bring new energy sources into use smoothly and painlessly. Such faith is especially unwarranted today in view of the growing restrictions being placed upon the market allocation of energy resources and upon technological innovation for the sake of social policy and environmental conservation.

Nevertheless, it shows a fundamental misunderstanding of the nature of fossil fuel resources and of the process of technological innovation to proclaim the imminent exhaustion of the world's oil and gas resources as an absolute "fact" which in itself demands a radical transformation of social organizations or lifestyles (whatever the other merits or demerits of such a revolution might be).

Imagine an observer of the energy future looking outward from a point on the outer limits of present accessibility to some resource, for example, natural gas. In every direction he sees that technological and exploratory efforts to increase gas supply will lead to rising costs and, inevitably, to the absolute limits of the resource itself. Deeper drilling means higher costs; development of smaller deposits means higher costs; greater recovery from known reservoirs means higher costs; geographically more remote prospects mean higher costs. Finally, at some point, there seems to be no more of the resource to be found at any price, by any means.

Such a point on the limits of resource availability is where we stand today with respect to our "petroleum" resources. But such a place is where we have always been with respect to the resources we know best. Diminishing returns are a nearly universal axiom of human action, but the static outlook described here has very little to do with how new resources are actually found and put into use. The frontiers of resource accessibility do not expand in an orderly, linear fashion, confined to one or a few dimensions at a time, but in a chaotic and unpredictable sequence of probes, wiggles and leaps in many different directions within the universe of potential resources.

SOME HISTORY

Let me illustrate: During World War I, the United States Geological Survey had already declared that the age of petroleum was over and that oil production would peak in the mid-1920's. Therefore, the experts agreed, U. S. industry would have to return to coal as its principal fuel, either directly or indirectly in the form of electricity and synthetic petroleum liquids and gases. The Standard Oil Company of New Jersey started a crash program to develop synthetic substitutes for liquid petroleum. The oil resource had not in fact been exhausted but what had happened was that the oil seeps and easily apparent anticlines of the onshore Continental United States had been drilled. The more sophisticated geologists did point out that a great deal of crude oil undoubtedly remained, but the conventional wisdom offered no hope for locating these reserves by any method other than random drilling on a grid pattern throughout the Nation's sedimentary basins, with its attendant and unacceptable high costs.

Seismic techniques were not unknown when the experts concluded that our economically accessible oil was almost gone, but these methods did not become commonplace until the 1920's — that is, until nearly all the seeps and surface anticlines had been explored. By 1930, however, geophysics had created a revolution in petroleum exploration, and the reserves discovered since the date on which U. S. oil supplies were first forecast to run out are many times the volumes found previously.

Shortly after World War II, the Paley Commission gave similar warnings: its conclusions have proved too pessimistic for even the onshore Lower 48, and they did not seriously consider the potential of the offshore frontiers and Alaska. Even more importantly, Paley did not foresee the postwar surge of pipeline construction which turned natural gas (formerly an inconvenient by-product of oil production) into the source of almost 40 percent of our total commercial energy. Gas resources in particular were chronically underestimated until the early 1960's because demand had never been sufficient to set wildcatters looking for non-associated gas. The natural gas that industry knew about in the 1940's and 1950's was mainly dissolved and associated gas produced from oil wells, or non-associated gas discovered accidentally in the search for oil.

Again, in the late 1960's and early 1970's, we were bumping up against sharply diminishing returns to investment in domestic oil and gas exploration, punctuated only by the unexpected bonanza at Prudhoe Bay. The next leap of national energy supply was half way around the world to the Middle East, to resources which were not competitive in the Western Hemisphere until the "easy" domestic oil was gone and large tankers made the cost of ocean transport reasonable. Some day soon — in one, two, or a very few decades, if not today — even those resources will prove insufficient to sustain the growth of United States and world energy consumption, if only because the political limits to Middle Eastern oil production will be reached before geological limits significantly increase the real costs of extraction. But it is not likely that this development will mark the end of the process I have been describing; our original stock of hydrocarbon resources will barely have been touched.

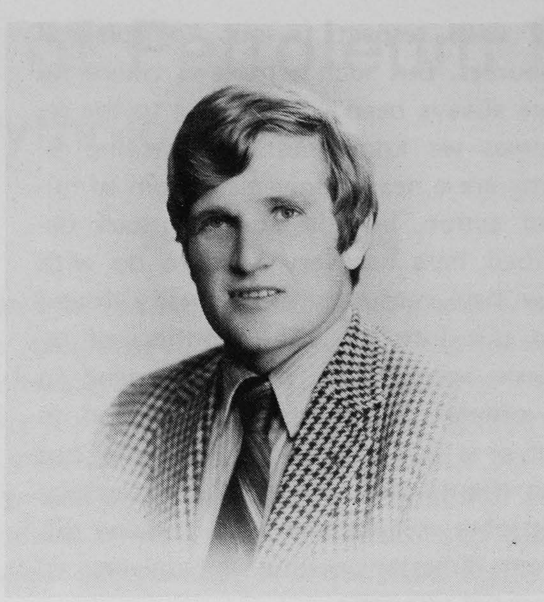
The significance of this history is that the quality and economic accessibility of natural hydrocarbons can be subdivided along numerous dimensions. The resource varies in chemical composition (including the presence or absence of harmful or inconvenient impurities like sulfur and metals); in mobility (which varies inversely with the size and complexity of hydrocarbon molecules, from gaseous methane to solid tars and waxes); in the closeness of its physical and/or chemical attachment to the surrounding rock, (from totally free fluids to the intimately bonded kerogens of oil shale); in the porosity of the surrounding rocks or sands; in distances below the surface of the earth, and depth under the ocean; in the size of deposits and the frequency of their occurrence; by the ease or difficulty of detection from surface geology or by geophysical tools; in distance from markets as measured by transportation costs; in the degree of pre-existing geological information (whether generic, regional or location-specific); in the development of necessary infrastructure; and in the degree to which the political jurisdictions in which they are located have favorable or unfavorable institutions and policies for resource development.

SOME OPPORTUNITIES

Petroleum resources (that is, crude oil, natural gas, and condensates as conventionally defined) represent only a portion of this multi-dimensional universe of potentially combustible hydrocarbons. Limiting one's vision to the specific resource forms that are currently exploited discloses only a small fraction of the opportunities within that universe for exploratory success and technical innovations.

My hunch is that there will yet be one more big cycle of discovery and development for conventional or near-conventional oil and gas before the age of petroleum ends. Its stimulus will be the present artificially high prices imposed by OPEC. In North America we can already see its outlines in the bottoming out of U. S. natural gas production, and in new Alberta and Mexican discovery booms.

A great new finding cycle for conventional oil and gas may not, however, even be necessary to avert the so-called energy "crunch." There are many hydrocarbon frontiers on which a breakthrough might take place. An *in situ* means for



The author.

extracting oil from the Athabasca tar sands, from the Colorado oil shales, from the Orinoco heavy oil belt or for coal gasification, or a technique for extracting methane from geopressurized aquifers that leaves the brine in the reservoir, could postpone the crunch for generations. Any one of these technologies, if it turned out to be at all feasible, would most likely deliver primary energy at *economic costs* somewhat higher than those of Middle Eastern oil, but no higher than its politically established present price.

I cannot forecast which resource and technical frontiers will turn out to give us the lowest-cost path to a renewed assurance of energy abundance. Progress in the exploitation of heavy hydrocarbons or novel sources of methane may not take the form of a radical breakthrough at all but rather a prolonged chipping away at technical barriers to extraction of the progressively heavier crude oils which are not now included in official reserve estimates. This evolutionary progress might well lead directly to the *in situ* extraction processes which would make economic resources of the tar sands, oil shales or the Orinoco heavy oil deposits. Likewise, methane in geopressurized aquifers may indeed become an economic resource, but production volumes may build only gradually as a host of site-specific engineering problems are solved.

Most likely, any *one* resource or technological frontier we can name today will prove more costly and less productive than our best current engineering estimates would indicate; the surprises in developing new resources or new extraction techniques for familiar ones tend on the whole to be unpleasant surprises. Most ventures in unconventional energy technologies are likely to have added capital and operating costs, delays and environmental problems that there is no way to foresee. Yet, because of the vast number of dimensions on which we can probe into the technological and physical limits of energy availability, it is also likely that there will be some pleasant surprises, and some unanticipated breakthroughs along some dimension of resource availability. Only a few — or possibly even one — unforeseen development needs to be of a cost-cutting nature because no matter how high the surrounding peaks, it is the valleys and the low passes which will carry the traffic. Unexpectedly difficult and expensive routes will be abandoned, as they ought to be.

GOVERNMENT NON-HELP

The establishment of research and development priorities, subsidies and incentives by the federal government is not, in my judgment, the most effective way to encourage development of abundant, economical and environmentally benign energy sources. The "experts" were usually wrong in the past about which frontiers were most promising and they are likely to be wrong today. If the United States had a Department of Energy and a national energy policy 60 years ago, we would have undertaken a monstrously wasteful campaign to drill wells on a grid pattern all over the U. S. public lands, and a crash program to develop synthetic fuels. We might well have subsidized these projects by taxes, entitlements or rolled-in pricing with respect to conventional crude oil. Very likely, we would have also subjected conventional fuels to price controls, "windfall profits taxes," and administrative allocation because, after all, the experts believed we were liquidating the last of a disappearing resource. These burdens and those of subsidizing unneeded alternate energy forms might well have stifled or delayed the seismic revolution that did occur. As it happened, the only lasting irrationality our generation inherited from that stir over a supposedly imminent energy crisis was the system of Naval Petroleum Reserves.

Today, the government-prompted boondoggles that compare with grid drilling on the public lands are such projects as Lurgi-method coal gasification, Fischer-Trospsch coal liquification, and the mining of oil shale and tar sands in order to haul them to retorts and to the pit again. Each of these methods would produce fuels costing far more than the current price of OPEC oil, even by their sponsors' most optimistic estimates. The governmental advocates of this "first generation of commercial production," do not justify them as a cost-effective way of replacing OPEC oil but as a "widening of options" for the distant future. This is nonsense because each of these projects incorporates dead-end technologies with huge and inescapable burdens in the handling of ore and spent rock, and consumption of water. None of them has any significant opportunity for cost-saving breakthroughs, and each of them promises a host of adverse engineering and environmental surprises. Industry would probably ignore all of these synthetic fuel technologies if it were not offered some form of direct subsidy by the government or some governmentally enforced consumer subsidy (through rate base treatment, entitlement transfers or rolled-in pricing). Each of these enthusiasms is an example of the orderly, linear bureaucractic reasoning which starts from some point on the present frontiers of resource accessibility and marches straight up the steepest cost gradient in sight.

PERSONAL COMMENTS

My program for energy research and development would be to "let a hundred flowers bloom;" that is, let us encourage every branch of industry to look for new approaches to energy supply. Let private enterprise face the risks of large failures and the rewards of great success. The rhetorical appeal of the President's energy program is exactly upside-down. Instead of telling Americans that they must sacrifice to stave off an energy crisis, and that nobody will be allowed to reap windfall profits from the effort, Mr. Carter should have proclaimed that the OPEC price upheaval has created opportunities for Americans (individuals and corporations) to become fabulously rich by service to the nation and the world, by inventing and implementing acceptable new means to produce and conserve energy. Uneconomic new supplies should not be subsidized with rolled-in pricing or entitlement gimmicks, nor should competitive ventures be limited to a utility cost of service routine. The slogan of Carter's NEP (National Energy Plan) should have been the same as that of Lenin's NEP (New Economic Policy), namely "enrich yourselves!" Give Americans encouragement and the chance to make money, and I believe that they can come up with more clean energy than we can use.

Let me conclude with a comment on intergenerational equity and efficiency. It is utterly irrational to save our "cheap" conventional oil and gas for future generations — we need these resources more than they will. Presumably, future generations will be richer than we are; in any case, they will at least have more abundant technological options than ours. Whether the emerging energy forms turn out to be heavy hydrocarbons, synthetics, nuclear, Ovshinsky's solar cells or whatever, technology will be able to deliver energy from any one of them at lower real costs, more safely and with less harmful environmental impacts 10, 20, 30 or 100 years later. Sacrificing present day welfare by mandatory conservation or substitution of high-cost, unsafe or dirty fuels for cheaper, safer or cleaner ones clearly harms the present generation; any benefits these sacrifices might furnish our descendants are highly speculative, so that our sacrifices may well be in vain.

My approach here depends no more on "blind faith" in technology or in market mechanisms than the President's program depends on "blind faith" in the wisdom and efficiency of government planning and regulation, or the advocates of the soft-technology, steady state approach depend upon "blind faith" in human altruism. No program (or paradigm) can guarantee results. But, my own judgment is that incremental changes in the eclectic, chaotic and decentralized decision-making techniques that have served us in the past offer a better chance of making a crisis-free and clean transition to new energy forms than would an expensive, authoritarian and centralized crash program to develop either "hard" or "soft" technologies.

The consequences of growing population, economic growth and technical change do give us plenty of topics that are legitimate to worry about. There is a small but finite chance that nuclear, chemical or biological weapons or accidents will destroy all higher life forms on this planet. In the richer countries today, there are chronic inflation and an upsurge of terrorism whose meaning and limits we do not comprehend, together with ineffective leadership. The poorer countries are beset with envy, rising expectations, and growing assertiveness also compounded by mostly ineffective leadership. As a result, there is some real chance of a world civil war. In the face of real dangers such as these and loss of legitimacy by traditional values and institutions, no thoughtful person can laugh at the deep moral pessimism of (for example) Solzhenitsyn. Any or all of these concerns may argue for new decision-making processes in society, not to mention different *decisions*. But the imminent exhaustion of the world's petroleum is not an urgent concern of the same order. Seen as a practical problem in resource availability, it is not a particularly new or unique issue. As an absolute first premise of social policy the finiteness of our petroleum resource is a truism, a trivial proposition, and practically useless as a basis for action.

* * * *

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by Claus-M. Naske

Transition: Economic to Recreational Resource

II. *Hatcher Pass*

INTRODUCTION

The discovery of gold on Turnagain Arm in 1888 led prospectors to further explorations of the Susitna and Matanuska Basins. United States Geological Service personnel as well as members of the United States Army also engaged in reconnaissance work. The stampede to the Klondike gold fields in Canada's Yukon Territory stimulated even more interest, and the federal government thereafter sponsored systematic surveys. Among these, the work of the Geological Service provided fairly extensive knowledge of the geology of the southwestern part of the Talkeetna Mountains, and subsequent monographs which that organization published contained many references to the Willow Creek Mining District.[1]

Donald J. Orth in his 1967 *Dictionary of Alaska Place Names* lists some 57 Willow Creeks located anywhere from the Brooks Range to the Seward Peninsula, and from Eagle on the Yukon River to the Chugach Mountains near Valdez. The particular creek which gave its name to the mining district, however, originates on Bald Mountain Ridge and flows west approximately 34 miles to the Susitna River.[2] The district is an irregularly shaped area of roughly 50 square miles located along the southern border of the Talkeetna Mountains in Southcentral Alaska, an area scarred by glacial erosion.[3] Within the Willow Creek District proper the elevation ranges from 1,500 feet in the valley of the Little Susitna River to 6,000 feet at the crest of the highest peaks in the northeastern part. In the western portion of the district the steep ridges change abruptly, descend gently and finally disappear in the glacial debris of the Susitna Valley, having been rounded off by flowing glaciers in times past.[4]

The vegetation is alpine since the district lies entirely above timber line, although small willows grow in the upper reaches of the Little Susitna River. Generally speaking, the weather in the mining district is somewhat cooler and wetter in summer and warmer during winter than at either nearby Wasilla or Palmer. Snowfall averages between four and five feet but records of anywhere from 16 to 20 feet are known; these often triggered severe snow slides and caused substantial property damage while mining activity was at its height. Although most snow occurs in the winter, the relatively high altitude makes light snowfalls possible throughout the year.[5]

EARLY DAYS

Archaeologists apparently have not uncovered any particular evidence of permanent aboriginal habitations in the area, although native peoples of the Athabaskan-speaking Tanaina group occupied the upper Cook Inlet region and often must have utilized the nearby Susitna, Little Susitna, and Matanuska Rivers to reach their fur trading contacts on the Inlet.

The Russians early established a permanent station, Alexandrovsk, near Port Graham. In 1778, the English explorer and navigator Captain James Cook sailed up the inlet which now bears his name. He only spent a few days surveying the shore lines, yet his chart was fairly accurate. (Cook, however, did not seem to recognize that Turnagain Arm was an extension of the ocean, because he called it "Turnagain River" on his chart.) Three of Cook's officers, George Dixon and Nathaniel Portlock in 1786 and George Vancouver in 1794, returned to the Cook Inlet area and all made additions to the early chart. Vancouver explored and mapped the upper ends of Turnagain and Knik Arms.[6]

By the 1860s Russian maps showed much of the Kenai, Susitna and Matanuska area, and Indians from as far away as the headwaters of the Copper River used the natural route of the Matanuska River to deal with the schooners and later to exchange their furs at Knik Station when it was established. The Susitna River and its tributaries represented another natural line of transportation and communication which the fur hunters and trappers used to reach Tyonek on the west shore of Cook Inlet, where a station had been established very early. Later a trading post was built on the Susitna River. As early as 1878 the Alaska Commercial Company, which had acquired assets of the Russian-American Company, salted salmon down in barrels. Fishing quickly became an important industry in the Cook Inlet region. Many canneries were established on its shores and on the banks of rivers flowing into it, while numerous fishing boats soon plied the waters and worked with weirs, gill and dip nets to catch a wealth of salmon.

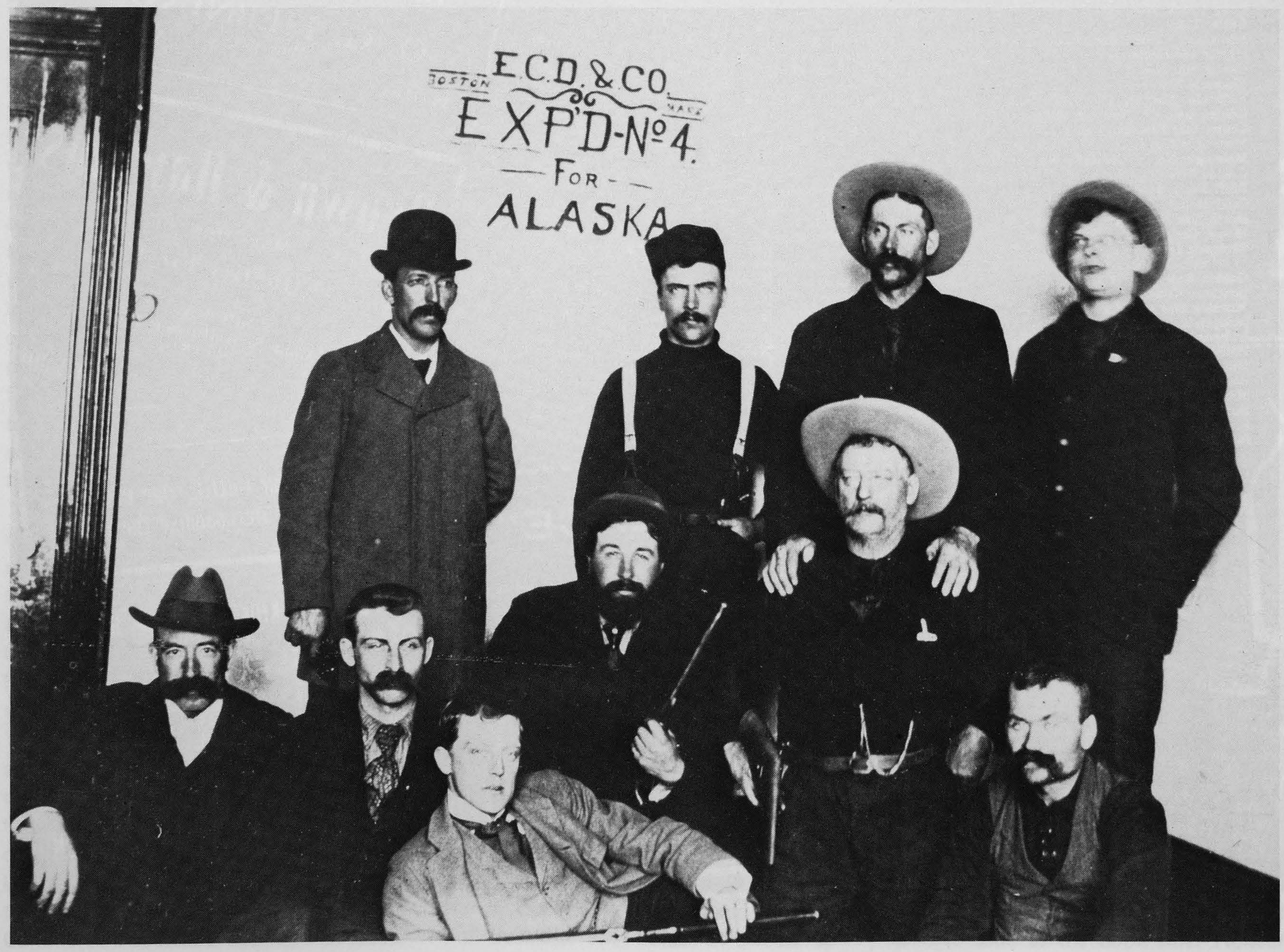
GOLD AND THE FORTUNES OF KNIK

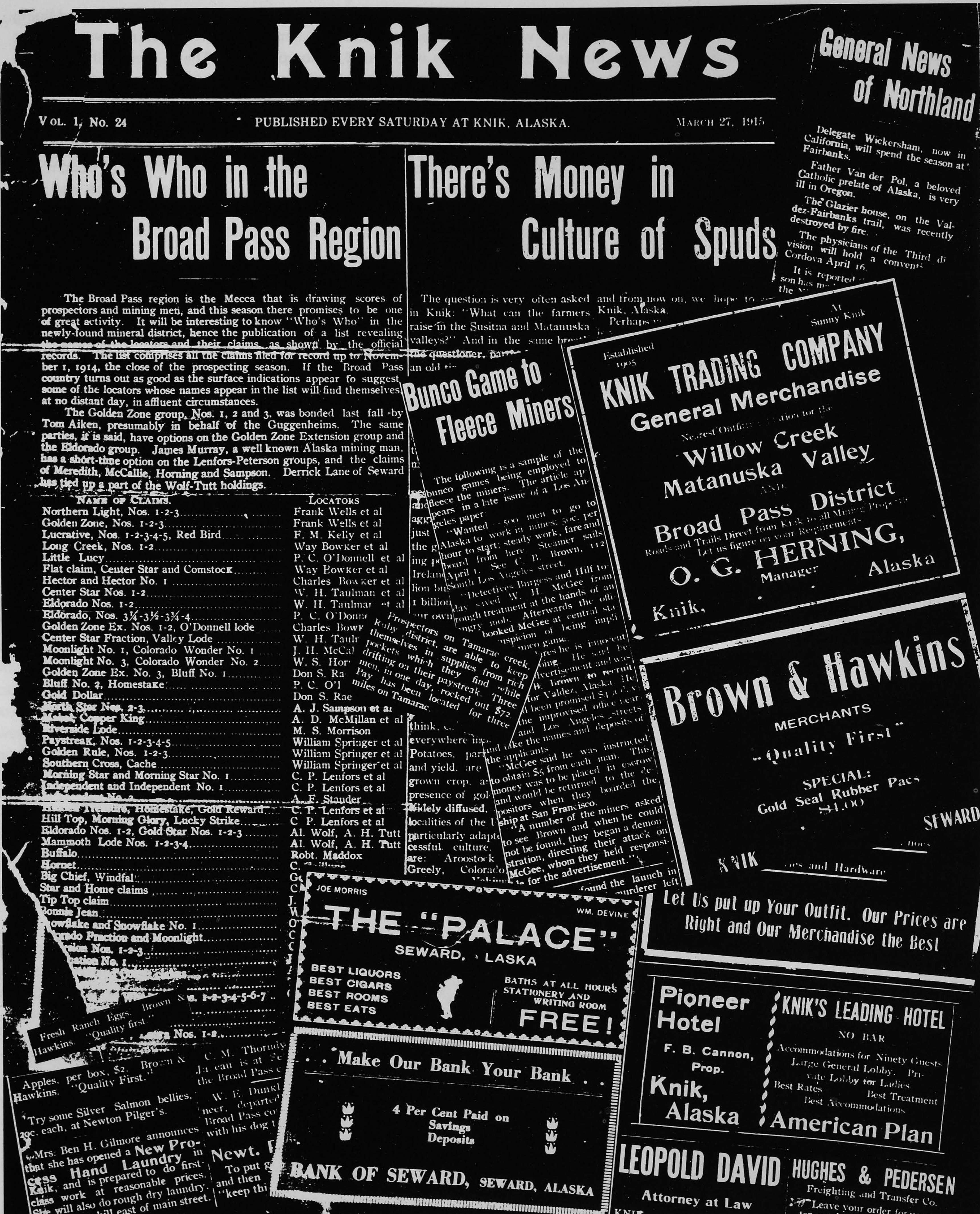
Miners and prospectors also drifted into the area as early as the 1870s. Unfortunately, the majority of these early pioneers did not leave any records of their activities. It is clear, however, that these men found that an Alaska Commercial Company trading post, later known as 'Old Knik,' had already been established on the east side of Knik Arm near the mouth of the river by the same name. The discovery of gold in the Hope-Sunrise District of the Kenai Peninsula led to intensified prospecting. Various minor rushes to new gold finds occurred, including to Cook Inlet in 1895 and 1896. Prospectors and miners soon drifted into the Matanuska and Susitna areas, and by the late 1890s George W. Palmer had moved the Old Knik station to a new location on the west side of Knik Arm.[7] Among those who arrived early were M. J. Morris and L. Herndon who found placer gold on Willow Creek in the vicinity of Knik in 1897 and staked some claims. The next year they reportedly took out some $4,000 worth of the yellow metal. Others soon followed, among them A. Gilbert who staked on nearby Grubstake Gulch. Total placer gold production amounted to approximately $3,000 in 1899.[8] In any event, enough gold seekers were in the area so that a meeting was held in Knik on June 11, 1898 to formally define the Willow Creek Mining District as beginning at the mouth of the canyon and including all tributaries to the headwaters of Willow Creek.[9]

Also arriving in 1898 in the new district was O. G. Herning, who headed the so-called Klondike Boston Mining Company. With him were seven or eight companions. They eventually reached Grubstake Gulch and spent the summer establishing headquarters as well as doing some prospecting.[10] In 1900 the Klondike and Boston Mining Company consolidated its position when it bought the claims on Grubstake Gulch as well as a number on Willow Creek.[11] In order to transport its goods to the site of operations at Grubstake Gulch and Willow Creek, the Company built a sled trail in 1900. The trail crossed Three Mile Lake, passed near Big Lake and crossed two other lakes near the Little Susitna River, then skirted the west end of Bald Mountain Ridge and continued almost due east until it reached Willow Creek.[12]

Placer mining, although requiring only a minimum of capital investment

In 1898 the so-called Klondike Boston Mining Company, headed by O. G. Herning, arrived in the Willow Creek Mining District. (Photograph courtesy of the O. G. Herning Collection, University of Alaska Archives, Fairbanks.)





The Knik News

Vol. 1, No. 24 — PUBLISHED EVERY SATURDAY AT KNIK, ALASKA. — March 27, 1915

Who's Who in the Broad Pass Region

The Broad Pass region is the Mecca that is drawing scores of prospectors and mining men, and this season there promises to be one of great activity. It will be interesting to know "Who's Who" in the newly-found mineral district, hence the publication of a list revealing the names of the locators and their claims, as shown by the official records. The list comprises all the claims filed for record up to November 1, 1914, the close of the prospecting season. If the Broad Pass country turns out as good as the surface indications appear to suggest, some of the locators whose names appear in the list will find themselves at no distant day, in affluent circumstances.

The Golden Zone group, Nos. 1, 2 and 3, was bonded last fall by Tom Aiken, presumably in behalf of the Guggenheims. The same parties, it is said, have options on the Golden Zone Extension group and the Eldorado group. James Murray, a well known Alaska mining man, has a short-time option on the Lenfors-Peterson groups, and the claims of Meredith, McCallie, Horning and Sampson. Derrick Lane of Seward has tied up a part of the Wolf-Tutt holdings.

Name of Claims	Locators
Northern Light, Nos. 1-2-3	Frank Wells et al
Golden Zone, Nos. 1-2-3	Frank Wells et al
Lucrative, Nos. 1-2-3-4-5, Red Bird	F. M. Kelly et al
Long Creek, Nos. 1-2	Way Bowker et al
Little Lucy	P. C. O'Donnell et al
Flat claim, Center Star and Comstock	Way Bowker et al
Hector and Hector No. 1	Charles Bowker et al
Center Star Nos. 1-2	W. H. Taulman et al
Eldorado Nos. 1-2	W. H. Taulman et al
Eldorado, Nos. 3¼-3½-3¾-4	P. C. O'Donn
Golden Zone Ex. Nos. 1-2, O'Donnell lode	Charles Bowk
Center Star Fraction, Valley Lode	W. H. Taul
Moonlight No. 1, Colorado Wonder No. 1	J. H. McCal
Moonlight No. 3, Colorado Wonder No. 2	W. S. Hor
Golden Zone Ex. No. 3, Bluff No. 1	Don S. Ra
Bluff No. 2, Homestake	P. C. O'I
Gold Dollar	Don S. Rae
North Star Nos. 2-3	A. J. Sampson et al
Copper King	A. D. McMillan et al
Riverside Lode	M. S. Morrison
Paystreak, Nos. 1-2-3-4-5	William Springer et al
Golden Rule, Nos. 1-2-3	William Springer et al
Southern Cross, Cache	William Springer et al
Morning Star and Morning Star No. 1	C. P. Lenfors et al
Independent and Independent No. 1	C. P. Lenfors et al
	A. F. Stauder
Hidden Treasure, Homestake, Gold Reward	C. P. Lenfors et al
Hill Top, Morning Glory, Lucky Strike	C. P. Lenfors et al
Eldorado Nos. 1-2, Gold Star Nos. 1-2-3	Al. Wolf, A. H. Tutt
Mammoth Lode Nos. 1-2-3-4	Al. Wolf, A. H. Tutt
Buffalo	Robt. Maddox
Hornet	C.
Big Chief, Windfal	G
Star and Home claims	C
Tip Top claim	J.
Bonnie Jean	W
Snowflake and Snowflake No. 1	C
Eldorado Fraction and Moonlight	C

There's Money in Culture of Spuds

The question is very often asked in Knik: "What can the farmers raise in the Susitna and Matanuska valleys?" And in the same breath the questioner... and from now on, we hope to ... Knik, Alaska. Perhaps ...

... think, ... everywhere ... Potatoes, ... and yield, are ... grown crop, ... presence of ... widely diffused, ... localities of the ... particularly adapted ... cessful culture, ... are: Aroostook ... Greely, Colorado ...

Bunco Game to Fleece Miners

The following is a sample of the bunco games being employed to fleece the miners. The article appears in a late issue of a Los Angeles paper:

"Wanted — 500 men to go to Alaska to work in mines; 50c per hour to start; steady work, fare and board from here. Steamer sails April 1. See C. B. Brown, 112 South Los Angeles street.

"Detectives Burgess and Hill to-day saved W. H. McGee from rough treatment at the hands of an angry mob. Afterwards the ... booked McGee at central station on suspicion of being impl... bunco game. ... ores he is innocent ... doing. He said he ... advertisement and was ... Brown to recruit ... for Valdez, Alaska. He ... had been promised $1 a day ... the improvised office near ... and Los Angeles streets ... and take the names and deposits of the applicants.

"McGee said he was instructed to obtain $5 from each man. This money was to be placed in escrow and would be returned to the depositors when they boarded the ship at San Francisco.

"A number of the miners asked to see Brown and when he could not be found, they began a demonstration, directing their attack on McGee, whom they held responsible for the advertisement."

Prospectors on Tamarac creek, Ruby district, are able to keep themselves in supplies from rich pockets which they find while drifting on their paystreak. Three men, in one day, rocked out $72. Pay has been located for three miles on Tamarac.

General News of Northland

Delegate Wickersham, now in California, will spend the season at Fairbanks.

Father Van der Pol, a beloved Catholic prelate of Alaska, is very ill in Oregon.

The Glazier house, on the Valdez-Fairbanks trail, was recently destroyed by fire.

The physicians of the Third division will hold a convention at Cordova April 16.

It is reported ... son has ... the ...

Established 1905 — At Sunny Knik

KNIK TRADING COMPANY
General Merchandise
Nearest Outfitting Station for the
Willow Creek
Matanuska Valley
and
Broad Pass District
Roads and Trails Direct from Knik to all Mining Properties
Let us figure on your Requirements
O. G. HERNING, Manager
Knik, Alaska

Brown & Hawkins
MERCHANTS
"Quality First"
SPECIAL:
Gold Seal Rubber Pacs
$4.00
KNIK — SEWARD
...ies and Hardware

Let Us put up Your Outfit. Our Prices are Right and Our Merchandise the Best

JOE MORRIS — WM. DEVINE
THE "PALACE"
SEWARD, ALASKA
BEST LIQUORS
BEST CIGARS
BEST ROOMS
BEST EATS
BATHS AT ALL HOURS
STATIONERY AND WRITING ROOM
FREE!

Pioneer Hotel
F. B. Cannon, Prop.
Knik, Alaska

KNIK'S LEADING HOTEL
NO BAR
Accommodations for Ninety Guests
Large General Lobby. Private Lobby for Ladies
Best Rates — Best Treatment
Best Accommodations
American Plan

. . Make Our Bank Your Bank . .
4 Per Cent Paid on Savings Deposits
BANK OF SEWARD, SEWARD, ALASKA

LEOPOLD DAVID
Attorney at Law
KNIK

HUGHES & PEDERSEN
Freighting and Transfer Co.
Leave your order for your winter wood with ...

Fresh Ranch Eggs. Brown & Hawkins. "Quality first."

Apples, per box, $2. Brown & Hawkins. "Quality First."

Try some Silver Salmon bellies, 10c. each, at Newton Pilger's.

Mrs. Ben H. Gilmore announces that she has opened a New Process Hand Laundry in Knik, and is prepared to do first-class work at reasonable prices. She will also do rough dry laundry. ... on hill east of main street.

C. M. Thorndyke ... can is at Se... the Broad Pass c...

W. E. Dunkle ... neer, departed ... Broad Pass co... with his dog t...

Newt. P...
To put g... and then ... "keep thi...

Papers from the files of the Elmer E. Rasmuson Library, University of Alaska.

and very primitive methods, produced very little return. Operators did not consider placer ground sufficiently profitable unless it could be made to yield ten dollars a day for each man employed. There were numerous places on Willow Creek where moderate amounts of gold could be and were recovered, but only the original claims and a few of those on Grubstake Gulch could be worked economically. Placer mining reached its peak in 1904 and 1905, but then the richest claims became exhausted. The Klondike and Boston Mining Company did most of the mining, using more than 6,000 feet of steel pipe anywhere from nine to 24 inches in diameter to loosen the ground hydraulically. Yet placer mining turned out to be relatively unimportant because the combined efforts of various operators produced only approximately $30,000 between the years 1897 and 1914.[13] Clearly, this was not enough economic activity to nourish the hopes and ambitions of the town of Knik.

Fortunately, however, a number of things happened elsewhere in Alaska to affect the town positively in the early years of the twentieth century. Among these was the start of construction for the Alaska Central Railroad, extending northward from the new town of Seward on Resurrection Bay. In the Tanana Valley, the interior of Alaska, Felix Pedro struck gold near a site which soon grew into the town of Fairbanks. These and other discoveries led to more intensive prospecting everywhere. Soon gold lode finds were made in the Talkeetna Mountains to the north of Knik, and placer gold was found on the Iditarod River far to the northwest.

Knik quickly became the major trading center for the gold and coal mines as well as sawmills throughout the Matanuska River Valley, the Susitna River Basin and the Willow Creek area, but at no time did the population exceed 500. And although summer traffic to the Iditarod proceeded by way of the Yukon and its tributaries, in winter the shortest route between the new Iditarod discoveries and an open port was overland to Seward. Knik happened to be squarely on the trail, and the little settlement soon became the major stopping point along the route when the Seward Chamber of Commerce dispatched two men to locate and publicize the winter route. As an added sign of Knik's importance the federal government established a post office there in 1904, and there were several trading posts as well as other businesses. Log cabins and tents went up to accommodate the influx of people, and the Alaska Road Commission began constructing a wagon road to Canyon.[14]

As if good fortune were not already smiling on Knik, Robert Lee Hatcher, a Texan who had prospected a little around Juneau, eventually reached the settlement where he trapped in the winters and searched for the elusive metal in the summers. On September 15, 1906, he located the first lode claims on the ridge west of Fishhook Creek.[15]

The discovery inaugurated a new era of gold lode mining in the Willow Creek Mining District. Placer mining operations had slowly become unprofitable as the richer grounds had been worked, and the Klondike and Boston Mining Company, the major placer operator, finally went out of business. (In 1908, O. G. Herning, its former manager, took over most of the claims of the defunct company.) By 1914, however, three lode mines operated to more than offset the loss from placer gold. Each mine crushed and treated its own ores on the premises, and recovered from each ton of ore approximately $34 in gold as well as some silver. Production statistics demonstrated the rapid rise in lode mining. While in 1908 only 87.08 ounces of gold were recovered with a value of $1,800, by 1914 this amount had risen to 14,367.28 ounces worth $297,184.[16]

Mining in the Willow Creek District during the summer and travel over the Iditarod Trail in winter promoted the growth of Knik. Residents would long remember January 10, 1912 when two freight sleds loaded with some 2,600 pounds of gold and pulled by 33 dogs arrived at the town from Iditarod on the Kuskokwim River. By 1914 the town even had acquired its own four-page weekly, the *Knik News*. It could also boast of two trading posts, three roadhouses and hotels, a restaurant, a general hardware store, bar, a transfer and fuel company, and a school, while J. T. Harvey operated a building and construction business. The 'Palace of Sweets' appropriately enough sold candies, as well as tobacco, magazines, stationery and postcards. Two dentists and two physicians ministered to the health needs of the community, while priests of the Russian Orthodox Church looked after the spiritual requirements of their flock. From 1911 until 1914 W. H. O'Connor represented the law as the city marshal of Knik.

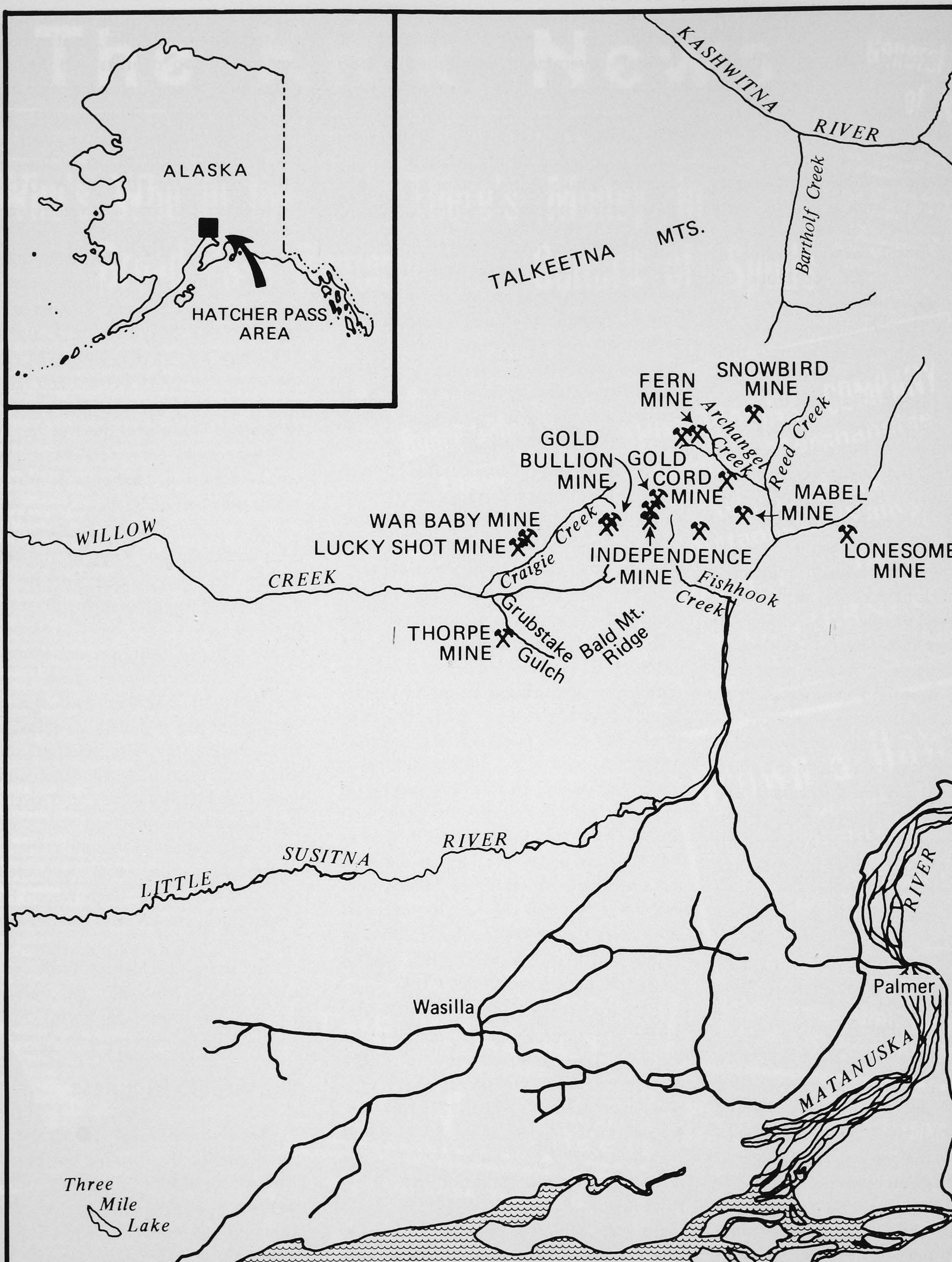
Each fall, with the onset of cold weather, the water supply necessary for the quartz mining operations froze and brought activities to a standstill. The single miners who had saved enough money would go to Seward and take one of the Alaska Steamship Company boats to Seattle. Those who had not acquired a nest egg would come to Knik and either rent a room in a roadhouse or move into cabins they had built.[17]

One summer route and one winter route radiated from Knik into the mining district. But, in order to handle the heavy machinery needed for lode mining operations, an all-season road had to be constructed. Three operators apparently got together and contructed such a route. The Bartholf brothers built the lower portion, which included a bridge across the Little Susitna River. Robert Hatcher continued the road up what now is known as Hatcher Creek and over Hatcher Pass. It is not clear what part the Carle outfit had in building the road, but since early day maps designated the 26-mile route as the 'Carle Wagon Road,' it can safely be assumed that the name was earned.[18]

In short, Knik prospered and for several years remained the transportation and distribution center for much of the upper Cook Inlet region.

DECLINE AND PROGRESS

Soon a series of events occurred which eventually resulted in the abandonment of Knik. The most important of these probably was the decision to build the government railroad via the Seward-Matanuska-Susitna route which bypassed Knik. In May of 1916 the town lost its post office. Although it reopened in 1917, it was closed for good in 1919. The *Knik News* moved to Anchorage in May of 1915 and published its first issue as the *Cook Inlet Pioneer*


ALASKA
HATCHER PASS AREA
KASHWITNA RIVER
Bartholf Creek
TALKEETNA MTS.
SNOWBIRD MINE
FERN MINE
Archangel Creek
Reed Creek
GOLD BULLION MINE
GOLD CORD MINE
MABEL MINE
WAR BABY MINE
LUCKY SHOT MINE
Craigie Creek
INDEPENDENCE MINE
LONESOME MINE
WILLOW CREEK
Fishhook Creek
THORPE MINE
Grubstake Gulch
Bald Mt. Ridge
LITTLE SUSITNA RIVER
Wasilla
Palmer
MATANUSKA RIVER
Three Mile Lake
KNIK ARM

Independence Day celebration, 1914, Knik, Alaska. At the turn of the century, Knik was a major transportation and distribution center. (Photograph courtesy of the O. G. Herning Collection, University of Alaska Archives, Fairbanks.)

and Knik News. Soon it dropped the latter part of the name and in no time at all the metamorphosis into the *Anchorage Daily Times* had been accomplished.

The railroad eventually reached the head of Knik Arm and then pushed across the lower part of the valley toward the Susitna. Soon Wasilla, a new settlement on the line, sprang up. Not only did the new town enjoy rail transportation, but it was also much closer to both the homesteaders and the miners. Knik continued to decline, businesses moved to Wasilla or Anchorage, and the houses were either abandoned or moved to new locations. Knik had become a ghost town.[19]

Although Knik did not survive, the Willow Creek Mining District continued to grow and flourish in a modest way. By the early 1920s, seven lode mines operated. The largest amount of gold then came from the Gold Bullion and Lucky Shot mines. The former boasted a 12-stamp mill, a classifying and amalgamation facility as well as a 50-ton cyaniding plant. The latter had an eight-stamp mill and operated throughout the year. The Willow Creek Mining Company owned and operated both properties and also was in the process of developing the adjacent War Baby mine.

The Kelly Mines Company controlled and operated a group of claims in the Fishhook and Willow Creek basins which included the Brooklyn, Independence, and the Free Gold. The Fern Mine on Archangel Creek operated throughout the year, while the Gold Mint Mine ran only 22 days in 1922. Development work, however, continued in various other locations, among them the Rae-Wallace property and the Homesteader-Martha. In short, production of some 77,127.92 ounces of gold worth $1,594,363 between 1915 and including 1922 reflected the increasing growth and development of the Willow Creek Mining District.[20]

By the early 1930s three automobile passenger stages as well as freight trucks made daily trips from Wasilla during the summer to all points in the district. A substantial road had been built to the northeast of Wasilla to accommodate this traffic. It ascended the slopes of the Matanuska Valley and entered the Talkeetna Mountains through the gorge of the Little Susitna River. At the junction of Fishhook Creek and the Little Susitna River, approximately 16 miles from Wasilla, a number of roads radiated to different parts of the district. The only one along the west bank of the Little Susitna River crossed Reed Creek near its mouth and continued upriver some two and one-half miles to the mill on the Gold Mint Mine property. Another road, slightly above Fishhook Inn on the junction, climbed the west slope of the Little Susitna Valley for roughly a mile in a northerly direction. One branch continued northward up Reed Creek Valley to Archangel Creek and on to the Fern Mine on the upper end; another branch doubled back around the mountainside into the hanging valley of Fishhook Creek and followed it upwards to the Gold Cord Mine. From the upper part of Fishhook Valley still another road ascended Hatcher Creek, crossed the divide at about 4,000 feet and then descended into upper Willow

Knik House on the winter route to the Iditarod gold fields, early 1900s. (Photograph courtesy of the O. G. Herning Collection, University of Alaska Archives, Fairbanks.)

Creek. From there it went westerly, skirted the mountainside and entered Craigie Creek Valley near the Lucky Shot Mine. From here the road ran northeast up Craigie Creek to the camp of the Marion Twin Mining Company at the headwaters.

During the 1931 season, as many as 120 men were regularly employed at the six operating mines in the district. Wages ranged around five dollars a day plus board for an eight-hour shift for carpenters, engineers, electricians and machine men. Other men did assessment work or prospected in the hills.

Of the six active mines, only the Willow Creek Mines, Ltd. had built facilities for year-round operations at their Lucky Shot Mine, which included a combination cook and dining house, and two well-insulated and heated bunkhouses for 40 men each, with such added amenities as showers, laundry and toilet facilities.

Other lode properties, once active but then closed down, included the Gold Bullion on the high ridge between Craigie Creek and the head of Willow Creek, and the Martin and Independence mines on upper Fishhook Creek.[21]

Mine operators in the Willow Creek District always faced a variety of problems. In the beginning, the lack of roads made it extremely difficult and expensive to get supplies and heavy machinery to the mines. Yet with the help of draft horses, tenacious and persevering teamsters were able to transport a few small stamp mills to various properties, and mining generally flourished. Only with construction of the railroad into the area shortly after World War I and the building of roads into the mines could heavier equipment be moved economically.[22]

Another problem was the so-called 'faulting' prevalent throughout the area. This phenomenon existed because in recent geologic times, layers of rock shifted, often squeezing off a promising vein. In such cases miners had to drill in the general direction they expected the vein to be. It was difficult, of course, to estimate the exact position of the ore, and also expensive to drill these 'drifts.'

Yet despite these and other problems, gold production, although varying from year to year, increased until 1943 and then fell steadily with a temporary upswing in 1949 and 1950 and a final decline thereafter. Between 1923 and 1942, the Willow Creek Mines produced gold worth $14,086,702. Although not one of the major Alaskan gold fields, it nevertheless was an important source of the yellow metal for three decades.

Some further production figures illustrate the cyclic nature of the industry. In 1929, the onset of the 'Great Depression' obviously affected gold production because miners took out only $12,000 worth of gold, whereas the year before the figure had been $104,000. Peak production of that decade occurred in 1925 when gold mined was valued at $454,581. In 1934, operators for the first time climbed over the one million mark with a production value of $1,391,000, while 1940 set a record with a gold output worth $1,858,999. Thereafter production slowly dropped to a low of $12,530 in 1947, only to rally slightly to $304,534 in 1950.[23] Actually, the peak productive years fell between 1931 and 1940.

Gold mining came to a virtual standstill with President Franklin D. Roosevelt's 1943 order which closed all operations not producing minerals considered militarily strategic. Obviously gold was not a metal considered necessary to win the war. Not until after the close of World War II did the gold mining industry again revive. This time, however, it did so only temporarily.

In 1948 a member of the United States Geological Service again visited the area and made an appraisal: Richard G. Ray spent three summers in the field between 1948 and 1950 surveying ore deposits in the district. He found that virtually all of the mines in the region had ceased to be practically operable, despite feeble attempts by a few to restart operations.

THE INDIVIDUAL MINES

Ray counted some nine mines which had been producing in the 1930s. The Gold Cord claims, originally located in 1915 by Byron and Charles Bartholf, had produced some gold in 1917 and 1918. There had, however, been no real activity until 1931 when W. S. Horning and C. Bartholf took over management. In 1939 they leased the property to L. A. Renshaw who built a new mill to regrind the accumulated tailings. The mine, like others in the area, closed for the duration of the war. After World War II development resumed, but only negligible amounts of gold were mined until the final closure in 1949.

One of the most active operations and one whose buildings still stand in good shape is the Independence Mine, Inc. Located on Fishhook Creek about one-half mile south of the Gold Cord properties, the Alaska Gold Quartz Mining Co. originally staked the first claims of this group in the area in 1907. There was little activity, however, until the late 1930s. In 1937, W. W. Stoll, Sr. assumed the duties of general manager, and under his energetic and knowledgeable guidance the Independence Mine quickly became one of the most important producers in the district. It was closed down in 1943. After the war, two unsuccessful attempts were made to renew operations until the third one succeeded temporarily in 1949. For the first time in the history of the Willow Creek Mining District the operators employed a so-called contract mining system whereby they assigned workers certain blocks of ground. Miners received a minimum wage in addition to a percentage of the returns on all gold they mined. Despite this innovation, economics forced closure and abandonment of the mine in 1950.

The Fern Mine, located on Archangel Creek on ground originally known as the Fern-Goodell property, was first staked about 1917 on the Hillis group of claims. Development occurred shortly after 1917 and gold left the mine in 1922. In 1925 the operators consolidated their holdings when they took over the adjoining Talkeetna Mine. Production, however, continued only from the Fern Mine. The mine lay idle in 1929 and 1930; T. S. McDougal finally continued active development in 1931 and recovered a substantial amount of gold that year. In the decade between 1931 and 1941, McDougal operated the mine almost continuously and recovered in the neighborhood of $1,000,000 worth of the precious metal. McDougal maintained his lease until the wartime ban on gold mining expired in 1945 when a group managed by A. G. Dodson acquired the works. The new lease holders continued development work in the same year. In 1946 a fire totally destroyed the Fern mill. Rebuilding took place the following year, and operations resumed in 1948, marking the first mining and milling of gold ore in the Willow Creek Mining District after the end of World War II. In July of 1950 the mine closed temporarily to prepare for new development work, but when the manager died in September all plans dissolved.

One of the oldest mines in the district was the Mabel Mine, located at the 3,850 foot level near the scenic top of the divide west of the junction of Reed and Archangel Creek. The first claim was staked in 1911, and mining and development work continued intermittently until 1917. Between then and 1930 the mine contributed steadily to the annual gold production in the area. Active operations ceased between 1931 and 1937, and a small amount of gold was taken out annually between 1937 and 1939. Among its physical assets, the mine boasted a double-track, gravity-operated aerial tram approximately 3,250 feet long which connected the lower camp with the mine. Although sporadic development work occurred in both 1946 and 1947, the mine closed for good in the latter year.

The Lonesome Mine was formerly a part of the Gold Mint mining property on the southeast side of the Little Susitna River about three miles above the mouth of Archangel Creek. It consisted of a small bunkhouse and a mill, both constructed by men in an obviously optimistic mood in 1948. It is not known when the first claims were staked in this group, but the property yielded an apparently intermittent living between 1931 and 1938. At that time Fred Johnson assumed a five year lease with an option to buy. The owner died in 1940 and the ground was abandoned and reverted again to public domain. In 1946, Lloyd Hill and Charles Cope restaked the ground and recorded nine claims in Wasilla. The new owners spent the next couple of years installing a mill and opening new veins. They even milled some ore in 1948 and 1949, but apparently ceased operations in 1950.

The poetically named Snowbird Mine was first prospected in 1921. It was situated at an altitude of 4,350 feet on the south side of a valley tributary to the head of Reed Creek Valley from the west. Little work was done until 1939-41 when the owners searched for profitable ore veins. In 1945 they constructed a road and a lower camp in Reed Creek Valley. Additionally, they began to install a 5,000 foot, heavy-duty, double-track, reversible, power-driven aerial tram to a campsite they were developing simultaneously in a hanging valley some 1,250 feet above, completing the job in 1946. They finally connected the mine portal to a mill building at the upper camp by a 1,600 foot, double-track, gravity-operated aerial tram. Milling installations were completed in 1950. After the heavy expenditures, this mine also closed down within a fairly short period of time.

The old buildings of Independence Mine still stand in good shape. The area is expected to become a historical park. (Photograph courtesy of Alan Austin.)

In addition to these larger mines there were a number of smaller operations, including the Schroff-O'Neil Mine perched precipitously at 4,100 feet on the Craigie Creek side of the pass from upper Fishhook Creek; the High Grade, Marion Twin, and Thorpe mines; the Webfoot, Kelley-Willow, Lane and Holland prospects, all with varying histories.

By the late 1940s, some of the big early producers had long been abandoned. By that time also, gold mining had virtually ceased in the Willow Creek Mining District. A number of factors were responsible. The employment opportunities, at high wages, on military bases near Anchorage in defense-related construction generally robbed the mines of prospective workers. Mine operators simply were unable to match the contemporary wage scales because their operating expenses had steadily increased over the years while the federal government had maintained the price of gold at a static $35 per ounce.[24]

In the 1970s, gold mining has become a mere memory for most.

THE PARK EMERGES

In 1978, the Alaska Division of Parks bought an option on the 638-acre Independence Mine for $7,500, and asked the legislature for an appropriation of $200,000 to buy the property. Just when it appeared that the legislature would refuse the funds, Texas miner Starkey A. Wilson, who had bought the property from out-of-state owners, agreed to donate half of the site, approximately 300 acres, to the state for a historical park. Wilson intends to operate a hard-rock mine on the remaining acreage. Alaska's Commissioner of Natural Resources, Robert Le Resche, is expected to designate the area a historical park. Plans call for stabilizing the old buildings and providing visitor services, such as a center on mining history, a restaurant, downhill ski area, and an arts and crafts center. These plans should be realized in the near future, for the state estimates that in the last few years, more than 150,000 people already have been visiting the old mining operation annually.[25]

The Hatcher Pass area, part of the Willow Creek Mining District, apparently was named after Robert L. Hatcher who staked the first lode claim on September 16, 1906 and thereby assured modest prosperity for the district for a good many years.[26] The region, beautifully located in the rugged Talkeetna Mountains, is easily accessible by good roads from Anchorage, Alaska's largest urban center. Historically important, it reminds modern Alaskans of the hardships endured by their pioneer predecessors who so diligently searched for and found gold.

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Index : Volume 1–10

Ten years' worth of *TNE* articles are listed below in alphabetical order, first by author's name, then by title (**bold type**) and subject (*italic*). Citations are by Volume and Number rather than year and season. The index does not include letters, meeting announcements or reports, book reviews, or editorial statements on items of magazine business (such as warnings of rising subscription rates). Unsigned articles have been listed only in the subject/title section; signed articles have been alphabetized by the first author's surname, with second and further authors listed at their own points in the alphabet with a *see* notation to refer the reader back to the first author and full citation.

Our usual approach to picking subject key words was to assume that the authors knew what their topics were and thus we assigned articles to headings selected from their titles. **InterContinental peace bridge**, to take an easy example, is listed under *Bridges* as well as its title. In some cases the title didn't provide enough information: **Or through Canada?** now has an invented parenthetical addition (**Alaska's gas**) and is listed under *Pipelines*. Now and again we simply made an arbitrary decision: *Ice fog* entries are not listed again under *Air pollution*; **SEV's for the Arctic** appears under *Hovercraft*. We counsel patience and cross-checking possible synonyms (if you're interested in *Sanitation*, scan the *Sewage* listings as well). Our selection of the most obvious possible subject may lead to challenging searches for, say, "that article printed a few years ago that talked about eutectic salts,"* but we hope this index proves to be more useful than aggravating to you.

Most back issues are available; they cost $2.50 apiece, including postage at book-rate speed to anywhere on the globe. Offprints of single articles are not available, but we will make and mail Xerox copies of any that are not copyrighted by their authors for $1.50. Please note: articles for which corrections were later printed are so noted at their title listings only. If you order one of these, or an issue containing one, remind us about the correction when you place your order and we'll copy it also. The corrections come at no charge, since they represent mistakes we made in the first place.

*Engine preheating with saved heat: something for nothing? 5(3):4-6.

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