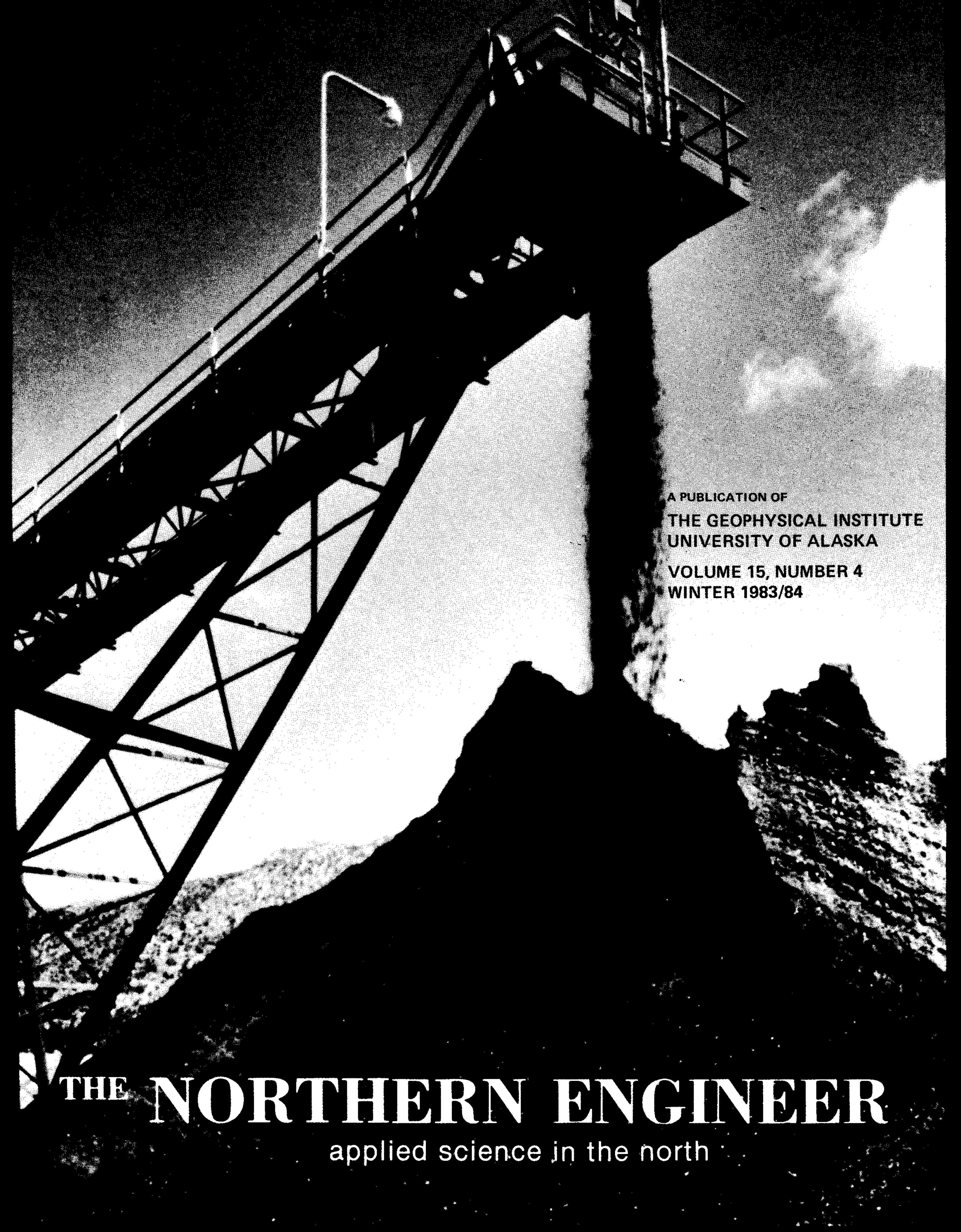

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THE NORTHERN ENGINEER

applied science in the north

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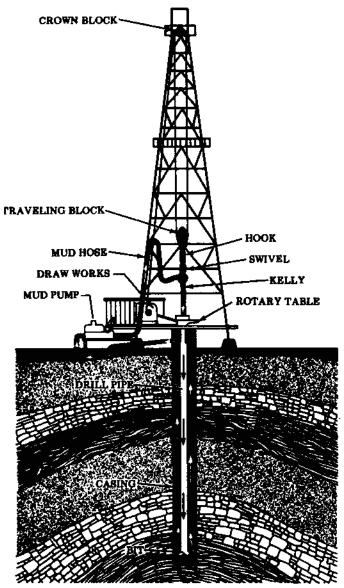

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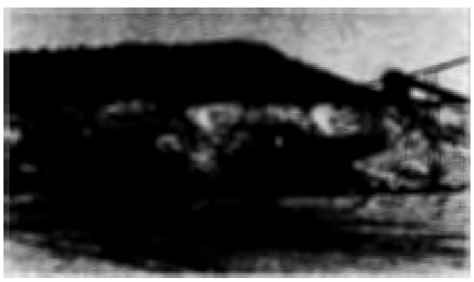

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COVER

Agglomerated and crushed gold-bearing material piling up on a pad at the Alligator Ridge mine in Nevada. The completed 15- x 300- x 700-ft heap will next be treated by chemical leaching (see p. 30), a process that may find profitable application in the north. (Photo courtesy of Tom Albanese.)

THE NORTHERN ENGINEER (ISSN 0029-3083) 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 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. (Opinions in the letters, reviews and articles are those of the authors and not necessarily those of the University of Alaska, the Geophysical Institute, or The Northern Engineer staff and Board.)

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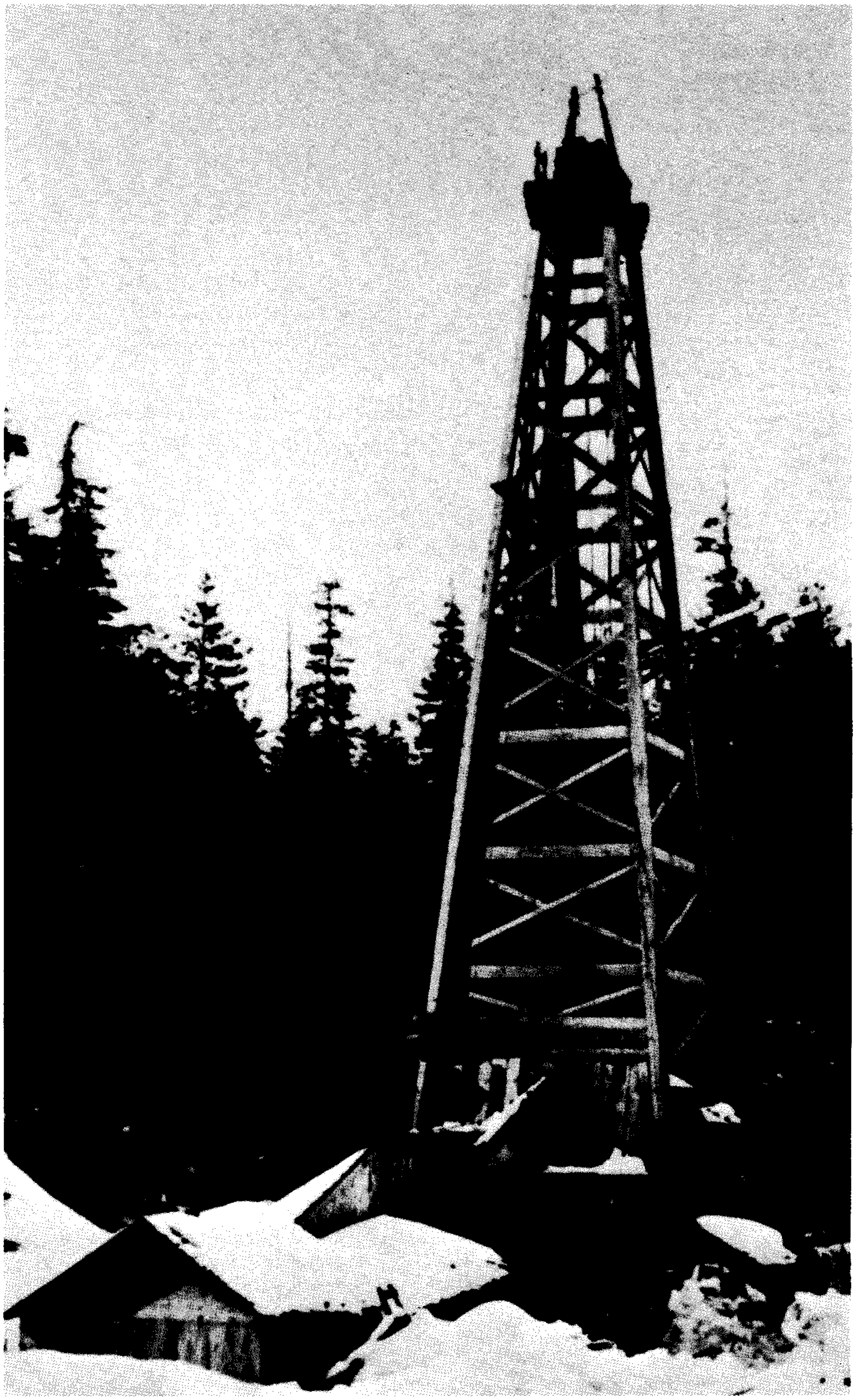

In the early years of the oil industry in Alaska, finding the bottom of the hole was easy — it was straight down. Shown here is one of Alaska's first producing wells, part of the Chilkat Oil Company's facilities at Katalla. (Photograph from the Barrett Willoughby Collection, courtesy of the Alaska and Polar Regions Department, Elmer E. Rasmuson Library, University of Alaska-Fairbanks.)

DRILL STRING MAGNETIZATION:
Its Measurement and Its Effect On Coring and Borehole Navigation

by David B. Stone

Boreholes are drilled for a multitude of purposes and on a multitude of scales ranging from shallow narrow-bore water wells to very deep (greater than 10 km) scientific exploration wells. For many of these boreholes, especially those drilled by the oil industry, the drillers need to have accurate information on the location of the bottom of the hole. A number of new navigation techniques are available (or are being developed) to determine this, but traditional magnetic methods are still very common. To use the earth's magnetic field for this purpose requires a knowledge of the direction of the earth's field at the location and also how this field is perturbed by the drill. To determine this latter point requires a knowledge of the magnetic properties of the drill string.

Core samples are taken in many exploration boreholes. If the magnetic properties of these samples are to be measured, and particularly if paleomagnetic measurements of the ancient magnetic fields recorded in the rock are to be made, then a knowledge of the magnetic fields to which the core has been exposed during drilling is necessary. This article describes a cheap, simple, ballistic magnetometer or fluxmeter that can allow estimates to be made of the magnetic field associated with drill strings.

BOREHOLE NAVIGATION

One of several techniques commonly employed to determine the path of a borehole is to measure the inclination angle of the hole and the direction in which it is inclined, relative to a magnetic compass. The actual mechanisms used to read the magnetic compass at depth vary from very crude to very sophisticated. Unfortunately, all have the same inherent problems, inasmuch as it has to be assumed that the magnetic direction read is that of geomagnetic north and that the drill string itself is not affecting these readings. These assumptions are particularly important at high latitudes. The higher the latitude, the steeper the inclination of the total magnetic field vector with respect to the surface, and hence the smaller the magnitude of the horizontal component, which is the component that interacts with the magnetic compass. This in turn means that extraneous magnetic fields such as those associated with the metal in the drill string become progressively more important. Magnetic borehole navigation at high latitudes requires that the actual direction of geomagnetic north at the surface be determined for every reading. This is because magnetic storms can cause fluctuations in the declination of the earth's field as large as 10° in as little time as a minute, with obvious deleterious effects on the navigation.

To overcome the magnetic effect of the drill, drill pipe and drill collars while they are in use, there are again a large number of different techniques. The most common is to place the compass at some distance from known magnetic material by inserting nonmagnetic stainless steel sections in the drill string. This immediately raises the question of what length of nonmagnetic section should be used, which in turn is related to both the induced and permanent magnetization of the rest of the drill string.

CORE MAGNETIZATION

In a number of cases where the remanent magnetization of cores extracted from boreholes has been studied, it has been observed that the cores are often magnetized along the core axis. Since this occurs frequently, it has been assumed that it is due to remagnetization effects resulting from exposing the sample to the fields associated with the drill string. The core can be exposed to the drill string field either as it is being drilled and then brought to the surface as part of the drill string, or, in cases where the core is brought to the surface through the center of the drill string, as it passes through the various drill string sections. In order to assess the possibilities of removing this remagnetization, or better, to avoid remagnetizing the core in this way, it is advantageous to know the magnitude of the field to which the core has been exposed. Unfortunately it is not generally practical to measure the detailed morphology of the field associated with the drill string, but it is possible to estimate the field magnitude if the overall magnetic fields at the ends of the various components of the drill string are known. Thus, a basic knowledge of the magnetic field strengths associated with drilling would be advantageous for both navigating boreholes and preserving the original magnetizations of core samples.

DRILL STRING MAGNETIZATION

The magnetization of individual components of the drill string has traditionally been estimated by measuring their effect on the local geomagnetic field. This is

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done by placing them horizontally on the ground, aligning them east-west in the geomagnetic field, and then using an ordinary magnetic compass to determine the null point. The null points are the positions where the magnetic field of the pipe (assumed to be magnetized along its long axis) is equal to the horizontal component of the earth's field. The null points are thus located where the compass points 45° east or west of magnetic north depending on the magnetic polarity of the pipe. If the magnitude of the horizontal component of the earth's field at the particular location is known, it is then easy to calculate the pole strength of the individual drill pipe or collar. Unfortunately, and for obvious reasons, this technique does not lend itself to systematic measurements during the course of drilling, so there is no way of estimating whether the magnetizations change with time or drilling conditions. What is required is either a method to measure the actual field variations in the vicinity of the navigation compass or core, or a quick way to measure the magnetic field of the various drill components as they are being assembled, thus allowing estimates of the magnetic field associated with the whole drill string to be estimated.

Down-hole magnetometers are available both as independent logging devices, which are generally expensive in terms of down time for the drill rig, and as assemblies built into the drill string. The latter are still relatively rare, and usually only used for large-scale drilling projects where they record and transmit measurements of several down-hole parameters at once.

Most of the usual techniques for measuring relatively large magnetic flux densities, such as the use of Hall probes or rotating search coils, are difficult to use to measure the *total* magnetic field threading through the end of something the size and shape of a drill pipe or collar. This difficulty is compounded because the field through the ends of these components is very nonuniform; to estimate an equivalent pole strength, one needs to know the total field threading through the end of the pipe. The extreme magnetic noisiness of the surroundings, the fact that the drill components themselves are not all of the same diameter, and the fact that the ends do not all have the same shape make the problem more difficult.

SNAP-RING MAGNETOMETER

To minimize these various hazards, we constructed a search coil of variable cross-sectional area. This magnetometer is based on the principle that if the sum total of the magnetic field escaping from the end of any given component of the drill string can be measured, it can be related to the overall magnetization or the pole strength. The variable cross-sectional area, or "snap-ring," magnetometer is a coil constructed by folding a multiconducter strip back on itself and connecting successive conductors together. If the ends of the folded multiconductor strip are then pushed towards each other, the tape bulges out to form a coil, thus maximizing its cross-sectional area. If the ends are now pulled outwards, the area of the coil goes effectively to zero (Fig. 1). If the area of the coil is changed from some finite value to zero in the presence of a magnetic field, an electric current will be generated proportional to the magnitude of the change in the magnetic field threading through the coil. By measuring the current generated, we can calculate the magnitude of the magnetic field.

We constructed the snap-ring magnetometer by connecting 30 conductor plastic strips 1" wide, to form a coil of 30 turns. Two handles fixed to the coil were constrained to slide in slots in a base plate. When the handles are moved relative to each other, the area enclosed by the strip changes, thus allowing measurement of the change in the magnetic field threading it. The snap-ring shown was connected to a multirange ballistic galvanometer with a period of about five seconds, and the deflection for a given field was calibrated using a standard solenoid. To use the snap-ring to measure the magnetic field associated with the end of a drill pipe or other drill string component, we placed the aluminum plate on the end of the pipe, formed the coil and snapped it closed several times, and noted the readings of the ballistic galvanometer. Mounting the snap-ring on the aluminum base plate enabled the ring to be snapped at a small and constant distance from the end of the drill component being measured. This both minimized the field leakage caused by the gap between the coil and the pipe and kept it approximately constant.

Using this system during the drilling of a number of oil wells in northern Alaska, we found that the earth's field

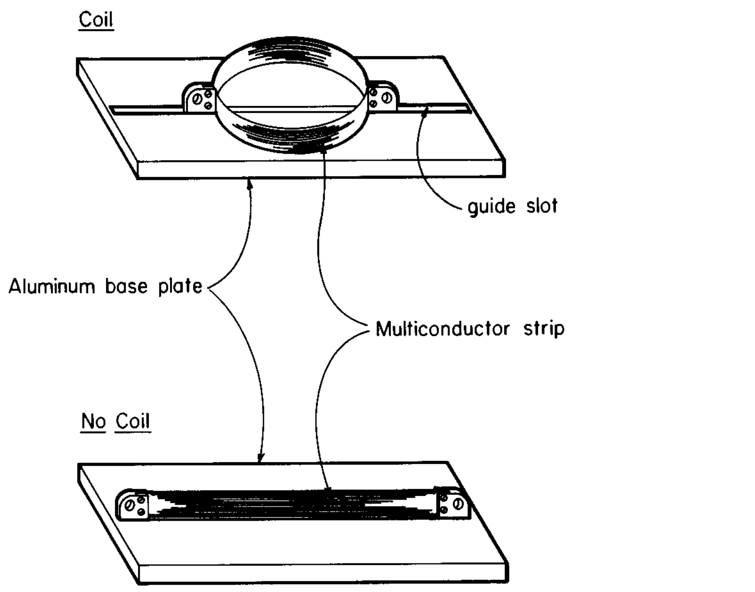


Figure 1. Snap-ring magnetometer design, showing the flexible multiconductor strip and sliding handles. The coil can be changed from a finite cross-sectional area (top view) to zero by sliding the handles outwards.

away from the drill rig gave a deflection corresponding to about 0.01 microamps on the galvanometer scale. Magnetization of the various drill components was typically three to four orders of magnitude larger than this, and of both polarities.

We also measured the field without a pipe or drill collar being present, to determine the background field caused by the drill rig. This was very much smaller than the usual drill string field, usually less than 1% of it, and was also found to be constant within a factor of two or so.

Because the pole strengths of adjacent pipes in various drill strings were found to vary considerably, often by more than an order of magnitude, and occasionally to be of opposite polarity, the errors inherent in the measuring technique are generally unimportant. It is not possible to estimate these errors directly because they depend on too many indeterminate factors, such as the amount of magnetic field leaking from below the point where it is being measured. This leakage can be due to many different factors such as machined lips and threads on the drill pipes, and to a lesser extent to the contact of individual pipes with other highly magnetically permeable material such as the casing or the drill rig itself. The overall technique, however, is justified on the basis that the measurements themselves were found to be repeatable to within a few percent. By measuring individual pipes in the "mousehole" on the drill rig, again while they were suspended before being coupled to the rest of the drill string, and once more after they were coupled, we concluded that the measurements gave values of the pole strength of components varying by factors of ten to within about ± 25%.

The system could no doubt be improved both by calibrating it for the different types of ends on the drill components, and by making the open cross-sectional area of the snap-ring more nearly that of the pipe being measured. This would cut down the flux around the edge of a too small snap-ring, or alternatively the "back flux" through one that is too large. This later modification could easily be achieved by means of a small clip to change the effective coil size. Such sophistication would seem unnecessary in the light of the large field variations found in drill strings. The main advantage of the device as it stands is its simplicity and speed of operation, and hence lack of disruption to the drilling operation. It has also demonstrated its ability to detect magnetizations sufficiently variant to upset both coring and many of the magnetic navigation techniques commonly employed. Its sensitivity is also adequate to detect and to follow any stress-induced or other changes in the magnetization of an individual component with continued use.

DATA

We first used the magnetometer to determine the pole strengths of individual drill pipes that had already been measured by the null technique mentioned earlier. Comparison of the data showed the two methods to agree within ± 25%. It was next used to determine the magnetic field in the vicinity of the drill platform. This latter field was at least an order of magnitude smaller than the fields measured for the more weakly magnetized drill components and approximately equal to that recorded for the nonmagnetic stainless steel sections.

The major set of measurements was made on drill string components both entering and exiting the borehole for a

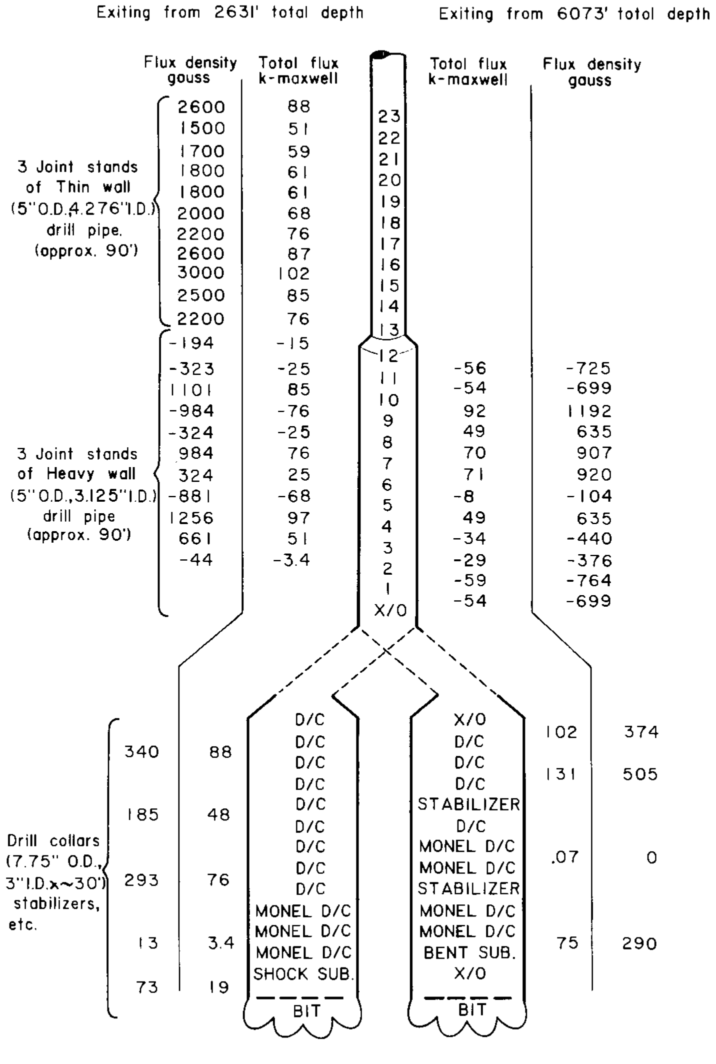


Figure 2. A diagrammatic view of two drill assemblies and associated drill strings. The magnetic flux listed is that through the topmost component of the drill string with all the components shown below it connected to it. The magnetic field is given as total field and field per square centimeter of cross-sectional area of metal. Negative numbers represent components magnetized north upwards.

well being drilled at Prudhoe Bay, Alaska. As can be seen from the data in Figure 2 for the drill string exiting the well, the intensities of magnetization range over more than three orders of magnitude. In general, the thinner-walled drill pipes were the most intensely magnetized. Perhaps more important, the polarity of the magnetization also varied. This is in direct contrast to the common assumption that

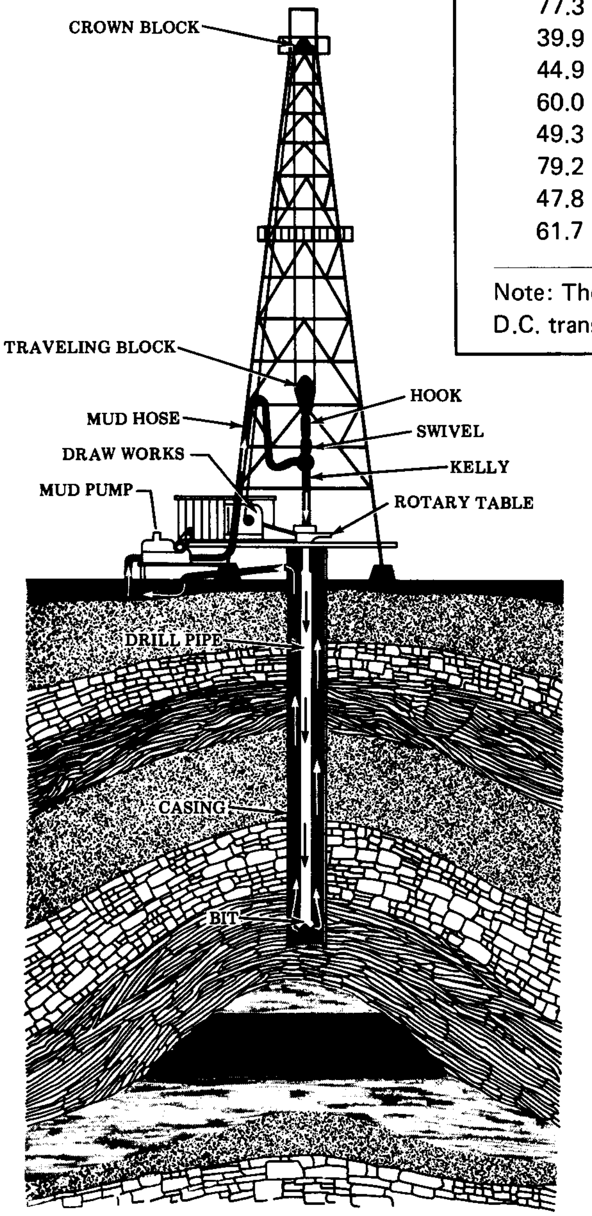
TABLE 1

TOTAL MAGNETIC FLUX THROUGH THE ENDS OF DRILL COLLARS

Demagnetization of Drill Collars (30′ x 7.75″ OD x 3″ ID)

Before Demagnetization Total Flux in k-gauss		After Demagnetization Total Flux in k-gauss	
S-end	N-end	S-end	N-end
53.7	63.4	27.4	25.3
58.5	41.6	16.7	24.1
77.3	73.8	42.2	50.7
39.9	30.8	33.1	18.4
44.9	23.3	22.3	7.5
60.0	50.7	33.1	28.6
49.3	39.4	28.6	22.3
79.2	66.8	46.4	42.2
47.8	13.4	30.8	–
61.7	44.9	39.4	27.4

Note: The flux was measured both before and after demagnetization using the D.C. transient technique. Measurements were made using the null method.



Schematic illustration of a rotary drilling rig showing the flow of drilling fluid used to clear drilled material from the bottom of the hole and to maintain pressure for the purpose of avoiding gushers or blowouts. (From Energy/Alaska **by Neil Davis, UA Press, in press.)**

drill pipes will be magnetized north down in the northern hemsphere, south down in the southern hemiphere. North-down polarities, however, were dominant in both numbers and intensities of magnetization.

The reasons for the reversed, or north-up, polarities of some pipes are not clear, but probably arise from the magnetic testing techniques used to look for flaws in the metal of the pipe. The basic technique in these tests is to magnetize the pipe by wrapping one of the conductors from an arc-welder around the pipe and passing direct current through it. The pipe is then painted with a magnetic colloid. If there are flaws in the metal, the field leakage associated with them will preferentially attract the colloid. After testing, the pipes are commonly demagnetized either by applying an alternating current (A.C.) from the arc-welder and reducing it slowly to zero, which theoretically demagnetizes the pipe by cycling it through successively smaller hysteresis loops, or by simply striking an arc. The arc is struck with the same arrangement of conductors that was used for magnetizing the pipe and presumably relies on transients generated in the breaking of the arc for the demagnetizing effect. The magnetizations for selected drill collars before and after demagnetizing, using the arc-striking technique, are shown in Table 1. The intensity of magnetization is usually reduced, but remains significant. It should also be noted from Table 1 that the drill pipes are not uniformly magnetized; frequently the field through each end is different. Both demagnetizing techniques can produce polarities of either sense. In the A.C. demagnetizing, the speed at which the field is reduced is critical, as is the need to avoid electric current "spikes" when the welder is shut off. Striking an arc and relying on transients produces very unpredictable results.

Though it was not possible to measure the field strength or polarity of each pipe as it entered and exited the borehole, we could measure the field through the ends of one set of drill pipes as they came out of the "mousehole" on the drill platform, before they were assembled into stands. Then we remeasured them as they were coupled to the existing drill string (Fig. 3). The magnetic field measured after coupling was roughly the mean of that through the existing drill string and that through the added pipes. Adding a pipe with opposite polarity significantly reduces the resultant field, as can be seen from Figure 3. In very general terms the measured field that passes through the top of the drill string is roughly the average of the top three or four drill string components, and thus drops significantly when oppositely magnetized components are added. It was not possible to get more measurements from individual and combined components of the drill string; however, the combination of the data presented in Figure 3, and the fact that both polarities plus a wide range of intensity variations were seen (Fig. 2), strongly suggests that the magnetizations roughly sum. This could be of great importance when it is necessary to keep the magnetic field low, such as when taking cores for magnetic measurements.

In general we could not follow pipes or individual stands through the whole drilling process because they were commonly assembled into three-pipe (90-foot) stands, and the arrangement of the pipes with respect to the stands varied, depending on such conditions as the depth of the hole and the type of drill assembly used. Because of the variable order of the pipes, it was not possible to track the magnetization of any given pipe or stand in the time available. In spite of this there is a suggestion that the magnetization of north-down pipes increases in intensity with time/depth, while magnetization of north-up pipes decreases in intensity. This is interpreted as the result of stress magnetization. Fundamentally a stress magnetization is caused by the internal strains upsetting the energy balance in the magnetic domain structure, thus allowing the domains aligned with the external and induced magnetic fields to grow preferentially. An interpretation involving a stress magnetization is supported by our observation that thin-walled pipes have much higher magnetizations, and presumably much higher stresses, than the thick-walled pipes.

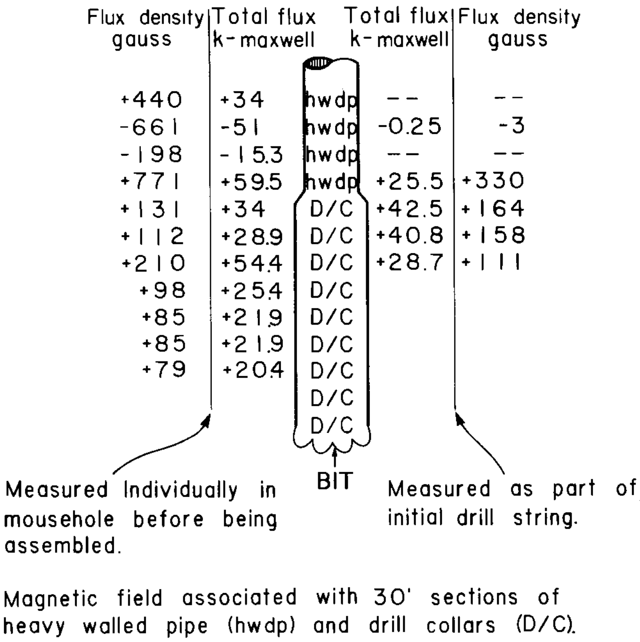


Figure 3. A diagrammatic view of lowermost section of a drill assembly and drill string. The numbers on the left represent the field through the top of the component while it was in the mousehole prior to being connected to the string. The numbers on the right represent the field through the top of the component after connection to the rest of the drill string. The numbers represent the total field and the field per square centimeter of metal. Negative numbers represent components magnetized north upwards.

CONCLUSIONS

The general conclusions we can draw from the results of this study are that the magnetic fields associated with drill strings can be, but are not necessarily, very large, depending on the stress history and polarity of the drill string components. If the bottom of the drill string has a high field, then more stainless steel sections are needed to allow the use of magnetic navigation devices. This is particularly important at high latitudes where the horizontal component of the earth's field is small. Modelling and empirical experiments show that for arctic Alaska about 120 feet of stainless steel is adequate to permit a magnetic compass to operate at its center.

The magnitude of the magnetic fields measured in the drill components also points to a possible origin of the remagnetization problems of rock cores collected for magnetic studies. An obvious technique to reduce this hazard is to demagnetize the drill components, particularly those at the end of the string or where changes in diameter occur and significant field leakage might be expected. This may be helped significantly by coupling N-up and N-down components so that their effective field is greatly reduced.

The main advantages of the snap-ring magnetometer are its speed of operation and its simplicity. Because of these features, it can allow monitoring of the fields produced by the drill string components without significantly disrupting the drilling procedure, and should allow drill strings with low resultant fields to be assembled.

ACKNOWLEDGMENTS

This work was done under the auspices of B.P. Alaska, and I gratefully acknowledge their help, cooperation and funding. I thank particularly Jack Krug and Brian Davies for their help. ♦

Reducing Frost Heave by Electro-Osmotic Dewatering and Soil Chemical Treatment

by Grant C. Baker and John C. Berg

INTRODUCTION

Frost heaving refers to soil expansion caused by the formation of ground ice in excess of the pore volume. It is associated with silty, fine-grained soils such as those found in the area of Fairbanks, Alaska. The widespread destructive consequences of frost heaving are well known. Both the expansion of soil during freezing and the loss of soil strength during thawing can destroy building foundations, roadways and airfields.

Excessive ground ice is able to form because large amounts of water move to the freezing zone during the freezing period. Although the exact mechanism for the water movement through the porous soil matrix to the freezing region is not known, we do know that for frost heaving to occur, three conditions must exist simultaneously:

1) a "frost-susceptible" soil (generally a soil containing at lease 2 percent by weight fines smaller than 20 microns in diameter),[1]

2) a prolonged period of freezing temperatures, and

3) an adequate water supply.

The freezing point of water, when confined to very fine capillaries, is substantially lower than that of bulk water.[1] Thus the fineness of frost-susceptible soil makes possible the transport of water as liquid through the soil to the freezing front where ice lenses form during the freezing period.

The specific requirements for frost heaving to occur suggest a number of methods to reduce or prevent it. One method which has shown promise is the treatment of the soil with chemicals which alter its frost susceptibility. Both flocculants and dispersants have reduced heaving in laboratory and field tests.[1,2] Flocculants are thought to increase the effective particle size in the soil (so that nonsegregated freezing would occur without liquid transport), while dispersants are believed to stabilize the fines so that they are swept into the flow channels, causing clogging. A potentially promising, but untried, process for frost heave reduction is soil dewatering by electro-osmosis, either before or during the freezing period. Electro-osmosis has been used since the early 1900s for dewatering peat and clays, and more recently by Sprute and Kelsh[3,4] for the dewatering of mine sludges in northern Idaho.

BACKGROUND

Almost all soil particles in contact with water carry an electric charge. It can be negative or positive, but it is usually negative. The negative charge results from the preferential adsorption of anions (hydroxyl ions, if none other are present) which are generally smaller, less hydrated and more polarizable than the cations present. The behavior of a soil particle in suspension is strongly influenced by the charge on its surface, which results in the accumulation of neutralizing, oppositely charged ions (counter-ions) in the layer of solution immediately surrounding the particles (Fig. 1). The "cloud" of counter-ions consists of two layers. The first of these is an

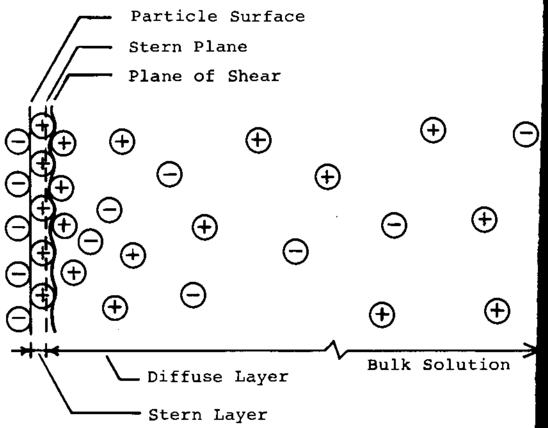


Figure 1. Ion distribution at and near the soil particle surface.[5]

adsorbed, compact monolayer of ions, termed the Stern layer, which usually partially neutralizes the surface charge. It may, however, either intensify or reverse the surface charge if the ions are specifically adsorbed (i.e., adsorbed due to forces other than electrostatic ones). The net resultant of the surface charge plus Stern layer charge is then neutralized by an array

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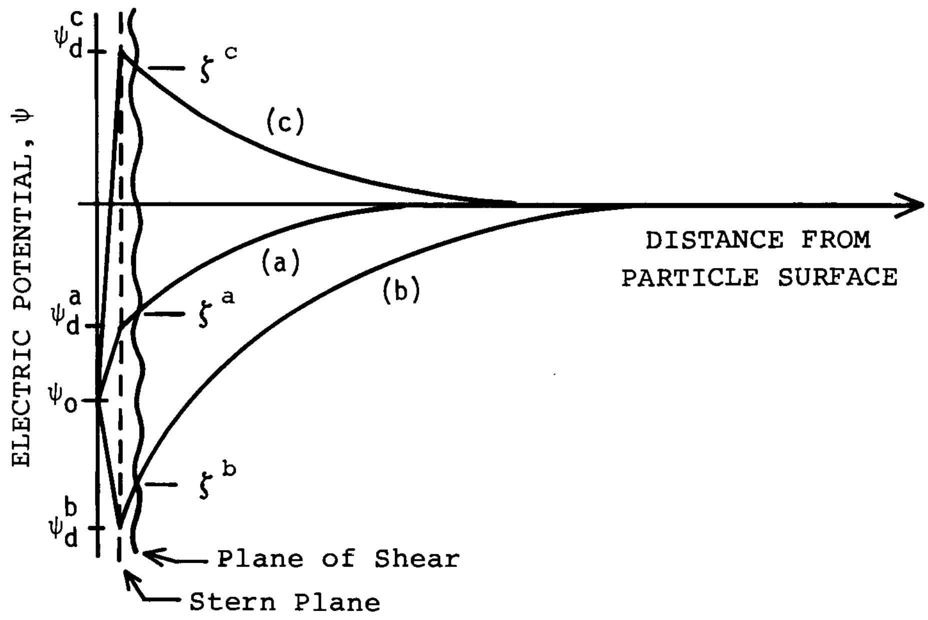

Figure 2. Effect of the adsorption mechanism on the Stern and zeta potentials. (a) Reduction in zeta potential due to preferential cation adsorption. (b) Increase in zeta potential due to preferential anion adsorption. (c) Reversal of sign between the surface and zeta potentials due to adsorption of strong polyvalent cations.[5]

of counter-ions farther away from but in the immediate vicinity of the soil particle surface. This outer stratum is called the diffuse, or Guoy, layer. The entire assembly of ions extending from the particle surface to the outer edge of the diffuse double layer is termed the electrical double layer.

Usually the concentration of counter-ions is highest close to the particle surface. At greater distances, the effective particle charge decreases, and the concentration of counter-ions decreases until it becomes the same as in the surrounding bulk solution. The surface potential, ψ_o, is the electrostatic potential difference between the particle surface and the surrounding bulk solution. As the distance from the particle surface is decreased, the potential decreases linearly from the surface potential to the Stern potential, ψ_d, and decays approximately exponentially from the Stern potential to zero in the diffuse double layer, as shown in Figure 2.

The Stern potential is an important parameter in determining the extent of soil particle interactions. When it is of sufficient magnitude, and the diffuse double layer is sufficiently thick, the soil particles will experience electrostatic repulsion when they approach one another and the diffuse portions of the double layers begin to overlap. This prevents them from approaching close enough to one another to flocculate. Such a dispersion is said to be "stable." When electrolyte is added to the system, the diffuse double layer becomes much thinner, i.e., "collapses," and the dispersion may be destabilized and flocculate. While the double layer thickness may be computed if the ionic content of the surrounding solution is known exactly, the Stern potential cannot be measured directly.

Fortunately, there is a measurable parameter which permits the assessment of the combined effects of Stern potential and double layer thickness and thus serves as a reliable indicator of the state of electrostatic stability of the particles. This is the zeta potential, ζ.[6] It is the electric potential at the hydrodynamic "plane of shear" around the particle, a surface located generally just outside the Stern plane. It can be determined for small particles by tracking their electrophoretic movement in an electric field of known strength. When the zeta potential is low (less than approximately 10 millivolts), it is either because the Stern potential is low or because the diffuse double layer has been collapsed to a distance inside the shear plane, or both. From the standpoint of predicting the stability of the particles with respect to flocculation, it is immaterial. The only requirement is that the zeta potential is sufficiently small. A finite zeta potential is thus required for electrostatic stability of the dispersion and is also a requirement for the possibility of electro-osmosis, as described below.

Electro-osmosis refers to the flow which occurs when a direct-current electric field is placed across a porous solid mass that contains a connected network of moisture throughout its void space. When the field is applied, the (generally) positively charged mobile part of the diffuse double layer migrates toward the cathode and carries with it the associated pore water (Fig. 3).

The electro-osmotic flow rate is given by:

$$V = \epsilon E \zeta / 4 \pi \eta \qquad (1)$$

where V is the linear flow velocity, ϵ is the dielectric constant of the water, E is the voltage drop per unit length along the flow path, η is the water viscosity, and ζ is the zeta potential. The zeta potential thus plays a key role in determining the potential effectiveness of electro-osmotic dewa-

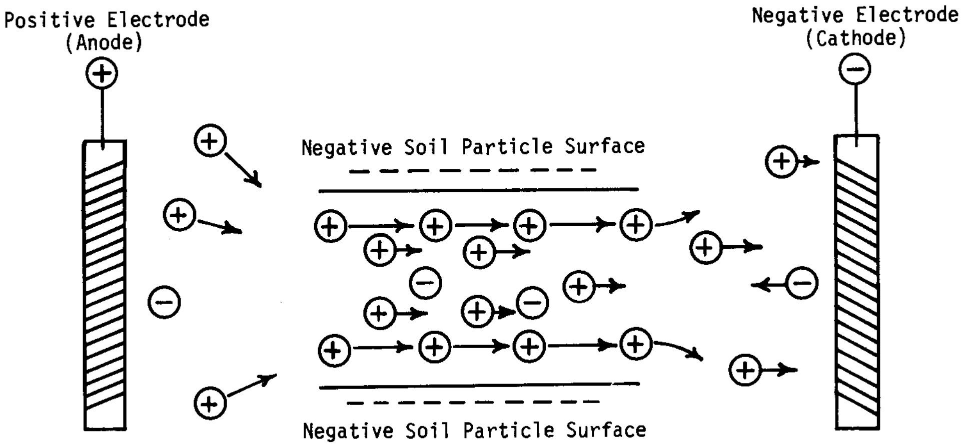

Figure 3. Illustration of electro-osmotic flow in an electric field.

tering. The addition of flocculants or dispersants is expected to produce significant changes in the zeta potential by altering the Stern potential and compressing the diffuse double layer, and thus should strongly influence the electro-osmotic behavior of the system. The total volumetric dewatering rate will, in addition, depend on the pore structure of the soil matrix (permeability), and this too should be affected by the addition of chemical flocculants and dispersants.

METHODS AND MATERIALS

Both laboratory and field tests were conducted. Laboratory tests were performed at the Engineering Center for Surfaces, Polymers and Colloids at the University of Washington, Seattle. The field test site was located at the CRREL (Cold Regions Research and Engineering Laboratory) testing grounds on Farmers Loop Road near Fairbanks, Alaska. The tests were conducted in an area of known frost heaving to determine the effectiveness of electro-osmotic dewatering procedures for reducing frost heave.

The soil for the laboratory tests was taken from the field test site to assure consistency in soil properties for all tests. The soil is relatively fine-grained (Fig. 4) and contains about 38 percent fines (size less than 20 microns). The natural soil moisture content is approximately 29 percent of the dry-soil weight (all moisture contents will be given as percentages based on dry-soil weight).

The chemical additives used in the soil treatments consisted of a flocculating agent, ferric chloride ($FeCl_3$), and a dispersant, tetrasodium pyrophosphate ($Na_4P_2O_7$ or TSPP). These chemicals were chosen for a number of reasons. Research by Lambe et al., indicated that these additives had successfully reduced frost heave at relatively low concentrations and cost.[1,2] Both additives should have strong and opposing effects on the soil particle double layer, yet they proved equally effective in reducing frost heave.

Soil samples were taken before chemical treatment, after chemical treatment, and after dewatering. These soil samples were analyzed for moisture content, zeta potential, and particle size distribution, and were examined by scanning electron microscopy (SEM). Zeta potentials were measured using a Rank Brothers Model Mark II microelectrophoresis apparatus. Care was taken in each case to obtain zeta potentials in the actual filtrate taken from the moist soil so that the chemical content of the liquid in the electrophoresis test cell was identical to that actually existing in the dewatering system. Particle size distributions were obtained using a Leeds & Northrup Microtrac particle size analyzer, and scanning electron micrographs of the soil up to 700X were taken using JEOL Model JSM-25 scanning microscope.

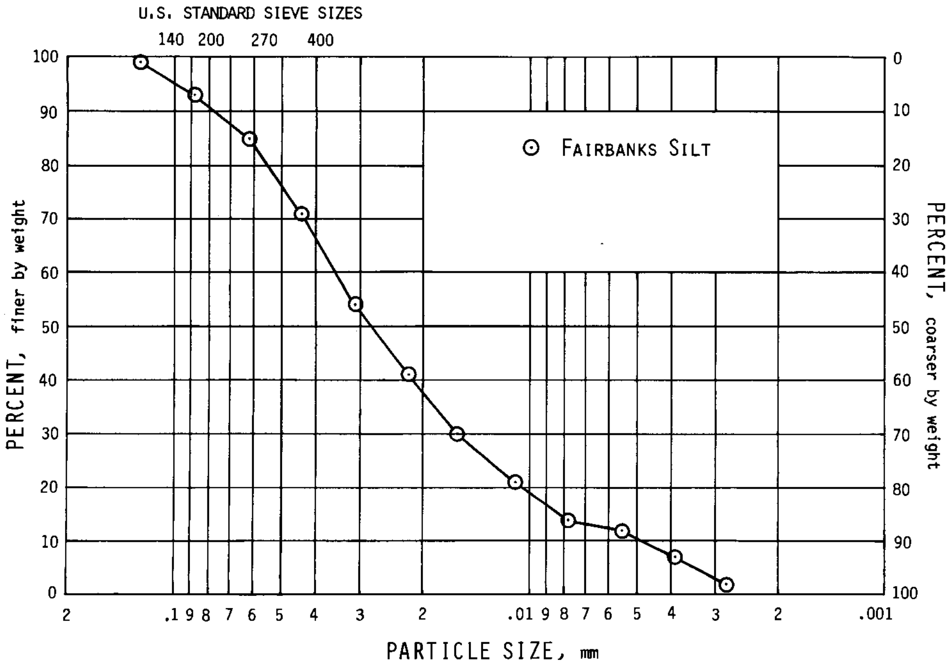

Figure 4. Particle-size distribution for Fairbanks silt test soil.

The field test plots were surveyed at approximately two-week intervals for the one year period between November, 1981 and November, 1982.

EQUIPMENT AND PROCEDURES

Laboratory test models, measuring 6x6x6 inches, were constructed of ¼-inch-thick Plexiglas™, as shown in Figure 5. Two cathodes were placed in each test cell to assure good soil contact. The cathodes were constructed of 1-inch O.D. copper tubing, approximately 8 inches long. They were perforated with ⅛-inch diameter holes at approximately ½-inch intervals to allow for water collection and removal. The anode was a plate measuring approximately 6x6 inches, 1/16-inch thick, and constructed of a special nickel-alloy stainless steel to resist anodic oxidation.

All test soils were initially dried. The chemical additives were dissolved in distilled water to give the desired concentration. The solutions were then added to the dried soil to give a moisture content of 43 percent. After chemical treatment, the soil slurries were mixed thoroughly and allowed to soak for about 18 hours.

At the end of the soaking period, the slurries were decanted and placed in the test models. Electro-osmotic dewatering commenced with the application of a DC potential to give a constant current density of approximately 900 $\mu A/cm^2$ (about 0.21 amps current flow); the current density is defined as the current per unit cross-sectional area perpendicular to the moisture flow. Electro-osmotic dewatering was stopped when its rate reached zero.

The field test plots measured 24x24x30 inches deep and had essentially the same design as the laboratory models, except that only one cathode was used. It consisted of a 2.5-inch O.D. perforated iron pipe, two feet long. Standard galvanized wire fencing was used as the anode. The test plots were spaced approximately ten feet apart to provide isolation from one another, yet close enough to ensure nearly identical soil conditions.

The field test site consisted of five test plots. One (Plot 5) was not disturbed in any way, and served as a reference. Plot 1 was prepared for dewatering but was neither dewatered nor chemically treated, and thus served as a second reference. Plots 2, 3 and 4 were prepared for dewatering, chemically treated and dewatered. Plot 3 was treated with TSPP, while Plots 2 and 4 were treated with $FeCl_3$. Plot 4 was enclosed with a Visqueen™ plastic membrane to isolate it from outside water sources.

Twenty-six gallons of 0.1 M (Molar) $FeCl_3$ solution were added to each of Plots 2 and 4, and a similar amount of 0.06 M TSPP was added to Plot 3. These amounts and concentrations assured that sufficient chemical would penetrate into the interior of the test area. The solutions were allowed to percolate naturally down through the soil for about one week. Dewatering was then completed over a three-week period prior to freeze-up. The voltage was varied to maintain a fairly constant current density of approximately 1000 $\mu A/cm^2$.

Frost heave field data were obtained in the form of measured heave and thaw ratios. The heave ratio is the amount of heave (elevation increase) of the surface of the treated soil divided by the corresponding quantity for the reference (in this case, the average of Plots 1 and 5). The thaw ratio is the amount of settlement (difference between the highest and lowest elevations) during the thawing period relative to the reference. Elevations of all plots were determined at regular time intervals by means of standard surveyors' instruments relative to a permanent monument on the test site.

The destructive consequences of frost action in soils are due to both the heave during the freezing period and the settlement during the thawing period, so both heave and thaw ratios are important in the evaluation of methods for frost heave reduction. Electro-osmotic dewatering and chemical treatment may affect these ratios differently, and they both should be examined.

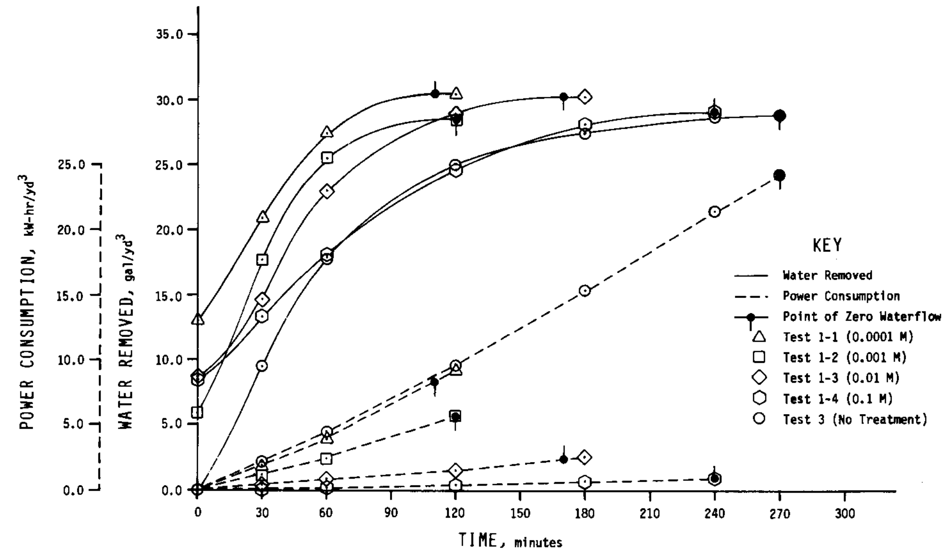

Figure 6. Dewatering and power consumption curves for laboratory tests using ferric chloride ($FeCl_3$) in soil treatment. Amounts of decant prior to electro-osmotic dewatering procedures are represented at time zero.

RESULTS AND DISCUSSION

Figures 6 and 7 give the results of the laboratory dewatering tests. The amounts of decant prior to electro-osmotic dewatering are included. Sprute and Kelsh showed that the excess or decanted water is the easiest to remove and requires a relatively small amount of power.[4] The amount of decant may also be affected by the type and concentration of chemical additive used. A comparison of the dewatering characteristics of the different tests should thus justifiably include the amounts of decant.

Generally all soil tests dewatered the same total amount, specifically to a moisture content of 28-30 percent. The notable exception was the test employing the 0.1 M TSPP treatment (Test 2-4). It stopped dewatering when the soil moisture content reached approximately 38 percent. This can be explained by the stabilizing effect of the dispersant which allows the smaller fines to be swept into the flow channels, causing clogging. In all cases, as moisture content reached its terminal level, the dewatering rates decreased dramatically.

The loss of permeability noted in the 0.1 M TSPP test would be a serious disadvantage for the practical application of such a dispersant during electro-osmotic dewatering. It is advantageous, however, with respect to slowing moisture movement to the freezing front in the absence of any prior dewatering. Thus, if dispersants are to be used in combination with electro-osmotic dewatering, the chemical dosing should be made *after* the dewatering has been completed.

A significant difference noted between the dewatering of the chemically treated and untreated soils was the increase in dewatering rate observed for the treated systems. For both the flocculant and the dis-

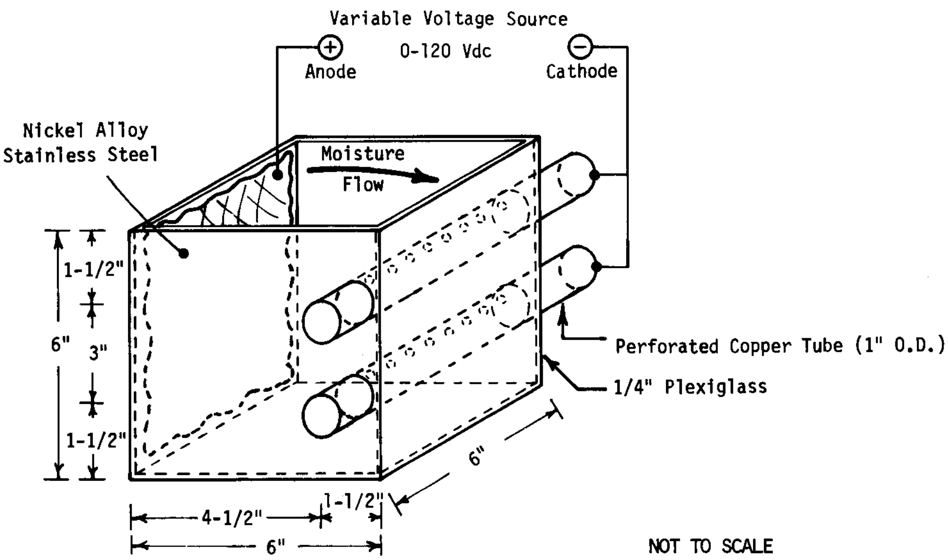

Figure 5. Laboratory test model schematic.

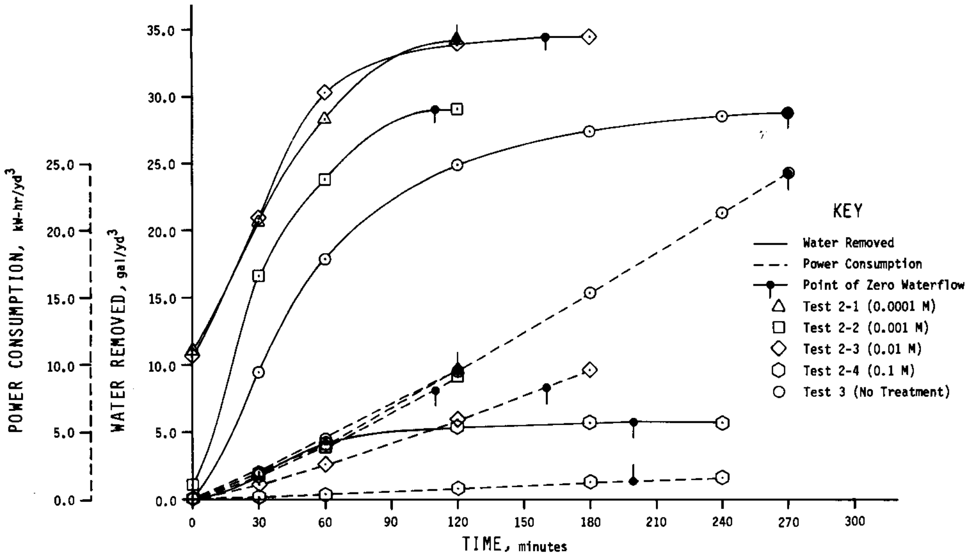

Figure 7. Dewatering and power consumption curves for laboratory tests using tetrasodium pyrophosphate (TSPP) in soil treatment. Amounts of decant prior to electro-osmotic dewatering procedures are represented at time zero.

persant, dewatering was completed in about half the time required for the untreated soil (approximately 120 vs 240 minutes). This might be partially explained as follows: The addition of a small amount of salt can be expected, first of all, to enhance the negative zeta potential of the soil particles through preferential adsorption of the unhydrated anions. Such a change in zeta potential did occur and is revealed in Figure 8, which shows the results of zeta potential measurements for all the conditions of the testing. The soil in contact with its natural ground water had a zeta potential of −16.0 mV, and the chemical treatment with both $FeCl_3$ and TSPP at the 0.0001 M concentration level increased it further (larger negative values) to −22.8 mV and −20.0 mV, respectively. Equation 1 suggests that the rate of electro-osmotic dewatering should increase in direct proportion to both the (negative) magnitude of the zeta potential and the electric field strength, other factors remaining the same. The increased zeta potential may thus explain the increase of dewatering rate with small amounts of salt addition of either type.

As salt concentrations increased, the electric field strength, E, decreased (since current density remained constant), so dewatering rates decreased slightly, as might be expected. It is puzzling, however, that a greater divergence in behavior between the $FeCl_3$ and TSPP cases was not observed in this respect, since the effect of the two salts on the zeta potential was opposite. It would be expected that the dewatering rates of the $FeCl_3$ runs would decrease more sharply with increasing salt concentration than those of TSPP. In particular, it would be expected that when the zeta potential approached zero, as when $FeCl_3$ concentration reached 0.1 M, electro-osmotic dewatering rates would approach zero. Apparently soil permeability assumes an overriding importance. The flocculating action of the $FeCl_3$ prevents clogging of the flow pathways leading to high permeability, so that even under conditions of low zeta potential, dewatering rates are significant. The TSPP promotes clogging action, so that increased zeta potential is offset by decreases in permeability.

Another observation is that for both types of chemical treatments, the amount of power required for dewatering significantly decreased with increasing levels of chemical treatment. This reduction is traceable to the increased electrical conductivity of the soil water when salt is added. Since the tests were conducted at constant current density, the required voltage was decreased with salt addition.

The results of the particle size analyses and scanning electron micrographs of treated and untreated soil samples were inconclusive but suggest that any detectable (involving fines larger than approximately 0.1 micron) changes in particle size attributable to chemical treatment were not significant. The mechanism by which changes in stability affect dewatering rates thus depends on changes in the particle-particle "stickiness" or adhesion without altering the geometry of the particle structure.

Evaluation of the field frost-heave tests is based upon the measured heave and thaw

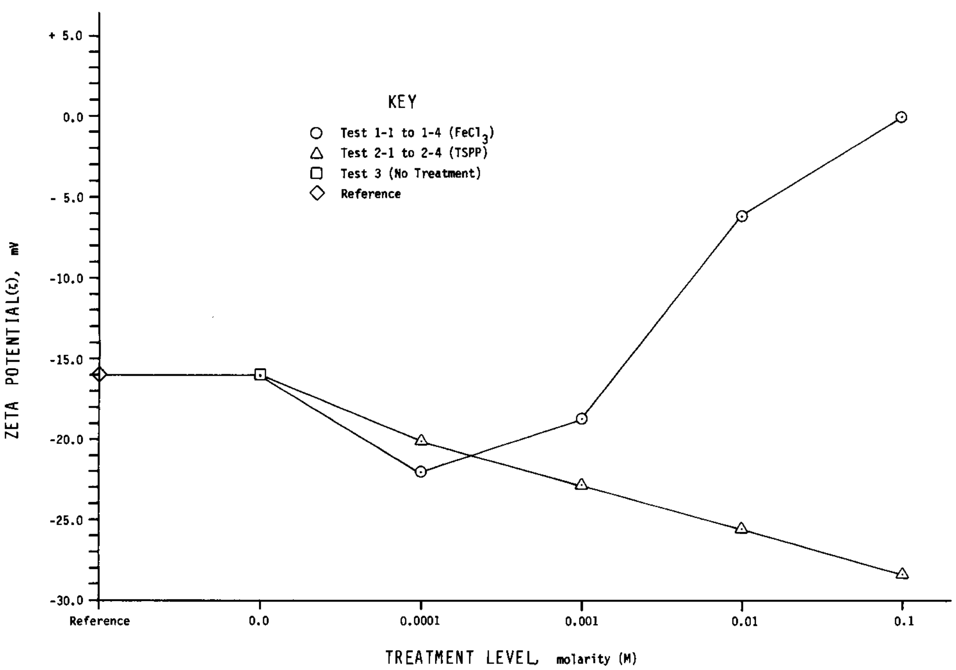

Figure 8. Comparison of laboratory zeta potential results for ferric chloride and tetrasodium pyrophosphate treated soils.

ratios, as shown in Table 1. Ratios less than unity indicate improvement, whereas ratios greater than one indicate impairment. Plots 1 and 5 were neither dewatered nor chemically treated, and the average of their freeze and thaw behavior was taken as the reference against which the chemically treated, dewatered test plots were evaluated. The difference in behavior between the two reference cases was 15-20 percent, giving a statistical measure of the reproducibility of the other tests, which were not repeated in the current work. Plots 2 and 4 show the positive results obtained for ferric chloride treatment with dewatering, Plot 4 differing from 2 in that the soil in Plot 4 had been dug up and reconstituted, with a plastic sheet buried beneath it. Both tests show significant improvement with respect to both heave and thaw ratios. Plot 4, the isolated system, showed the best results, indicating that heave due to water transport from soil adjacent to the plots was a factor in the other tests. Plot 3 employed the dispersant TSPP with dewatering, and it also showed significant improvement in both ratios. In all cases there was consistency between the heave and thaw ratios, i.e., those tests yielding the greatest heave also yielded the greatest degree of settlement.

It is important to note that the test plots were installed only to a maximum depth of 30 inches. The active layer in the test area extends to a depth of about eight feet. The reduction in the amounts of heave and settlement are thus a reflection of only the top third of the active layer. This suggests that treatment of the entire depth of the active layer may produce even greater reductions in the amounts of heave and settlement.

A possible side effect of electro-osmotic dewatering in this test series should be noted. The metal electrodes (particularly the anode) may have acted to conduct heat out of the soil during the winter (when the surface temperature is less than the soil temperature beneath the surface) and into the soil during the summer (when the temperature difference is reversed). This would have the detrimental effect of promoting both heave and settlement. These effects, if any, were apparently overridden in the tests run.

CONCLUSIONS

1. Electro-osmotic dewatering with soil chemical treatment can significantly reduce frost heave in soils such as Fairbanks silt.

2. The rate of soil dewatering is enhanced with the addition of low concentrations of either a flocculant or a dispersant.

3. High concentration levels of dispersant can significantly reduce the amount of water removable by electro-osmosis.

4. The addition of salts can significantly reduce the power consumption for electro-osmotic dewatering.

5. The anticipated changes in soil particle zeta potential were produced by the addition of ferric chloride and tetrasodium pyrophosphate.

6. Changes in macroscopic (>0.1 micron) particle size distribution are not affected by the addition of a flocculant or dispersant.

RECOMMENDATIONS

Further study of the effects of a wider variety of chemical additives and soils on dewatering procedures should be made. Test plots should involve the entire active layer.

The related process of electrophoresis (movement of the negatively-charged particles toward the anode: the opposite of electro-osmosis) should be tested in conjunction with chemical treatment of settling ponds for the mining industry. The use of a low DC potential within the settling pond could greatly enhance the settlement rate of the very fine suspended particles. The rate would be greater in conjunction with appropriate chemical treatment (to increase zeta potential) at very low treatment levels. Further research should find the optimal levels with respect to cost and environmental factors.

ACKNOWLEDGMENTS

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TABLE 1

Amounts of Heave and Settlement and Heave and Thaw Ratios for Field Test Plots

Test Plot Number (Type of Treatment)	*Maximum Amount of Heave (inches)*	*Maximum Amount of Settlement (inches)*	*Heave Ratio*	*Thaw Ratio*
1 (Electrodes installed, no treatment) 5 (No treatment)	4.79 (averaged)	5.95 (averaged)	1.00	1.00
2 ($FeCl_3$)	4.00	4.75	0.84	0.80
3 (TSPP)	4.50	4.91	0.94	0.83
4 ($FeCl_3$, enclosed)	3.60	4.14	0.75	0.70

Remote Sensing In the North

A LOW-COST METHOD FOR INVENTORYING CORDWOOD

by William J. Stringer
and Janis Zender-Romick

Photos taken during field observations supplemented the use of Landsat imagery for inventorying cordwood. The southeast-facing slope shown above overlooks the Tanana River; the photograph was taken in late May. The foreground is largely aspen (B1 vegetation category), with a large area of brushy bog (D1) just above center.

Because of the growing use of wood as a heating fuel, the demand for cordwood has dramatically increased – and so has the need for cordwood estimates and maps of cordwood availability. Existing timber inventories or vegetation maps are seldom directly applicable to cordwood inventory needs; timber inventories are often purely statistical and usually involve only commercial species or sizes. Vegetation maps often require extensive reinterpretation to yield cordwood densities.

In addition to these problems, cordwood and other forest products are usually managed in a given region by federal, state and local governments as well as private interests. Each of these managing entities tends to inventory only for economic value on lands it manages and tends to manage that inventory as if it were the sole source of that resource in the region. For instance, the State of Alaska manages its lands so as to produce a sustained yield in each region and makes pronouncements regarding the general availability of resources such as cordwood based on these estimates. Depending upon the fraction of the total resource located under state management, these pronouncements may or may not reflect the actual availability of the resource to the local community.

For these reasons, citizens and citizens' groups concerned about the overall availability of a resource such as cordwood need access to methods of locating and inventorying the resource regardless of its management. Only then can a true picture of resource availability to the community be developed. Based on the results of such surveys, the community may wish to arrange for coordinated management of cordwood by governmental owners, or private entrepreneurs may seek out owners of identified woodlots.

The project described in this article was undertaken to demonstrate the use of Landsat imagery as a low-cost source of information for cordwood reconnaissances. The techniques demonstrated here could be used by local governments, local resource-oriented businesses and even individuals to inventory cordwood at map scales greater than 1:63,360 (one inch on the map equals a mile on the ground). The techniques described are not intended to compete with more expensive and higher-resolution inventories made with aerial photography obtained especially for a given purpose, but rather are a method of

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performing a region-wide reconnaissance. Such a reconnaissance should identify areas of high cordwood potential and give an estimate of the useful volume available.

LANDSAT IMAGERY

Landsat imagery has been obtained by a series of polar-orbiting satellites, the first of which was launched in July, 1972. Each satellite produces an image of a particular point on the earth's surface approximately every 18 days. There have been a variety of imaging systems aboard these spacecraft, but one particular system, the multi-spectral scanner (MSS), has been aboard all of them. MSS imagery was used for the project described here. Each image is relatively inexpensive and covers an area approximately 100 miles square. The images can be enlarged several times without significant loss of detail. Although a standard 4X enlargement (the same scale as 1:250,000 United States Geological Survey Maps) can be obtained from the government, 16X enlargements (inch-to-the-mile) can be made that still retain utility.

The MSS imagery is obtained separately and simultaneously in four wavelengths and it is possible to obtain a black and white image representing light reflected from the earth in each of these wavelengths. The wavelengths monitored are green, red, and two wavelengths in the near-infrared. Some explanation is necessary. First, reflected blue light is not monitored because it is scattered a great deal in the atmosphere (which is why the sky is blue) and images obtained in that part of the spectrum would appear quite foggy. Second, the two near-infrared wavelengths monitored are actually just a bit more "red" than the red light visible to human eyes. They do not indicate heat in normal earth surface temperature ranges. (That requires radiation much more "red.")

The imagery obtained in the various wavelengths can be combined to produce multicolor images. The most common combination is called "simulated color infrared," because it has very nearly the same color characteristics as color infrared film. (Sometimes this is called "false color" imagery. While this is technically correct, color infrared is one particular "false color" combination. Hence, the term "color infrared" is more specific than "false color.")

In producing color infrared imagery, the green, red and one infrared wavelength are combined. This is done because the amount of infrared light reflected from the earth's surface is highly sensitive to chlorophyll and its general health and, therefore, infrared radiation is an excellent indicator of vegetation. However, as one might anticipate, there is a problem with representing the infrared information since it is invisible. This problem is solved not by representing it with blue (which might be the easiest solution since blue light is not monitored), but rather by representing the infrared with red. Red is a bright color and the human eye can detect many of its different shades and hues. Therefore, red is chosen to represent the highly informative near-infrared.

This, of course, leaves the problem of how to represent ordinary red light. Reflected red light is a very good indicator of bare ground, rocks, roof tops and other unvegetated solid surfaces. In combination with the infrared, it produces a sensitivity to biomass cover over the earth's surface, and clearly identifies nonvegetated areas. Since red has already been chosen to represent the near infrared, another color must be selected to represent red. The color used is green.

The only primary color remaining is blue, so it is chosen to represent reflected green light. Reflected green light is clearly sensitive to vegetation, but less so than the near-infrared with respect to vegetation type and health. Actually, reflected green light is a highly sensitive indicator of the depth of clear water and the sediment content of turbid water. However, when combined with the reflected near-infrared, the reflected green light signal (represented on film as blue) tends to modulate the overall combined color.

Although Landsat operates year-round, the most useful data by far for vegetation analysis is the summertime imagery. However, in regions with a wintertime snow cover, early springtime imagery is useful as well. In this case, a black and white representation of the light reflected from the earth's surface in a single color may be all that is required. If an image can be found in which snow is mostly off the trees, but remains on the ground, then relative darkness on the image becomes a measure of the extent to which the tree crowns cover the area – the crown cover. The near-infrared wavelengths have been found most useful for this purpose because they give the most contrast. However, a color infrared winter image can be used to some advantage because of a slight difference in hue between deep shadows and thick crown cover which is not apparent on single-band black and white images.

INTERIOR ALASKAN FORESTS

Viereck and Little's description of interior Alaskan forests in terms of the dominant tree species and other vegetated areas in terms of their characteristic appearance are well suited for interpretative analyses based on Landsat imagery.[1] Their categories include the following:

Closed Forests

White spruce type. The best example of these are stands of commercial-sized (lumber, house logs) trees with a closed canopy on warm, south-facing slopes. Generally, these areas would not be considered to be potential cordwood areas because of the high commercial value of the timber.

Quaking aspen type. Many of the interior forests represent some stage in species succession following fires. Lightning-caused fires are frequent in interior Alaska, and numerous fires have been caused by human activities. The vegetation types found in burned-over areas represent a combination of seed sources, slope and aspect, and time since the last fire. Following a fire and willow stage, fast-growing aspen stands develop on well-drained, south-facing slopes. The aspen mature in from 60 to 80 years and are usually replaced by white spruce.

Paper birch type. Paper birch is the common invading tree after a fire on east- and west-facing slopes and occasionally on gentle north-facing slopes and moderately well-drained flat areas. Although pure stands occur, most birch are in mixed stands with white spruce, aspen and even black spruce. In some localities slight changes in slope and aspect are responsible for the mixture. This forest type can be found over a wide range of tree maturity.

The final stage of the birch/spruce mixture is often one where white spruce have outgrown the birch and the birch are dying; frequently, standing dead birch can be found in large numbers. This forest next becomes a stand of pure spruce. At intermediate stages, this forest is a good source of fuel cordwood.

Balsam poplar type. Commonly called "cottonwood" in Alaska, this species is most commonly found on newly aggregated riverine soils such as elevated sandbars. Although relatively large stands do occur along rivers in interior Alaska, very few poplar stands were included in the study areas we considered.

Open Forests

Low-growing (black) spruce forest is characteristically found on north-facing slopes and poorly drained lowlands. However, isolated stands can be found on poorly drained southern-facing slopes as well. In addition to the black spruce (which are very slow growing and seldom exceed 20 cm in diameter) small-sized paper birch, tamarack, and occasionally white spruce are found. At times the black spruce can be quite dense, and approximate a closed canopy.

Recent Burns

Recent burns are succeeded by willows and saplings of aspen, birch, alder and even spruce. Although low in height, they can often exhibit a closed crown cover in summer, but appear void of vegetation from a distance in winter. Such areas are quite common in interior Alaska.

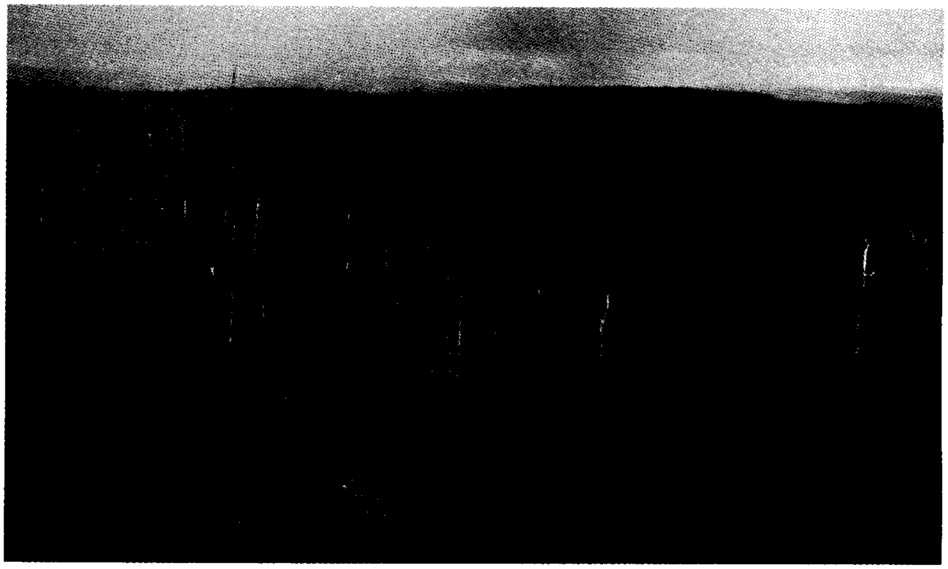
Treeless Bogs

Located in areas with soils too wet to support trees, bogs are found in valley bottoms and even some poorly drained hillsides (generally north-facing). Vegetation includes willow, dwarf birch, blueberry, cranberry, and labrador-tea. Such bogs represent no cordwood potential.

Shrub Thickets

Flood plain thickets. In interior Alaska these thickets are generally found along the flood plains of rivers and streams. The principal species (most apparent at a distance) are alders and willows.

Elevated thickets. These thickets are composed of dwarf birch, alder, and willow and are found near and beyond the treeline.



A southeast-facing slope, similar to the one shown in the preceding photo, as it looks in late May. Vegetation units on the hillside are A1 and B1 (largely aspen).

Alpine Tundra

This plant community is found near the tops of high hills in interior Alaska. It consists of dwarf birch and other shrubs as well as extensive areas of low mat-forming plants.

DATA

For this method of analysis, two types of imagery were used: a mid-summer scene (1 August 1976) to determine cover types and a winter scene (24 February 1979) with snow-covered ground showing through the defoliated canopy to determine density of crown cover. An initial attempt using a May 1979 scene proved unsatisfactory because the color differentiation between vegetation types was not well-enough defined; May is too early in the growing season for a maximum variety of species to be represented. Therefore, the mid-summer image was selected. This particular scene had been computer enhanced to produce much clearer color and tonal definition.

Color infrared enlargements of the scenes were obtained at 1:250,000 scale. Four sections near Fairbanks were chosen and photographically enlarged from color negatives to 16 x 20" prints at inch-to-the-mile scale (1:63,360).

The study area coincides with the junction of four United States Geological Survey quadrangle maps at 1:250,000 scale: Fairbanks, Big Delta, Livengood, and Circle. Photographic enlargements covered the vicinities of Fairbanks (quads D-3 and D-1), Livengood (A-2), and Big Delta (D-6 and C-6). Maps were used to locate sample areas in the field and in the final mapping of vegetation units.

High-altitude aerial photos in color infrared at inch-to-the-mile scale (provided by the National Aeronautics and Space Administration and archived at the Geophysical Institute Remote Sensing Archives, University of Alaska-Fairbanks) were used for comparison to aid in unit classification, especially for inaccessible areas.

Field observations were made several times during the project. Observations in the fall as the leaves were changing colors were best for determining stands of deciduous versus coniferous trees. Field trips in the early spring before trees leafed out proved useful for discriminating aspen stands, which have a greenish tinge from a distance, from birch, which have a reddish cast to their bare branches. Spring trips were also helpful for determining density, as the snow makes it easy to see the ground through a sparse stand of trees. Distant units were observed from the roadside with binoculars and recorded with a camera. In some areas which were accessible by a short walk from the road, density and trunk size were noted as well as vegetation type.

ANALYSIS

First Cut Color and Gray Scale Delineation

The first stage was to make a preliminary map. The summer image was overlaid with acetate, and boundaries were drawn around apparent vegetation units based on their color. Four main color scale classes were developed and labeled:

A – Bright red and pink, most homogenous tone.

B – Mostly red with some mottling of blue-gray, generally darker than A.

C – A dark reddish-purple color with only occasional patches of red and more mottling of dark blue-gray than in B. Some areas of C were a pale lavender color.

D – Dark blue-gray to black. Small patches of purple, but not sufficiently bright or sufficiently large to label as C.

The boundaries between each adjacent class (i.e., A and B) were often difficult to map. However, the boundaries between alternate classes (i.e., A and C) were relatively clear. At this enlargement, Landsat MSS data is very blurry, making precise delineation of details in the darker classes especially difficult.

The overlay was then registered on the corresponding winter scene and the previous color scale classes were broken down into four categories according to gray scale classes as seen on the winter image:

0 Very bright, indicating ground totally barren of vegetation, usually on hilltops or man-made features. They were even brighter than frozen rivers which were a light gray.

1 Light gray or brown, being mostly light gray in urban areas and a light to medium brown on the hillsides.

2 Medium to dense brown, found mostly on hillsides.

3 Dark black-brown, usually a hillside in shadow.

First Level Field Check

The preliminary map was taken into the field to determine the composition of each category. Part of the investigation was to determine the level of detail that could be detected on the images, the effect of shadows on spectral responses, the vegetation density compared with observations at ground level, and the consistency of the map units in terms of vegetation content.

Adjusting the Mapping Procedures

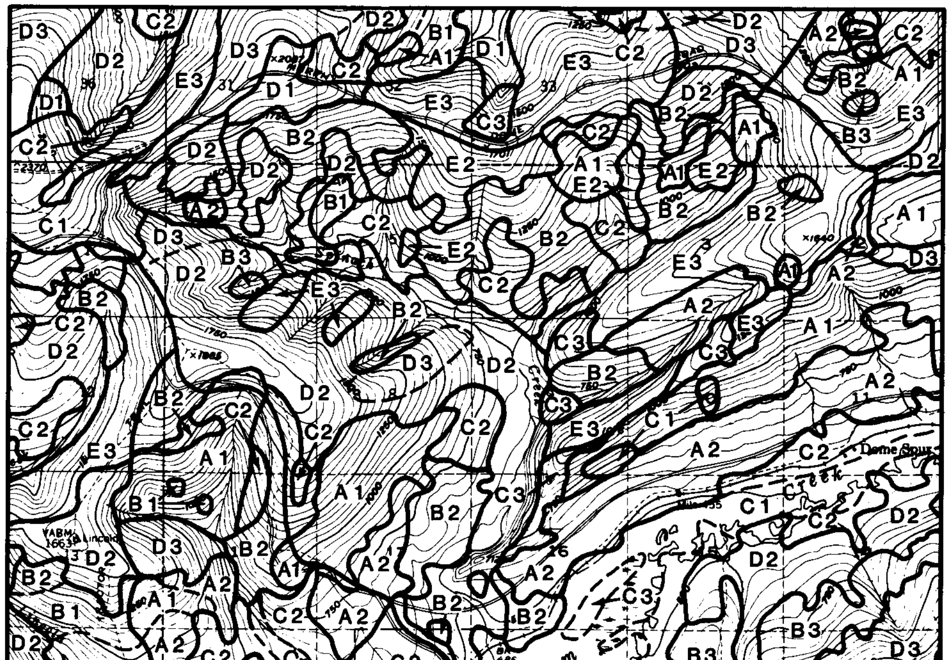
Information gathered in the field caused some adjustments in the mapping criteria. It appeared almost impossible to separate pure aspen from pure birch stands. What seems to be subtle shades of red in a class A unit might be due to slope, aspect, and shadows rather than vegetation differences. Alder and willow show up as a very bright red, similar to birch and aspen. Where all of these types occur together, it is impossible to separate them, because there is not enough detail on the image to determine the useful minute changes in texture that can be found on aerial photos. The only way to infer where there may be a difference is by knowing something about the area in question or by looking for a very light pink shade, which indicates new-growth saplings. These bushy trees tend to be found along roadsides and creeks, or in a cleared area caused by a fire or man-made disturbances.

Bright red areas may appear to be very dense deciduous growth on the summer image, yet show up only as medium-dense to sparse on the winter image (a class 1). Field checking indicated that much of the bright red reflectance was caused by undergrowth (such as wild roses, high bush cranberries, or grass) showing through a sparse canopy.

Shadows affect the reflectance values for the summer scenes when the solar elevation is around 39° as well as the winter scenes when the solar elevation is around 13° above the horizon. In summer the north-facing slopes are a few shades darker than south-facing ones, although useful information can still be derived. A deciduous stand appears darker on the north slopes due to a greater occurrence of spruce as well as the presence of shadow, making these regions trend more towards the B and C ranges of the spectrum.

On the summer image, a D class in sunlight is a bluish-gray, whereas that in shadow is very dark, almost black. At first these very dark areas were thought to be low-lying black spruce in shadow. However, field checks revealed that some of these areas were not shaded, but were indeed thick stands of tall conifers, most likely white spruce, in full sunlight. This observation warranted the creation of another color class, E.

The C class is a broad range of vegetation types found in a variety of habitats,



Portion of vegetation unit map showing area just west of Fairbanks, Alaska.

from hillsides containing some important cordwood areas to creek drainages predominately covered with shrub and black spruce. The blurry nature of the enlargements makes it very difficult to make visual judgements in this area. In broad wetlands with interweaving streams and swampy ground, a wide range of colors (from lavender with smooth texture to a mottled red and dark blue) blend into each other without distinct boundaries or mappable units. Because this project emphasizes cordwood mapping, not as much effort was made to break down the shrub and black spruce into detailed classes. However, it is desirable to make a distinction between the shrub/black spruce and potential cordwood areas. When the C spectral class is combined with the gray scale class, the smaller scrub trees tend to fall into the light bluish-gray, or 1 class. A mixed forest with large trees near the climax stage appears dark brown, in the 2 class.

A topographic map aids in interpreting some units. The locations of creek drainages and hilltops are important for such broad spectral classes as C. An experienced observer using a map could judge among different vegetation types with similar spectral responses based on the topographic context in which they were found.

A topographic map also shows slope and aspect, which can help differentiate between color and gray shade due to vegetation and that due to shadow. In winter the shadows become more pronounced. Class 3 usually indicates an area in deep shadow, and only limited density determination can be derived from it. In the subarctic these steep north-facing slopes are typically covered by sparse forests of black spruce and tundra. However, less steep north-facing slopes are often covered with birch and relatively large black spruce.

In general, it was determined that map units should be made larger. In part, this was in recognition that distinctions between birch and aspen were difficult, if not impossible, and that many vegetation units were simply too small to map at the chosen scale. (At inch-to-the-mile scale, 40 acres is 1/4" square. Clearly, a useful map cannot include many units of this size. In practice, the map units became at least 160 acres.) As a result, some of the color units came to be described in terms of the combination of colors and hues contained. This unifying of color groups also tended to broaden the range of vegetation types contained in these map units (Table 1).

TABLE 1
SUMMER IMAGE - COLOR

WINTER IMAGE - GRAY SCALE	Bright Red Scarlet, Magenta A	Red with Some Blue Mottling B	Some Mottled Red-Blue, Maroon Purple, Lavender C	Blue-Gray, Very Few Red Patches D	Blue-Black E
0 White	deciduous young trees or saplings, grassy fields, tundra, recent burns, urban areas	deciduous forest; some spruce, urban areas	tundra with black spruce, urban areas		
1 lt. blue-gray lt. brown-gray	deciduous forest; small to medium trees	deciduous forest with some spruce; small to medium trees	shrub, alder/willow, black spruce; small trees	black spruce, some shrubs; small trees	
2 brown-gray to deep brown	deciduous forest; medium to large trees	deciduous forest with some spruce; medium to large trees	mixed forest, climax stage; medium to large trees	spruce; medium to large trees	spruce forest; medium to large trees
3 black deep shadow			mixed forest	spruce forest	spruce forest

Notes: For the mostly deciduous A and B categories, moving from a 1 to a 2 indicates older trees as well as a higher proportion of conifers.

C1 areas, usually found in drainages and floodplains, are not useful sources of cordwood; C2 areas on a slope are likely to be good cordwood sources.

D1 areas of black spruce appear as a light-bluish-gray in winter images; deciduous vegetation appears light-brownish-gray in the winter color infrared image.

An E2 category is often a forest of tall white spruce in a sunlit location. The E3 category is not well defined, but probably has a low cordwood potential.

Preparation of Final Maps

Based on the described analysis, preparation of the final maps began. A clear acetate overlay was prepared for each area to be mapped. The overlay was made by tracing lakes, roads, streams and other features from a USGS map onto the acetate, using pen and ink. This way, information from the summer and winter images could be registered for vegetation analysis and these results could, in turn, be registered back to section and township grids for the purpose of numerical inventory.

The overlay was then registered to the summer image. Boundaries of spectral class units as described above were delineated. Next, the overlay was placed on the winter image where subunits based on gray scale class were delineated. A few anomalous map units were found, usually as a result of human activities or naturally occurring barren ground. These were labeled accordingly (for example, urban, barren, or field).

In all, approximately 962,000 acres in the vicinity of Fairbanks were mapped on acetate overlays keyed to inch-to-the-mile maps. The area covered ranged from lower Goldstream Valley in the west to the Salcha River in the east, and between the Tanana River in the south and the Chatanika River in the north. A small portion of one map is shown in Figure 1.

Composition of Map Units

Table 1 represents only a qualitative relationship. To obtain a quantitative relationship, a more rigorous sampling technique must be used. Thus, once the maps were prepared, ten sample units from each category were chosen at random. Each map unit was superimposed on a color infrared, high-altitude aerial photograph and the species composition and overall density estimated. The values from the ten units were then averaged and standard deviations found for birch, aspen, spruce, willow-alder and shrub. Examination of the standard deviations showed that birch and aspen should be combined into a broad-leaf tree descriptor, while willow-alder should be included in the shrub descriptor category. These results are shown in Table 2.

In the table, standard deviations are not a measure of error as much as they are an indicator of the range of percent composition of vegetation type found in each spectral/gray scale category. In many respects, the standard deviations reflect two factors: Most interior Alaskan forests are actually "mixed" to some extent; and at the scale used here, the minimum useful map unit size employed often results in grouping of vegetation types.

Distribution of Categories According to Aspect

In Table 3 the map units used for the preceding work have been analyzed in terms of direction of topographic slope (aspect), thus yielding a more refined matrix of categories. This table shows that while the 1 and 2 gray scale classes are generally found on slopes of all aspects, the 3 class is found on slopes with a north-

Table 2

PERCENT COMPOSITION AND
AVERAGE DENSITY OF MAP UNIT CATEGORIES

	Broad-leaf	Spruce	Shrub	Average Density (0-3)
A1	81 ± 13	5 ± 5	14 ± 13	2.5 ± 0.8
A2	96 ± 8	3 ± 8	1 ± 1	3.0 ± 0.0
B1	68 ± 18	20 ± 13	12 ± 9	2.3 ± 0.4
B2	81 ± 17	17 ± 15	2 ± 3	2.9 ± 0.3
B3	75 ± 19	17 ± 14	18 ± 20	2.4 ± 0.7
C1	14 ± 17	28 ± 24	58 ± 31	1.1 ± 1.0
C2	49 ± 15	36 ± 13	15 ± 12	2.5 ± 0.5
C3	50 ± 27	24 ± 17	27 ± 34	2.3 ± 0.7
D1	3 ± 12	35 ± 18	62 ± 19	1.2 ± 0.4
D2	12 ± 18	68 ± 16	20 ± 19	2.2 ± 0.6
D3	12 ± 10	56 ± 19	32 ± 19	1.9 ± 0.7
E2	9 ± 7	79 ± 18	13 ± 21	2.3 ± 0.7
E3	5 ± 4	53 ± 32	42 ± 32	1.8 ± 0.8

Table 3
DISTRIBUTION OF CATEGORIES
BASED ON ASPECT

	N	NE	E	SE	S	SW	W	NW	O
A1				4	4	2			
A2		1	3	3	2	1			
B1			1		8				
B2			2.5	2.5	1	2.5	.5	1	
B3	2	2					1	5	
C1				1	3			1	5
C2	1	1	1		1	3	2	1	
C3	5						3	2	
D1	1								9
D2	2	1	1	2	1	1		1	1
D3	6	2						1	1
E2			1	1	3	4	1		
E3	5							5	

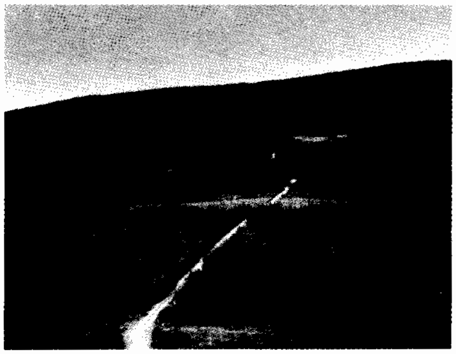
erly component and, therefore, is often related to shadow. Also, the A1, A2, B1, and B2 classes are found generally on east- and south-facing slopes. Thus a more refined category can be defined.

Final Designations

It is now possible to improve the preliminary matrix relating color and gray scale units. In the matrix shown in Table 4 the potential cordwood-yielding categories have been outlined in black.

Area Measurements

Finally, estimates of the total area covered by each classification were made. Each acetate overlay was registered to its respective map and placed on a map-area digitizer. Each square mile section on the map was measured separately, with the digitizer calculating the area for each category in fractions of a square mile.



North facing slope as viewed across a flat valley in late July. Vegetation units are C2, foreground; open area to base of hill, C1; large tree area at base of hill, C3; and hillside stands of A2, B1, B2, D2 and E3.

Since a section on the map is approximately one square mile and equal to 640 acres, the fractional area was multiplied by 640 to derive an approximation of the total acreage for each section. The acreage measurements for some of the sections do not total exactly 640 acres because:

- On a topographic map each section is not exactly one inch square.
- Some of the sections are on the boundary of the map and are not a full section.
- It is difficult to trace each boundary exactly the same way each time.
- The photographic enlargements of Landsat images are slightly off scale from the map, requiring that the acetate overlay be periodically shifted to register with the topographic map. Because some of

Table 4

FINAL DESIGNATION OF COLOR - GRAY SCALE UNITS IN TERMS OF VEGETATION DESCRIPTIONS

WINTER IMAGE - GRAY SCALE	SUMMER IMAGE - COLOR Bright Red A	Red with Some Blue Mottling B	Some Mottled Red-Blue, Maroon Purple, Lavender C	Blue-Gray, Very Few Red Patches D	Blue-Black E
0 White	Low-lying deciduous vegetation. Open crown cover, grassy fields, recent burns, urban areas. Sapling size trees.	Low-lying deciduous vegetation with some spruce. Some urban areas. Sapling size trees.	Alpine tundra with some black spruce.	Largely bog.	Not observed.
1 Lt. Blue-Gray Lt. Brown-Gray	Largely closed deciduous forest with ~10% shrub, little spruce. Sapling to pole size trees.	Largely closed deciduous forest with 20% spruce and 10% shrub. Sapling to pole size trees.	Open crown cover shrub thicket and treeless bog, 60% shrub, 30% black spruce, 10% deciduous trees.	Medium crown cover shrub thicket, 65% shrub, 35% spruce. Sapling size trees.	Not observed.
2 Brown-Gray to Deep Brown	Completely closed deciduous forest with little spruce or shrub. Pole to commercial size trees.	Completely closed deciduous forest with 20% spruce, no shrub. Pole to commercial size trees.	Largely closed crown cover. 50% deciduous, 35% spruce, 15% shrub. Pole to commercial size trees.	Largely closed crown cover spruce forest, 70% spruce, 20% shrub, 10% deciduous. Pole to commercial size trees.	Largely closed crown cover, 80% spruce, 10% deciduous, 10% shrub. Pole to commercial size trees.
3 Black Deep Shadow	Not observed.	Largely closed crown cover. 75% deciduous (very likely largely birch), 17% spruce, 18% shrub. Pole to commercial size trees.	Largely closed crown cover. 50% deciduous, 25% spruce, 25% shrub. Commercial size trees.	Largely closed crown cover, spruce forest, 80% spruce, 10% deciduous, 10% shrub. Commercial size trees.	Moderate crown cover, 50% shrub, 50% spruce (largely black spruce). Sapling to pole size trees.

Table 5
ACREAGE MEASUREMENTS BY SECTION
AND SPECTRAL/GRAY CLASS
FAIRBANKS D-3 QUAD

T1N R4W	A1	A2	B1	B2	C1	C2	D1	D2	D3	E3
Sec 1				45	234			164	62	85
Sec 2					221	6		219	100	
Sec 11						246		391		
Sec 12	24			28		91		355		198
Sec 13	164	9	94	39				230	70	79
Sec 14	146		5	15		43		253		207
Sec 23	25	39		365		79	54	62		
Sec 24	3	67	29	376			74	62		
Sec 25		176		221			49	209		
Sec 26		19		235			211	186		
Sec 27				235						
Sec 34				19			178	114		
Sec 35		209		358			57	17		
Sec 36		92		88	185	98		179		

Note: Vegetation classes not listed here (such as A0, C3, and E1) were not present in this township.

the boundaries are arbitrary, the cumulative accuracy is probably not changed much. The acreage estimates were presented in a set of tables; Table 5 is one of these. Due to time limitations, only half of the Fairbanks D-3 quadrangle was inventoried.

Volume Estimates

Wieczoreck[2] has estimated the sustained yield of the State of Alaska forest lands within 60 miles of Fairbanks and found that 31,000 cords of hardwoods and 2800 million cubic feet of softwoods could be harvested per year. (Interior Alaska's deciduous broadleaved trees — aspen, cottonwood, and birch — are considered to be hardwoods; the coniferous spruces are softwoods to foresters.[3]) In 1975 personal-use fire permits for 20,000 cords were issued and the projected 1980 permit issuance was for 34,000 cords. One can conclude that State of Alaska forests in the Fairbanks area appear to be near their sustained-yield limit. Use of Landsat imagery can help verify or disprove this assumption. Wieczorek[2] defined a three-dimensional matrix describing forest types by species, size class, and stocking density, so that volume estimates could be made. His five species codes included not only keys for uniform stands of, for example, paper birch or white spruce, but mixed stands (no single species composing more than 69% of the stock) and hardwood stands in which the species could not be ascertained. The size class codes were saplings, pole timber, and saw timber; the three density codes were based on percentage of crown closure, from 10% minimum for code 1 to 100% maximum in code 3.

Wieczorek divided the resulting categories into immature and mature timber types. He calculated gross volumes for the mature types and mean annual increments for the immature types. Furthermore, he computed spruce and hardwood volumes separately, apparently assuming that spruce would become construction material and that hardwoods would be used as cordwood. Wieczorek's work was directed toward computing a mean annual cut giving a sustained yield. Clearly, this involves not only the standing gross volume of mature trees, but also the mean annual increment of the immature trees.

In our work we only used Wieczorek's volume estimates to arrive at the volume of mature trees now available (Table 6). Clearly, the process could be extended to give a sustained yield if such a calculation is desired. Furthermore, we assumed as

Table 6
SATELLITE IMAGERY RELATED TO WIECZOREK'S VEGETATION MATRIX

Matrix Element (Wieczorek)	Gross Volume/Acre in ft^3 of Hardwood	Closest Vegetation Category (Satellite Imagery)
H21	810	A1
H22	1120	A2, B3
H23	1430	B1
H32	1500	B2
H31	1130	*
H33	1900	B2
M21	470	*
M22	630	C2
M23	790	C2
M31	680	*
M32	890	C3
M33	1100	C3

*There is no correspondence for three categories. In each of these cases, either the volume/acre is low or the frequency of occurrence is low, or both.

Northwest-facing slope as seen across a broad valley in late May. Foreground and lower hillside are D1 and D3 vegetation units, with a band of D3 across the middle of the hill. A B2 area (mostly birch) covers the upper slope.

did Wieczorek that spruce will not be used for fuel purposes. Inverting Table 6 and averaging in the cases of dual correspondence, we have the estimates shown in Table 7.

In order to arrive at a volume estimate of cordwood potential in each square mile section of the area of the Fairbanks D-3 quadrangle measured, the area measurements were multiplied by the corresponding volume values just described to yield seven pages of tables giving the standing mature cordwood volume estimates by township and section within the Fairbanks D-3 quadrangle. Table 8 gives the estimate for the same township and sections as noted in Table 5.

DISCUSSION

The objective of this work was to demonstrate a low-cost method of inventorying cordwood at a reconnaissance level. In all, 962,000 acres were mapped. However, because of time limitations only 120,000 acres were inventoried by means of measuring the areas of the various vegetation categories in each section. The cost for the area actually inventoried came to 16¢ per acre. It is estimated that adding the relatively small incremental cost of measuring the vegetation categories on the balance of the maps (and increasing the area inventoried by a factor of eight) would decrease the cost per acre to 2½¢.

Mapping and inventory were performed at 1:63,360 scale (or one inch to the mile). This scale is probably the limiting one for the mapping technique described here. We suggest that, if possible, inventories should be done on as small a scale as is practical for the purpose in mind. For instance, reducing the scale by half (125,000 scale) decreases the actual map area by four. At this scale, map unit boundaries become more distinct, so that maps are easier to draw. However, it should be realized that position of the map unit categories will change. This stems from the requirement for greater grouping of color and gray scale classes as map units necessarily include larger portions of the earth's surface. (The actual size of the minimum useful map unit as drawn on the map remains constant.)

People using Table 8 need to consider several factors.

1. The right-hand column of Table 2 shows that there was a wide variation in the density within each of the vegetation classes, averaging about 30%. Although one would expect these variations to balance out over a large area, one section is considerably too small to rely on this effect. Hence, a variation of around 30% should be anticipated for the cordwood volumes given here for each section.

2. An inventory by section can be somewhat misleading (though the circumstance of ownership pattern practically demands that the reconnaissance be performed in this manner) because vegetation unit boundaries meander across sections, and entire vegetation units are rarely contained in a single section. At the same time, the vegetation units are usually considerably smaller than a section. The result is that portions of several units are found in each section, which produces averaging-out that tends to mask the locations of highly significant stands of potential cordwood.

3. On the other hand, low-density stands found throughout an entire section may yield a cordwood volume equal to that of a section with one relatively small area of high density and the balance of the section with no useful trees at all. In this case, the first section may not be worthy of consideration because the cost of providing access throughout the section would be prohibitive while the cost of access to the small high-density stand in the second section would be acceptable.

Bearing these factors in mind, we see that while the values given in Table 8 yield an estimate of the total volume of cordwood technically available, this is far from the volume pragmatically available. The best use of the table is that of an indicator of locations where large volumes of cordwood from mature trees might be available. After identifying candidate areas from the table values, a person seeking firewood should consult the vegetation unit map to determine whether cordwood is available at a useful density and, by considering vegetation units in adjacent sections, whether truly large volumes are actually available. Next, access should be considered. This is very important in interior Alaska, because access may require tens of miles of roads. Finally, ownership of potential cordwood areas must be considered: some cordwood areas are virtually inaccessible because of other planned uses for the land. For instance, the Fairbanks North Star Borough has received title to large areas of state land in the Fairbanks area. The Borough Assembly has announced its intention to subdivide and sell this land for development purposes. It is quite unlikely that much of this land will be available for cordwood cutting except along road right-of-ways as access is created and by

Table 7
VOLUME OF MATURE HARDWOODS PER MAP UNIT CATEGORY
(rounded to nearest 100 cubic feet per acre)

A1 =	800 ft^3/A
A2 =	1100 ft^3/A
B1 =	1500 ft^3/A
B2 =	1900 ft^3/A
B3 =	1100 ft^3/A
C2 =	700 ft^3/A
C3 =	1000 ft^3/A

Table 8
STANDING MATURE CORDWOOD VOLUME ESTIMATES FOR TOWNSHIP 1 NORTH, RANGE 4 WEST OF THE FAIRBANKS D-3 QUADRANGLE MAP

Section	Volume (cu ft)	Volume (cord)
T1N R4W		
1	8.55×10^4	9.5×10^2
2	4.2×10^3	4.67×10
11	1.72×10^5	1.91×10^2
12	1.36×10^5	1.51×10^3
13	3.56×10^5	3.96×10^3
14	1.83×10^5	2.03×10^3
23	8.12×10^5	9.02×10^3
24	8.34×10^5	9.27×10^3
25	6.14×10^5	6.82×10^3
26	4.67×10^5	5.19×10^3
27	4.46×10^5	4.96×10^3
34	3.61×10^4	4.01×10^2
35	9.1×10^5	1.01×10^4
36	2.68×10^5	2.98×10^3

the new private owners. Since the timing of these uses is difficult to predict, it is not possible to consider how wood in these areas will impact the overall availability of cordwood.

As an example of the use of Table 8, it can be seen that section 35 in Township 1 north, Range 4 west is estimated to contain 9.1×10^5 cubic feet of cordwood. This is the largest volume per section listed. A check with the vegetation-type map shows that this section contains a great deal of B2 and A2. Nearby, sections 23 and 24 contain an estimated 8.12×10^5 and 8.34×10^5 cubic feet of cordwood respectively. These units also contain large areas of B2. As Table 7 shows, vegetation category B2 contains the largest potential cordwood volume per acre (1900 ft^3/A). These three sections contain the three greatest potential cordwood volumes of all the sections inventoried, but all three are located within the Goldstream compartment of the State Forest Lands. Sections 23 and 24 are currently being offered for cordwood cutting by the State.

The Goldstream compartment extends to the west from the area mapped and inventoried here. A glance at the satellite imagery suggests that it contains many more sections with high cordwood density. The State's sustained-yield cordwood estimates are based partly on these high-volume timber stands, and even if additional cordwood areas are harvested elsewhere, Table 8 suggests that the density and maturity of the trees probably will be such that the harvesting process will be less efficient than in the cutting areas currently being offered by the State.

A caution concerning the use of the tables should be made: whenever a section is selected for closer scrutiny, the statistical variation in density should be borne in mind. The area should be examined for factors such as aspect which may cause the actual density to be on the low side of average for that vegetation category.

Finally, it should be stressed that the technique described here is largely a reconnaissance process aimed at exploring a wide region quickly in order to locate areas for closer investigation. Before consideration of a potential cordwood area progresses very far, a site should be visited.

RECOMMENDATIONS

It may appear that this demonstration project has identified a number of areas with immediate cordwood potential in the Fairbanks area, and therefore a continued supply of cordwood may not be a major problem. This is probably misleading. As has been pointed out, the state is already offering the best sites. Many of the remaining sites are relatively inaccessible or of considerably lower density. In addition, although we were not able to take ownership into account in a thorough way, many of the accessible and relatively high-density sites appear to be in private ownership or will be sold into private ownership in the near future. Therefore, the yearly sustained yield from state forests may very well approximate the total cordwood production available to the community without building expensive roads to remote timber stands.

We recommend that if any local entity is concerned about providing the Fairbanks area with long-term cordwood supplies at quantities greater than the sustained yield from the state forest lands, they take the following steps:

- Complete the reconnaissance begun here.
- Perform adequate field verification.
- Identify source areas which are likely to remain in the public domain.
- Enter into negotiations with the agencies managing these lands, with the objective of securing the cordwood supplies on these lands for future use.

For example, we found large areas of immature forest on the federal military reservation north and east of Eielson Air Force Base. Originally the area contained a bombing and gunnery range, and later there were anti-aircraft missile sites, so it also has an extensive road network. It is possible that this area could yield significant cordwood supplies even now; however, the yield could be significantly greater in a decade or two. If this area were to be set aside for this use, a management plan including fire protection should be initiated soon.

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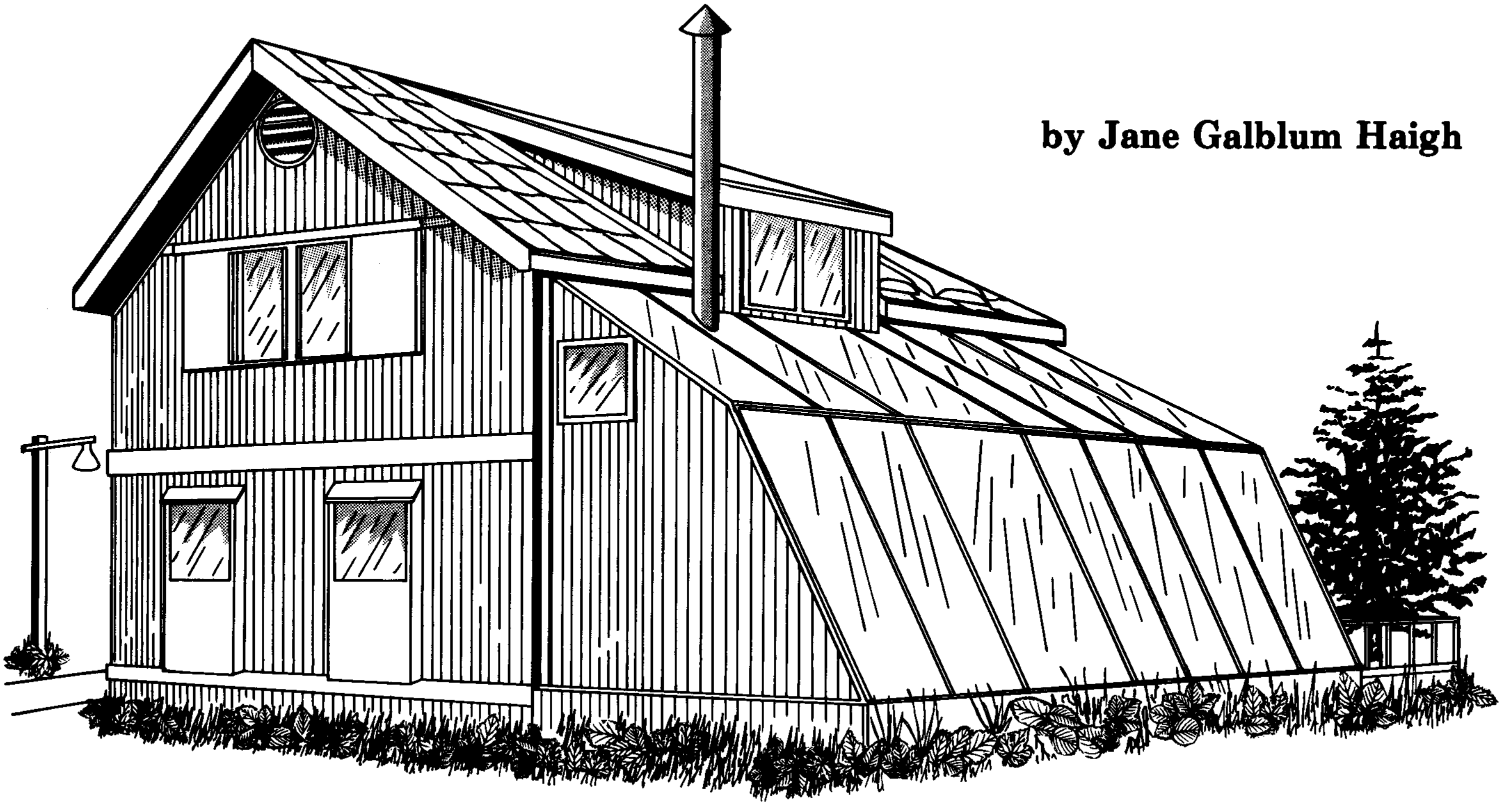
THE SUPERINSULATED PERSPECTIVE HOUSE

by Jane Galblum Haigh



PERSPECTIVE

The most energy-efficient shelter would be a small superinsulated box with no windows, but houses have to meet more of our basic human needs than simple shelter. Energy efficiency has to be put into perspective with our other needs: light, air, and space. The "Perspective House" is designed to be extremely energy efficient, and yet provide a rich and varied environment as a preventative for cabin fever. It is also designed to permit year-round food production via features that are integrated into the total energy program for the house.

The design begins with a small superinsulated story-and-a-half box (24′ x 32′) for greatest energy efficiency. There are no bays, projections, or cantilevers which are costly to construct and difficult to insulate properly. Architectural gymnastics are confined to the interior of the house, where a variety of levels and spaces "explodes" the basic box, demonstrating that a square house does not have to be boring.

The open-plan first floor provides a living room with sunken seating area and a sunny dining alcove open to a high ceiling. Patio doors in the dining room open into the attached greenhouse/sunspace. The large centrally located kitchen is open to the living area and also has windows into the sunspace. The first-floor bathroom connects directly into the sauna which, together with a hot-tub in the sunspace, provides for family bathing and relaxation.

The large sunspace provides flexible family living space with a large deck, sauna and hot-tub as well as growing beds for vegetables and flowers. The sunspace is separated from the house with double-

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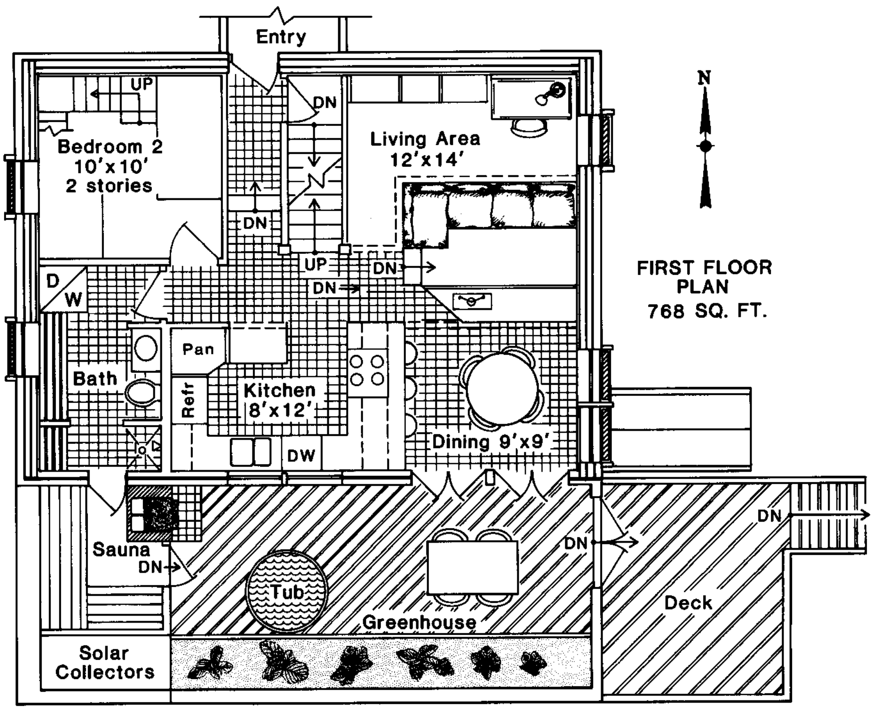
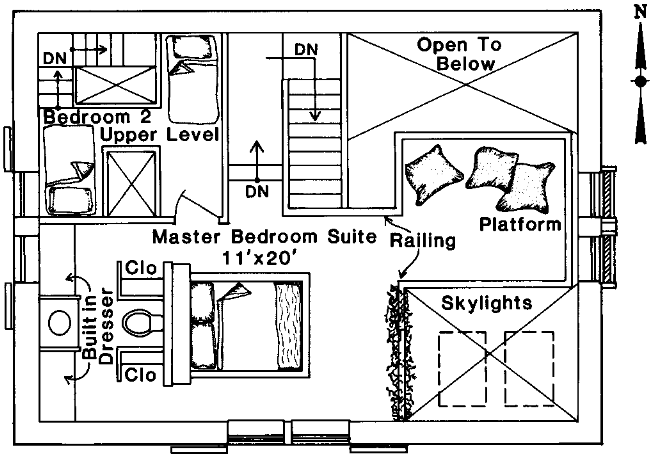
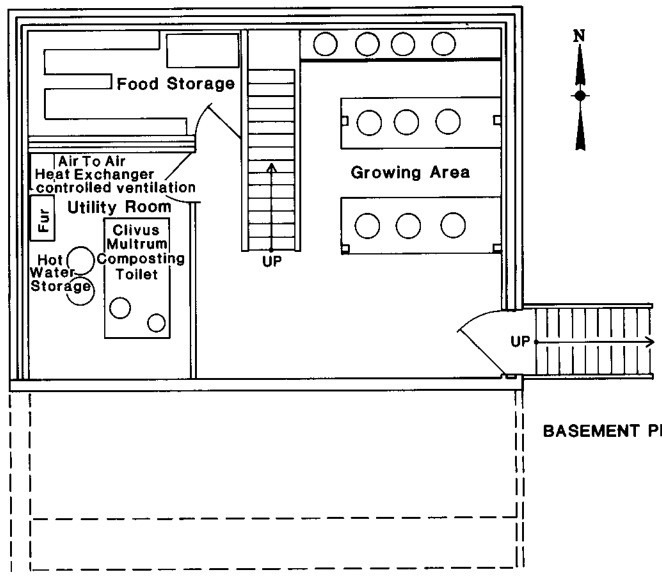


FIRST FLOOR
PLAN
768 SQ. FT.



SECOND FLOOR
PLAN
552 SQ. FT.



BASEMENT PLAN

pane windows and doors so that it does not have to be heated during the coldest months. However, it would probably be usable from late February through October in Fairbanks.

For the children, or for a studio, there is a unique 10 x 10 bedroom/playhouse, a full story and a half in height, with its own built-in loft beds. The spacious master suite occupies the entire second floor, with bedroom, half-bath and dressing area, plus a skylight-enhanced platform overlooking the living and dining areas.

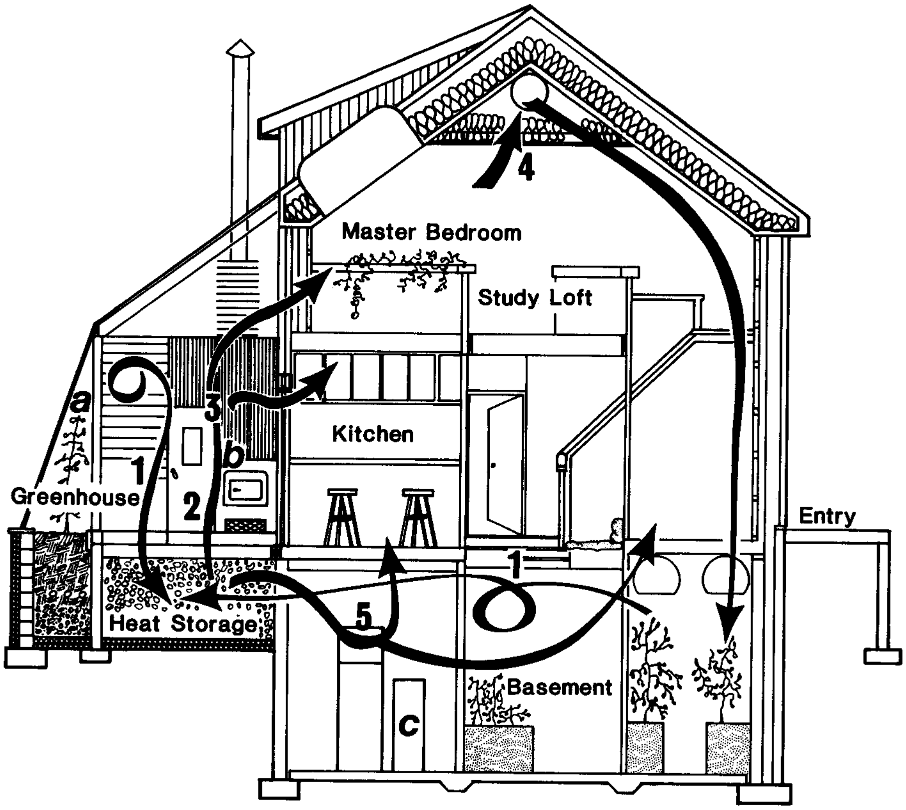
The basement is designed to accommodate a growing area for producing flowers or vegetables such as tomatoes, equipped with metal halide lights, and deep gravel-and-earth growing beds which can filter and reuse greywater. The growing area complements the function of the greenhouse, providing a place to start seedlings in late winter before they are transplanted to the greenhouse as it warms up in the spring.

ENERGY SYSTEMS

Superinsulated shell

Basically, the primary energy system is an energy-conserving one: the superinsulated exterior shell. This cuts the energy needed for heating to a bare minimum so that a large percentage of that energy can be supplied by solar heat gain from the sunspace. Double 2 x 4 walls are insulated with 16" of fiberglass batts (R-52). The roof is constructed with 24"-deep lumber and plywood trusses filled with 18" of fiberglass batts (R-60), thus allowing a 6" space for ventilation.

The foundation walls consist of double 6" concrete block walls with 4" of Styrofoam™ between them (R-18). The inner block wall acts as thermal mass for the basement, providing a thermal flywheel effect for the house. The floor joists are



AIR

1 Hot air pulled into heat storage from basement lights and greenhouse.
2 Hot air rises through deck in greenhouse.
3 Hot air enters house through upper story vents, doors and windows.
4 Hot air is drawn from ceiling into basement through ducts, some heat is stored in walls and floors in basement.
5 On colder days, heat is pulled from rock bed storage into house. Conventional forced air furnace may augment heating if necessary.

HOT WATER

a Water is heated in solar collectors on south side of sauna, inside greenhouse and in:
b Wood stove in sauna.
c Hot water is stored in 250-gallon insulated water tank with exchanger.

MECHANICAL SYSTEMS

supported on the inner wall, allowing a continuous sealed vapor barrier of 6-mil polyethylene to run under the slab, onto the outside of the inner block wall and the rim joists, and on the outside of the inside frame wall and up across the ceiling. This effectively prevents cold air infiltration through the rim joist area, one of a conventional home's greatest problem areas. To further cut down on infiltration, the front door is protected by an arctic entry.

Air-to-air heat exchanger

With the house constructed to be completely tight, an air-to-air heat exchanger is recommended. The exchanger provides forced ventilation, recapturing the heat from warm exhaust air and using it to heat fresh incoming air, thus eliminating 70 to 90 percent of the heat normally lost through infiltration.

Windows and shutters

The house is designed with only a few windows on the east and west and none on the north side, where they would be net heat losers. For greatest thermal efficiency, the house was designed with double-pane windows and automatically operated exterior shutters made of 2" foam covered with nylon fabric. Shutters would be programmed to open at daylight and close at sunset. (A shutter of this type was designed by Ed McGrath, and a prototype was installed on the Energy Demonstration Building at the Tanana Valley Fairgrounds. Unfortunately, exterior shutters are probably not cost effective. Triple pane or heat mirror windows might be substituted if the house were to be constructed today.) A generous number of doors and windows are located on the south side, opening into the protected environment of the sunspace.

Greenhouse/sunspace

With the heat loss from the house cut to an absolute minimum (typically 10,000 to 15,000 BTUs/hr maximum for houses of this type), solar heat can make a major contribution to the total heating load. The large greenhouse/sunspace is the major solar feature. The sunspace is thermally isolated from the house so that it cannot rob house heat in the coldest temperatures, although the occupants could choose to heat the sunspace. Heat that is captured by the sunspace can be moved into the house directly through windows, doors and vents, or stored in a rock bed beneath the greenhouse deck. A hot tub within the space contributes thermal mass, as does a masonry chimney for the sauna's wood-burning stove.

Solar collectors

Active solar collectors are located within the greenhouse on the south wall of the sauna, where they are protected by the greenhouse glazing. The collectors contribute to domestic hot water heating, and heat the hot tub.

Wood heat

The principal backup heat is provided by a water-jacketed wood-burning stove located in the sauna within the greenhouse. The heat produced can be used or stored in a variety of ways. The water-jacketed wood stove together with the solar collectors should supply most of the domestic hot water throughout the year. With a masonry chimney mass and provision for heat transport and storage by means of both air and water, the sauna stove could be fired mostly at high temperatures and thus would operate very efficiently.

Lights

The final backup heating system is in the form of halide lights in the basement growing area. Operation of the lights would be the largest utility expense, but would have a tremendous payback in the form of year-round fresh tomatoes, cucumbers and melons or even fresh flowers. Conversely, heat produced by the lights as a by-product of the growing operation can be used or stored directly in the mass of the basement or indirectly in the rock bed.

EAST ELEVATION

MECHANICAL SYSTEMS AND HEAT STORAGE

Air systems

An air handling system is used to transport and store heat produced from various sources. A rock bed under the greenhouse deck that is insulated from the surrounding ground is the main storage device. Solar- (or stove-) heated air from the green house is allowed to enter the house through windows, doors and vents into the upper story. In the house, heated air is collected from the peak of the ceiling and moved mechanically through ducts into the basement. The mass of the basement itself will store some of the heat. When the temperature exceeds a predetermined point, excess heat is pushed into the rock storage bed. Hot air from the greenhouse may also be pulled directly into the rock bed. Heat stored in the rock bed may be allowed to radiate directly into the greenhouse, or the warmed air may be pulled in through ducts to heat the house.

Water

Domestic hot water is produced by solar collectors within the greenhouse, and by the water-jacketed wood stove. A closed-loop system is used to transfer heat to a large water storage tank with an electrical backup coil.

Wastewater

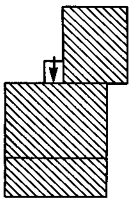
The house is designed to accommodate a Clivus Multrum composting system, with two toilets and a chute for kitchen wastes. The composted material can be used for ornamental plants in the growing beds.

The greywater is filtered and then is piped into a 6"-deep gravel layer under the growing beds. Filtered by the soil layer, it feeds the plant roots, and also contributes waste heat to the mass of the soil.

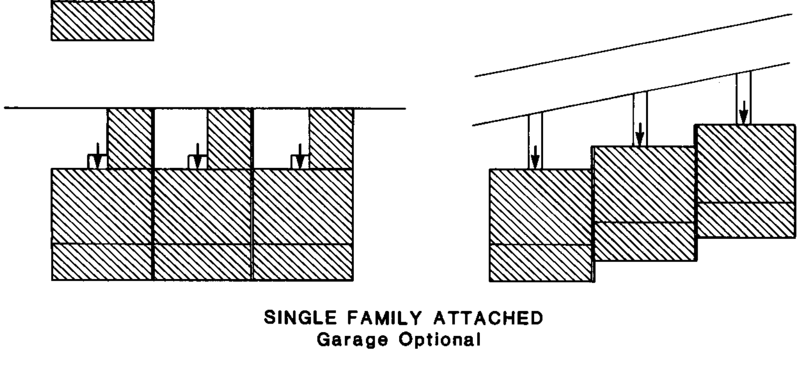
MARKETABILITY

Even with the long dark winter hours encountered in the far north, this house provides an environment that is light, spacious, warm and activity-centered. The Perspective House is designed to provide maximum comfort at a minimum maintenance cost.

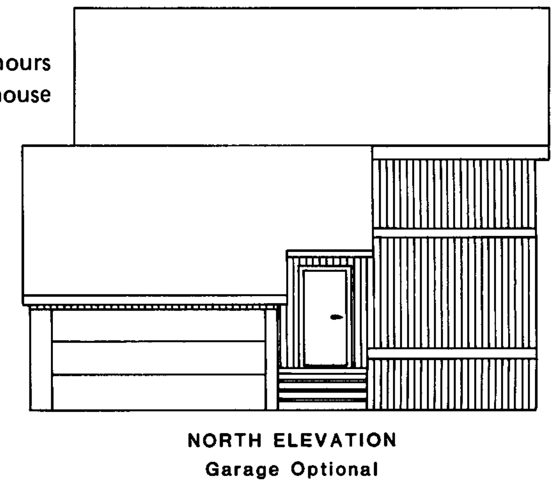
Despite its many contemporary energy-saving features, the Perspective House blends quite nicely into traditional urban or rural housing developments. Because these units can be easy "add-ons" to create a townhouse effect, their versatility and saleability are enhanced. None of the energy-conserving or passive solar mechanical features of the Perspective House detracts from its "conventional" appearance. And – vitally important for standard financing – the house conforms to all HUD and FHA requirements. ♦



SINGLE FAMILY
Garage Optional



SINGLE FAMILY ATTACHED
Garage Optional



NORTH ELEVATION
Garage Optional

Heap-Leaching for Low-Grade Precious Metal Deposits

by Thomas Albanese

The Candelaria Mine, Nevada, is one of the largest heap-leach operations in the world. This photo, taken in early 1983, shows the Lucky Hill pit in the foreground and the Mt. Diablo pit behind. (All photos courtesy of Tom Albanese.)

BACKGROUND

Over the past two decades, technological and metallurgical advances have made possible the exploitation of extremely low-grade precious metal deposits. The process, known simply as "heap-leaching", enables mine operators to forgo many of the capital and operating costs normally associated with a mining venture. This article will describe the heap-leaching process in detail, and point out some potential applications of this technology which may be utilized in Alaska. Particular emphasis will be given to the Candelaria Mine, Nevada, owned and operated by Nerco Minerals Company of Fairbanks, Alaska, and the Alligator Ridge Mine, Nevada, in which Nerco Minerals holds a 50 percent interest.

THE HEAP-LEACHING PROCESS

The basic heap-leach process is relatively simple. The ore is crushed to ½" to 2" size, placed in heaps on an impervious platform and subsequently sprayed with a weak solution of cyanide and lime or caustic soda. As the solution percolates through the heap it will absorb the gold and silver contained in the ore. The absorbed (pregnant) solution then drains off the impervious pad into a solution pond at the base of the heap.

This pregnant solution is pumped to a process facility where it is processed in one of two different ways: the Merrill-Crowe zinc or carbon-in-pulp (CIP) processes.

The Merrill-Crowe process has been used since the turn of the century by various South African mines. The pregnant solution is initially passed through a deaeration process which removes most of the oxygen from the pregnant solution. The solution is then brought into contact with zinc powder under pressure in precipitate filters. The zinc replaces the gold and silver in the solution, and the two precious metals come out as a sludge collected on filter cloths. The barren solution is treated and recycled through the leaching system. Flux is added to the sludge which is then charged into a furnace for melting into a doré product. The doré, poured into 500-

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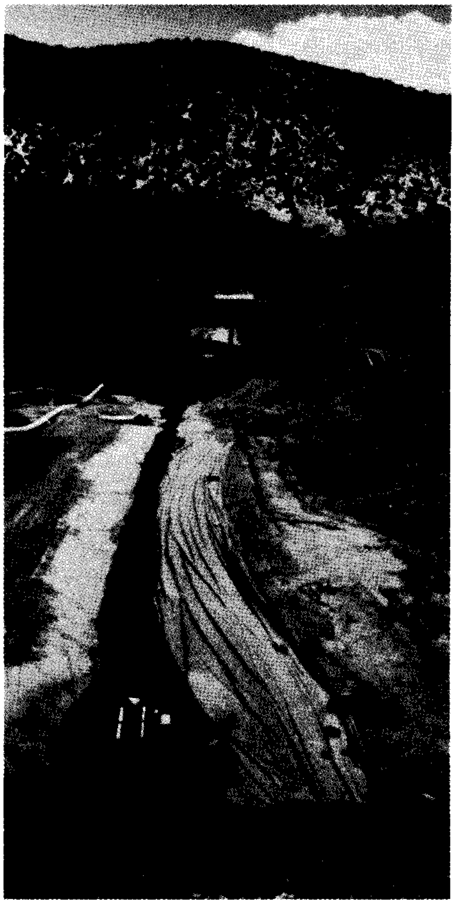
700 ounce buttons or bars, is ready for shipment to a refinery for upgrade to 999 fineness Hallmarked gold and silver products.

The CIP process is a recent innovation, thanks to both the U.S. Bureau of Mines and the Homestake Mining Company. This technique takes advantage of the ability of activated carbon to absorb complex precious metal ions. The pregnant solution, after passing through vats of the activated carbon (roasted coconut shells in many cases), will deposit the gold and silver in the carbon granules. As in the Merrill-Crowe process, the barren solution is treated and recycled through the leach process. The carbon granules are loaded with precious metals until the carbon itself assays between 100-500 ounces per ton, depending on the nature of the ore. The loaded carbon is stripped of the precious metals by a hot caustic cyanide solution. The precious metals are electroplated from this solution onto steel wool. The electroplated precious metals are added with flux and charged into a furnace to produce doré bars. As in the Merrill-Crowe process, these bars are shipped to a refinery for final upgrade.

These two processes each have their particular application, depending on the economics and the nature of the ore. Generally, the Merrill-Crowe process is less capital intensive and more economical in silver-rich ores; the CIP process is usually more efficient on an operating-cost basis. In either case, total recovery of the precious metals in the ores ranges between 50-80%.

DEVELOPMENT OF HEAP-LEACHING

Leaching of ores dates back to the mid 1700s when it was used at the Rio Tinto Mine in Spain to recover copper from oxide ores. In the United States, the basic leaching process has been increasingly employed since the 1920s to recover copper from low-grade oxide ores. Leaching has also been used to extract uranium from western roll-front deposits.* It is not until recently, however, that the leach technology has been available for ores containing gold and silver.



A ditch from the heap-leach pads drains pregnant solution loaded with gold to the refinery, Alligator Ridge Mine.

The initial heap-leaching work was performed by the U.S. Bureau of Mines in 1967. Initially it was evaluated as a potential low-cost technique to recover submicron-size gold particles from limestone and dolomite-sandstone ores. By the end of the 1960s it became apparent that heap-leaching was in fact an economically viable technique for processing low-grade ores.

In 1970 a 2000-ton test heap was leached at Carlin, Nevada, and by 1971 commercial heap-leaching of 10,000 tons per month began. During the 1970s more companies became interested in heap-leach technology and its application. Additional research by the U.S. Bureau of Mines and others perfected the technique of agglomeration to assist recovery in clay-rich ores. By 1979 an estimated 10 percent of total U.S. primary production was from heap-leach operations; by 1982 this had increased to 20 percent. Additionally, many new projects are being contemplated which would employ heap-leach technology.

THE ECONOMIC BENEFITS OF HEAP-LEACHING

Heap-leaching is a relatively simple operation mechanically. Except for crushing the ore to the size of gravel and building the pads, there is no mass movement of materials through a series of complex mechanical processes. Movement is only of solution through the process; in fact, the only major moving parts in a typical process are the solution pumps. This simplicity not only removes the burden of high capitalization from a plant but it also reduces operation costs throughout the life of the mine. An added advantage is that fine grinding of the ore, an expensive process needed in most mining operations, is eliminated.

Economically, the benefits of a heap-leach operation may be applied to the entire spectrum of mine operations. Small-mine operators in the western U.S. have applied heap-leaching techniques to deposits not much bigger than a typical Alaskan placer. On the other hand, an operation like Candelaria can successfully employ heap-leaching on a 10,000 tons per day (TPD) operation.

TO USE OR NOT TO USE HEAP-LEACHING

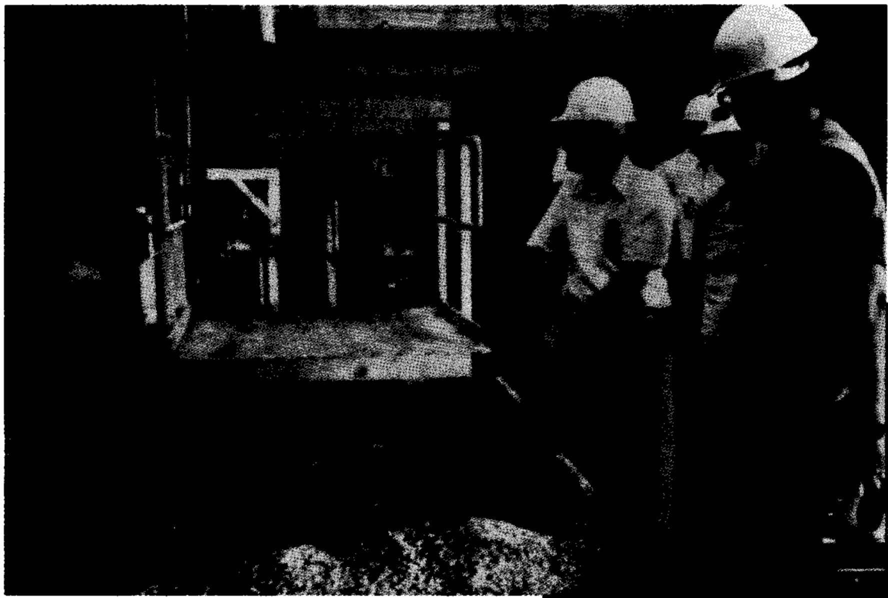
In deciding whether to employ heap-leaching in a prospective new mine, there are several technical and economic variables which need to be considered.

The most important constraint is the ore itself. It must be determined if the physical characteristics of the rock and the enclosed precious metals are amenable to heap-leaching. Generally, an ore must have the following characteristics to be suitable for heap-leaching:

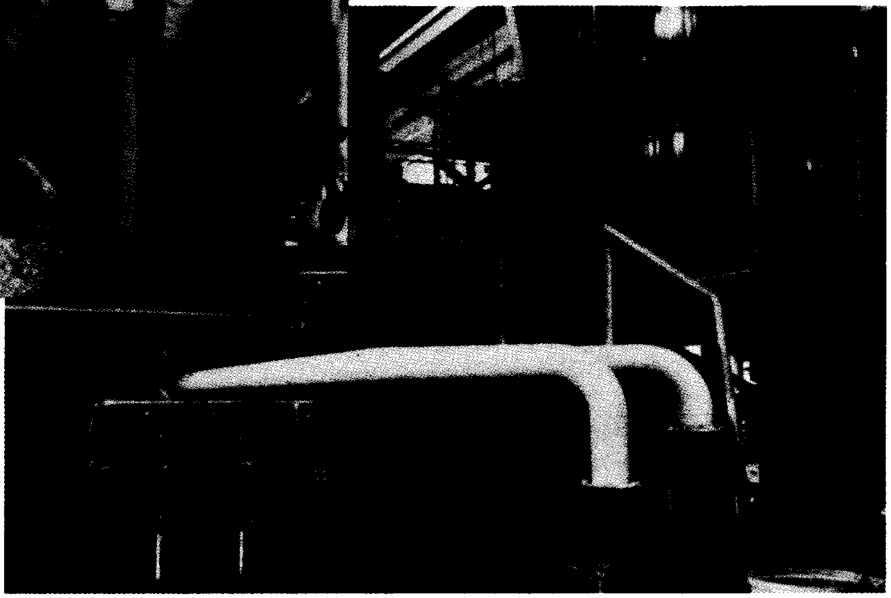
- Extremely small gold particles.
- Gold and silver mineralogy that is leachable by cyanide.
- Host rock porous to cyanide solution.
- Relative freedom from cyanides (calcopyrite, pyrite, arsenopyrite, sphalerite, etc.).
- No excessive amounts of fine, clay materials.
- Few acid-forming constituents which could cause high lime consumption.

The location of the site itself plays an important part in the mine operator's abil-

*A "roll-front deposit" is a uranium or vanadium orebody in a sandstone lens or layer that cuts across bedding in sharply curving forms, commonly C- or S-shaped in cross section.



Inspecting silver precipitate in the secured area of the refinery at Candelaria.



A pipeline at Candelaria transfers loaded cyanide solution to the secured area for final recovery of silver doré.

ity to utilize heap-leaching successfully. As discussed later, this is the area in which unique innovations may be required in order to use heap-leaching effectively in Alaska. Temperature is a critical factor. Below 10°C the solubility of gold and silver is significantly reduced. Below the freezing temperature, open spraying of the cyanide solution becomes hindered by freezing in the pipes and in the sprays. Excessive rainfall is another constraint; high precipitation can dilute the solutions and seriously affect the economics of either the Merrill-Crowe or CIP process. Storage capacity for the excess diluted cyanide solution is also a problem.

The trade-off in using heap-leaching is lower recovery of the overall metal content than could be expected from more conventional vat mill operations. In many potential mine operations, the economics could not stand up to such low recoveries, particularly in high-unit value underground deposits. Generally heap-leaching is most economic in low-grade open-pit, low stripping-ratio reserves with low base metal values. The bulk disseminated gold-silver deposits are particularly good examples of ores suitable for heap-leaching. The mine life is less important in a heap-leach project than in a conventional mill project because the capital requirements for a heap-leach project are virtually nil when compared to a vat-process, with its associated grinding, flotation, and other requirements. All of these economic constraints need to be considered in addition to the metallurgical and physical factors.

THE CANDELARIA SILVER MINE

An old mining camp, Candelaria was investigated by Occidental Minerals during the late 1970s. Based on feasibility studies, OxyMin decided in 1979 to build a heap-leach, 10,000 TPD operation. The facilities were built by Bechtel, Inc.

OxyMin suspended mine operations in May, 1982, due to short-term weak metal prices. In early 1983, by purchasing the outstanding common stock of OxyMin, Nerco Minerals gained the controlling interest of Candelaria and became the operator. Mine operations resumed, and in late 1983 Nerco Minerals acquired the remaining interest in the mine and became full owner. Candelaria is currently operating at full production.

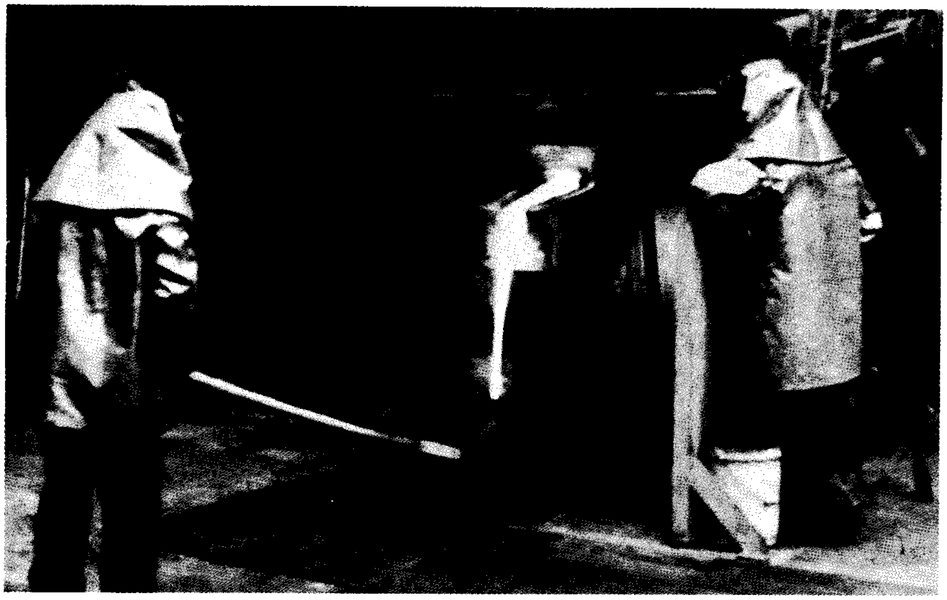
The Candelaria deposit represents the oxidized cap of a shale-hosted subvolcanic massive sulfide. Mining is by standard blast-hole open-pit techniques. The blasted ore is loaded by 992 loaders into 85-ton trucks, which transport it to a crushing complex where it is agglomerated and crushed to a uniform one-inch size. The agglomerated material is placed on 300 by 1200 foot leach pads, built to a height of 20 feet and underlain by impermeable clay. Standard irrigation techniques are used to spray the cyanide solution. The Merrill-Crowe zinc process is employed on the pregnant solution.

Total capacity of the Candelaria Mine is over 1,700,000 ounces of silver and 9500 ounces of gold annually. The Candelaria Mine is the largest open-pit primary silver mine in the country, in addition to being one of the largest heap-leach operations in the world.

THE ALLIGATOR RIDGE GOLD MINE

A relative newcomer to the western U.S. mining scene, Alligator Ridge was originally discovered in 1976. Following feasibility studies and drilling, it was decided to develop the deposit in 1979 with a heap-leach 3000 TPD operation. Bechtel, Inc. built the facilities in less than nine months. AMSELCO operates this project and holds a 50 percent interest. Nerco Minerals Company, after its acquisition of OxyMin, holds the other 50 percent interest.

The Alligator Ridge gold deposit is a "Carlin-type" ore-body composed of micron-sized gold particles embedded in



Molten material from the furnace is poured into a conical mold to form silver doré buttons, Candelaria Mine.

an iron-streaked limestone. (Such deposits are commonly referred to as "no-see-um" gold deposits.) Mining is by blasthole openpit techniques. The blasted ore is loaded by 988 loaders into 35-ton trucks and taken to a crushing complex where it is agglomerated and crushed to a ¾" size. The agglomerated material is piled to a height of 15 feet on 300 by 700 foot leach pads underlain by impermeable clay. Standard irrigation techniques are used to spray the cyanide solution. The CIP carbon process is employed on the pregnant solution.

The Alligator Ridge Mine is one of the ten largest gold mines in the U.S.; its total capacity is over 60,000 ounces of gold annually.

THE FUTURE IN ALASKA FOR HEAP-LEACHING

Except for the climatic constraints, Alaska may have all the other parameters necessary for heap-leaching. Particularly, these include the economics and the types of ore deposits.

Although the exploration for disseminated gold/silver deposits in Alaska is only a relatively recent phenomenon, early work already indicates that this type of deposit may be widespread throughout the state. The elusive "no-see-um" ore-bodies that may have been the source of some Interior placer deposits (and that have frustrated prospectors since the first gold rush) may well be of this type. So may the potential new gold districts only recently identified through the advent of plate tectonics and current economic geology theory. A particular example of this may be the recent discoveries on the Alaskan Peninsula and Aleutian Islands.

The end result: 300-600 ounce silver doré buttons, stored here in the mine vault at Candelaria.

Most of the known and potential deposits are very remote and far removed from infrastructure, including towns, roads, and power. Should heap-leaching prove to be technically workable in Alaska, the simplified nature of the process will prove ideal in construction, start-up, and day-to-day operations. Miners will need to haul in less equipment, fewer employees will be required than in a conventional mill, and the power requirements will be much less. Such advantages will be even more important for any operation starting in a completely undeveloped area.

Of course, the climate of Alaska does not provide the same operating environment as Nevada or Arizona. As discussed earlier, heap-leaching is extremely temperature-dependent and may be impossible in many parts of Alaska. On the other hand, there are many areas in Alaska where conditions may be amenable to heap-leaching, given innovations and applications of existing technology.

In the Interior, heap-leaching may be approachable in much the same way as a placer operation. Setup, stripping operations and leach pad building could take place during the winter, and the actual leaching could take place during the brief but warm summer. This approach would provide at least five months of leaching, and this period could be extended by burying the irrigation lines (as is done at Candelaria during the winter) or actually heating the solution (as is done at Round Mountain). While the season would be short, it would not be much shorter than some operations currently have in the Rocky Mountains. The low amounts of precipitation would also benefit heap-leaching. A covered operation may also be possible.

Along the southern coast of Alaska, the mild temperatures may allow heap-leaching for most of the year. The challenge would be in dealing with the high precipitation that normally occurs there. Proper engineering would prevent drainage of hillside runoff into the solution pond (which would probably have to be enclosed). The heap pads themselves would need to be covered by an impermeable fabric to prevent rain or snowfall from diluting the cyanide solution. A cable-weighted fabric dragged into place with heavy equipment could work on much the same principle as a tarp dragged into place during a rainy baseball game. It would need to be heavy and strong enough to withstand the high winds common in southern coastal Alaska.

In summary, heap-leaching is a new and very exciting technology which has revolutionized mining in the western U.S. Given the desire and the innovation of the mineral industry, it may be possible to develop Alaskan ore deposits economically, not 20 or 30 years from now, but during the 1980s. ♦

The Arctic Science Prize

The Arctic Science Prize was established by action of the North Slope Borough Assembly on March 23, 1983. The Borough includes 88,000 square miles across the top of Alaska, from the Chukchi Sea to the Canadian border and from the Arctic Ocean coast to the Brooks Range; approximately 9000 permanent residents live in this vast territory – not counting the temporary inhabitants of Prudhoe Bay. The Borough is a local jurisdiction, like a county. The equivalent to a county seat is Barrow, which has changed in character from a village to a small city during the past two decades.

The official Prize announcement, sent out recently by the NSB as an updated reminder, is no glossy advertisement; it provides much detail in an unpretentious format. Soon ten scientists who have specialized in arctic research will become very much aware of what the announcement says: they will be notified that they are finalists in the judging for the first Arctic Science Prize, which involves not only considerable honor but also a $10,000 gift.

BACKGROUND

After the passing of the Yankee whaling fleet, the North American Arctic had nearly a century's rest, but in recent years resource development has again brought technological impact to the far north. The people and government of the North Slope Borough are not willing to accept passively whatever transpires during this round of resource exploitation above the Arctic Circle. Their Prize announcement explains:

> ...it seems reasonable that adverse environmental impacts can be reduced through a better understanding of natural processes in the Arctic. It would therefore seem to be in everyone's interest to stimulate careful investigation of the physical and biological aspects of the Arctic.
>
> During the past decade major research programs have been conducted in the vast expanses of the North American Arctic. These investigations have resulted in the establishment of a modest data base and in the formation of a group of scientists with expertise in the Arctic. Unfortunately, within the past few years such science programs have been reduced in both scope and funding level. In order to try to reverse this unhealthy trend, the North Slope Borough is conducting a modest program aimed at fostering arctic science. The major aspect of this program is the funding of specific research projects. Another aspect is to be the recognition of individual excellence in the conduct of arctic science. This recognition of excellence is to be through the awarding of the Arctic Science Prize.

It is worth noting that the Prize alone amounts to an expenditure of more than a dollar apiece for every man, woman and child in the Borough; it's as if New York City announced a prize of $7 million (and committed tens of millions more through a science agency to funding urban research). It is also worth noting that the State of Alaska would not sustain its science advisory/funding agency, and dispensed with the Alaska Council on Science and Technology. With their willingness "to try to reverse this unhealthy trend" and to encourage a strong effort in northern research, evidently Barrow, Anaktuvuk Pass and Point Hope perceive something that evaded Juneau, Anchorage and Fairbanks.

One advantage of supporting science – and honoring specific scientists – is that it provides a great deal of control over what subjects are studied. Thus, the people of the North Slope Borough need not convince a distant federal official that research on Alaska's tundra, for example, is more deserving of money than are studies of New Jersey's pine barrens; instead, they can issue requests for proposals in areas that they can specify, and can attract unsolicited proposals from interested researchers who wish to work on arctic problems. Presently the North Slope Borough is responsible for supporting several research projects on animals valuable to the arctic subsistence economy. The

Barrow: the community, the point, and two seas—Point Barrow divides the Chukchi Sea from the Arctic Ocean. (Photo courtesy of John Kelley.)

bulk of these — about a dozen projects — are on the bowhead whale.

There is a danger for those funding science, however. They may be perceived as buying results rather than supporting science; that is, of seeking advancement for certain political or economic goals instead of seeking knowledge to illuminate the best routes to those goals. The NSB has exerted itself to avoid that perception. Though the Borough sets budgetary limits as well as general priorities, it is the Science Advisory Committee that reviews major proposals for technical merit. The scientific findings are subject to further review and assessment; the completed bowhead whale studies, for example, are submitted to the Scientific Committee of the International Whaling Commission. And, as described below, the NSB has gone to great lengths to be sure that the competition for the Arctic Science Prize is a process beyond reproach.

THE PRIZE

The Borough Assembly intended that the award would be made every two years to "distinguished scientists who have made significant contributions to man's understanding of natural processes in the Arctic." The explicit aims which the NSB has are that the Prize serve as recognition of its recipient's contributions, further stimulate excellence in arctic science, and focus attention on the Arctic and its unique problems.

The winner of the Prize will have survived an exhaustive process. First, he or she must be among the perhaps 55 nominees suggested by the candidate review committee — each of the 11 members may introduce a maximum of five scientists' names for consideration. The membership of the committee broadly represents many possible fields and interests in arctic science:

- Chairman of the North Slope Borough Science Advisory Committee (presently Dr. John Kelley, an associate professor at the Institute of Marine Science, University of Alaska-Fairbanks, and a former director of the Naval Arctic Research Laboratory near Barrow);
- Director of the Geophysical Institute, University of Alaska-Fairbanks (now Dr. Juan G. Roederer);
- Director of the Institute of Arctic Biology, UAF (Dr. John Bligh);
- Director of the Institute of Marine Science, UAF (Dr. Vera Alexander);
- Representative of the North Slope Borough government (presently Dr. Thomas F. Albert, Senior Scientist in the NSB Conservation & Environmental Protection Office and present chairman of the candidate review committee);
- Representative of Alaska State government (the NSB requested a person from the Department of Fish and Game, to be named by the Commissioner; as with all "representative" committee members the Borough required that the named individual have direct experience in conducting and/or managing arctic research. John Burns of ADF&G is the representative now holding this seat);
- Representative of a U.S. federal agency that is conducting research in the Arctic (the Borough anticipates that this seat will rotate among the several federal agencies involved in arctic research; it is presently held by Jerry Imm of the Bureau of Land Management, OCS-MMS);
- Representative of industry (the Alaska Oil and Gas Association was asked to propose this member, and Roger C. Herrera of SOHIO was chosen for this panel);
- Chairman of the Polar Research Board of the U.S. National Academy of Sciences (Charles R. Bentley);
- Chairman of the Science Advisory Board of the Northwest Territories of Canada (James M. Harrison);
- Executive Director of the Arctic Institute of North America (Peter Schledermann).

For each of the Prize nominees they propose, the candidate review committee members must prepare a one-page profile sheet. There is no indication on these sheets as to who nominated which scientist. Each member gets to read and evaluate every profile sheet; he or she then weighs the scientific accomplishments of each nominee, selects the top ten, and then ranks them from 1 up to 10. This provides a kind of weighted vote, a procedure roughly similar to that used by U.S. sportswriters to select the top ten college football teams. It is after these votes are tabulated that the hardest work begins for the committee, however.

An alphabetically arranged list of the ten highest-scoring scientists is then distributed to the members of the committee and the finalists are notified. The names of the finalists will be made public at this time as well. (Only the members of the score-tabulating team, consisting of the Borough mayor, the Borough's director of administration and finance, and one of the special assistants to the mayor, will know the numerical ranking of these top ten. Their only direct contact with the whole Prize-judging procedure is to calculate the vote, prepare the alphabetical list — and lock the raw voting material in a safe in case of later question.) The ten candidates must each prepare complete documentation, in effect presenting their careers in arctic science, teaching and public service. Prize competition rules require a very specific form in which this supporting material is to be submitted, so that the candidate review committee can deal with similar presentations even if they must judge dissimilar careers. By May 1984 they will have had a chance to assess all documents, and will meet to debate and decide the winner. The North Slope Borough's announcement laconically notes, "This meeting of the committee will occur in Barrow, Alaska, and will last two days (more if needed)."

The complex and careful procedures underline the seriousness of the Borough's commitment to the meaning of the Arctic Science Prize.

WINNER'S DUTIES

The North Slope Borough has a few expectations of the Prize recipient. He or she must agree to come to Barrow for the August meeting of the Borough Assembly, at which the $10,000 gift and award certificate will be presented; the Borough will pay for the required travel and associated expenses. In Barrow, the honored scientist will present a half-hour lecture, outlining and reviewing the work that led to the Prize. (The Borough hopes to see this lecture published. It will probably appear as a review article in a journal such as *Arctic.*) Later, the winner will be expected to give a more detailed presentation of his or her work, probably at the University of Alaska-Fairbanks; again, the NSB will underwrite any travel necessary for the Prize recipient.

The people of the north have long had the sense that arctic research sometimes seems to travel a one-way path. Scientists arrived, studied, and departed, but the results of their studies were not necessarily conveyed to Arctic residents. Villagers who shared their hunts and even their homes with visiting researchers have often been left to wonder what their visitors learned and reported to the rest of the world. Thus it seems particularly appropriate that the Arctic Science Prize recipient must return to the Arctic and report to its people.

CONCLUDING THOUGHTS

Since the Prize may be awarded only to living scientists, many of the great names in arctic research – Louis Giddings, Per Scholander, Sydney Chapman, or Lawrence Irving, among others – cannot appear on the award certificate. The name that does appear, however, should resound with theirs in the annals of the north. Having been judged by a diversified and distinguished review committee, the recipient of the first Arctic Science Prize should indeed be someone who has made (as the certificate phrases it), "outstanding contribution to man's understanding of the natural processes of the Arctic."

In effect, the certificate's concluding sentence is a statement of understanding, a kind of admonition to the winner and a reminder to the people of the North Slope Borough of why they are supporting research and awarding the Arctic Science Prize: "It is through the wise application of such new knowledge that man will hopefully be able to both live and work in the Arctic and yet preserve the environment for future generations."

The report above was prepared by the editor with the help of Dr. Thomas Albert, Senior Scientist in the North Slope Borough's Conservation & Environmental Protection Office. ♦

MEETINGS

The **1984 Annual Meeting of the Alaska Chapter of the American Water Resources Association** will be held at the Alyeska ski resort, south of Anchorage, on November 8 and 9. The meeting organizers have invited papers on three main topics: institutional aspects of Alaskan water management, including discussions of the political, social, legal and environmental aspects of developing Alaska's water resources from both regulatory and developmental perspectives; recent technical advances, emphasizing innovative analytical methods and data collection techniques; and data, research and assessment needs.

Further information is available from *Stephen Bredthauer, Conference Chairman, c/o R&M Consultants, P.O. Box 6087, Anchorage, AK 99502;* phone *(907) 561-1733.*

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The Arctic Division of the American Association for the Advancement of Science will hold its annual conference October 3-5, 1984, in Anchorage, Alaska. The **1984 Arctic Science Conference**—which is also the **35th Alaska Science Conference**—has the overall theme of "Science and Public Policy." Symposia reflecting that theme will include Science and Public Policy; Science Education; Credibility and Acceptance of Sciences in the North; Telecommunications and Policy; and Earthquake Hazards Reduction. As usual, the conference will also accommodate an array of technical sessions, and there will also be other special topics symposia: Meteorology and Oceanography of North American High Latitudes (jointly sponsored by the American Meteorological Society); Pure and Applied Mathematics; and Vegetation Inventory and Mapping.

Potential authors considering presenting papers or posters should provide titles by June 1, and one-page abstracts by July 31, 1984, to *Dr. John Davies, 1984 Conference Chairman, AAAS Arctic Division, P.O. Box 80271, Fairbanks, AK 99708.*

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The first announcement is already out for the **Fourth International Symposium on Ground Freezing,** which will be held August 5-7, 1985, at Sapporo, Japan. This symposium emphasizes artificial freezing of ground for stabilization and for controlling ground water seepage, but the main topics for the Sapporo meeting underline how applicable the presentations are likely to be for geotechnical problems in cold regions: Thermal properties and processes in earth materials; Mechanical properties and processes in earth materials; Frost action; and Engineering design and case histories, including permafrost engineering.

The organizing committee wants to hear soon from anyone who hopes to attend, especially those intending to submit a paper; people who are yet undecided about attending can ensure they are on the mailing list for the second announcement by writing *ISGF 85, Institute of Low Temperature Science, Hokkaido University, Sapporo 060, Japan.*

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On May 15 through 18, the Arctic Section of the Society of Naval Architects and Marine Engineers in Calgary are acting as hosts for **ICETECH '84**, the third international symposium on marine problems in ice-infested waters. The program indicates a wide array of topics, from "Nine Months in the Making of a Mobile Arctic Drilling Caisson" to "Estimation of Icebreaking Resistance by Ship Motion Simulation," and many noted authors from several countries.

The price of attendance, which includes a formal banquet and the proceedings volume, is $90 (Canadian). Further information is available from *D.R. Miller (Chairman)* or *D.L. Speed (Publicity Chairman), c/o Arctec Canada Ltd., #16, 6235 11th Street S.E., Calgary, Alberta T2H 2L6, Canada*; telephone *(403) 253-4883* or *telex 03821972.*

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The British Hydromechanics Research Association (BHRA) has announced that the **2nd International Symposium on the Large Scale Application of Heat Pumps** will take place at the University of York, England, on September 25 through 27. "Large scale," according to the meeting's first announcement, includes industrial applications and district heating and cooling projects. The second announcement is now available from the *Conference Organizer, 2nd Heat Pumps Symposium, BHRA, The Fluid Engineering Centre, Cranfield, Bedford, MK43 OAJ, England.*

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It's been 20 years since the disaster itself, so in wary commemoration, during 1984 several meetings will be held under the umbrella title of **"The Great Alaska Earthquake: Retrospect and Prospect."** According to the tentative planning schedule, in March the meetings concentrated on a retrospective of the Good Friday earthquake combined with a review of the present level of preparedness; the Alaska Academy of Engineering and Science had major responsibility for the March events. Chiefly responsible for presentations during May will be the Alaska Chapter of the Earthquake Engineering Research Institute. The emphasis will be on technical views of present hazards, and a featured event will be a joint meeting of the Geological and Seismological Societies of America (30 May-1 June). In September, largely as a part of the Alaska Science Conference and under the supervision of the Arctic Division of the American Association for the Advancement of Science, a series of symposia and other meetings are planned to focus on improving public policy decisions bearing on natural disasters.

A steering committee has been formed to coordinate the several different meetings, and two people have been designated to serve as acting information officers: *Dr. William E. Davis, P.O. Box 103844, Anchorage, AK 99510;* and *Dr. John N. Davies, State Seismologist, Geophysical Institute, University of Alaska, Fairbanks, AK 99701.*

PUBLICATIONS

The **Proceedings of the Second National Conference on Ethics in Engineering, Beyond Whistleblowing: Defining Engineers' Responsibilities**, is now available. The contents include revised versions of the refereed papers presented at the conference, commentators' replies, an introduction by the editor, and a bibliography. The papers' chief focus is on issues of individual moral choice for engineers and on ethical aspects of institutional practices and public policy that involve engineers, but the volume also contains essays geared to engineering education and to teaching.

The 334-page book may be obtained from the proceedings editor (and conference director): *Vivian Weil, Center for the Study of Ethics in the Professions, Illinois Institute of Technology Center, Chicago, IL 60616.*

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Every few months we receive an issue of **Synopses of Swedish Building Research** and are reminded yet again that there should be better communication across the North Pole. *Synopses* contains abstracts in English of several series of publications issued by or funded from the Swedish Council for Building Research. According to *Synopses'* masthead, the Council is "a government agency with the task of initiating, and supporting research, development and rationalization. Its field of responsibility covers the whole range of community development—from physical planning through the design of buildings, construction techniques and production methods to the use of buildings."

The range of topics and approaches is impressive; usually several alternative energy studies are included. Some of the reports abstracted are available in English, and the abstracts themselves seem detailed enough to indicate whether the publication would be worth ordering and translating. **Synopses of Swedish Building Research** is sent free on request from *Svensk Byggjanst, Box 7853, S-103 99 Stockholm, Sweden.*

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Conservation and Renewable Energy, Inc. (CARE), organizers of the recent 1984 Alaska Alternative Energy Conference, have announced that a few copies of the **Energy Conference Proceedings** are still available. In addition to containing abstracts (and in some cases, full texts with illustrations) of the papers presented, the proceedings volume also contains a list of the names and addresses of conference speakers and resource persons, making it a valuable reference for finding experts in various aspects of energy production and conservation in the north. CARE's address is *P.O. Box 734088, Fairbanks, AK 99701*; they're asking their cost price of $16 for copies of the 200-plus page proceedings volume, but please add $1.50 for postage.

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We are pleased to announce the return of a popular neighbor: **Biological Papers of the University of Alaska** has resumed publication. Issue number 21, **Contributions to the Science of Environmental Impact Assessment: Three Papers on the Arctic Cisco** *(Coregonus autumnalis)* **of Northern Alaska**, appeared in December 1983. The monograph costs $5 ($4 to members of the Arctic Institute of North America). Some previously published volumes in the papers series are also available; for a list of titles, or to order the latest issue, write *David W. Norton, Editor, Biological Papers of the University of Alaska, Institute of Arctic Biology, University of Alaska-Fairbanks, Fairbanks, AK 99701.* Checks or money orders should be made payable to the Institute.

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There are a spate of **publications available from the Fourth International Conference on Permafrost**, held this past summer in Fairbanks. Titles, prices and places from which to order are given below.

Proceedings

Permafrost: Fourth International Conference, Abstracts and Program; 278 p. with supplement, $10. (Geophysical Institute, University of Alaska-Fairbanks, Fairbanks, AK 99701.)

Permafrost: Fourth International Conference; 1524 p., 276 papers, $65. (National Academy Press, 2101 Constitution Avenue NW, Washington, DC 20418.)

LETTERS

Back to basements

Editor:

With reference to Richard D. Seifert's article, "The Basics of Proper Design for Residential Basements in Alaska," *(TNE* 15(2):30-33), I raise several questions regarding Fig. 2.

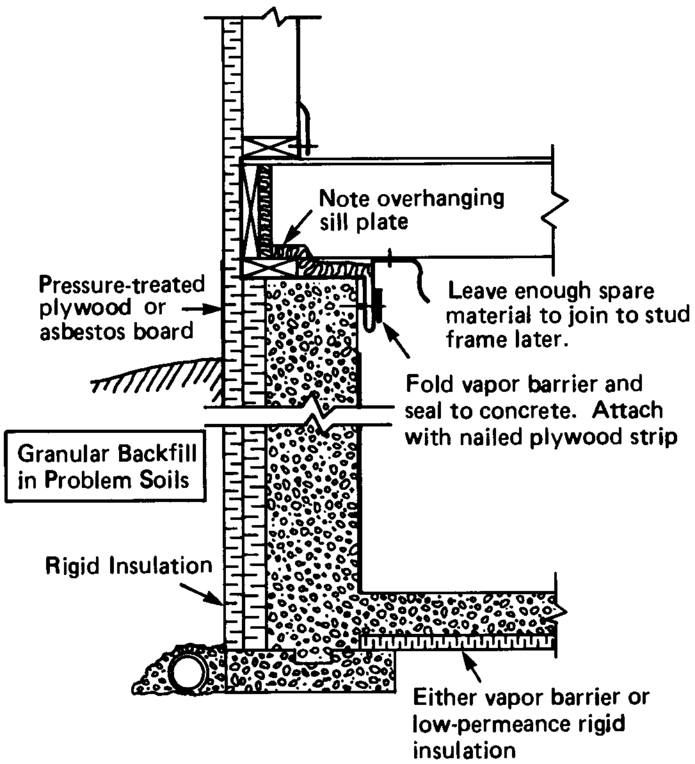
First, the type of insulation has not been described. For below-grade installation, highly impermeable and nonabsorbent foamed plastic, Styrofoam SM or equivalent, *must* be specified.

Second, since this is a basement, why not place the insulation on the interior surface where much less costly beadboard types may be used? It is very simple to install insulation with compatible adhesives, and then gypsum wallboard over the insulation. Interior insulation also eliminates the necessity for overhangs (Seifert doesn't indicate how to do this on the sides of the building where joists are parallel to the wall) and the necessity for continuous protection of the exterior insulation from physical damage at and near the soil surface. As shown, the detail is very good for a slab-on-grade type of building.

Third, Seifert states that the vapor barrier strip (which is to be folded into the vapor barrier on the ceiling later) will ensure continuity and airtightness of the house. This simply will not provide vapor barrier continuity because moisture will be transmitted to the rim joists through the floor sheathing above. Anyway, why would anyone want to place a vapor barrier in the basement ceiling, between two warm areas?

Fourth, a note of caution should have been included in the "Granular Backfill in Problem Soils" notation. In many areas the soil is fine-grained and poorly draining, and perimeter drains cannot be run to "daylight" or a storm drain. For these conditions, a good impermeable water shed must be placed over the top of the granular backfill and the ground surface sloped away from the walls. Even with the perimeter drain, lack of attention to the foregoing concerns will still result in some flooding of the basement.

Fifth, if insulation is placed on the exterior, it should be continued over the edge of the footing to prevent soil under the footing from freezing and possibly heaving. If the basement wall is insulated on the inside, a plank of Styrofoam SM (or its equal) should be placed horizontally above the top of the footing, depending upon the severity of the winter climate and soil characteristics.



Seifert's Figure 2: Basement wall insulated on the outside. (From D. Eyre and D. Jennings, "Air-Vapour Barriers," SRC Publication #E-825-2-E-81. Saskatchewan Research Council.)

Sixth, regardless of which side of the wall is insulated, insulation under the floor is not necessary in any basement – or for a slab-on-grade building, for that matter – although for a daylight basement a two-foot width around the perimeter might be desirable in colder regions. Insulation under the entire floor suggests an intent to prevent degradation of underlying permafrost; it's useless for that purpose.

Although outside the scope of the article, the economics of placing insulation board on the exterior of the walls ought to be analyzed with respect to the greater difficulty of obtaining lateral stiffness (for seismic or wind loads) and for attaching the siding.

John L. Cerutti, P.E.
Frank Moolin & Associates, Inc.
Anchorage, Alaska

Guidebooks

(All are published by, and available from, the Alaska Division of Geological and Geophysical Surveys, 794 University Avenue, Basement, Fairbanks, AK 99701.)

#1: Richardson and Glenn Highways, Alaska. T.L. Péwé and R.D. Reger (eds.), 263 p., $7.50.

#2: Colville River Delta, Alaska. H.J. Walker (ed.), 34 p., $2.00.

#3: Northern Yukon Territory and Mackenzie Delta, Canada. H.M. French and J.A. Heginbottom (eds.), 183 p., $8.50.

#4: Elliott and Dalton Highways, Fox to Prudhoe Bay, Alaska. J. Brown and R.A. Kreig (eds.), 230 p., $7.50.

#5: Prudhoe Bay, Alaska. S.E. Rawlinson (ed.), approx. 200 p., $6.00.

#6: The Alaska Railroad Between Anchorage and Fairbanks. T.C. Fuglestad (ed.), approx. 130 p., in preparation.

#7: Fairbanks Area Geology. R.D. Reger and T.L. Péwé (eds.), in preparation.

Other

Permafrost: A Bibliography, 1978-1982. Glaciological Data Report GD-14, 172 p., $10. (World Data Center for Glaciology, University of Colorado, Box 449, Boulder, CO 80309.)

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According to a recent report from the U.S. Geological Survey's Water Resources

Division, the Tanana River might well be nicknamed the Big Muddy: at a site near Fairbanks, the suspended sediment load in the river for 1982 was 26 million metric tons. Documenting such details, authors Phillip E. Harrold and Robert L. Burrows have written Water Resources Investigations Report 82-4213, **Sediment transport in the Tanana River near Fairbanks, Alaska, 1982.** The Water Resources Division also has other recent publications that cover other parts of the state. W.R.I. Report 83-4173, **Trace metals in surface water and stream sediments of Healy and Lignite Creek Basins, Alaska**, by Bruce Parks, deals with a different Interior area. (Miners there may be pleased to learn that neither water-borne metals nor sediments presently constitute an environmental hazard.) For Southcentral, there's a two-sheet map report by Bonnie J. Bailey. **Hydrologic Data Stations and Lake Levels, Kenai-Nikiski area, Alaska, 1983,** Open-File Report 83-938, indicates among other things that the lakes were a bit low there last year, but nowhere near their record lows of the mid-1970s. Southwestern Alaska work is reported in **Reconnaissances of Surface-Water Resources in the Togiak River Basin, Southwestern Alaska, 1980 and 1982.** This W.R.I. Report 83-4170 concludes that stream flow characteristics in the river basin are similar to those in adjacent ones with better stream gage records; D.R. Kernodle, R.R. Squires and J.M. Childers are the authors.

Copies of these reports may be requested from the *Open-File Services Section, Branch of Distribution, Box 25425, Federal Center, Denver, CO 80225.* Copies for inspection only may be seen at various U.S.G.S. centers in the western states.

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Sun/Earth Buffering and Superinsulation, according to the packet of information received here, stresses practical advice based on the author's 30 years of experience—plus the experiences of many other people as well. The nine chapters apparently go from the general (an introduction to the "sun-tempered superinsulated house" begins the first section) to the very specific (Chapter 9 presents a survey and data analysis, based on the experiences and measurements made by more than 100 owners of envelope homes). There is also a reference section, including a glossary and list of product sources, and an index.

Judging by the page samples, this is a very well-done book, attractively printed and clearly written. The overall tone seems heartening; at least in the temperate zone, alternative approaches have indeed come of age, so this book presents not just probably good ideas but actual performance data, costs, and experiences.

Written by Don Booth, Sun/Earth Buffering and Superinsulation is available from *Community Builders, Canterbury, NH 03224.* Paperbound copies are $17.95, hardcover $24.95; postage costs $2.

NOTED

Usually this loosely run office operates just well enough, but once in awhile . . . Some months back, a note signed "Reb" or "Rob" appeared on my temporarily unoccupied desk. It had a few sentences and diagrams setting forth a simple but effective-looking device for cleaning wood-burning stove chimneys. A likely subject for an article in *The Northern Engineer*, but who wrote it? The staffer who had delivered it recalled that it arrived in a great clot of mail with postmarks from no more than two or three countries and a handful of states. She had tidily tossed the envelopes.

The handwriting was faintly familiar. The name certainly was. When I had worked about halfway through the list of a couple of Rebs and nine Robs who might have sent the note, someone pointed out to me a very nice little report of an Alaskan's chimney-cleaning idea in the March 1984 issue of *Popular Science.*

O well. Herewith I thank Rob Reinhardt of Aniak, Alaska (*TNE* Vol. 14, No. 4) for thinking of us first; commend the editors of *Popular Science* for knowing a good idea when they see one; and ruefully suggest that the rest of you check out p. 144 of the March *PS.* That's a copyrighted publication, so we can't show you Reinhardt's idea. Rats.

****

The December issue of *Benchmarks* noted with justifiable pride that **five of the Cold Regions Research & Engineering Laboratory's staff members have received Army Research and Development Awards for 1983.** According to CRREL, the researchers and their projects were:

Yoshisuke Nakano, Joseph Oliphant and Allen Tice who were honored for their research in use of nuclear magnetic resonance (NMR) techniques for investigating water content and transport in frozen soil. The researchers demonstrated that NMR provides an accurate and rapid method of measuring these factors, an important finding because the unfrozen water content significantly affects the strength and hydraulic conductivity of frozen soil.

David Deck received an award for designing a frazil ice control structure at Oil City, Pennsylvania, a town plagued by recurrent ice-jam flooding. Deck's structure consisted essentially of floating pontoons attached to cables stretched across the river; it forced the frazil crystals to accumulate behind it, thus forming a solid ice cover in a place unlikely to lead to jamming during breakup. The device did help prevent flooding last year at Oil City, and it will be further tested and observed in the future.

Michael G. Ferrick received his award for leading a research team that included K. Itagaki, G. Lemieux and S. Minas in successfully modeling the potential for ice accumulation on the external fuel tank of the proposed Air Force space shuttle. One of the team's important findings was that the highly variable thickness of the insulation greatly affected the chances of ice forming on various parts of the tank; they also demonstrated that the icing could be suppressed by blowing heated air onto the tank before a launch.

****

It's too late to worry about this year's **Management Seminar and Short Course in Applied Thermography**—that was held in March—but it's not too early to start thinking of next year. The one-day seminar provides an overview of infrared technology, its applications in the building, petrochemical and electrical industries, and its profitability. The short course consists of 30 hours of classroom instruction and one major hands-on assignment. Participants who complete the short course successfully will be certified at Level I of the standard for thermography proposed by the Canadian General Standards Board.

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AUTHOR

SUBJECT/TITLE

To be sure you receive timely notice of the next seminar or short course offering in applied thermography, write *Dr. Harold J. Dyck, President, North American Infrared Thermographic Association, Suite 504, 77 Metcalfe Street, Ottawa, Ontario K1P 5L6, Canada.*

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Abbott, Langer & Associates, the job market experts, report that in 1983 it was still true that the **best diploma for a new graduate to have was in engineering.** Graduates with bachelor's degrees in engineering had average starting salaries of $2071 per month; unfortunately for new engineers in the north, the lowest-paying jobs were in construction and engineering firms (starting salary averaging $1877) and the highest in manufacturing ($2206). The highest-paid new graduates had specialized in chemical engineering. Junior/community college graduates with engineering-related A.A. degrees averaged 70% of the starting salary of that paid to engineering graduates holding bachelor's degrees. A master's degree in engineering gave a new graduate a starting salary of $2289 per month on the average. For comparison, new graduates with nontechnical master's degrees had starting salaries averaging $1739.

Complete details (including analyses by industry and size of firm, extensive data on starting salaries of inexperienced graduates by degree level, curriculum, and type and size of employer) are available from *Abbott, Langer & Associates, 548 First St., Crete, IL 60417*, in the *1983 College Recruiting Report* ($95).

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The National Association of Corrosion Engineers has announced the formation of a technical committee that may be of interest to northern engineers: **Unit Committee T-3S, entitled Arctic Corrosion Problems**, was created by the NACE's Technical Practices Committee in September 1983. The purpose of the new unit is "to provide a forum in which the corrosion problems unique to Arctic industries could be discussed, according to the press release received here. Some of the topics that the committee may consider are marine corrosion problems intensified by low temperatures, the performance of coatings in cold environments, corrosion problems of various structures used by industries in cold climates, and methods of preventing and controlling corrosion in low-temperature environments.

For further information about the Arctic Corrosion Problems technical committee, contact the *National Association of Corrosion Engineers, Technical Activities Department, P.O. Box 218340, Houston, TX 77218.*

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Albert E. Belon

We conclude this issue on a note of regret and gratitude: **The Boss has retired.**

The name of **Professor Albert E. Belon** did not appear on our masthead, but as far as the University and the Institute were concerned, he was the person in charge. He allowed us great independence; he was careful to read *TNE* only after it was published. But he was our defender, critic, and link with the administration of the Geophysical Institute, and did a great deal to keep us intellectually and fiscally responsible.

Associate Director at the time of his retirement, Al Belon had worked with every director of this Institute since it was established. His career has been highlighted with accomplishments as a physicist, professor and administrator. Beyond his teaching and research duties here at the Institute, Belon served as program director of the Solar-Terrestrial Research Program of the National Science Foundation from 1968 to 1970, for which he received the Meritorious Service Award in 1970. In 1974, he received the Exceptional Scientific Achievement Medal from the National Aeronautics and Space Administration. He served as acting program director of the NSF Aeronomy Program from 1968 to 1969; U.S. Coordinator for the 1970 Solar Eclipse Program in NSF from 1968 to 1970; and coordinator of the Remote Sensing Program at the Geophysical Institute from 1971 until his recent retirement. At the 1984 University of Alaska-Fairbanks commencement ceremonies, he will receive an honorary Doctor of Science degree.

In a far less formal ceremony to be held at another time, he will also receive an honorary subscription to *The Northern Engineer* in the hopes that he will enjoy reading it, now that he needn't worry about what it says.

THE **NORTHERN ENGINEER**

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