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Sixth Annual Conference  
on

# **Alaskan Placer Mining**

School of Mineral Engineering  
and  
Alaska Miners Association

March 28 - 29, 1984  
Fine Arts Concert Hall  
University of Alaska  
Fairbanks, Alaska

*An abridged format of papers, presentations and addresses  
given during the 1984 conference  
compiled and edited by:  
Daniel E. Walsh, M. Susan Wray*



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## **ACKNOWLEDGEMENTS**

This report is an abridged transcription of the papers and presentations given at the Sixth Annual Conference on Alaskan Placer Mining, held on March 28-29, 1984, and co-sponsored by the School of Mineral Engineering, University of Alaska, Fairbanks, and the Alaska Miners Association.

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**School of Mineral Engineering,  
Mining Extension**

**Leah Madonna**

**Alaska Miners Association**

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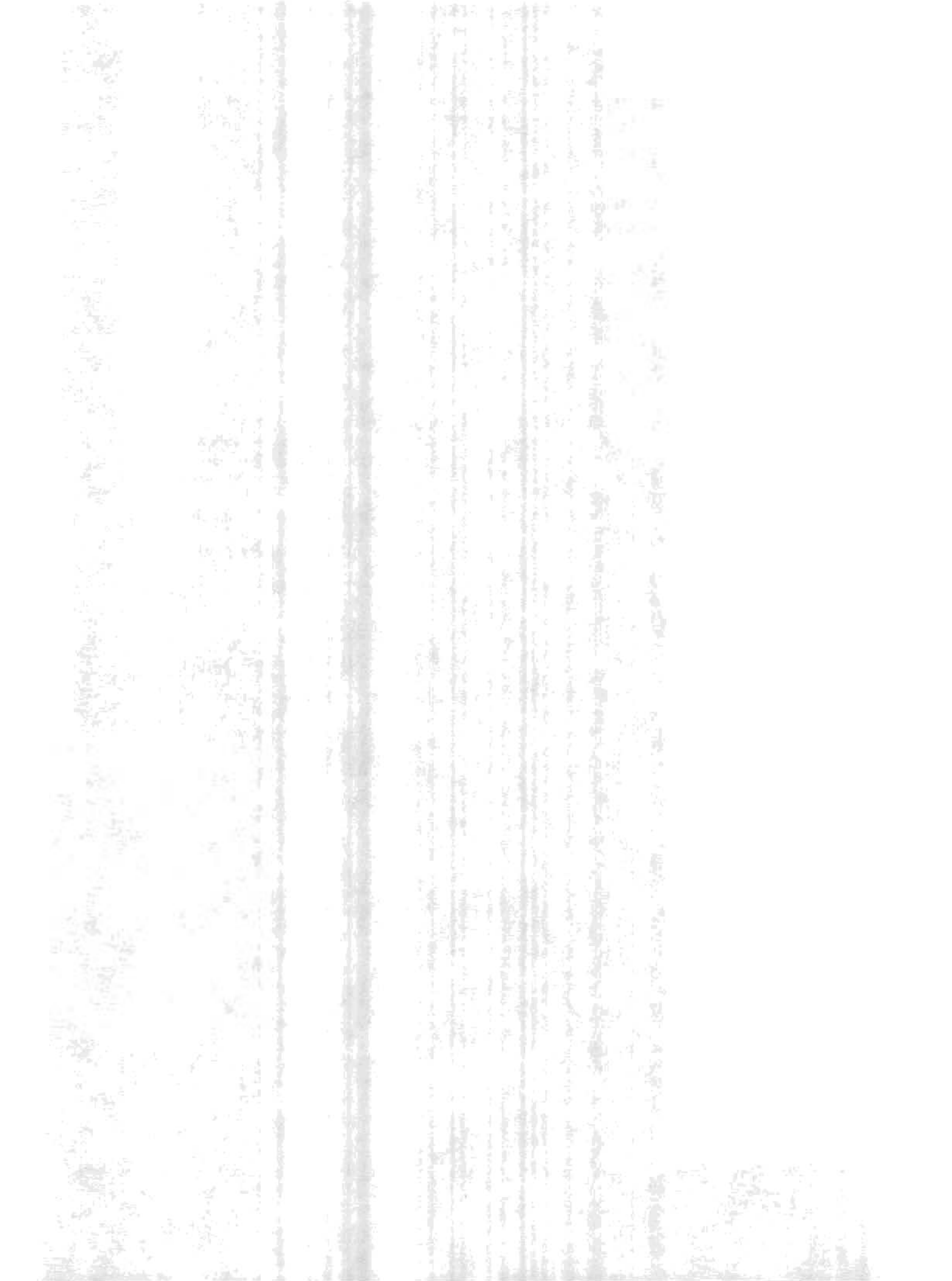
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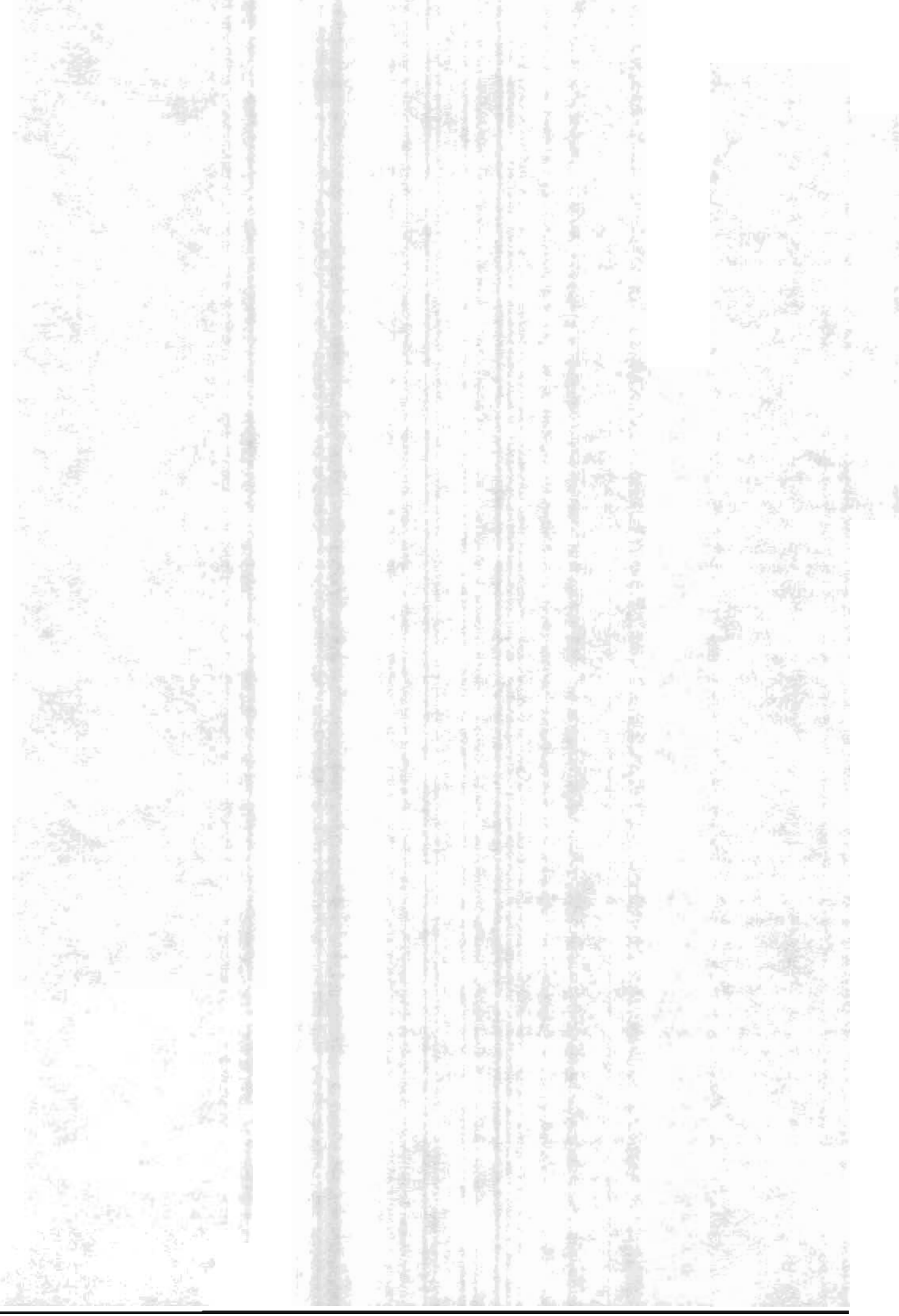
**Dan Walsh**

**School of Mineral Engineering, MRL**



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## Welcome

*Nolan B. Aughenbaugh*

Dean, School of Mineral Engineering

On behalf of the University of Alaska and the School of Mineral Engineering, I would like to welcome you to the Sixth Annual Placer Mining conference. We appreciate your attendance and hope the conference will be of value both technically and in renewing friendships.

Both Chancellor O'Rourke and Vice Chancellor Phillips have asked me to extend their regrets at not being here at the opening ceremonies. Unfortunately, they have to be out of town because of the legislative review of the campus budget for next year.

At this time I would like to introduce Bill Allen, Mayor of the Fairbanks North Star Borough.



## Welcome

*Bill Allen*

Mayor, Fairbanks North Star Borough

The mining sector in the Interior of Alaska is important to the Fairbanks North Star Borough. Not only the mining activity but also the support and services from the business community in Fairbanks. We are talking about a 100 million plus business. For that reason, and it makes good business sense, the Borough needs to protect the interest of the mining industry and I would like to discuss very briefly a few things that we are doing to support your endeavors. We recently adopted a comprehensive land use plan, however, during the drafting and development of this plan, we forgot an important sector of our economy, the miners. They brought it to our attention very readily and we were able to sit down with them, identify the mineral deposits within the North Star Borough and classify them as mineral areas to our satisfaction and also the miners in Fairbanks North Star Borough. This past weekend we held an Alaska Export conference, inviting people from throughout the United States to sit down with us here in Fairbanks and talk about the opportunity and potential we have in developing our resources. Certainly mining played an important role in that. It is our hope that we can do whatever possible in the government sector to provide the support necessary for mining to expand and continue to develop to the point where we become an export state and trade some of those resources for money and stabilize the economy creating more jobs within the North Star Borough. Something very appropriate to talk on this morning is the lawsuit of the trustees of Alaska and other environmental groups versus the State of Alaska Department of Natural Resources. The suit challenges the method of handling mining development in the State of Alaska. The plain-

tiffs contend that the current state laws addressing hard rock minerals violate the State Constitution in Section Six I of the Alaska Statehood Act. The kicker to that law suit is that the plaintiff seeks to enjoin all production of hard rock minerals until State Legislature brings the statute into compliance. Simply stated, this means that the hard rock mineral industry would be closed down until our legislature adopted statutes to the satisfaction of the trustees for Alaska and other plaintiffs in that lawsuit. That has a very negative economic impact on mining obviously, but as I said earlier it also would strangle our opportunity to provide the service and support from our business community to the mining activities outside the North Star Borough. Because the suit could have such a significant negative impact on the Borough's economy, it is only proper that we, the North Star Borough, participate. I have instructed the Borough attorney to engage the specific legal foundation to represent us in joining the State of Alaska to fight this lawsuit and keep mining as a viable part of our economy.

You're also having problems with the environmental protection agency. Don't feel alone. I am having the same problem with the clean air act and the regulations to be imposed upon the Fairbanks North Star Borough. The way we approached this after we resolved the fact that it was something we had to live with, was to sit down and talk to Ernesta Barnes and compromise on several issues. I found Mrs. Barnes to be a very fair but firm person. I don't agree with the law she was administering to a certain extent, but there again, I think she met us half way. And I guess that brings me to a point that many people have been talking about lately, and that is the resource coalition made up of folks from the mining industry as well as petroleum, agriculture, farming, and fishing. Let's get together and find out what barriers stand in our way for resource development. I think united we stand a better chance to clear some of those hurdles rather than try to take them on one by one as single industries. I appeal to you before you start drawing your guns from your holsters and blasting away, that you do attempt to compromise with EPA, see if there is a point to where we can continue developing the mineral industry but at the same time, be in compliance with the laws. In the event this is not possible, again, the Borough is prepared to protect its economic interests in the North Star Borough. I have instructed our Borough attorney to attend a three day law course next month, entitled, 'Practical Law and the Environment.' What it does is outline and address the responsibilities of the developers but it also addresses what I think is very important and the key to the issue, the rights of the people to earn a living in the State of Alaska. And we are prepared. I have met with the assembly and we see a storm in the future coming. I have met with the Fairbanks North Star Borough Assembly and explained the negative impact the regulations, as they are interpreted today, would have on the economics of our Borough and have recommended and received their concurrence to do whatever is possible to protect the economic rights of the mining industry in the Fairbanks North Star Borough. I just returned yesterday from San Francisco where I met with one of the



owners of the natural gas in Prudhoe Bay. Right now we have gas to the north of us, we have gas to the south and there is no reason why we can not enjoy the benefit of low cost power in the Interior of Alaska. I am pleased to tell you that the reception we received in San Francisco was very favorable. Until we get low cost energy in the Interior, our ability to expand and develop our natural resource base is very limited.

This concludes my remarks. I guess coming from the private sector, I have heard this adage before and I have laughed at it, but I am sincere when I say to you that I am from the government and I am here to help you. I wish you a very successful conference and thank you for meeting here at Fairbanks.



## Welcome

**Earl H. Beistline**

*President, Alaska Miners Association*

Thank you Dr. Aughenbaugh. Mayor Bill Allen, fellow miners and friends, on behalf of the Alaska Miners Association, I am pleased to add my welcome, to each of you, to the Sixth Annual Conference on Alaskan Placer Mining. The conference committee has arranged an informative and educational program on pertinent subjects important to all persons directly or indirectly involved in placer mining. The conference is sponsored by the School of Mineral Engineering, University of Alaska-Fairbanks, and the Alaska Miners Association. The conference committee this year was chaired by James A. Madonna and committee members were: Del Ackels, Jeff Burton, Leah Madonna, David Maneval, Rose Rybachek, John Sims, Don Stein, and Dan Walsh.

In addition, a number of people from other mining organizations have contributed in various ways to the conference. These are:

Placer Miners of Alaska	<b>President - Henry Warner</b>
Miners Advocacy Council	<b>President - Bob Aumiller</b>
Alaska Women In Mining	<b>President - Connie Parker Carl</b>

### Mining Districts:

Circle	<b>President - Del Ackels</b>
Livengood	<b>President - Rose Rybachek</b>
Koyukuk	<b>President - Bob Aumiller</b>

The Alaska Miners Association is represented by its various branches. These are:

Anchorage Branch	<b>John Rense</b>
Fairbanks Branch	<b>Don Stein</b>
Nome Branch	<b>Ron Engstrom</b>
Juneau Branch	<b>Ray Renshaw</b>
Ketchikan Branch	<b>Ralph Yetka</b>
Sitka Branch	<b>(no chairman at present)</b>
Haines Branch	<b>Merrill Palmer</b>

The recently appointed full-time executive director for the statewide association is James R. Jinks. Jim was formerly deputy director of the Alaska Resource Development Council. In about ten days, he will begin his full-time activities for the association.

Also, present from the statewide organization are: Ethyl 'Pete' Nelson, Vice President and Sandi Thomas, Secretary-Treasurer.

In addition, many companies have cooperated by bringing to the conference displays of services, supplies and equipment of interest to people in the mining industry resulting in an excellent 'trade show' adding to the effectiveness of the overall program.

Greatly important to the success of this meeting are those persons who have 'gone the extra mile' in preparing presentations of papers for the benefit of each of us - information that may stimulate creative thinking and discussion of ideas that can be of value to each operator and service business persons to improve their specific operations and/or businesses, as well as the mining industry in general.

In addition, other scheduled meetings and short courses during the period of this conference allow pertinent operating regulations to be explained and the opportunity for conference participants to express their thoughts and learn of various innovations. The most important constituents of this conference are you, the participants. If you were not here, the total idea of bringing forth current operating experiences, new thoughts, recent and proposed information pertinent to the industry, displays or equipment and the resulting cross-fertilization and, hence, improving your respective operations, the objectives of the conference could not be achieved.

Equally important are session chairmen who are on the front lines and responsible for speakers actually making their presentations.

We are happy you are here and encourage you to participate fully in the activities of the conference. Do not hesitate to raise questions you may have and to pursue obtaining information that you desire.

It is my pleasure to read a letter from Congressman Don Young which is addressed to all Alaska miners.

"As you all well know, the news for our placer miners has not been very good lately. In my opinion, E.P.A.'s decision to move for BAT implementation by July 1 is unreasonable. I just want to let you know that I will continue to work and pull for you in this matter. I have written to E.P.A. administrator Ruckelshaus as well as to the democratic and republican leaders on the house public works and transportation committee which is currently reviewing the clean water package. Senator Stevens, Senator Murkowski and myself will be doing all that we can to ensure that Alaska's placer miners have the time they need to adjust to these changes in regulations.

"Best wishes for a successful conference and I look forward to seeing you the next time I am in Alaska. With best wishes, Sincerely, Don Young, Congressman for all Alaska."

Best wishes for a stimulating, informative and pleasurable conference experience.



## Letter from Bettye Fahrenkamp

To all my friends. I regret that I cannot be with you at this annual conference banquet. I had planned to attend, however, at the last minute the press of legislative business and its time constraints has made it impossible. Perhaps the most distressing is that I will miss all the abuse that I have grown accustomed to receiving at these little roasts, but I know that your days will be productive and that you will address the issues which so grip your industry. Good luck in your efforts, God knows we need it.

Bettye Fahrenkamp  
Alaska State Senate.

## The Placer Geology of the Wiseman Area

Ed Armstrong

Vice President of Exploration and Development  
Tri-Con Mining Company

Placer deposits are the product of a number of geological processes. It is therefore relevant that we take a look at the geologic history of the southcentral Brooks Range for a clearer understanding of the genesis of the Wiseman area placer deposits.

During early paleozoic times when the most primitive fishes were beginning to swim the seas, this area was an expanse of sea bed. Gradual thickening of the sediments caused a crustal downwarping and the orogenic cycles had begun their formation of the Brooks Range. Large blocks of sea bed sediments were synchronously metamorphosed and thrust upward to heights which would dwarf today's peaks. Mobile bodies of super heated magma were injected into the cracks, working their way to surface in the form of rhyolite flows. Pressurized magmatic gases, rich in ions of gold, silver, iron, copper, lead and antimony as well as other base metals and non metals, traveled through cracks where combinations of pressure, temperature and chemical differentials caused precipitation as hydrothermal veins. Jagged drainage systems were carved into the elevated plateaus by mountain streams as climatic events began mass wasting and shaping the terrain, supplying sediments for their eventual return to the sea beds. During the ice ages the main valleys served as limits for long glacial threads flowing away from the tallest peaks. The ice advanced as many as four different times. The most recent advance ended only 20 to 30 thousand years ago. The main river valleys, including the valleys of the middle fork of the Koyukuk River, Wiseman River, Glacier River, and others, contained glaciers. The tributary valleys, including Nolan, Ema, Gold, Many Creek, Linda and many others were blocked by ice causing the formation of many long glacial lakes. The last ice retreat caused the draining of the lakes and the land forms which we recognize today; the hanging valleys, terraces, deltas and moraines.

The placer deposits of the Wiseman area have yielded some unique specimens. Clara Creek, an 18 ounce nugget, Union Creek, a 33 ounce nugget and Hammon River, a 55 ounce nugget, while early operations on Nolan Creek yielded a 40 ounce nugget. The gold occurs in three types of deposits. The oldest deposits are referred to today as the deep channels, which may correlate with the deep deposits of the Tanana basin. They are incised into bedrock and have a slope gradient generally steeper than the present valleys. The gold is intermixed with coarse gravel and boulders overlying residulant clay and decomposed bedrock. Gravel thicknesses may range from just a few feet to 20 ft. The deep channel gravels are buried under 50 to 200 ft of overburden consisting of muck, slide rock, silts, gravel and clay layers. Below the seasonal frost line the column is generally frozen to bedrock. The pay streaks are frequently interrupted by features referred to as drop-offs, which are near vertical bedrock faces which created waterfalls in the ancient channels. If man had been alive then, he could have walked the stream, simply rolling boulders aside and retrieving the large chunks of gold which were being transported by the torrential streams, causing such minimal environmental impact that even the E.P.A. would have smiled, so long as he put the boulders back in their original positions. But God and Mother Nature played a trick on future mankind by sending the glaciers down the main valleys.

Deep channel gold was scoured from the main valley channels, transported, then redeposited. The steep mountain tributaries were dammed by the glaciers at their mouths causing lakes to occupy the steep wall canyons. This caused the stream beds to be elevated some 50 to 200 ft. above the ancient channels resulting in the burial of the remaining deep channels under fine silt and clay sediments, the lakes playing the part of mega settling ponds. This rise in stream base level caused the deposition of the placer deposits which we recognized today as the bench placers. They're generally 50 to 200 ft. above the present valleys, occupying positions defined by structural features of the bedrock, such as intersections between bedding dip plains and block fault plains. The result was the formation of rich bench placer deposits according to a theory which we referred to as vector travel. This simply means that the heavy gold particles will travel by the most direct route to the plane of lowest elevation within a given rock block. This theory is supported in Nolan valley and its tribu-



Figure 1. Smith Dome -- looking up Archibald Creek.



Figure 2. Smith Dome.

taries by a dip of the bedding at 5 to 22 degrees to the northeast and a west-northwesterly strike of intersecting vertical faults. Given these two measurements, bench channels should be, and generally are confined to the northerly and easterly limits of any particular stream. The bench gravels are intermixed with boulders resting directly above clay or decomposed bedrock. The gold bearing gravels are covered by frozen muck, slide rock and loess accumulations from 50 to a 100 ft. thick. The gold from the bench placers has generally been found to be slightly less chunky than that of the deep channel gold, although further development of the bench placers may ultimately disprove this idea. The old timers developed and mined the bench placers by hydraulic ground sluicing, requiring the construction of many miles of hillside ditches. The abbreviated run offs each year made for short seasons and the thick overburden made cleaning to each square foot of bedrock a slow process without the aide of pumps or heavy equipment.

Once the glacial dams were removed from the main valleys, the drainages readjusted their baselevels and coarses, removing some of the upper silt and clay beds, and moving into what are referred to as their present positions. The present channel deposits, the third type of placer, rest directly above clay or decomposed bedrock and are intermixed with coarse gravel and boulders. The present channels, in many cases, have truncated the benches owing to the down cutting action produced by a steep gradient and stream advance. The rugged topography and narrow canyons where the gold occurs are the result of these actions together with the presence of local resistant beds such as those which have been solidified. Local gold bearing, present channel placers occupy east-west trending canyons, probably the result of structural weaknesses from the west-northwesterly trending block faulting system. The present channel placers are actually a group of channels which have wandered laterally due to solifluction, hillside creep, and mass wasting, together with regional uplift which is still going on today. Therefore in most instances, even the present channel placers are covered by 20 to 60 ft. of frozen muck, slide rock or loess. Development and production is best accomplished by combinations of hydraulic ground sluicing and open cut mining using heavy equipment. The same vector theory seems to hold true as a guideline for exploration. While a nugget or a pan color may be found nearly anywhere in a gold bearing drainage or side slope from any appar-

ent matrix ranging from muck to slide rock, these large gold pieces are likely in intransit to a present channel concentrating area. The gold from the present channels is generally chunky, with nuggets ranging to 5 ounces fairly common. Less common is the recovery of nuggets up to 20 ounces. In defining the relationship between each of the three types of placers one must step back and ask, was the fluvial process greatly accelerated from one phase to the next, from the deep channels to the benches, to the present channels? The answer is definitely yes and the dynamic depositional change was directly or indirectly caused by pleistocene glaciation.

Figure 1 shows Archibald Creek to Smith Dome. Note the particular bedding. The apparent bedding of the general area is approximately 5 to 22 degrees to the northeast and we can see just how that bedding lies in relation to the valleys, and the drop offs I referred to, the little guys that gave the old time miners such a headache when they were trying to follow the pay streaks. Figure 2 is a close up shot of the same thing, giving an idea of the steepness of the drop offs and also the bedding.

The character of the material in Wiseman Valley is primarily that of tills and glacial fluvial type deposits.



Figure 3. Nolan Valley.

What gold has been found thus far does not appear to be economic. The deep channel in this area, when it's encountered is a narrow V shaped channel. It's relatively narrow in breadth and it is incised into the bedrock.

Figure 3 is a look at the upper Nolan Valley. You can get an idea of the V shaped canyon, stream type canyon. You can picture a feature such as this carved down into the bedrock further down into lower Nolan Valley.



Figure 4. Claim at 4 miles below Discovery.



Figure 4 shows a claim approximately 4 miles below Discovery, just as it comes out of the narrow V shape valley and the flood plain gradually begins to widen in this area. It was right in this area that two Swedes in the winter of 1909 sunk their shaft and took 5,000 ounces out of that deep channel.

Figure 5 is a schematic sketch of the confluence of Fay Creek and Nolan Creeks showing some data which we have developed by drilling. Note the deep channel incised into the bedrock. Fay Creek was the original gold discovery in the Nolan drainage and it's been extensively mined at the mouth. We sank a shaft on claim No. 1 above Discovery, just above the confluence of Fay and Nolan Creeks. The shaft was sunk by drilling and blasting as opposed to the old stream thawing methods and it appears by all appearances to have the old method beat by a long shot.

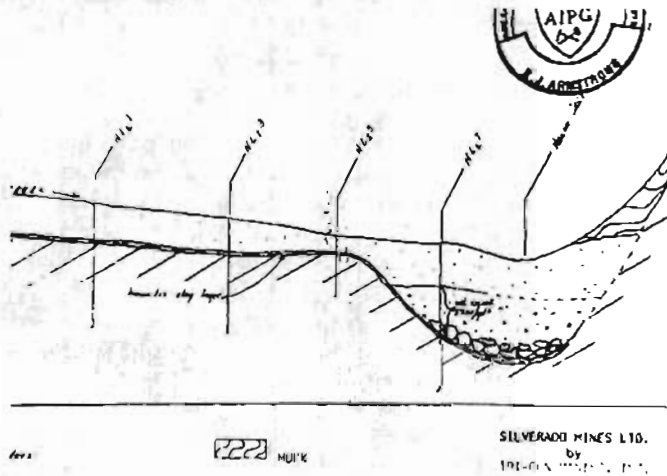


Figure 5. Drill section on Nolan and Fay Creeks.

Figure 6 shows a geologic feature called Gobblers Knob in Nolan Valley. This seems to be a delta type gravel deposit formed when the William Bench channel dumped into the ice dammed glacial lake. It consists almost exclusively of gravel, very poorly mixed, stratified in many different directions containing some gold but was not economical apparently during the time it was prospected.

Figure 7 shows Thompson Pup, a truly steep narrow canyon containing excellent placer gold. Note the high ditches where the old timers brought their water in. This is some 500 ft. above upper Fay Creek. The drainage contains some of the most beautiful placer gold nuggets of a crystal variety that you'll ever want to see.



Figure 6. Gobblers Knob.



Figure 7. Aerial view of Thompson Pup.

Figure 8 is the gravel washing out of the Thompson Pup. This area has been stripped above and the thawing is taking care of itself. Note the subangular quartz boulders and the green stone boulders.

Figure 9 is a sketch of some early prospecting data on Archibald Creek. Note the drift which we drove into the hillside. This drift yielded 3.1 ounces of nuggets from approximately 15 square ft. of bedrock cleaned. The gold occurred in and around the boulders resting on a clay layer. In this particular section this was the proposed pit which we had determined to process.



Figure 8. Thompson Pup.

Figure 10 is a sketch of the drift. What we did here was to go into the drift and chip out each of our samples, measuring the volume of each one, computing the cubic feet from each sample and washing each one independently. The red layer is the rusty pay gravel and right at the break where it began to downwarp is where most of the gold occurred. This was some of the early beginnings of this vector travel theory that I talked

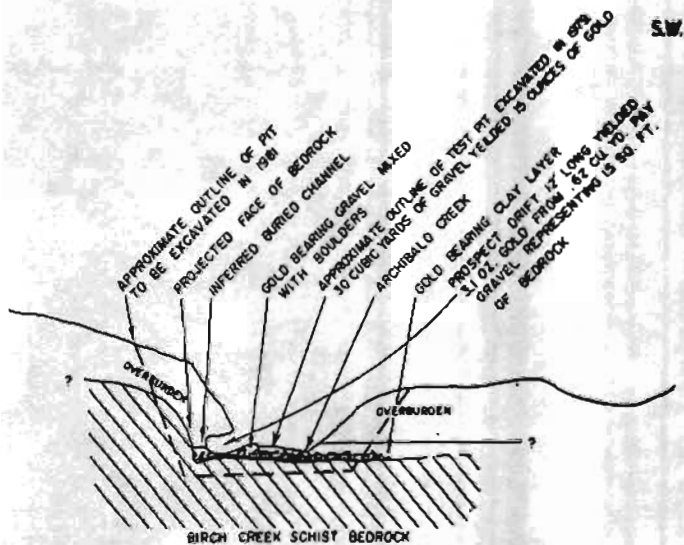


Figure 9. Schematic of prospecting data from Archibald Creek.

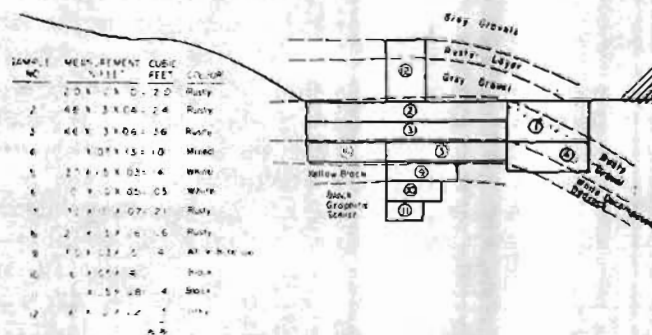


Figure 10. Drift section.

about. The rusty gravels are the best gravels underlain by a white decomposed clay, which overlies the bedrock.

Figure 11 is a longitudinal sketch of the same exploration program showing where the drift was driven. A pit was excavated in 1979. Approximately 30 yards of material yielded 15 ounces of gold which led us into the winter program. We tried to sink a number of shafts here and we kept encountering live ground water once we got through the seasonal frost line, so we couldn't get into bedrock. Finally, we got to an ice lense, went

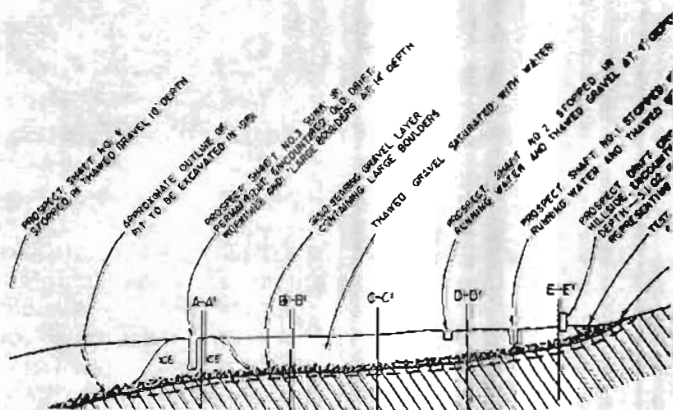


Figure 11. Longitudinal section along Archibald Creek.

down the shaft and came to large boulders. We started removing the boulders from side to side and we turned up an old flat Hills Brothers coffee can. We weren't the first ones to be there.

Figure 12 is a cross section further up Archibald Creek showing two distinct present placers developed by drilling and pit sampling. The creek right now is flowing with placer pay material, and then there's a little reef of bedrock exposed and the relatively flat deposit contains paying quantities of gold.

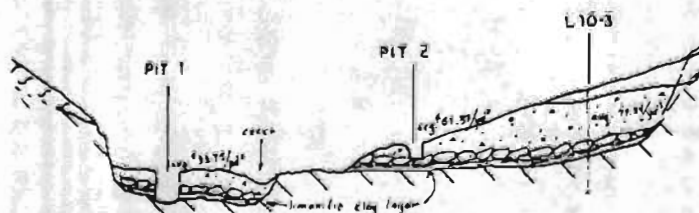


Figure 12. Two distinct placer deposits on Archibald Creek.

Figure 13 is the final pit from 1981. Note the bedrock and how steep it plunges. Again the vector theory and the gold, primarily the best gold, was lying right down in this deep channel. The sketch is looking downstream through the completed cut. Note again the gravel bank in this section, with one drill hole, determined to be pay. Note the premining topography and a gravel boundary layer containing subeconomic gold. This gold is in transit down into the present channel.



Figure 13. 1981 sample pit.

Figure 14 shows the right limit of the pit with three to five feet of limonitic clay overburden, eight to ten feet of frozen ice and muck, and fifteen feet of gravel containing scant quantities of gold. Note the oxidation of the bedrock and the boulders occurring in and around the upper part of the bedrock and the rusty pay gravels. The rusty pay gravels rest right above the decomposed clay. Taken from the bedrock of this pit were a 12 ounce nugget, about a 3 ounce nugget and a couple of smaller nuggets. The great majority of the gold which we found is of this size. Greater than 50% of all of the gold which we removed has been +4 mesh.

To bring the geomorphological information into a practical prospective I'd like to add some information about the Nolan Placer deposit. Consistent with all of the deposits shown above, development requires playing by the rules set by nature. Limiting factors include steep topography, narrow canyons, a scant water supply except during periods of runoff, permafrost, large boulders and thick overburden consisting of clays and silts which settle out in the glacial lakes over long time periods. All of our mining efforts have been focused on the remaining present channel deposits while ongoing exploration and development of both the bench placers



Figure 14. Right limit of sample pit on Archibald Creek.

and the buried channels have proven encouraging. Once the present channels are worked out they will be the recipient of tailings from the bench placers. The deep channels will be worked by underground mining methods, quite different from the steam thawing of the old timers. Most likely this will involve drilling and blasting and mucking by diesel powered equipment or perhaps John Miscovish's Misco Giant. As long as we have an economic and industrial system which values properties of gold, someone will endeavor to extract the gold from its resting place. As part of the long range development plan for the Nolan placer, the State of Alaska's Department of Transportation has succeeded in upgrading the state road into Nolan. This has been for the mutual benefit of the families who reside year round in Nolan as well as the mining community. We've also followed guidelines set by DEC and EPA to reclassify Nolan and its tributaries for industrial use. This is the logical and best use for the Nolan area as defined by all the guidelines set forth by those agencies and supported by oral and written testimony at public hearings by the great majority of all who testified. Owing to a combination of ice, steep canyons, which limit the effectiveness of heavy equipment, and fine grained overburden which must be stripped and transported downstream to expose the gravels, the water cannot help but be temporarily dirty. While settling ponds can remove many of the settleable solids, the retention time required to remove all the finest clay and loess particles may require ponds larger than available space permits. While DEC tentatively approved the reclassification, it now seems that EPA is changing its posture regarding state stream reclassification. It is our hope that simple logic will prevail and that Nolan as well as other resource rich areas in the state can contribute to the Alaskan economic development and be allowed to function under relaxed guidelines to their full industrial potential.

## Alluvial Mining Methods and Jig Treatment Plant Technology

Mike Green

Vice President, Alluvial Dredges International Ltd.

### Introduction

The context of this paper is based mainly on developments in the alluvial tin mining industry in the Far East, but is equally applicable to gold and other alluvial minerals.

### Mining Methods

#### Bucket Line Dredging

Bucket line dredging is the most effective and efficient method of mining alluvial deposits. Cutter suction dredges and bucket wheel dredges do have applications under certain conditions but the bucket line dredge is the only unit which can cope with all situations - heavy clay, free sand, buried timber, boulders, nests of cobbles and differing types of bedrock.

The objective of bucket line dredging is to dig and process as large a volume of material as quickly and as cheaply as possible. Bucket dredge sizes range from 4 cubic foot bucket capacity, digging to 25 ft. at a rate of 240 cubic yards per hour (1.7 million cubic yards per annum) to 30 cubic foot buckets digging to 180 feet at a rate of 1,400 cubic yards per hour, (10 million cubic yards per annum). As the minimum economic life of a dredge is 10 years, we would consequently be looking for reserves in the region of 17 million cubic yards for a 4 cubic foot dredge and 90 million cubic yards for a 30 cubic foot dredge. Under Alaskan conditions, one would also look for higher grades in order to reduce the initial pay back period.

With respect to future developments in bucket line dredges, we are currently associated with the design of a dredge which will dig to 180 feet. This dredge will operate in reserves with a depth of 300 feet of which 120 feet is barren overburden. The mining scheme involves dry stripping of this overburden and lowering water level to allow the bucket line dredge to dig to the cut off depth (180 foot dredging depth).

#### The Combi Miner

Where the volume of reserves is either insufficient to sustain a shallow digging dredge, or where there are isolated high grade deposits which are not interconnected (such as may occur in riverine deposits), the alternative method is the Alluvial Dredges' Combi Miner. The concept of the Combi Miner evolved in the 1930's, and consisted of a floating treatment plant fed by a land operated drag line. In 1938, there was reported to have been some 77 of these units operating in California alone.

The ADL Combi Miner utilizes a modular, portable, pontoon configuration which can be easily transported

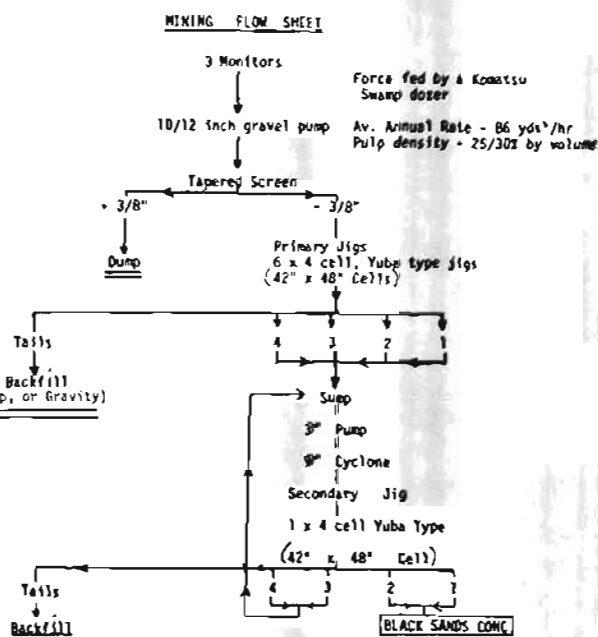
The smallest economic unit would be the Combi 80 (80 yds<sup>3</sup> hr) and the largest the Combi 180 (180 yds<sup>3</sup> hr).

Gravel pump mining is still used extensively in the Far East for mining small, rich areas and the rich pockets left by the bucket line dredges in areas having pinnacly limestone bedrock.

The sluice, or palong, is now being replaced by cyclone/jig plants as studies indicate that a jig plant improves the recovery by some 15% to 20%. The flow sheet of one particularly efficient gravel pump mine in Indonesia is given in Figure 1.

Depth of overburden - 0 ft. to 50 ft.  
Depth of tin bearing ground - 6 ft. to 18 ft.

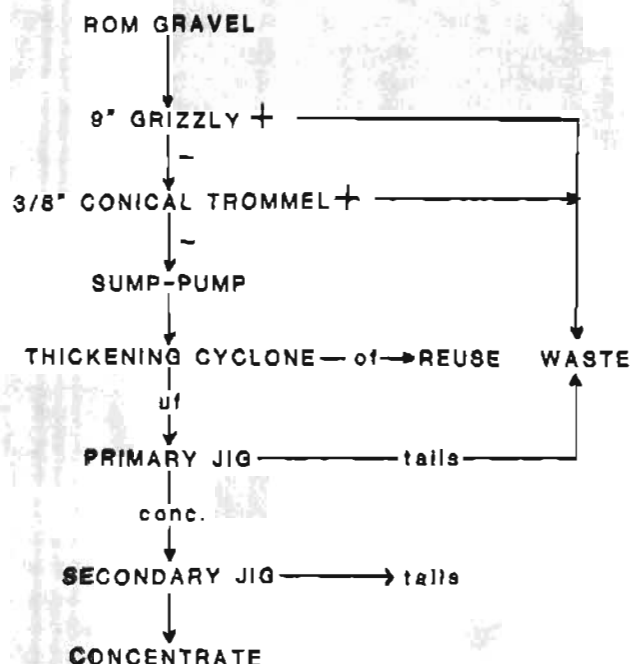
Overburden is removed by bulldozing, if less than 16 ft. in depth.  
If more than 16 ft. a Manitowoc, 6 1/2 yd' dragline with a 140 ft.  
boom is used, stripping being carried out by side casting.



**Figure 1. Gravel pump mining flow sheet.**

This is the closest approximation to Alaskan mining methods and is employed where the deposit is shallow with a high percentage of oversize. Figure 2 shows the flowsheet of one such operation.

Mining is carried out using a 3/4 cubic yd. backhoe and 6 on/off highway tipper trucks of about 12 cubic yd. capacity. The plant needs to be located either on high ground, or adjacent to a worked out area in order to facilitate tailings disposal by gravity.



**Figure 2. Dry mining flow sheet.**

## Jig Performance

Very little meaningful data has been published on gravity concentration of alluvial gold by jigging. By this I mean recoveries relating to the optimum feed rates, optimum operating settings required to obtain maximum recovery and recoveries by mesh fractions. This is a similar situation to that which faced the alluvial tin mining industry in the late 1960's. During this period I was working for the London Tin Corporation, who controlled 13 companies operating 36 bucket line dredges Malaysia and Thailand. These dredges ranged from 9 cubic ft. digging to 20 ft. depth, to 24 cubic ft. bucket dredges digging to 159 ft. and were equipped with a wide variety of jigs; Rouss, Hartz, Hartz Bandelari, Bendelari, Pan American, Yuba and later circular jigs.

During this period, the economics of alluvial tin mining were changing significantly. The shallower, high grade deposits, which contained coarse, easily recoverable cassiterite were rapidly becoming worked out and the characteristics of the new deposits were markedly different. These deposits were deeper, with a high ratio of overburden to tin bearing ground, the grades were lower and the mesh size of the cassiterite was much finer and in many cases the percentage of accessory minerals had also increased. This demanded not



only dredges having much higher digging rates but also improved plant efficiencies and, consequently, a jig research program was initiated to determine the operating criteria necessary to obtain a 95% recovery from a primary jig circuit and 99% from the secondary and tertiary circuits having a typical mesh size distribution of cassiterite in the feed.

The basic parameters to be determined were:

- The optimum feed rate, cubic/yds. per square foot bed area.
- The required intensity of stroke, cubic feet per minute per square foot bed area. (This is a function of the stroke length, stroke frequency and area of the diaphragm over the bed area).
- The average sand flow speed over the jig bed. (This is a function of the slope (or step) of the jig bed, the makeup water flow, the pulp density of the feed, and the height of the tail board at the end of the jig, above the top of the ragging.)
- The recovery obtainable from each mesh size fraction.

Other factors examined were the size and depth of the jig ragging, the effect of the value of the feed on recovery, the effect of feed rate on the pull through (percentage of feed reporting to the spigots) and the effects of variations in the pulp density of the feed and the slime content on recovery\*.

\*Batzner, D.J., "Recovery of Cassiterite in a Rouss Jig," Bulletin of International Mining and Metallurgy, Dec., 1966, pp. 286-292.

Subsequently, I was able to apply this criteria in establishing operating efficiencies of the dredges in the organization and to progressively upgrade their performance and recoveries to the required level. This program in turn led to further research into plant design and operation, as related problems were defined and other causes of losses were pinpointed. This research covered such elements as revolving screen performance, jig feed distribution, jig makeup water control, jig spigot design, cyclone performance, bucket spillage and angle of repose of underwater tailings. Blinding of jig screen plates was found to be both a major source of jig losses and of time consuming maintenance, and design research resulted in the development of the all rubber 'patented' Tiger rubber jig screen plate, which is non blinding and which is now used exclusively on all types of jigs in the Far East and Africa.

### Types of Jigs

Three types of jigs are currently used in the industry:

- 1) Square or rectangular jig
- 2) Circular jigs
- 3) Trapezoidal jigs

#### Square/Rectangular Cells

These are installed on the majority of dredges and land based plants, the Yuba type drive being the most favoured in the tin industry. This is a side drive which provides easy access for maintenance and is more mechanically economical in that one drive will operate two banks (4 flow lines) of jigs.

The alternative is the Pan American drive which has the diaphragm drive located below the jig body, with one rocker arm operating two adjacent cells. Consequently, the jigs can be located immediately adjacent to

one another using less deck space but with the disadvantage that it is not possible to physically check the beds of the jigs when they are operating.

The above mentioned jigs are used in multi-cell configurations, usually either 3 or 4 cells in a flow line, and are arranged in either single or double banks. The number of cells and configurations used depends on the deck area available and the permutation which matches the required treating capacity.

The multi-cell configuration is more versatile metallurgically than the circular and modular jig, as the latter is only a single cell unit consequently with one point of control for stroke length and makeup (hutch) water.

With the rectangular jig both the intensity of the stroke and the supply of makeup water for each individual cell may be adjusted. This is an advantage when there is a high percentage of fine ore (gold or tin) present in the feed as the last two cells may be operated with a longer stroke length and reduced makeup water to scavenge the 'fines.' In this circumstance, and also when there is a high proportion of black sand present in the feed, a high and low grade circuit may advantageously be installed. This is illustrated by the recovery pattern which can be obtained from a 4-cell Yuba type jig, under optimum feed rate for tin ore, as given below:

Feed Rate - 20 yds<sup>3</sup>/hr

Cell No.	1	2	3	4	
% Dist. of total cassiterite recovered, by wt.	55	27	12	6	(100)
% Dist. of back sands recovered, by wt.	28	30	27	15	(100)
% Dist. of silica recovered, by wt.	14	16	31	39	(100)
	To high Grade		To low Grade		

### Recovery of Cassiterite by Mesh Size

A typical recovery of cassiterite by mesh size from an operating dredge equipped with yuba type jigs follows:

Specific feed rate - 0.38 yds<sup>3</sup>/ft<sup>2</sup> bed area  
 Makeup water - 4.28 Imp. gal/ft<sup>2</sup> bed area  
 Slope of bed - 1 in 19  
 Intensity of stroke - 2.02 ft<sup>3</sup>/ft<sup>2</sup>/min.

Mesh size B.S.	% Dist. SnO <sub>2</sub> in feed	Recovery by mesh fraction %
+10 (+1.67 mm)	Nil	Nil
-10+25 (0.60)	0.1	100
-25+52 (0.30)	0.2	97 (locked tin)
-52+72 (0.211)	1.4	99
-72+100 (0.152)	42.7	98
-100+120 (0.125)	39.0	98
-120+150 (0.100)	12.0	98
-150+170 (0.088)	2.2	93
-170+200 (0.076)	1.2	86
-200+240 (0.065)	0.8	77
-240+300 (0.053)	0.3	47
-300 (-0.053)	0.3	11
	100.0	97

## Circular Jigs

The circular jig is divided into modules or segments, each segment being a one cell unit. The feed enters at a central boil box and radiates out to the periphery of the jig where the tailings are discharged. These jigs can handle a higher specific bed load (feed rate) than rectangular jigs due to the reduced side wall effect and possibly the decelerating effect on the sand flow. Specific bed loads of between 0.42 and 0.62 yds<sup>3</sup>/ft<sup>2</sup> bed area are obtained, as opposed to 0.36/0.38 for rectangular jigs (To obtain a 95% recovery of cassiterite with a normal mesh size distribution). The circular jig concept dates back to pre-World War II but the first successful circular jig to be used in the Far East was designed by Norman Cleaveland of Pacific Tin. This was 22 ft. in diameter with 8 cells, or modules, and was operated by a Pan American type mechanical drive, one rocker arm assembly driving two adjacent modules.

Subsequently, MTE Holland introduced a circular jig, with a 25 ft. diameter having 12 segments or modules but using a mechanical/hydraulic drive, for which an improved recovery, particularly in the finer fractions, is a theoretical consideration. This drive imparts a sharp upward stroke which dilates the bed and gives a longer settling period, without complete compaction of the bed taking place. The jig attained favor in the dredging industry with the development of large, high capacity dredges. A dredge treating over a 1,000 cubic yds. an hour would demand a large number of flow lines if rectangular jigs were installed, consequently, the higher capital cost of the mechanical/hydraulic circular jig was outweighed by the greatly reduced number of flow lines and reduced deck space. My comments on the relative merits of the two drives are confined to factual data obtained from personal jig sampling programs which were carried out by my immediate associates and me on operating dredges, using both types of drive. Using the mechanical drive, I have obtained 99% recoveries with specific bed loads (feed rates) of between 0.42 and 0.62 cubic yds. per square ft. bed area, with a 97% recovery in the 120 +200 mesh fraction containing 2% of the total cassiterite. A 95% recovery was initially obtained from the mechanical/hydraulic drive with a specific bed load of 0.63 cubic yds./sq. ft. bed area under close supervision. However, the major operators are now basing jig capacities on a specific bed load of between 0.42 and 0.50 (max.) cubic yds./sq. ft. bed area, for a 95% recovery of cassiterite. This is believed to be due to the problem of maintaining the stroke frequency necessary for the optimum displacement at the jig bed.

## Trapezoidal Jigs

Tests were also implemented during this period on an Anglo Oriental (Malaya) Ltd. designed Trapezoidal (Modular) jig, having a mechanical drive and a sloped bed. This proved to have a specific feed rate of 0.58 cubic yds./sq. ft bed for cassiterite, under operating conditions.

## The Effect of Fine Ore and Slime Control on Jig Recovery

A case history illustrates the effect of the combination of a high percentage of fine ore and slime in the feed on recovery.

"Check sampling of the dredge on which the trapezoidal jigs were eventually installed showed that the recovery of the jig(s) had dropped to 90-93%, but that

the feed contained 20% of the tin ore in the -120 mesh fraction and up to 1,000 grains/Imp. gallons of slimes in the feed (-300 mesh B.S.). Full scale tests were initiated simulating these conditions and it was determined that by increasing the stroke intensity (stroke length), the recovery was restored to 96%.

"This was adopted on the dredge, but the dredge conditions again worsened and the slime content in the feed increased as much as 5 times with a consequent fall off in recovery. In order to offset the effect of this additional slime, it was found that the next step was to reduce the feed rate to the jigs in order to maintain optimum recovery."

The same sequence would apply to fine gold and/or a feed having a high slime content, perhaps even more so, depending on the shape factor. However, before going overboard on fine gold losses, I must emphasize that it is first necessary to determine whether or not there is sufficient fine gold present to warrant the expenditure of additional capital on new equipment and/or reducing throughputs to achieve a better recovery in the finer fractions.

## Conclusion

In conclusion, I would emphasize that in determining the type of jig to be used, the jig layout and the treatment plant flow sheet, there is no 'be all' and no 'end all.' It is a matter of 'horses for courses,' with consideration being given, not only to the mineral processing flow sheet, but also to such factors as the availability of power and water, tailings disposal and slime settlement, environmental harassment, the location and related problems, the space available, and the people who are going to operate the plant. The advantages of sophistication have to be weighed against the operational advantages of mechanical simplicity.



## Techniques of Alluvial Placer Evaluation

Rodney Blakestad

President, Sedco Exploration Limited

The importance of placer evaluation of course is obvious to experienced miners and engineers. Still it surprises me to know that numerous property transactions and mining ventures are undertaken in Alaska without any prior or with inadequate property evaluations. The purpose of placer evaluations is to move the question of economic viability of a particular deposit from the realm of chance into the perspective of basic financial decision making. I hope to expose some of the basic criteria that should be considered and examine the goals and some of the techniques of various programs relating to an effective placer evaluation.

Most alluvial placer deposits have a few basic similarities. The first similarity is the fact that these placer deposits, whether gold or other mineral, are found in gravel. The second is that gold and the other ore minerals have a higher specific gravity than the other





Figure 1. Gravel lens.

clastic components of the gravel. The third similarity is that placer minerals generally have a relatively high unit value.

Beyond these three similarities, it should be recognized that alluvial placers are geologically complex mineral deposits with a wide variety of differences existing between individual deposits and even within deposits from one locale to another. This latter characteristic is exemplified in the distribution of some of the typical gravel lenses or layers that one might find in a



Figure 2. Gravel layers.

seemingly typical gold bearing alluvial deposit. (Figures 1 and 2) Selection of an effective evaluation technique is commonly controlled by other factors such as the goals of the program and the nature of the deposit itself. Often the resources available to the investigator turn out to be a major contributing factor in the type of technique used.

A most often asked question relating to placer evaluations is, "what constitutes an acceptable density of testing to prove the value of a particular deposit?" In order to answer this question, one must know what level of assurance the investigator requires and what the particular characteristics of the placer deposits are. Both of those factors range widely. For a relatively raw placer prospect, I approach this question with the concept that the property should be examined in two basic phases. The first phase should be a relatively inexpensive and general assessment of the property and the second phase, a more detailed evaluation of the positive aspects of the first phase results. It's important to keep in mind that the total cost of both phases of evaluation should not exceed the profit potential of the ore body.

Figure 3 is a flow diagram which exemplifies some of the basic concepts relating to placer evaluations. The basic goal of a cost effective evaluation program should be to obtain a sufficient number of appropriately representative samples of the ore zone, from which reasonably accurate projections of ore grade can be made. This has to be made with an acceptable degree of confidence. In general, sampling from many sites pro-

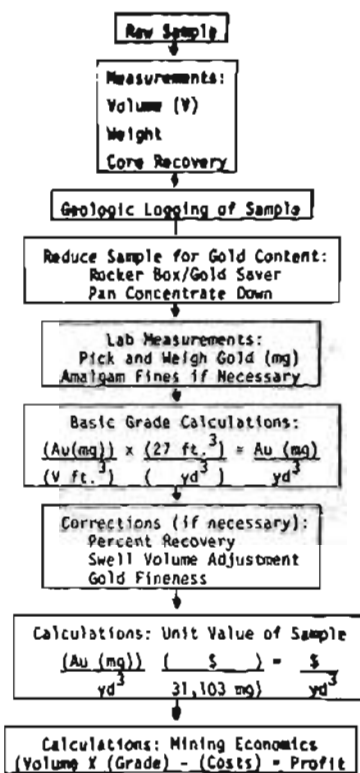


Figure 3. Sample evaluation flowsheet.

vides more confidence than sampling from just a few sites. Likewise large samples tend to exude more confidence than small samples, and close spaced samples generate more confidence than wide spaced samples. Similarly, sampling of the entire host horizon increases the effectiveness of the evaluation program, and well documented sampling procedures carry more weight than sketchy notes. So, when investigating a placer deposit either for development or for possible purchase or sale, it's highly recommended that proper notes be taken. These can be documented and shown in relationship to the value of the deposit.

A good sample generally is one as close to perfectly representative of the sample medium as can be reasonably acquired. From this sample, of course, the valuable placer minerals have to be extracted and accurate unit value determinations made. So if the sample is representative at the beginning of your sampling program the results of that sampling will reflect this in the overall evaluation. Two factors which influence the size of a good sample are (1) the degree of coarseness of the alluvium and (2) the mean size of the gold particles within the placer concentration. Due to the effect of boulders, coarser gravels require relatively large samples as representative. Also those deposits containing a substantial component of large gold nuggets require larger samples to be effectively evaluated. After a sample site has been selected and a representative sample is in hand, it's important to carry out a sample reduction process that systematically extracts all of the valuable placer minerals and in the process records the critical sample information of the values, grain size, washing characteristics and other data acquired from the evaluation proceedings. This type of information is very useful in deciding the kind of mining method and recovery plant which might be subsequently used.

Figure 4 shows a typical sample reduction area where several different types of reduction equipment are to be employed in reducing placer samples. The sample location needs to be carefully noted and clearly marked so that it can readily be found in the future. The sample



Figure 4. Sample reduction area.

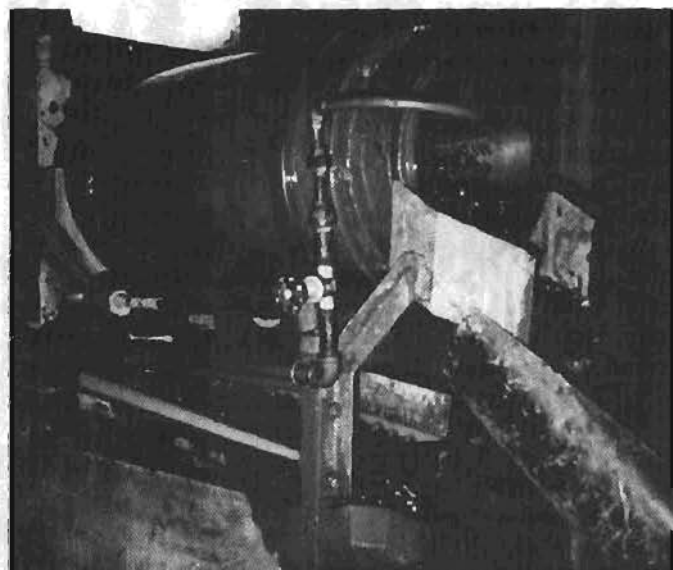


Figure 5. Denver Gold Saver.

area or sample site should also be located on an appropriately scaled map for reference and for other possible engineering studies. Secondly, it's important to record the nature of the sample site, i.e. any biases which might affect the results from the particular sample site. The volume and/or weight of the sample must be accurately measured as either in-place volumes or loose volumes. The loose volume sample measures are generally larger than actual in place equivalent volumes by a factor of 15% to 30%. Loose volume measures are generally converted to in-place volume measures prior to unit volume calculations at a particular sample site. The sample can be reduced to a heavy mineral fraction by any number of means, such as panning or standard rocker box. Other popular techniques for concentrating samples are the the Denver Gold Saver (Figure 5) and the Gold Screw. Bulk samples may be processed by small scale sluicing techniques.

The sample reduction process used is determined by the number and size of the samples to be tested. The other controlling factor is the amount of extremely fine grained gold present. Free gold contained in the heavy mineral concentrates must be carefully extracted. I prefer the picking technique which is appropriate for those types of deposits having relatively coarse grain gold. The picking technique is simply using a pair of tweezers to pick up every little speck of gold in the concentrate that you can. Very fine grained gold, often referred to as fly specks, is generally not amenable to picking.

It is important to note the type of sample reduction technique used and the number of these fine grained gold flakes. Most sample techniques used today are chosen primarily for their speed and low cost parameters, and do not necessarily collect the very fine grain gold. If you get more than 10 or 20 flakes of fine grained gold, you must recognize that the technique you're using may not be designed for retention of that type of gold and that there may be considerably more of it in the gravels than what you see in your processed sample material. It is also important to retain the gold

Fire assay has been used by a number of people over the years as a means of placing a value on their particular placer deposits. However, it should not be used to delineate the value of placer deposits because of what is termed the "nugget effect" and the fact that inaccuracies in the process are multiplied many fold in the subsequent calculations. Heavy minerals assays if used, must be viewed cautiously.

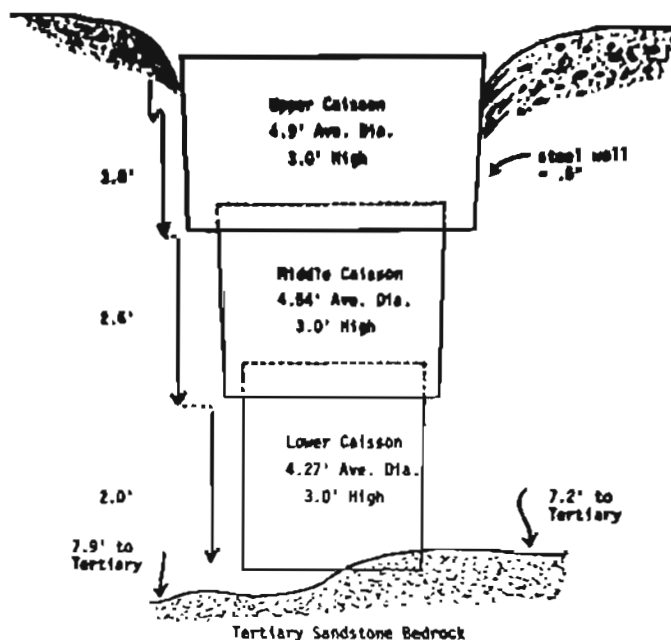
Natural bank sampling and shallow pitting or dozer trenching (Figure 8) are among the least expensive and fastest ways to obtain good evaluation data if your placer deposit is suitable to this type of technique. Channel sampling is taking a channel of material out of the side wall of the excavated corridor, or a natural exposure, measuring that volume, extracting the gold and prorating the values obtained. Extreme caution should



always be exercised when working near the face of these dozer cuts as they tend to be unstable and can collapse with remarkable speed. Boulder grounds are also difficult to sample with channel samples because of the invariable boulder in the side wall right where you want to cut your channel. Volume estimates and/or

Larger and deeper samples can be obtained with hydraulic excavators when such equipment is available. In backhoe sampling it is recommended that vessels of known volume be used to collect the samples from different depths as the backhoe hole is being dug. It may not be practical to sample the hole continuously through the host horizon, but volumes from intervals in the hole can be used to obtain reasonable and representative results, even if done below the water table.

Placer drilling offers a cost effective means of evaluating alluvial gravels as well. Drilling is relatively fast and it provides the ability to evaluate a large area in a short period of time. There are numerous drill types available to carry out evaluation programs such as the



Location: D.H. 7, L-PC, (6500N, 9110E), Ventna District Alaska  
Depth: 7.6'  
Water Table: 1.5 deep (55 gallons/minute pumping required)  
Volume Removed: 7.60 yd<sup>3</sup> (loose)  
In-Place Volume: 6.23 yd<sup>3</sup>  
Gold Recovered: 1923 mg  
Gold per Cubic Yard: 310.2 mg/yd<sup>3</sup>  
Losses Volume Small: 20%

13





Figure 8. Truck mounted resonant drill.

churn drill and the reverse circulation rotary drill. I would like to briefly describe the resonant or sonic drill system because it provides a unique sample that overcomes many of the critical aspects of placer sampling. The resonant drill system unit weighs about 16,000 lbs. and is readily adaptable to skid mounting, truck mounting or track vehicle mounting (Figures 8, 9 and 10). The unit should be fitted with hydraulic rams and stabilizers in order to be adaptable to irregular terrain. We found the super drill to be a reliable and a well



Figure 9. Track mounted resonant drill with mast in traveling position.

engineered piece of equipment requiring low maintenance on a routine basis. The drill head generates an axial vibration which is transmitted to the drill stem. The drill is able to core unconsolidated sediments whether these sediments are frozen or thawed. The drill pipe amplitude varies from 1 mm to as much as 4 mm under different drilling conditions. We utilized a 6-3/4 inch diameter single wall drill pipe which is fitted with a 7 inch outside diameter drill bit. We usually use 10 or 20 foot long drill stems threaded on the ends for evaluating deeper ground. The drill bits have carbide inserts on the



Figure 10. Track mounted resonant drill in operation.

leading edges. Carbide inserts allow drilling through boulders in the alluvial environment. The resonant drill is designed to obtain sediment cores (Figure 11) with only minor disturbance of the sediments and their contained gold. Our experience with the sonic drill has shown it to be mobile, fast and capable of sustained high quality core sampling.

Sampling and placer evaluation are the most important aspects of a mining operation. The technique one chooses to evaluate a placer deposit, if properly conducted, will remove a substantial degree of risk in developing the placer deposits.



Figure 11. Sediment core from a resonant drilling program.

# Resource Potential and Underground Mining Research of Permanently Frozen Deeply-buried Placers An Interim Report

James C. Barker

Supervisory Mining Engineer

Alaska Field Operations Center, B.O.M., Fairbanks  
and

Frank J. Skudrzyk

Head, Mining and Geological Engineering

School of Mineral Engineering, University of Alaska - Fairbanks

## Introduction

This paper consists of two parts. First I will briefly review the inferred potential of frozen, deeply buried placer gold deposits in interior Alaska. These deposits are typically overlain by 50 to 250 feet of ice-rich Pleistocene muck and are frequently uneconomic to mine by surface methods. Secondly I will summarize the research efforts and results of an experimental mining project by the Bureau of Mines and the University of Alaska. This work was initiated at the permafrost tunnel near Fox, Alaska, in 1968, and it has continued intermittently thereafter.

## Historic Drift Mining

All of central and northern Alaska lies within the zones of discontinuous or continuous permafrost. Consequently many of the placer deposits are completely

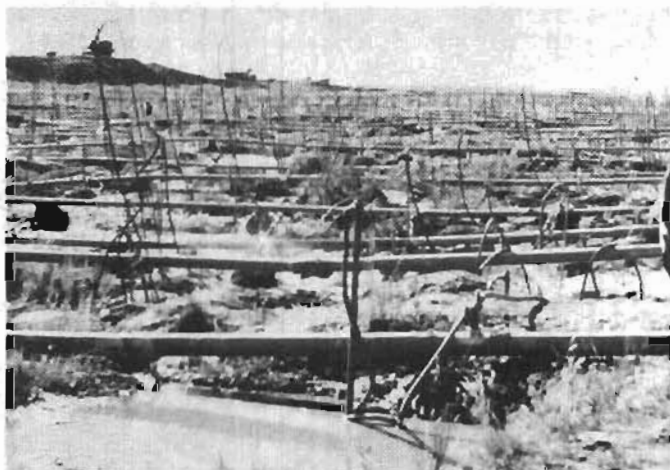


Figure 1. Thaw field -- thawing frozen ground ahead of a dredge was costly.

frozen. While this adds significantly to the cost of dredging, (Figure 1), it also offers the unique opportunity for underground alluvial mining.

From early in the 1900's until World War II, small scale, labor intensive, 'drift mining' was widely practiced in Alaska. Several years ago, Carl Heflinger, a well known local miner, presented to this group an excellent discussion of the mining techniques formerly used. Drift mining, as with most small scale underground mining ventures, is difficult and somewhat dangerous work,

and requires experienced miners. Over the years this experience has been largely lost in North America and there have been only a few recent sporadic attempts to develop underground placer mines.

Meanwhile it has been reported that considerable gold produced in Siberia has recently come from underground placer operations. These mines incorporate room and pillar mining techniques using rubber-tire equipment and conveyors. The underground operations are worked on a seasonal basis with the crews being transferred to the surface operations during the summer.

## Inferred Deep Placer Deposits

Let's look now at the resources inferred to exist in central and northern Alaska. One can compare the placer districts of Alaska with the distribution of permafrost. Even in the discontinuous zone the placer deposits are deeply frozen. Most everyone here is aware that deep placers occur in the Fairbanks district and have been driftmined in the past. Deposits have also been explored and mined in the Manley Hot Springs, Tolovana-Livengood, Ruby, and Nome districts, and to a lesser extent at Wiseman, Richardson, Valdez Creek, McGrath, Rampart, Circle, Innoko, Fortymile, and elsewhere. In short, many of the known gold districts of Alaska also contain or are inferred to contain poorly known deep placer deposits which have not been developed largely because of the depth of overburden.

At this time I would like to acknowledge Bruce Thomas, formerly with the Bureau of Mines in Fairbanks, and John Mulligan with the Bureau in Juneau, who assembled the data on the Fairbanks District.

The Fairbanks district is a northeast-trending area roughly 45 miles long and 15 miles wide, and consists of three principle drainages: Goldstream Creek, the Chena River, and the Chatanika River.

Placer gold production from the district has totaled about 7.5 million ounces. The district is characterized with thick overburden accumulation composed of ice-rich, wind-blown loess deposits. Consequently the placers are deep and nearly all of the production has come from former dredge operations capable of mining at these depths. Dredging stopped in the 1980's not



Figure 2. Inferred deeply buried, frozen, placer deposits of the Fairbanks Mining District.

because of a depletion of the resource, but because operating costs had exceeded the value of the gold.

Figure 2 shows the creeks inferred to be underlain by deep placer deposits that remain today. The location of possible channels are based on a variety of data ranging from drill evaluations to mere geologic extrapolation.

### **Goldstream Creek Drainage**

#### **Biglow Bench**

Unworked bench placer lies along Goldstream Creek near Irish Gulch. Average depth: 70 ft. muck, gravel 12 ft.

#### **Goldstream Creek**

Dredge mining stopped below the confluence of Engineer and Goldstream Creeks. A paystreak 300 to 400 ft. wide extends at least two miles downstream and may extend further yet to Ester Dome. Average depth: muck 70 ft., gravel 30 ft., although downstream sections may be deeper.

#### **Moose Creek to Nugget Creek**

Widely spaced prospect shafts along Goldstream Creek indicate a goldbearing channel between Moose Creek and Nugget Creek. Average depths: muck 20 ft., gravel 30 ft.

#### **Nugget Creek to Straight Creek**

Between Nugget Creek and Straight Creek, the valley fill deepens and prospect shafts reach depths of 200 ft. and more. Average depths: muck - 200 ft., gravel - 50 ft.

#### **Happy Divide to Cripple Creek**

Prospecting has indicated a buried channel in the 'flats' near the east flank of Ester Dome in the vicinity of Act, St. Patrick, and Happy Creeks. The depth to bedrock reported along the inferred channel is over 250 ft. The gold-bearing gravel is partially thawed in some places. Average depths: muck 200 ft., gravel 50 ft.

#### **Sheep Creek to Chena River**

Goldstream Creek may have once discharged into the Chena River. Ace, St. Patrick, Happy, and Sheep Creeks, cutting the gold lodes of Ester Dome, would have contributed to deep placer channel along the projected course of this ancient stream.

#### **O'Connor Creek**

Some gold has been recovered from upper O'Connor Creek. There may be an enriched channel on a bench along the gently sloping western side of the valley.

#### **Big Eldorado Creek**

Gold has also been recovered from upper Big Eldorado Creek and a deeply buried channel may occur along the gently sloping northwestern side of the valley.

### **Chena River Drainage**

#### **Isabella Creek**

A portion of Isabella Creek is known to have been drill sampled, but no mining is reported.

#### **Steele and Smallwood Creeks**

A small amount of gold has been recovered from the deep placers on Steele Creek and Smallwood Creek. Placer channels are projected along their course on the basis of only sparse information.

### **Upper Fish Creek**

Upper-most Fish Creek has been mined by open-cut and driftmining methods. Average depths: muck 10 ft., gravel 20 ft.

#### **Slippery Creek**

Previous drift mining and prospect drilling in the vicinity shows that gold occurs along the buried channel. Average depths: muck 80 ft., gravel 20 ft.

#### **Lower Fish Creek**

Old dumps along the creek indicate the continuation of a paystreak downstream. Average depths: muck 15 ft., gravel 35 ft.

#### **Deep Creek**

Some gold production indicates a possible paystreak.

#### **Deep Creek to Walnut Creek**

A bench deposit along Fairbanks Creek has been worked periodically. Average depths: muck 35 ft., gravel 15 ft.

#### **Upper Fairbanks Creek**

Sporadic prospecting and old workings indicate a narrow channel. Average depth: muck 10 ft., gravel 30 ft.

#### **Fourth of July Hill**

Unlike other placers in the Fairbanks district this deposit consists of gold-bearing, loosely cemented Tertiary conglomerate. The conglomerate weathers to gravel, and some gold has been recovered from gravels high on the slopes of the conglomerate remnant.

### **Chatanika River Drainage**

#### **Little Eldorado Creek**

The upper portion was dredged and downstream sections extending to the Chatanika River Valley were drilled and drift mined. Average depths: muck 100 ft., gravel 35 ft.

#### **Ruby Creek to Dome Creek**

Sporadic drift mining along sections of the Chatanika River Valley indicate a paystreak about 8 ft. thick at bedrock. Average depths: muck 30 ft., gravel 140 ft.

#### **Dome Creek**

Lower Dome Creek was extensively drift mined in the early days and is marked by drift mine tailings and caved and iced shafts. Some gold in recoverable quantities probably remains. Average depths: muck 70 ft., gravel 40 ft.

#### **Vault Creek**

Buried channels are defined by old drift mine tailing piles. Average depths: muck 70 ft., gravel 40 ft.

#### **Our Creek**

Previous reports show three small channels on upper Our Creek although the valley was never prospected systematically. Depths along the main part of the valley were reported to be: muck 60 ft., gravel 10 ft.

To summarize the first part of this presentation, substantial reserves of auriferous gravels are known or are inferred to exist as deeply buried permanently frozen paystreaks overlain by barren gravel and frozen muck. It is important to note that while some deep placers are known, there has been little systematic exploration for them or their actual extent since they lie at depths too great for sluicing or dredging. Surface min-



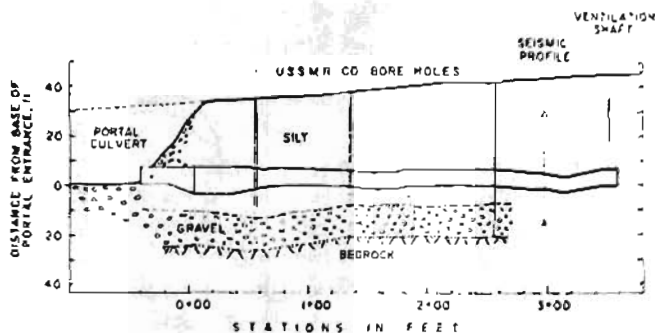


Figure 3. Longitudinal section of the Fox, Alaska, Permafrost Tunnel as it existed prior to 1988-89.

ing methods of deep ground are generally uneconomic today due to mining costs and environmental restrictions. There has been only small-scale underground mining of these deposits, nearly all of which took place many years ago. During the last several decades deep placer mining in permafrost has become something of a lost art in Alaska. Meanwhile considerable research and development of underground placer mining has taken place elsewhere, and is reported in the literature, but unfortunately is nearly all printed in Russian.

### Experimental Mining Research

In the winter of 1988-89, the Bureau of Mines undertook an experimental mining project at the permafrost research site near Fox, Alaska. At the time the site consisted of a tunnel excavated in frozen silt for a distance of 360 ft. into an embankment left by previous dredge mining (Figure 3). The Bureau project consisted of developing a ramp into the lower gravel section laying on bedrock, and then excavating a room approximately 30 by 70 ft. in size (Figure 4). The ambient ground temperature was 28°F and this temperature or lower was maintained during the excavation. The gravel, Figure 5, consists of a poorly sorted mixture ranging from silt-sized fines up to 14-in cobbles. As seen in the

upper part of Figure 5, sand and silt lenses occur within the gravel section. Water content is 10 to 15 percent by weight. The uniaxial compressive strength of gravel core samples typically ranges 400 to 800 psi, but is highly dependent upon temperature.

Mining was done by standard pneumatic drill and blasting techniques. However, due to the sub-freezing temperature the drilling was done dry. This created a

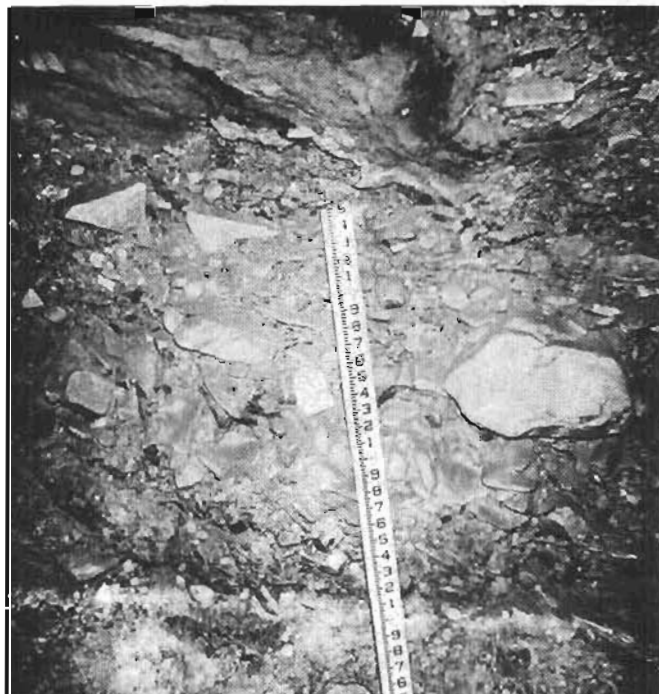


Figure 5. Permafrost Tunnel -- gravels and sediments.

considerable problem with dust which was further complicated by sublimation of interstitial ice particles which released even more dry fine-grained silt dust.

During excavation of the underground gravel room a number of things were learned, either intentionally or accidentally. Briefly these are:

1) There is a dangerous potential of roof failure if the excavation approaches too close to the overlying gravel-silt interface (Figure 6). In December of 1968 a gravel slab approximately 12 by 16 ft. in size and 1.5 ft. thick failed at the silt interface in the roof of the newly excavated room. Similar roof failures have been reported by drift miners in the past.

2) Following excavation of the room (Figure 7) relatively rapid deformation was recorded for the first month and a half which was then followed by a lower rate of closure. The increased rate of deformation was later found to be directly attributable to temperatures greater than approximately 26 to 27°F.

3) It was found that roof bolts (Figure 8) could be successfully installed in the frozen gravels. Best results were achieved by use of simple rebar which was driven into undersized holes.

4) Fragmented frozen gravel as a result of blasting could be mechanically loaded into a mine shuttle car and then transported by conveyor to an outside ore dump. Conveyor was set at a relatively steep angle of 20° and handled the material well. Unless the broken

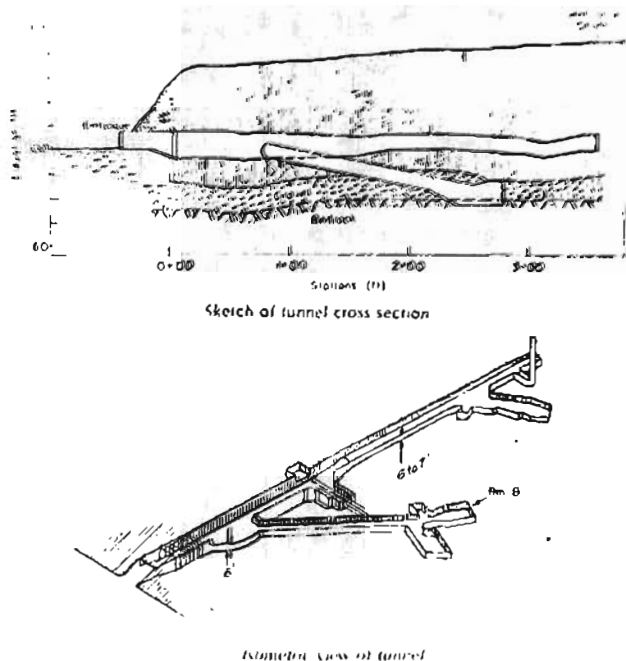


Figure 4. Views of the Fox Permafrost Tunnel after ramp construction by the U.S.B.M.

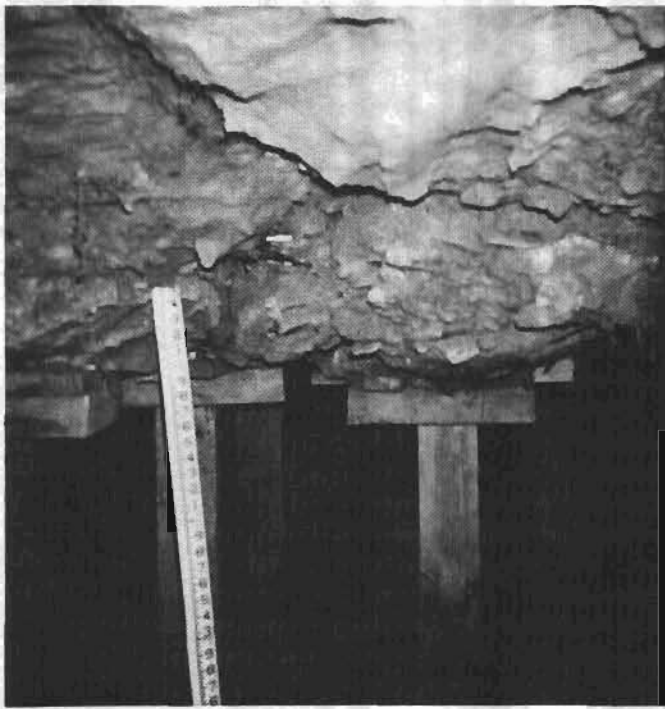


Figure 6. Gravel - silt interface at roof of tunnel.

material was allowed to thaw, it remained loose and no problems with refreezing or sticking to equipment were experienced.

5) Next, it was quickly learned that the intense dust conditions presented health and equipment problems.

6) Finally, a room 30 ft. by 70 (or longer) ft. in size could be safely excavated and kept open for extended periods of time. The room is still open 16 years later.

In addition to the standard drill and blasting techniques, two brief experiments using high pressure air injections and water jetting were tried in an attempt to

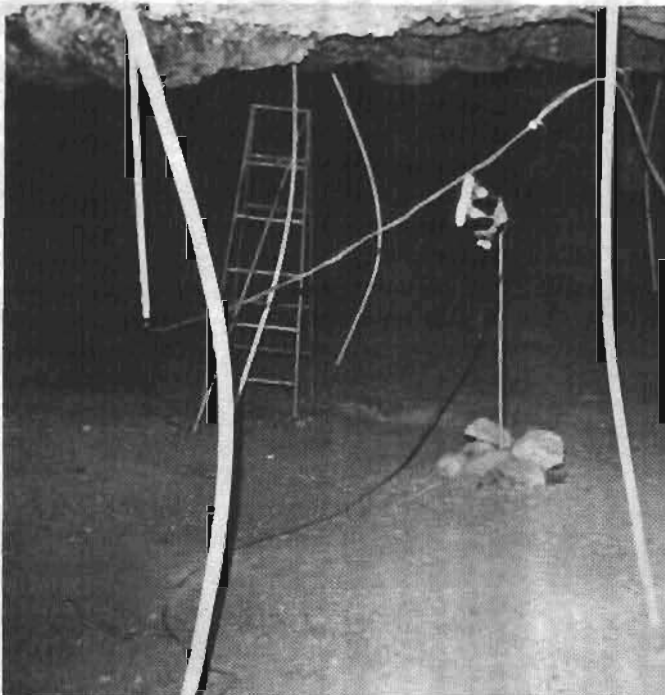


Figure 7. Roof deformation in excavated area of Permafrost Tunnel.

develop a lower cost fragmentation system of frozen gravel. Results of these tests were inconclusive.

In 1982, the Bureau of Mines and the University of Alaska's Mineral Industry Research Laboratory (MIRL) began a joint project to:

1) Further investigate the thermal properties of frozen ground stability of an underground opening,

2) Investigate a method of controlling sublimation and dust in a permafrost mine, and finally, to

3) Develop and evaluate a water jet mining technique.

Results of the first objective were compiled by Scott Huang of MIRL and are presently available. The sublimation control project is still in progress. Sublimation is the process by which interstitial ice crystals are removed by evaporation at sub-freezing temperatures. When this happens, previously ice-rich, rock-hard silt becomes loose dry dust which floats in the air when disturbed. Similarly, it results in a continuous loss of pebbles and cobbles from the roof in the gravel section. Sublimation occurs rapidly following creation of a fresh



Figure 8. Roof bolt installation.

surface, particularly if the surface is exposed to the passage of air and slows as an outer layer of dry material is accumulated.

Our sublimation-control project has consisted of an attempt to apply a water spray creating an ice film over the surface which would then protect the underlying material from sublimation and creation of dust. Apparatus was assembled and performed relatively well on frozen gravel. However, the ice film would evaporate within a matter of a few days to a week or two depending upon the degree of air exchange at the test plot and the relative humidity. The application of the water film to the dry silt accumulations on the floor or the silt walls was totally unsuccessful, due to the high organic content of the dry silt causing the water to bead-up and run off before it could freeze. By removing the dry material, however, water could adhere and freeze to the fresh silt face with interstitial ice. Chemical additives to increase the wettability of the silt may help but have not yet been tried.



To investigate high-pressure, low-water volume water jetting we acquired a 125 hp, 440 volt AC electric triplex plunger pump which develops working pressures up to 6,000 psi at a water volume of 40 gal/min (although 15-25 gal/min was our common operating range).

Heat tapes are used to prevent freezing within the pump and fittings. The water lines are drainable for the same reason. Water is stored in a 500 gal insulated storage tank which is heated with a 150-watt light bulb and equipped with a 1/2 hp booster pump. The tank is set at a higher elevation which provides 15 feet of head. A 3 inch line supplies water to the high pressure pump and expelled water during jetting collects in a sump where it is then returned to the storage tank. No significant problems have been encountered with freezing within the sump. During operation the air temperature rapidly approached the temperature of the water. To prevent thawing of the roof, cold outside air was pumped through a 12 inch ventilation pipe to the work area. Visibility during operation was found to be surprisingly good although the operator was occasionally bathed in backwash.

High pressure jetting penetrates frozen gravel by both fragmentation of ice and ground, and by thawing. The freeze/thaw point of ice in the impact area of high pressure is inversely proportional to the pressure level brought against it. Thus, frozen gravel can be thawed at sub-freezing temperatures by raising the pressure.

Our objective is to evaluate two basic applications of the water jet to the face. These are to cut continuous slots, which could be used to break the gravel into manageable blocks, and secondly, to drill holes that could be used in conjunction with other methods of ground breaking. Tests are still under way and will be the subject of a later report and a Master of Science thesis, however, sufficient data has been accumulated to present some general ranges of performance.

As seen in Figure 9, our apparatus consists of a stationary vertical support to which is mounted a horizontal bracket to hold the water jet. The bracket is attached to the vertical member by the use of a universal joint

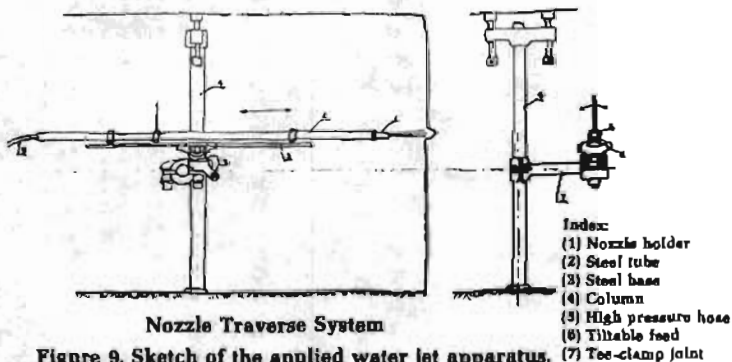


Figure 9. Sketch of the applied water jet apparatus.

which allows the operator to manipulate the direction of the nozzle while the experiments are in progress. A series of nozzle diameters are being tested which range from 0.155 to 0.03 inches.

We have performed slotting tests by passing the water jet over the face at a rate of 1 in./min. The depth of the slot from a single pass varied from 12 to 36 inches. The



Figure 10. The water jet in action.

slotting tests so far have only been run at pressures up to 3,000 psi, so we anticipate some improved performance at higher pressures.

Experiments to drill (Figure 10) horizontal holes into the face were conducted by mounting the nozzle in a fixed position perpendicular to the face and approximately 2 inches from it. The face was prepared by removing loose pebbles and cobbles and exposing the underlying ice-rich gravels. Tests were run on one-minute increments during which we monitored the pressure, the flow rate, and water temperature. We also collected the cuttings to determine efficiency rates. After each one-minute test we measured the hole diameter. With a stationary setup we have drilled a series of holes to depths of approximately 6 feet. Our drilling rates for one minute have varied from 0 to 34 inches. The mean average for testing so far is approximately 10 in./min. Since the gravel section consists of particles ranging from silt-size all the way up to small boulders, the performance of the water jet varies from one place to another. Occasionally, we encountered a large cobble which required abandoning the hole and moving to another site. However, this was found to occur infrequently, and most obstructing cobbles were eventually washed out by the backwash from the jet. Generally, the holes that were drilled varied in cross section from a couple of square inches at the base to approximately 9 inches in diameter at the front. Diameter

of the holes increases with jetting time and the consequent erosion from the backwash. Figure 11 shows the progressive enlargement and lengthening of a typical hole at intervals of 1 minute. Note that no depth was achieved for minutes 2 and 3 due to a large cobble. The cobble was eventually washed out and the hole then progressed deeper. Efficiency of the water jetting system is normally considered to be maximum within a few inches of the nozzle. However, we were unable to

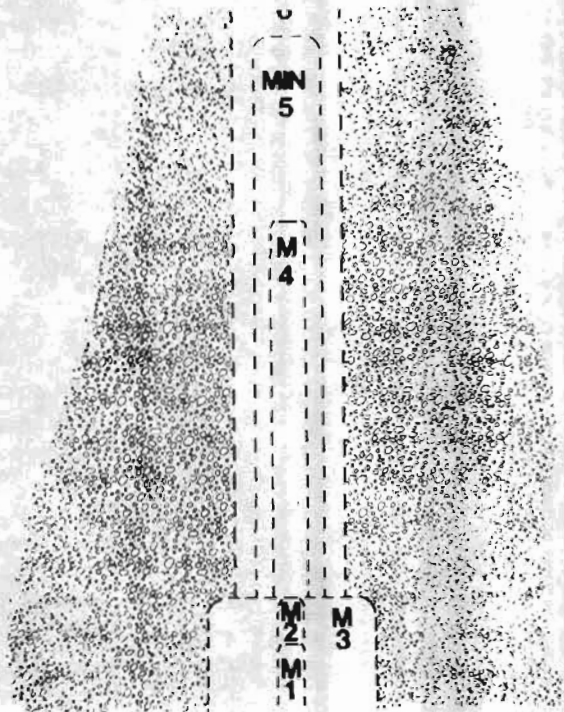


Figure 11. Diameter and length change with time of a water jet drill hole.

detect substantial efficiency losses until the hole was nearly 4 feet deep. Ideally, a mining system would incorporate a water jet nozzle on an advanceable slide similar to a pneumatic hammer on a drill jumbo. Thus, it would allow an operator to advance the nozzle and drill to depths greater than the 5 to 6 feet we were able to achieve with a stationary setup.

Additional tests are being conducted on the underlying fractured bedrock. The bedrock at Fox consists of a highly weathered micaceous schist typical of the Fairbanks area. At the test site we have exposed the upper 2 feet of the schist bedrock. Drilling tests indicated somewhat improved average penetration rates.

To summarize the results of the water jetting research, we have found it to be a promising technique of mining frozen gravels. There may also be application of this technique in construction. The testing conducted thus far has provided practical experience which has overcome most of the problems of working with water in a freezing environment. While we cannot yet compare the efficiency of this system to steam thawing or to pneumatic drilling, we have achieved penetration rates of 10 in./min. and it is likely that this could be improved further.

While actually removing blocks of ground with the jet alone may be considered, a combination of water jet drilling and blasting, using either explosives, air

pressure or hydrofracturing may prove workable. It's not hard to imagine development of a system which could rapidly drill a series of deep holes in bedrock immediately below the pay channel and then incorporate the proven methodology of cold water thawing.



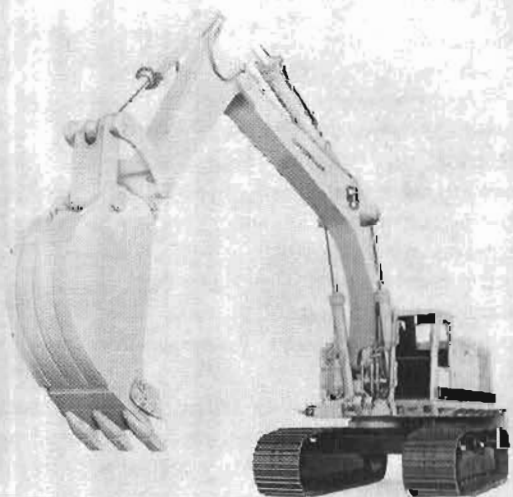
## Excavating Frozen Muck

*Fred Wilkinson, Miner*

I want to share with you a technique for stripping frozen muck overburden. I operate on Miller Creek which is probably unique in the Circle District, having deep muck deposits. In lower regions of the drainage the main pay streak lies under a bench muck. It was customary to remove the muck hydraulically using giants. Due to environmental constraints we have had to rip and remove the overburden mechanically. This began eight years ago, when we started using a D-9G Cat with ripper. It was moderately successful and allowed us to do the stripping in April and May, well before the sluicing season. It also let us stack waste before it melted into an unmanageable ooze.

There were problems. We couldn't apply effective power and down pressure while ripping due to lack of traction. Ripping imposed high shock loads on the bulldozer resulting in the loss of teeth and occasional shank breakage.

Four years ago, we purchased a Caterpillar 245 excavator (Figures 1 and 2). It quickly became apparent that its penetrating force in hard bedrock was superior to the D-9G. This was due to the application of hydraulic



**CATERPILLAR**

**245**  
Excavator

Figure 1. Caterpillar 245 Excavator.

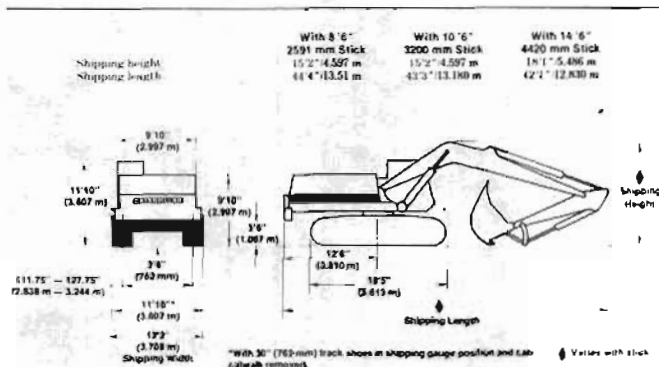


Figure 2. Dimensions of the Caterpillar 245 Excavator.

force creating down pressures while ripping, 50% greater than a D-9G. The following spring, after a consultation with N.C. Machinery, we purchased a Balderssen ripper attachment to fit the excavator. The bucket was removed at the pins and replaced by a holder group into which fit a D-7 ripper shank (Figure 3).

At this point there were about 1800 lineal feet left in the bench we were working. Approximately 20 feet deep in the back, the bench had an average depth of 10 feet and was approximately 125 feet in width. The first year we advanced upon the face at the gravel level, ripping with the excavator and stacking with the D-9 into a worked out area (Figure 4). We blocked out 400 lineal feet of this bench. We soon found an imbalance with the equipment. The excavator could rip far more than the D-9 would hook out from the back and stack mechani-

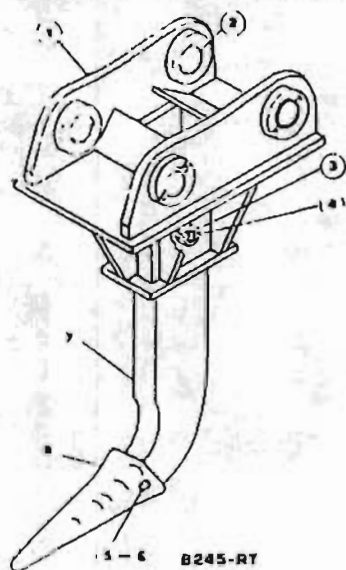


Figure 3. Bucket Ripper Holder Group and Ripper Tooth.

cally. The next season, we tried a different approach. We climbed up on the bench and worked down on a step (Figure 5). This gave the bulldozer a greater advantage. That spring we blocked out 800 lineal feet of the bench with 37,000 estimated in place yards. This material has a swell factor between 40 and 50 percent. We cleaned up the stripping in twenty-one days averaging 1,750 yards in a 10 hour day. The bottleneck was still the D-9. At this point in the diagram (Figure 6), the bulldozer began to fall behind. The 245 can easily rip 200 in place yards per hour. The third season using the same approach we

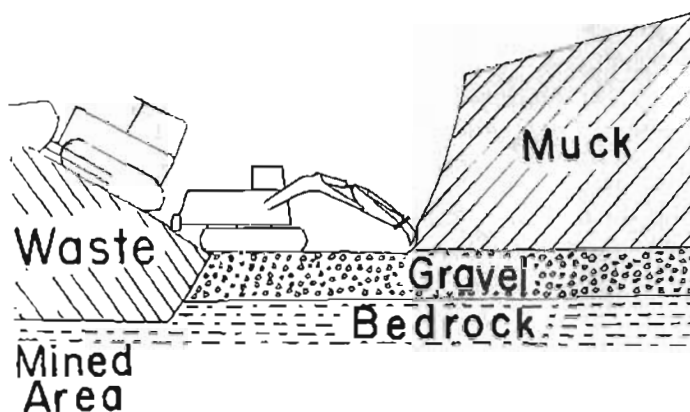


Figure 4. First year mining sequence with the C-245 Excavator.

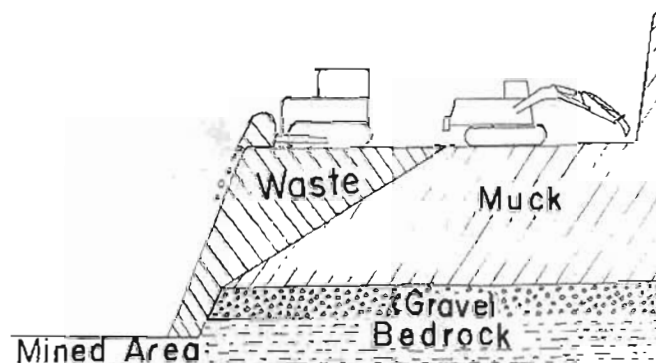


Figure 5. Second year mining sequence with the C-245 Excavator.

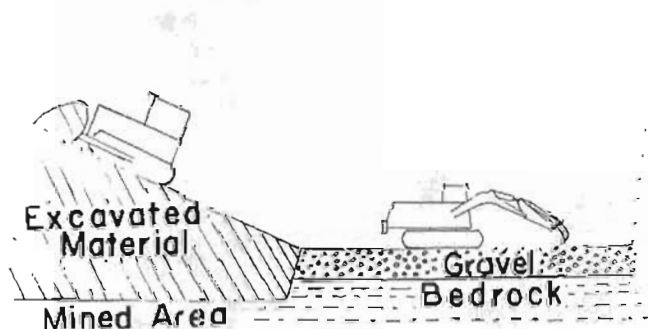


Figure 6. Second year mining sequence with the C-245 Excavator.

excavated the remaining 600 feet of this bench in just over two weeks.

There were problems. The first season we had many failures in the steel hydraulic lines of the 245. We tried to weld and repair them but weren't very successful. They would usually rupture again. Finally, we replaced the problem lines with new steel tubing. This cured that problem, apparently the steel tubing had fatigued. The line pressure is around 4,000 psi on this machine in the hydraulic system. The flexible hydraulic hose held up very well. The other serious problem was that the D-7 tooth would break. We substituted a cut down D8 shank and tooth. This cured the problem. The advantages of ripping with an excavator over conventional bulldozers are: 1) greater penetration, pull through and breakout force, 2) less dependency on traction forces on frozen ground, 3) far less operating cost because of less machine travel, trackwear and shock. 4) Ability to reach out, rip, and dress slopes down much steeper. 5) The ability of the operator to see the location of unripped



material. The ripper point may therefore be placed in the right location. Also, the operator can see immediately any loss of teeth.

Figures 7 through 9 show the excavator working at our mine. You can see the shank very readily and you can also see the shank in the ground. Now, one of the secrets to this technique is that it's not a very deep penetrating shank. It's only about two feet from the rip-



Figure 7. The Caterpillar 245 Excavator.

per point up to the holder. The secret is to avoid those shock loads and just rip a multitude of times with a shallow bite. You can feel the bedrock, where your high spots are, even though you can't see them. It works very well. Normally, the technique from the operator's point of view when using a bucket is to draw in with the stick and curl your bucket to get the load. With a ripper shank, you uncurl to hold the correct alignment between the ripper shank and the ground for your best penetration. As you're reaching in, you uncurl, then, at the last moment and just as you're reaching the end of your stroke, you curl and break out. It tears out some pretty enormous sized chunks and is very effective.

This machine has about a 45 foot reach from the center pin and about 35 feet from the front of the tracks. It pulls in to about 5 feet of itself. In other words, we are breaking about 35 feet per pass.



Figure 8. The Caterpillar 245 Excavator.



Figure 9. The Caterpillar 245 Excavator.

Cost per yard of the ripping operation is site specific, but ours is very tough material; it has a high moisture content. The cost of ripping with the excavation is about half of that when using a Cat. Not only because of lower capital cost of the machine, but also due to a far more effective cost per ripped yard. The stacking will remain the same because you are still using the bulldozer. I'm doing the whole operation for approximately \$1.50 per cubic yard.

# Mining and Recovery Techniques on Eagle Creek

Douglas B. Colp  
Consulting Mining Engineer

The Eagle Creek operation is located less than a mile southeast of Mile 103 on the Steese highway, northeast of Fairbanks, Alaska.

Gold was found on Eagle Creek in about 1895. Berry Holding Company took over most of the better ground in 1906 and mined it intermittently by hydraulic methods until 1942. Starting in 1982, G.H.D. Resources has been mining the lower part of the Berry property.

In the late summer and early fall of 1981, G.H.D. Resources did some churn drilling and put in a few dozer trenches on the property in order to learn more about its value, depth, frozen or thawed characteristics, width and length of the pay zone, depth of overburden and bedrock conditions. The ground varied from 6 feet to 26 inches in depth. The depth of muck or overburden ranged from 1 to about 8 feet. Both thawed and frozen areas were encountered. It was also determined that from a foot to almost 3 feet of bedrock would have to be mined in order to recover all economic values.

Based on the estimated value of the placer deposit at that time and an undetermined property life because of insufficient exploration, it was determined that the expense of a mining plant should be kept at a conservative level, especially for a year or two or until more was learned about the recovery over the estimate factor and longevity of the project. It was further estimated that the mining plant must be able to average at least 1,000 cu./yd. in a 10 hour shift before the property would be considered economic. With this information in hand the following equipment was procured.

- 2 - D-8 Hs, one equipped with a winch and the other with a ripper.
- 1 - 966 C front end loader with a 4 cu./yd. bucket.
- 1 - 3 Section sluice box, 40 feet long, capable of handling up to 100 cu./yds. per hour.
- 1 - 8 x 10 slurry pump, capable of delivering 2,500 g.p.m.
- 1,000' of 6" & 8" Aluminum pipe complete with couplings, elbows, reducers, valves, etc.



Figure 1. Cook and Bath House.



Figure 2. Bunk House.

One sluice box feed hopper complete with grizzly bars, water manifold and spray nozzles.

2 - 5,000 gal. fuel Storage Tanks

1 - 500 gal. Gasoline Tank

Welder, Shop tools, Pickup, Shop Truck and many other items necessary to run an operation

The Eagle Creek camp will accommodate 12 people as follows:

- 1 - Atco trailer unit providing space for a dining room, kitchen, bathhouse, toilet and washing facilities (Figure 1).
  - 1 - 8 Man Atco trailer bunk house (Figure 2).
  - 1 - 8 x 16 Office with double bunk beds.
  - 1 - Trailer for the cook and her husband.
  - 1 - Small shed for freezer space and extra food storage.
  - 1 - 12.5 KW Light Plant
  - 1 - Electric water pump for domestic water
  - Underground cess pool and leaching field
  - 2 - 12' x 14' x 4' Wall tents for the Sluice Box cleanup procedure
  - 1 - Gold Hound
  - 1 - Spiral sluice
  - 1 - 6" Knelson Concentrator unit
- Pumps, Screens, Panning Tubs and other necessary concentrating equipment.

## Mining - 1982

The mining plant composed of the 3 section sluice box and the feed hopper-grizzly unit was placed in the center of the cut, amounting to approximately 100,000 sq. ft. Since the auriferous gravels were only about 8-8 feet deep, the discharge end of the sluice box was placed on bedrock (Figure 3). The sluice water drain was excavated into bedrock and all gold bearing gravels and bedrock were stacked conveniently near the sluicing operation. The settling pond also had to be excavated and prepared to accept the sluice water. A pump pond was constructed up stream from the sluicing plant and water was piped to the water manifold on the feed hopper and into the spray nozzles on the grizzly. Stop and waste gates had to be built into the pump pond, to take care of the desired water level and to eliminate prob-

lems of excess water due to rains and flash flooding. After the feed hopper and sluice box were in place a ramp was dozed in so that the 966 could conveniently feed the hopper (Figure 4).

The grizzly in the hopper was set on a slope of approximately 38 degrees. The spacing of the grizzly bars tapered from 1-1/2 inches to 2-1/2 inches to prevent rocks from jamming between the bars (Figure 5). The feed or dump hopper itself had a grade of 12 to 15 degrees depending on the clay content of the materials being washed.

Washing is accomplished in the dump box, on the grizzly and in the 3-sectioned sluice box. The sluice box has a 30 inch center section with 2-24 inch side channels. A 5 foot length of punch plate 4 inches above the sluice bottom with 5/8 inch holes is used to deflect all of the plus 5/8 inch material into the center section. The



Figure 3. Operation during the 1982 mining season.

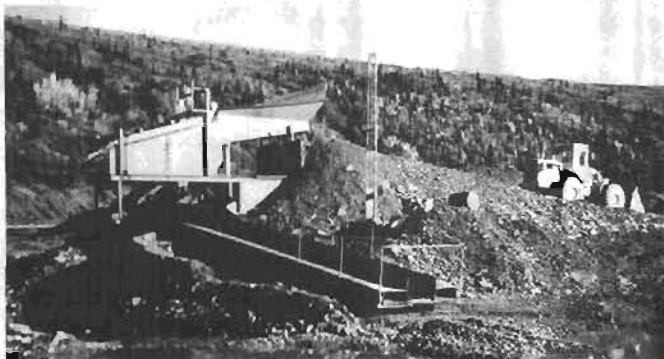


Figure 4. Wash box, Grizzly, Sluice and Loading Ramp.

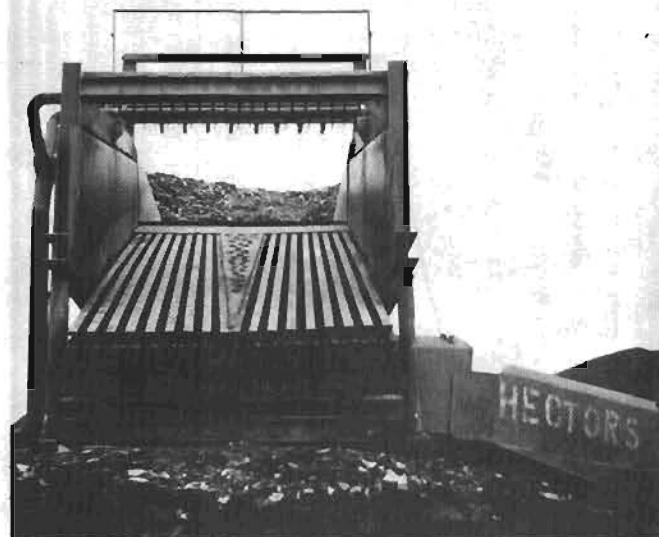


Figure 5. Diverging Bar Grizzly used in the 1982 mining season.

minus 5/8 inch size is deflected into the two 24 inch side sluices. The "Hungarian" riffles in the center section are made of 2 inch angle iron, spaced 4 inches apart. The angle iron is tipped up 15 degrees with 5/8 inch holes punched through the top or overlapping surface on 2 inch centers, which allows for more turbulence and less compaction between riffles. The upper 20 feet of the side sluices have "Hungarian" riffles made of 1-1/4 inch angle iron, also with a 15 degree slope and 5/8 inch holes along the leading edge. The lower 20 feet are covered with No. 4 expanded metal. Astroturf is used under the riffles to help arrest the passage of gold through the sluice. Astroturf has good retention characteristics, saves considerable fine gold and is very easy to clean. The grade of the sluice box is roughly 1-1/2 inches per foot.

### Mining - 1983.

During the 1982 mining season the batch loading and grizzly hopper with the 4 yard bucket on the 966, created a slugging condition or an uneven feed to the sluice box. In order to eliminate this condition a reciprocating pan dozer trap feeder and a 36 inches x 75 feet conveyor was added to the Eagle Creek mining plant. This addition allowed a continuous feed into the washing plant and sluice box (Figure 6). A 50 KW



Figure 6. Feeder - conveyor system used in the 1983 mining season.



generator provided power for the feeder and conveyor. It also provided power for the necessary flood lights for night operation. A new "T" bar type grizzly replaced the 1982 model, which eliminated many of the hangups that occurred previously (Figure 7). About 70 percent of the feed is actually washed in the 3 section box. The remaining 30 percent slides over the grizzly bars and is removed and stacked with the loader. The loader also removes and stacks the sluice box tailings.

Last season a sizeable sump was dug into bedrock at the end of the sluice box. This not only contained the sluice tailings but acted as a presettling pond which allowed a lot of fines to be picked up with the loader and stacked, thus extending the usefulness of the settling ponds.

A total of 204,600 cubic yards of gravel was mined in 100 days or an average of 2,046 cubic yards per day in two 10-1/2 hour shifts. The crew consisted of a total of 8 persons: Two Dozer operators; 2 loader operators; 1 Mechanic-welder; 1 Cleanup man; 1 Foreman and a Cook. The foreman operated the 2nd D-8 occasionally, whenever there was need to remove overburden or to help the Dozer trap man, because of a longer than nor-



Figure 7. T-Bar Grizzly.

mal haul, as when cleaning up bedrock in the back end of the cut. Bedrock was panned as often as was necessary to insure that no pay was overlooked.

Studies indicated that about 60 percent of the captured gold is recovered in the two side channels and 40 percent from the center channel. Approximately 85 percent of the gold is recovered in the upper 3rd portion of either the center or the side channels when clean water is used. During the 10 days that a return system (partially closed circuit) was used, due to insufficient clean water, a larger percentage of gold appeared to have been recovered from the lower portion of the box, however, no actual weights were recorded.

## Cleanups

The upper 1/2 of both side channels and center section were cleaned up about once a week. The bottom portion of the center channel was cleaned up twice during a cut or about every 2 weeks, but the lower portion



Figure 8. Box clean-up.

of the side channels were only cleaned up once very cut. Cleanups were made between shift changes (Figure 8).

The following cleanup procedures was used:

### In the Sluice Box

1. Remove and wash riffle tiedowns and riffles with a garden hose.
2. Shovel material on Astroturf to the head of the sluice box.
3. Using a light flow of water, work material over Astroturf with garden rakes, paddles and by hand until gold has concentrated on top of and in the Astroturf.
4. Roll up Astroturf and place in tubs to prevent gold spills.
5. Wash the bottom and channel sides with a garden hose to clean away all sands and clay sticking to the metal.
6. Pick up all loose material with a scoop, or shovel and whiskbroom.
7. Lay down spare set of Astroturf, replace riffles and secure riffles with tie or holddowns.
8. Dump loader bucket containing any material discharged from the sluice box during the cleanup procedure back into the sluicing circuit to be rerun through to washing plant.



Figure 9. The clean-up tent.

#### At Cleanup House (Figure 9)

1. Clean sections of Astroturf (24" x 36") and (30" x 36") in a 4' x 6' x 1-1/2' deep tub, using hot water with some liquid soap.
2. Drain tub and run material from the tub over a 1/4" vibrating screen. The minus 4 mesh material goes directly to the Knelson bowl. Nuggets are hand picked from the +4 mesh fraction.
3. The Knelson bowl concentrates are then screened to make 4 fractions; a -20 mesh, -20-12 mesh, +12-8 mesh and a plus 8 mesh fraction.
4. The -20 and the +20-12 mesh fractions are both run through the Goldhound wheel (Figure 10).
5. The +12-8 mesh fraction is run through the spiral sluice to reconcentrate and upgrade the material. Hand pan the concentrate.
6. Hand pan the +8 mesh material.
7. Dry gold and clean with a magnet. Cleanup is now ready for shipment.

Considering the total amount of gold G.H.D. Resources sent into the refiner in 1983, 95.7 percent was minus 8 mesh and 4.3 percent was larger than 8 mesh. The fineness was 875 and the shrinkage amounted to 2.8 percent.



Figure 10. Working at the gold hound.

## Mining on Porcupine Creek Circle District

*Helen Warner, Miner*

The reason I have selected this topic is because we are in the process of changing mining systems. We have been mining down midstream on Porcupine and we are moving upstream into the head water area where we are going to have a significant water problem. It seems that since 1964 when we bought the creek, water has always been a problem. In 1964 Henry and I purchased the creek from a man who had relocated in 1960 and had been drilling on it. When we purchased the creek, we purchased a set of steel sluice boxes, some hydraulic pipe and 56 placer claims with 102 drill holes. The owner, Matt was a good business man. He checked our bank balance, found we had a \$756 balance, and asked for \$750 down. That was the beginning of the next twenty years on Porcupine Creek. Gold was then \$35.00 an ounce. This might have been a moment of insanity but it's since been a delightful experience.

The reason I chose to talk about the creek is obviously in reference to the Federal Clean Water Act. We have received a permit to which there is no way we can comply, nor do I know many people who think they can comply with the standards adopted by the EPA.

We have been involved in clean water studies since we have been at Porcupine Creek. The settling pond demonstration project should have been sufficient proof that the settling pond was certainly not going to solve the water discharge problem in the placer mining industry. The Federal Clean Water Act relates to our problems through its regulations involving heavy metals and discharge limits. The state compounds the problem, by classifying fresh water resources in Alaska as drinking water. I'd like to talk about the federal aspects first, and then talk about the state aspects. Moving up the stream, since 1964 we have been sluicing with two sets of sluice boxes. Our newest one is a 3 channel box, 60 ft. long with a 24 ft. long sledge pipe preceding it. We use approximately 12 ft<sup>3</sup>/sec. of water in the washing operation. The creek is producing approximately 5 ft<sup>3</sup>/ft. per second, so we are already in a position which requires pumping, in order to have sufficient water. We examined our situation and asked, "Since we are pumping anyway, is there any way we can meet the standards?" We didn't even come close with settling pond technology. Are we forever going to be operating on the fringe of the law, subject to being declared criminals by regulatory policy? We concluded after doing a lot of study on the nature of the soil at our creek, that we have a lot of clay and silt, and not enough gold, which, I think is everyone's complaint. We considered the possibility of eliminating the problem by becoming a non discharge operation by recycling.

Last season we drilled in a new area to determine our pay limits and pay horizons. We also tested some old tailings to see if they should be removed or processed.



With these ideas in mind, we decided to discharge on an upland site, by positioning our box with the discharge on the hillside, since we are pumping anyway. The discharge water would be ditched back upstream so that it would return to the stream above our pumping point. This would give us siltation occurring on the hillside where it would be covered up with the tailings.

We haven't had a significant problem in our testing even with all these things, and we have done this on a limited scale at another cut. We found that we could definitely meet the suspended solids standards if we were sending almost everything back the other way, but we could not comply with the turbidity regulations.

I have had many illusions about turbidity, and also a great deal of anger. In fact, I'm tired of receiving notices from EPA to the effect that at 20,000 parts per million the first adverse effects on fish were known. My question, "What do 20,000 parts per million look like?" I went to a lab and talked to a water consultant friend, taking some water samples of our various products with me. From that, the first thing I would like to consider is the concept that turbidity has nothing to do with potability.

Let's look at liquids essentially good for us. Our mothers always told us to drink milk, which has a turbidity of 51 NTU. Water from our well measures 1.1 NTU. Orange juice at 30 to 1 dilution reads 120 NTU. Sunkist orange juice is 3600 NTU. At least we can still drink coffee, which is only 5.6 NTU. The point of this, obviously, is that we do drink liquids which have high turbidity and that NTU's are not meaningful to the concept of potability. NTU's just are not a meaningful standard of measurement.

Let's think in terms of aesthetics. Many people tell us "but aesthetically who wants to put their foot in that muddy water?" Again, coffee is 5.6 NTU. I don't think I'd be too enthused about sticking my foot in a river running with coffee either. I think that we will find that color and turbidity are not necessarily related and of course we associate aesthetics with color. So again turbidity is not meaningful as a measure of aesthetics. I have made up a number of samples of various turbidities using silts, clays, and overburden (containing organic material). We would be willing to make up a number of sets of such samples if there is a demand for them.

At Porcupine Creek, we had some settling tests done with a settling column. The settling column test involves taking a sample of water and putting it into a column 12 ft. high and then waiting. We started out at 4,500 NTU and 60 days later we were down to 25 NTU. Since in mining we use water at the rate of 3,600 gallons per minute or better, in order to hold the water for 60 days we would be facing the possibility of building another Grand Coollee, so a settling pond is not the solution to our technical problems.

There are two solutions. One of them of course is the potential achievement of some sort of recognition from the State of Alaska in that turbidity is neither a measure of potability nor aesthetics. The other option is changing the drinking water classification for all streams in Alaska. The State of Alaska, in one breath states, "Oh, all water is drinking water," and at the same time sends out little brochures saying, "Don't drink the surface

water in Alaska." Those are political solutions essentially.

The second solution, as near as we can determine, is to figure out how to be a non-point source, which is what we're aiming for. We are planning to discharge our water at an upland site, since we are pumping anyway. There's a point I wish to make here, you have to know what you're washing. A lot of people wash only sand. Sand settles very quickly and you can meet standards with a very simple settling pond arrangement. If you're washing clay, there's just no economic way of meeting the turbidity standards.

## Mining at Flat, Alaska

*John Miscovitch*

I'm glad to be back in Fairbanks to attend this conference. It's always good to be among miners and share the problems you are facing today. In the application of mining in Alaska, those of you who have your draft permits and even those of you who have yet to apply, be sure to include the hydraulic mining process as part of your system. The miners trying to prove that we can economically move overburden in Alaska by mechanical means are just adding fuel to the EPA's demands and their regulations. Livengood is a prime example of what has happened to the dream of mechanically removing overburden overlying the pay gravel.

The Iditarod district was struck in 1908 by John Beaton and Frank Dykeman on Discovery Otter Creek

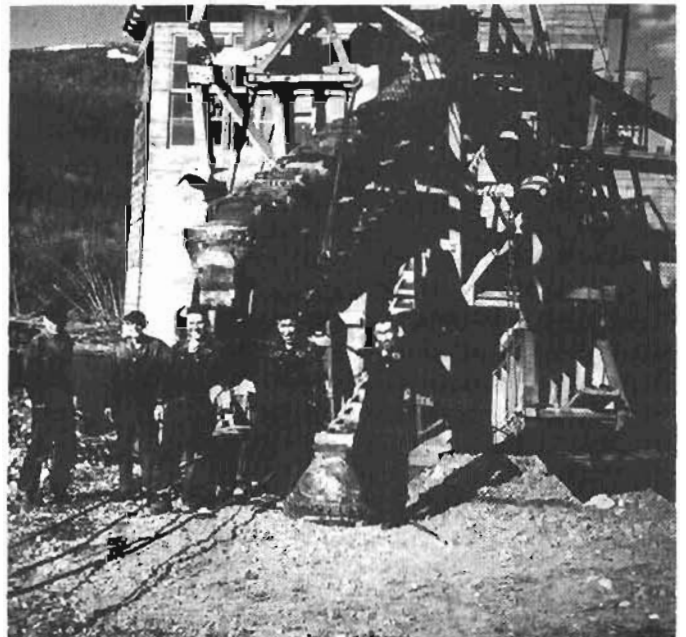


Figure 1. The dredge of Beaton and Donnelley.

just a short distance from where I was born. The district has produced well over 1-1/2 million ounces of gold. Silver ran about 1 ounce to every 4 ounces of gold. The population of Iditarod at the time of the big rush was nearly 5,000 people. Flat and Discovery each had 2,500 people.

Flat, Alaska is situated between the Kuskokwim and Yukon Rivers about 90 miles southwest of Fairbanks. It's 8 miles from the town of Iditarod, with which all of you are familiar because of the Iditarod dog races. The Iditarod post office was the central distribution point for mail coming in from Nenana by dog team. Dog sledding was the main means of transportation before the advent of the automobile and snow machine.

In 1910, Iditarod had all the facilities of today's city of Fairbanks and was a docking area on the Iditarod River. Thousands of people and tons of freight landed here, headed for the stampede on Discovery Otter Creek. John Beaton discovered gold on Otter Creek and I plan to

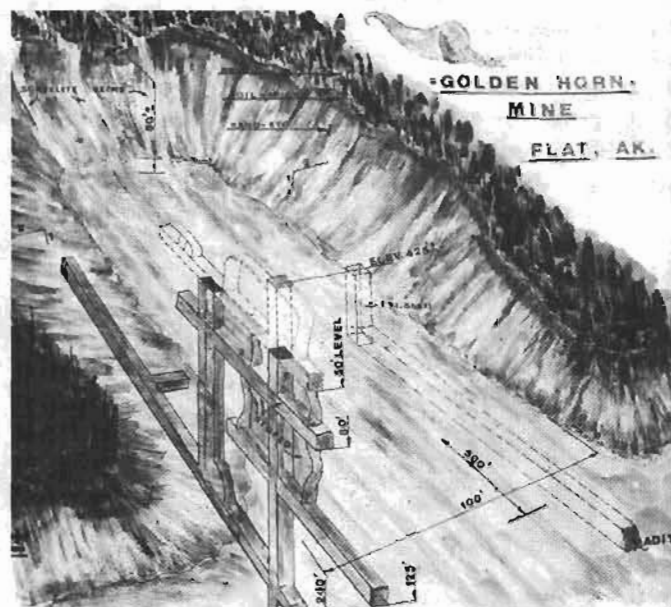


Figure 4. Underground section of the Golden Horn Mine.

erect a monument to him this summer at the location of the strike.

The predominant geological unit of the valley of Discovery is the Golden Horn Monzonite structure. The values of gold that came into the valley of Otter Creek came out of this structure; there is no gold in the valley east of this unit.

The valley of Discovery was dredged and mined by large companies with modern-day earth-moving equipment. Some 100 million yards of fish food has been sent down Otter Creek over the years. Figures 1 and 2 show the dredge of Beaton and Donnelley. They worked their way 2-1/2 miles up Black Creek, then jacked the dredge up and with 8 horses, moved the dredge back down Black Creek on the ice glacier to mine in the valley. It seems like an impossible task. I ran a dredge for a number of years and learned a great deal about the valley floor. Dredging is a beautiful way to mine, but it is gone forever. The old dredge today sits there as a monument and I wish the story could be told of J. Riley, a promoter, who couldn't pay his bills. One of his wood cutters heard about it and shot him. The wood cutter was tried here in Fairbanks and hung.



Figure 5. Hydraulicing.



Figure 2. The dredge of Beaton and Donnelley.



Figure 3. Golden Horn Mine ore dump.

Figure 3 shows the Golden Horn Mine, which worked a load deposit, a residual load deposit. It was struck in 1915, mined in 1920 with a stamp mill, and later developed in 1935-36 by Mr. Dunkel of Anchorage, who went broke on another operation and was forced to quit. There are 9,000 tons in the pile. It contains scheelite, gold, silver and several other minerals. The Golden Horn is a monzonite intrusive containing veins. There are approximately 75 to 80 million tons of mineralized reserves in this deposit. The Golden Horn ore dump came from an exploratory adit that Dunkel had driven to determine whether he should make a mine out of the property. He ran out of money, however, and was forced to quit. You can see the head frame. There was a big building and a tramway over the top to the dump.

Figure 4 shows the underground section. There is a massive deposit running upwards to 17 oz. Au/ton, at a depth of 228 feet. Shown also is my plan to excavate 185,000 cubic yards hydraulically over the next three



Figure 6. Hydraulicing.



Figure 7. Hydraulicing.

years. The material will be deslimed and processed through a long sluice box. I have learned in my work that the only process to use for liberating placer particles of scheelite and free gold is hydraulicing (Figures 5, 6 and 7). We cannot grind this material, because a slime develops and that's what we're all fighting. After we get down to the 100 ft. level we plan to go underground with the Miscovich Underground Miner. I learned a great deal about the structure of this valley through the bedrock cleaning, which we had to do by hand, and which is overlooked by so many mechanically oriented miners who do not understand that bedrock must be cleaned if there's to be an efficient recovery.



## Considerations for Applying Reichert Mark VII Spirals in Alaska

*Kelly Dolphin, Owner*

*The Miners' Company*

Spirals have been used for gravity concentration for many years. The Reichert spirals were initially developed for the alluvial tin industries of Australia and Southeast Asia (Figure 1). Each of over twenty different Reichert spiral designs is contoured to separate materials of a given specific gravity range. The Mark VII has been on the market since 1982 and is designed to recover tin with specific gravity of 6 or 7. On the opposite end of the spectrum, the Mark X separates heavier waste shale from coal.

The crosssectional shape of the Mark VII spiral changes from top to bottom. Material fed to the top of the spiral is progressively concentrated over its full length. Fine grained, high specific gravity solids are concentrated at the inside of the spiral's turns. The concentrate is separated from the middlings, which may be recirculated, and the tailings, by splitters at the bottom of the spiral. Depending upon the nature of the feed material, one usually obtains concentration ratios of 50:1 to 100:1.

The Mark VII Reichert spiral is a lightweight and low cost fiberglass - plastic unit. It has no moving parts. The spiral is designed to be used 24 hours a day, 365 days per year for many years before wearing out. A single spiral may be mounted on the support column for test work, or two or three identical spirals mounted on the

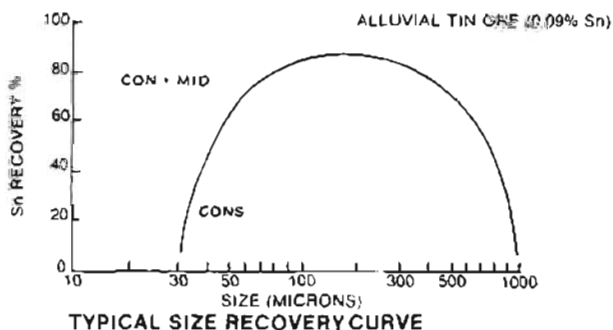


Figure 1. Tin recovery curve for the Reichert Mark VII Spiral.



same column for production. A full scale production operation may require eight or more triple-start spirals.

The Mark VII spiral is fed a 40% (w/w) solids slurry of minus 10 mesh (or finer) feed (Figure 2). It achieves high efficiency when recovering gold between 40 and 350 mesh in size (350 to 40 microns). A four part split is made at the bottom of the spiral. Concentrates, which can be observed as a thin dark line on the inside edge of the spiral, are separated for further processing. The middlings may be recycled and act as a buffer, preventing loss of fine gold should the feed surge or fluctuate. The tailings are discarded. A water split, low in solids, is either discarded or recycled.

Concentrates from the spiral are processed either on a conventional Wifley or Diester table or on the new Gemini table. Tabling is employed to make the difficult separation of the heavy minerals from the gold.

## DESIGN DATA

### HEAD FEED (PER START)

Capacity:	up to 3TPH solids depending on application
Pulp Density (w/w):	up to 60% solids
Size Range:	0.03 - 2mm
Pulp Volume (max.):	5.0 m <sup>3</sup> /hr.

### CONCENTRATE REMOVAL (PER START)

Rate:	up to 0.3TPH solids
Pulp Density:	30-60% solids w/w

**NOTE: SINGLE, TWIN, TRIPLE STARTS AVAILABLE.**

Figure 2. Plant design data for the Reichert Mark VII Spiral.

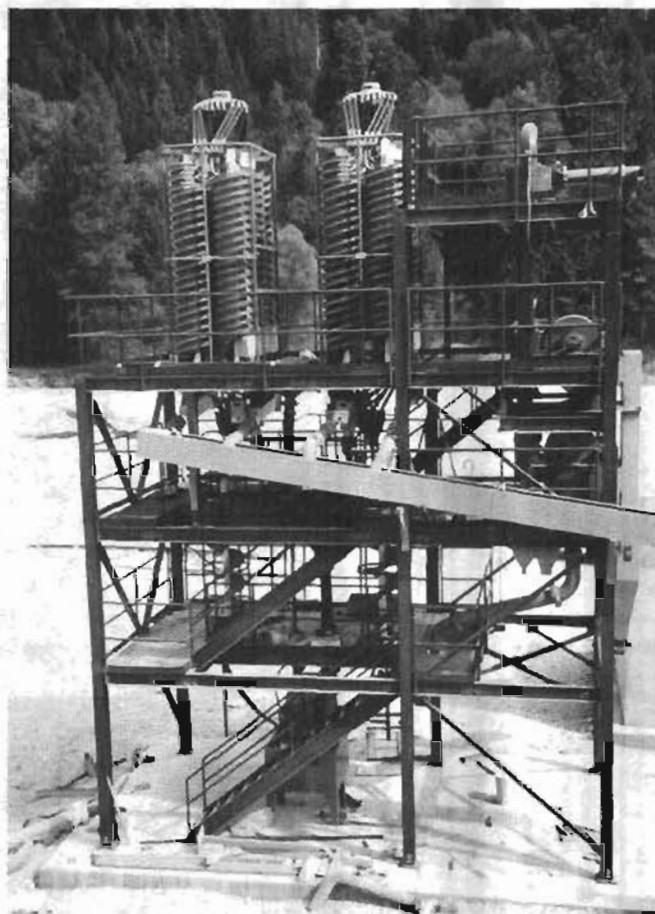


Figure 3. Spiral plant, Grass Valley, California.

A single spiral trough accepts a feed of up to three tons per hour (approximately two cubic yards per hour) of minus 10 mesh material. A triple start spiral can be fed up to nine tons, or six cubic yards, per hour.

Spirals are presently utilized in gravel pit operations in Arizona and California (Figures 3, 4 & 5). The Arizona operation feeds a 200 yd.<sup>3</sup>/hr. plant with 50 ton dump trucks. The material is sized, with the minus 3/8" plus 20 mesh, passing across four double hutch jigs. The minus 20 mesh material is pumped through a 24" Linatex Hydrocyclone Separator then across a Dings double drum wet magnetic separator. The magnetics are stockpiled and the nonmagnetics are processed by eight triple start Reichert spirals for primary concentration, and 4 single start spirals for secondary concentration.

The gravel plant in California processes 200 tons/hour (130 yds.<sup>3</sup>/hr.) of minus 3/8" material, which is screened to minus 16 mesh, dewatered in a hydrocyclone, the magnetics removed by a Dings wet

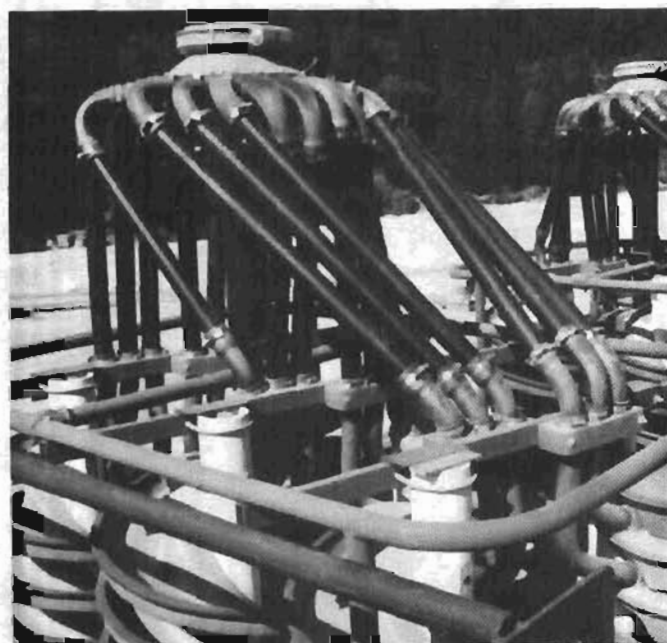


Figure 4. Pressurized manifolds feeding spirals. Grass Valley, California.

magnetic separator, and finally pumped to a bank of 12 triple start Reichert Spirals. Tailings will be sold as sand, middlings recycled through the spirals, and concentrates gravity fed to 2 single start Reichert spirals.

These are sophisticated, well engineered plants and may be good examples for setting up a new operation. Spirals are also adaptable as an add-on to existing sluice box operations (Figure 5). Prior to the design of a production system both lab testing and field testing of the spiral are essential to assure that the operation will pay for itself. The amount of fine gold, its size range, shape, and surface characteristics all play a part in this evaluation and vary considerably from one placer deposit to another.

To date, limited testing by the Miners' Company of the Mark VII spiral includes laboratory testing of placer samples and introductory on-site field work (Figure 6). Initial results of these tests were determined by fire

assay. This method has proven unsatisfactory as it measures both free gold and gold locked in the minerals of the concentrates. Fire assay is also inappropriate for placer gold evaluation since it is very vulnerable to the "nugget effect," which in this case is produced by the coarser of the minus 10 mesh gold. The development

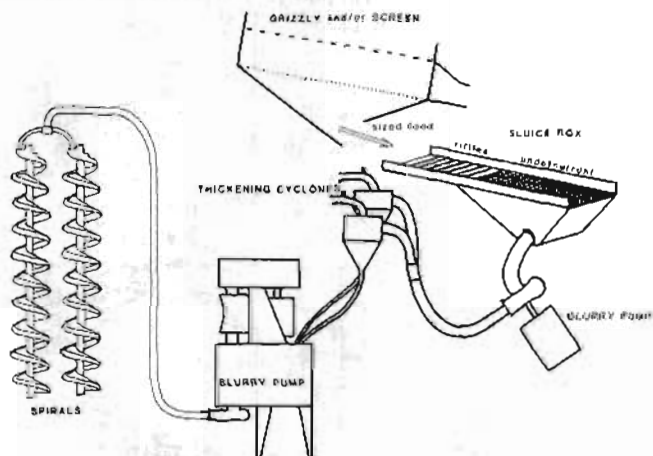


Figure 5. Equipment schematic for spiral processing of sluice box tailings.

and manufacture of the Gemini Table by Wendell Rogers, (9725 W. 21st Ave., Lakewood, Colorado, 80215) should allow for a more accurate evaluation of all future spiral production testing (Figure 7).

Spirals, unlike sluices, are continuous production devices. They are not batch systems which need to be cleaned out at intervals. They have no moving parts other than the well proven slurry pumps. When used in conjunction with hydrocyclones, also well proven by the mining industry, up to 40 to 60% of the water in the system can be recycled. Spirals can be installed on a skid and moved easily from cut to cut during the mining season.



Figure 6. Portable spiral pilot plant being tested at Coal Creek, Alaska.

The gold lost by most sluice boxes (minus 60 mesh gold) can be recovered to a large degree by the addition of a spiral plant. If one already has a sluice, it may well be more cost effective to add a spiral system for secondary recovery than to discard the sluice and install an expensive jig plant. If one had both a sluice and a spiral plant and relocated to a placer deposit without an economic quantity of fine gold (\$0.50 to \$1.00 per cubic yard of minus 100 mesh gold) then one could simply set the spiral system off to the side (Figure 8).

In as much as any additional recovery system will require a substantial capital investment it is crucial that adequate testing precede the acquisition of any new system. In fact, very few placer deposits contain enough fine gold to warrant any additional expenditure on a recovery system. For most creeks an increase in the amount of material sluiced during the mining season will create the only cost effective increase in gold production.

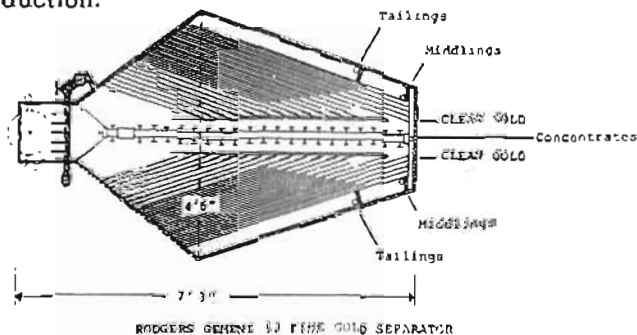


Figure 7. Plan schematic of the Gemini Table.

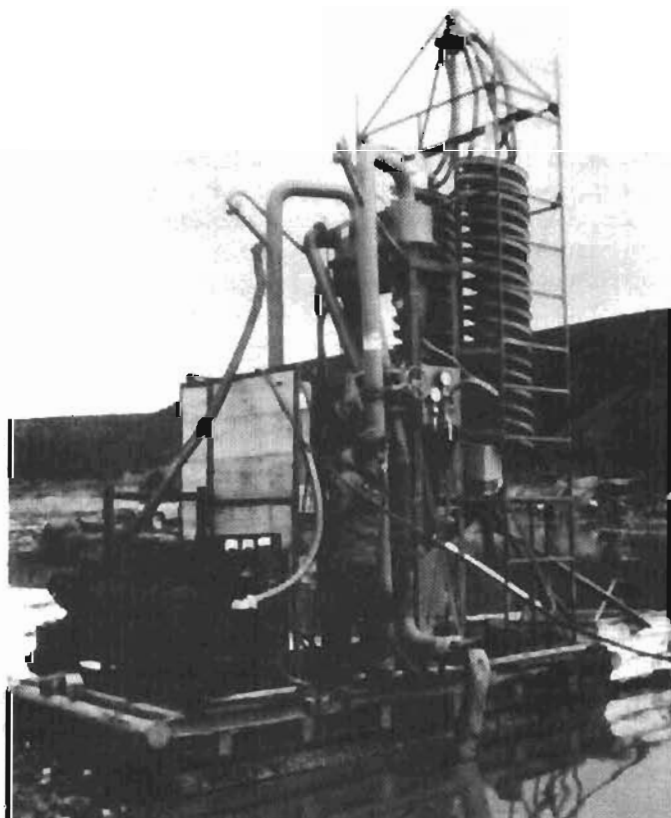


Figure 8. Portable skid mounted spiral plant in production on the Chena River, Alaska.

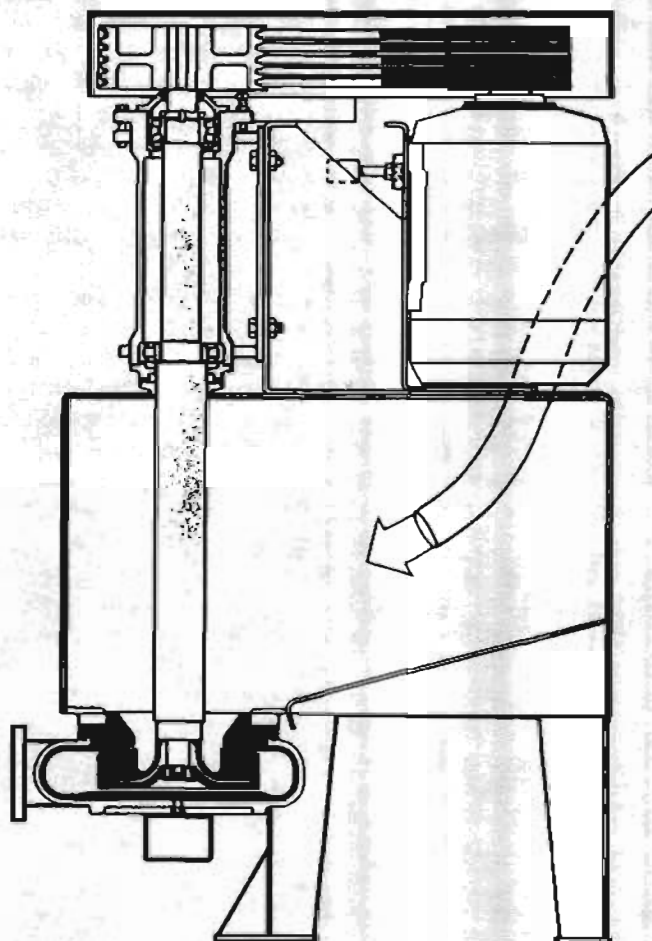


Figure 9. Sala Vertical Pump.

Experience in the evaluation of creeks for fine gold recovery systems has led to several conclusions. First, fine gold is not difficult to pan. In fact, panning is a very good first step to evaluate the quantity of fine gold in a creek. To be worth further consideration an average pan of material should contain 50 to 500 colors of minus 100 mesh gold; not merely ten or twenty colors. One should obtain more individual colors than one can readily count, and this quantity of fine gold should be found over much of the creek. Next, one must be able to demonstrate that a substantial quantity of minus 60 mesh gold is being lost by a sluice box. Feed sizing to

-10 mesh for spirals requires several steps, therefore one should be able to classify to -1" or -1/2" prior to sluicing. This will improve recovery in the sluice box substantially and is a prerequisite to the consideration of a secondary recovery plant. Another step that will improve recovery in the sluice is the installation of riffles and ports that allow for rapid, daily clean-ups.

A spiral plant consists of more than the spirals themselves. The most technically difficult equipment to select is the screening plant. Screening to -10 mesh is not simple. However, one does not need complete passage of all the -10 mesh sand through the screen, rather we only wish to pass all of the minus 20 mesh gold from the sluice tailings. As such, a static screen, or sieve bend, may be the simplest, and least expensive sizing device. If a vibrating screen is advised, the Derrick Multifeed Wet Sizing Screen is recommended.

Hydrocyclones are usually needed to dewater the undersize from the screening plant prior to pumping. The Sala slurry pump has proven effective in our test programs. It requires a small amount of maintenance time and routinely handles the transport of the 40%-60%(w/w) feed slurry to the spirals (Figure 9).

Spirals recover fine gold and other heavy minerals. In some circumstances these heavy minerals may also be economic. Because of the presence of these other heavy minerals, the task of separating the gold from the spiral concentrate becomes a very formidable one. Amalgamation will work, but often is not cost effective for this material. The best piece of equipment presently on the market is the Gemini 12 Fine Gold Separator (Gemini Table). Although new and still undergoing structural modifications it is an effective method for separating fine gold from a heavy concentrate.

As examples of some of the field testing we are doing in Alaska with the Reichert Spiral, I'd now like to describe two such cases for you. The first is one we performed on a mine in the Koyukuk mining district. Known volumes of material were taken from three locations in the pay zone on bedrock. These samples were processed separately by screening each at 10 mesh and processing the -10 mesh material on a single start Reichert Mark VII Spiral. The +10 mesh gold weight was not used in the calculations since we desired to obtain the ground value on a fine gold basis only. The spiral concentrate from each sample was processed on a

Table No. 3  
Manely Spiral Test Assay Summary

Sample No./ Volume	Concentrate Volume	Visible Gold	Fired Weight of Visible Gold	Fire Assay of Table Concentrates	Average Assay	Weight of Table Concentrates	Calculated* Weight of Gold in Table Concentrates	Total Gold in Sample	\$/yd <sup>3</sup> **
5/50 gal.	1/2 gal.	5 colors	12.05 mg	a) 0 mg b) 0.39 mg	0.195 mg	405 gms	2.7 mg	14.75 mg	\$9.56
5/50 gal.	3/4 gal.	40-50 colors	111.25 mg	a) 1.53 mg b) 0.70 mg	1.115 mg	508 gms	19.38 mg	130.63 mg	\$5.04

\* Calculated gold weight =  $\frac{\text{average assay Au (mg)}}{29.1 \text{ grams}} \times \text{weight of concentrates (grams)}$

\*\* \$/yd<sup>3</sup> = weight of gold (mg)  $\times$  \$0.01/mg  $\div$  1/4 yard per sample.



Gemini table and the gold weight recovered by the table's clean gold split was used in the subsequent calculations of ground value (\$/yd<sup>3</sup>). Table No. 1 shows the results of this series of tests. All ground values were determined assuming a gold price of \$300.00/oz. and no gold fineness correction was made.

Table No. 1

Results of Spiral Test Performed in Koyukuk Mining District

Sample No.	Sample Volume	Gold Wt. Recovered (mg)	Ground Value (\$/yd <sup>3</sup> )
1	¼ yd <sup>3</sup>	288.39	11.16
2	¼ yd <sup>3</sup>	80.94	3.12
3	¼ yd <sup>3</sup>	+20 - 86.52	
	Gold wt.	20 × 40 - 139.89	
	versus	40 × 60 - 37.71	
	ASTM mesh	-60 - 5.73	
TOTAL		289.85	10.41

A second series of tests were run in the Manley mining district. The procedure for running the samples was as previously described for the Koyukuk test work. However, the tests at Manley were run at two different times during the 1984 mining season. In the Spring, before mining began, samples were taken from the previous mining season's tailings piles. Tables No. 2 and 3 show the results of this test series. Note that Table 3 also includes an estimate of the gold in the Gemini table's concentrate split. This gold weight was estimated by fire assay and hence these values should be viewed with caution.

During the 1984 mining season, a test was run on a ¼ yd<sup>3</sup> sample from the working sluice box's tailings. The test recovered a total of 214.96 mg of free gold, yielding a sample value of \$8.29/yd<sup>3</sup>. This figure reinforced our earlier conclusions that the sluicing operation was losing gold values in the area of \$5.00/yd<sup>3</sup>. We will follow up this test series with additional on-site work in the 1985 mining season.

Table No. 2  
Manley Spiral Test Sample Results

Sample	Sample Volume (5 Gallon Buckets)	Oversize Volume (5 Gallon Buckets)	Concentrate Volume (Gallons)	Results
2	10	8½	1	Panned, no color
3	10	5	1	Panned, no color
4	10	1	½	Tabled, 5 colors
5	10	3½	½ to 1	Tabled, 40-50 colors
6	5	5	½	Panned 18 colors. Field estimate, 15 mg., \$1.20/yd <sup>3</sup>
7	10	2	½	Panned 2 very fine colors

## The Hydro-Laser and its use in Underground Placer Mining\*

Hugh B. Pate, Jr., D.M.D.

### I. Underground Placer Mining

#### A. Underground placer (drift mining) operation.

1. Low heat rise in frozen placer deposits.
2. Low water production.
3. Removal of frozen gravel in blocks.
4. Good production potential (especially if mechanized).
5. Small space requirements underground.

#### B. Advantages of underground placer mining.

1. Selective removal of pay gravel
2. Development of high quality placer deposits that are too deep for conventional operations.
3. Less water volume used for sluicing causing fewer settling problems.
4. Fewer environmental disturbances and/or problems.
5. Comparatively low capital costs.
6. Comparable or lower operating costs.

#### C. Disadvantages of underground placer mining.

1. Fairly high grade of ground is needed due to low volume output.
2. Very strict compliance with Mining Safety and Health Administration (MSHA) in mines with shafts over 100 feet vertical depth.

### II. Hydro-Laser

#### A. Description of Hydro-laser.

1. Model 3100 SS with triplex plunger pump.
2. Powered by 4-71 Detroit Diesel Engine coupled to positive displacement pump.
3. Nozzle tip range (.05 - 1.5 mm)
4. Gun type nozzle with shoulder stock.
5. Operating pressure range (3000-16000 psi).
6. Entire unit is trailer mounted and can be pulled by light pickup.
7. Two hose reels with high pressure hoses.

#### B. Operating parameters.


1. Requires regular daily lubrication inspection.
2. Requires fresh water supply with at least 25 psi.
3. At high pressures, constant flow is needed to forestall rupture.
4. Nozzle is dangerous during high pressure operation.
5. Safety gear is required for splash-back.

#### C. Common uses.

1. Cleaning hardened deposits from radiators or louvered structures.
2. Cleaning large storage tanks.
3. Demolition of concrete.

- D. Disadvantages of the hydro-laser.
1. Splash-back limits visibility.
  2. Heavy hoses and back-pressure preclude a miner from getting in a full work day.
- Both the above problems might be alleviated by automating the laser gun, using a computer controlled machine or a cam operated device.

*\*Editor's Note: Due to technical difficulties an audio recording of Dr. Fate's paper was unavailable for transcription and inclusion in its entirety. Dr. Fate was kind enough to construct this outline of his presentation.*



## Conference Banquet Speech on Mining in Alaska Today

*Dr. William R. Wood*  
President Emeritus, University of Alaska

The mineral industry of Alaska in its present embryonic stage, particularly placer mining, is complex, confusing, and in a combative mood. All of the mining people I meet these days seem to be candidates for the advanced degree, doctor of frustration. There is a large amount of fussing, fuming, and blaming somebody else for something. The target is not always clearly identified, yet the overall situation is sticky, unpleasant, and irritating enough. An enormous amount of energy, obviously, is being wasted in beating one's fists against the muck and spitting into the unseen winds of change. For change is in process even in some of the methods and thinking that have resisted change it seems for the better part of a hundred years.

Once spent in futility, human energy is gone. This we know. Still the cry within persists, "Don't just stand there. Do something!" If there is a message in this, some handwriting on the wall, it would likely read, "Don't go it alone. Target your energies together where the total force mustered has a chance to be effective."

After extensive reading of studies, reports, economic assessments, both gloomy and pie-in-the-sky, regulations and pronouncements, after extended discussions with knowledgeable Alaskans, whose perceptions and practical experience I respect, one question regarding the mineral industry of Alaska cries out for thoughtful exploration: "What could be done today that would make a difference tomorrow?"

Grope with me in the dark for whatever pin points of light we can find in the tunnel. Here a little brainstorming would seem in order. Lay aside for a time conventional wisdom or extend it in new directions. This could be on a tangent or directly opposite the way now being followed.

In any game requiring wit and skill, it pays to learn the fundamentals, master them, and use them consistently when the stress is greatest. For the mineral industry game in Alaska, look at these three: 1) From time immemorial the two basic sources of new wealth for

mankind have been, and are, agriculture and mining; (The button given me yesterday reads, "If it can't be GROWN, it has to be MINED.") 2) Unused or under-utilized resources - people, renewables, and non-renewables - inevitably deteriorate, ultimately to the point where they cannot be afforded by any people, tribe, community, state, or nation; (This was originally referred to in manpower studies as "The Theory of Idle Resources.") and 3) To see one's self as a victim leads to deeper frustration, whereas to perceive one's self as a part of the problem can be the wellspring of hope. (Perhaps Pogo summed up today's situation for the Alaska mining fraternity in the comment, "We have met the enemy, and they is us.") Ponder this for a while. It is meant as a tonic for thinking.

The exploration and production sector of the mineral industry represents fewer than one-half of one percent of the work force and even a smaller fraction of the total population. Processing and primary manufacturing involve a larger segment. Marketing and distribution, including transportation, communications, the sales force, advertising, short-term financing, and the like encompass a much, much larger portion of the whole. The consumer of products directly and indirectly dependent upon the mineral industry, of course, is everybody, everyday in a thousand ways.

Yet only a handful of people, perhaps fewer than three to five per cent, are even vaguely aware of this fact of life. They act daily out of ignorance and indifference. They vote whatever prejudices emerge from this seed-bed. Indeed, there are among them, propagated by the ultra-preservationists, the non-humanistic ones who some term our modern cynics, the myth that somehow the mineral industry is evil, a menace to mankind. The myth is perpetuated, or at least its proponents are aided and abetted by the conventional wisdom of self styled expert analysts and consultants on Alaska's oil wealth and our mining prospects. We are told that surplus wealth should not be wasted on developing a transportation and energy in-state infrastructure for production, value-added processing, or for marketing. We are told that investments should be concentrated outside Alaska - apparently to protect the future of the very special few who might choose to remain as residents in a non-producing state. We are told that every developmental project must clearly show that it can pay its own way - in advance of start-up. The legacy of Hammondism!

Now consider the political implications of our inverted pyramid of voting strength, where the mineral industry is one-half of one per cent, or less, the tip at the very bottom of the upsidedown structure. Ask again "Just what can be done today that will make a difference tomorrow?" Two possibilities seem obvious - friends and education. These are urgent necessities if any measureable improvement is to be made in the condition of Alaska's mineral industry, other than oil and gas, during the remainder of this century. As President Heinze of ARCO Alaska and others have advocated, it's time to build and coalition. In the process let there be no fighting within the mining fraternity, no matter how independent anyone may claim to be. This is an interdependent world, inescapably so, in the world-wide mineral industry.



Include in the coalition all dealers in equipment and hardware, the transportation people, the entire agriculture industry, including grain and hay farming, fertilizer production, livestock and poultry production and processing, fur farming as well as the wild harvest, both commercial and sports fishing, vegetable and flower production, seed growing, potato farming, and forest utilization in all its many facets. Work with the fisher folk and the lumber people. Don't fight them, you need them. Work out the tough compromises together as partners. Each should be ready to try a little give and take on the basis of what is fair and just for all concerned, not merely what is best for one's own special interest at the time. Remember, in building the coalition we are considering what can best be done today that will make a difference tomorrow. Not an easy task.

To bring a binding coalition into being, as a force that will attract voter's attention, there must be common understanding and genuine, total commitment based upon that understanding. It will take time to build a lasting coalition of friends of the mineral industry in Alaska, at least a generation. For the means is persuasion through education of the population as well as through the advancement of knowledge and technology applicable to the mineral industry of Alaska. A substantial, sustained investment of time, talent, and treasure is the basic ingredient. It won't happen of itself. There is no Santa Claus to do something nice for the industry sometime. The industry itself takes on the chore, even if it means a self-imposed special assessment for the crusade, perhaps on ore produced.

But there is hope for Alaska. Proper utilization of its exceptional known mineral resources is possible. At some point in time this becomes an absolute requirement for the civilized world. Then make ready now. Invest wisely for tomorrow's pay-off. Take the calculated risk involved. Please note, there is plenty of risk, too, in those fabulous outside Alaska deals.

To say that production and processing of Alaska's mineral resources can't be competitive in the world marketplace is a worm's-eye view of an apple from another tree in the orchard. High labor costs are cited, ignoring both the enlightened self interest of labor as a partner in development, as well as the offset provided by the stability of our government in attracting investment of risk capital. Remoteness from world marketing centers is cited, apparently by those unfamiliar with maps, globes, history, or the potential creativity of the Alaskan mind. Alaska is closer to the burgeoning markets of the Pacific Rim countries than almost any possible competitor. Of course, we have to cope with the Jones Act and a few other odds and ends of "non-sense."

We are told by the "experts" that we can't compete because of all that cost of remoteness. Myth and bugaboo. Run that pertinent data through the computer again and include the variables of the human factor. Remote, from what? Let's seek out ways to outwit the hazards and quit wasting energy on trying to bull our way through them.

We have some genuine advantages. We are Alaskans - perhaps in the twentieth century a breed apart. Exploration in recent years has identified several world-scale ore deposits near tide-water: Red Dog, Quartz Hill,

Beluga, Johnson Creek, Greens Creek, Bering River, Yakobi Island, and others. There are, also, the great Ambler District copper deposits, the Slate Creek asbestos ores, the Lik, Lu lead, zinc, silver deposits, and Lost River, the only major tin ore body in North America. There are enormous quantities of coal, of industrial-type non-metallic ores, sand and gravel, limestone, and peat to be mined sensibly for useful purposes of people.

In Alaska, exploration at this time is ahead of production, but the search must go on and on. As the known world-scale deposits are mined, many smaller ones will be discovered that are feasible to utilize. Identify them now. Add to the known inventory of reserves. Don't stop looking.

Great emphasis needs to be placed upon the development of the high technologies pertinent to utilization of Alaska's mineral resources. Is there a better way of mining placer gold than muddying the creek? Is there some dry process possible or a filtration mechanism or technique? Just when conventional wisdom shouts loudest "it won't work," some character drifts in with a new idea that does. Encourage invention, technological breakthroughs, the entire spectrum of research - people, land, sea and space - involved in the advancement of knowledge of Alaska.

Admittedly we are plagued by bureaucratic regulations imposed by the uninformed, the misinformed, and the mistaken. Such impositions can be modified by reason and understanding, just as soon as the coalition can muster enough votes backed by pertinent factual information to be persuasive. Change is not so much a matter of interpreting "Constitutional Rights" as it is of demonstrating to the general public that mining is not a menace but an everyday necessity for everyone seeking the good life.

One of the truly hopeful signs in this educational process is "The Three M's Project: Mining, Minerals, and Me" as promoted by Dr. John Sims and others. Let's get on with this splendid learning effort promptly and push it to the hilt. The proposal by Leah Madonna and others for an Alaskan mineral exhibit showing everyday products using these ores is a grand idea. Let's put it to use. Couldn't we have such a mineral exhibit in place for the public to see before the end of eighty-four? There is talk of a "Miners' Advocacy Council" with two or three members to be drawn from each of the organizations concerned with the mineral industry. This could be a good idea if established on a sound basis to undertake positive, constructive work in policy formulation and planning. It would need to be staffed properly to handle an action agenda on key issues. It could make a difference.

Pinpoints of light in the tunnel - friends, education, selfdiscipline, initiative, self-reliance. There is no quick and easy way out of the tunnel, but there are leads to follow in seeking the sunlight of a new day for Alaska's mineral industry. Take a step or two today that will make a difference tomorrow.

# Mining and Recovery of Placer Minerals

J. M. Dankers, Managing Director

and

T. H. Nio

IHC Holland

## 1. Introduction

The organization which I represent, IHC Holland, is a group of manufacturers specialized in the design and construction of all types of dredging equipment, including mineral dredgers and ore separation plants. The group has a record dating back to 1880, and has built

- 152 mineral dredgers
- 374 bucket dredgers
- 280 trailing suction hopper dredgers
- 680 cutter suction dredgers
- 47 barge unloading dredgers
- 680 barges for transporting dredged soils
- 79 rock breakers
- 172 tugs
- 639 ferries and cargo ships
- 22 self-elevating platforms
- 23 jig treatment plants
- and numerous jig units.

With this record IHC fully qualifies as a major supplier to the mining and dredging industry.

## 2. Placer Mining

A multitude of mining methods are available to win the valuable minerals from alluvial deposits. When we talk about placer or alluvial deposits, we define these as 'potentially commercial deposit of detrital natural material containing valuable minerals in the form of discrete grains.' It is a successful coincidence of exposed mineralized catchment, vigorous drainage and the right conditions for 'selective accumulation' as a geologist aptly described.

A placer can be formed by weathering and/or transportation of mineral-bearing rock. The transport can be done by glaciers, wind, wave action, and rivers over long or short distances. The mineral bearing layers may be covered later by deposited layers of barren material. The degree of segregation can vary widely, as can the grain size of the valuable minerals; these in turn can be very different (cassiterite, gold, diamonds, heavy minerals such as rutile, magnetite, ilmenite etc.) and the size of the deposit may vary from thousands to many million of tons.

Thus the variety of placers has no limit, and (subject to the laws of economics) mankind has devised many different ways to extract the valuable minerals from their environment. Placer mining is one of the earliest

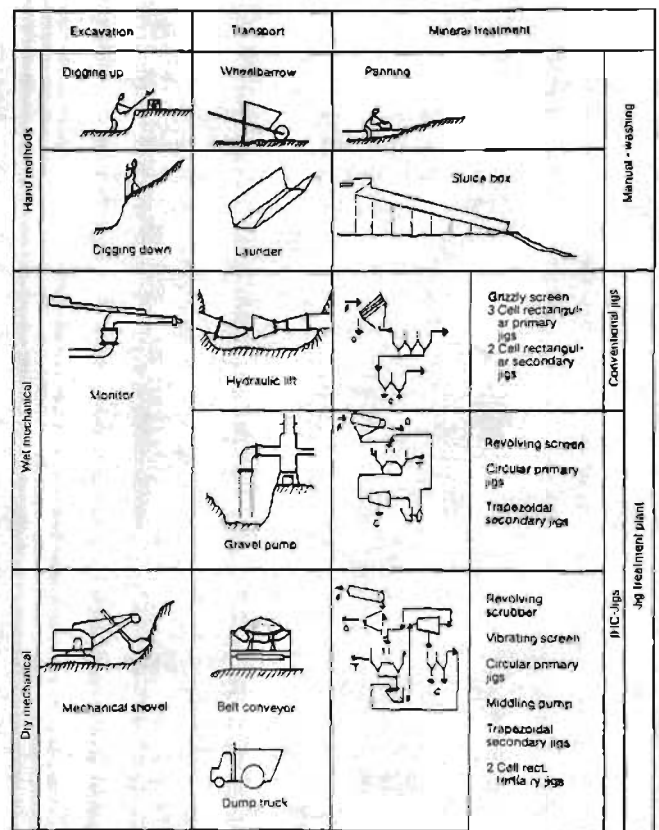


Figure 1. Open cast mining systems.

and simplest forms of mining. All methods involved movement of relatively large quantities of material, the most used methods being dry earth moving, gravel pumping and dredging. Each has its own characteristics as to required technology, cost, and attainable throughputs. Often the characteristics of the alluvial deposit more or less determine the technical possibilities for handling the material.

Figure 1 shows the different open cast mining systems in a simplified form. Most of the methods will be familiar to a practicing miner.

All but the small pick and shovel panning operations warrant a study at some depth. It is beyond the scope of this paper to cover all aspects of such a study; we only mention some of the obvious.

Mineral Specific Gravity	Mineral Name	Chemical Composition	% Valuable Constituent	Hardness Mohs Scale
20.0 18.0 16.0 14.0 12.0 10.0 8.0	16-19 Platinum 15-19 Gold 10.3 Silver 8.8 Copper	Pt (Fe, Zn, Rh, etc) Au (Ag, Cu, Fe) Ag Cu	Pt: 80-90 Au: 50-95 Ag: 100 Cu: 100	4.0-4.5 3.5-3.0 2.8 2.8
7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5	7.0-7.5 Galena 7.0-7.5 Wolframite 6.8-7.1 Cassiterite 5.9-6.1 Scheelite 5.5-7.5 Columbite/Tantalite 5.2 Magnetite 4.9-5.3 Hematite 4.9-5.3 Monazite 4.5 Xenotime 4.5 Bixbite 4.4-4.8 Zircon 4.3-5.0 Ilmenite 4.2-4.3 Rutile 4.1-4.7 Chromite 3.9-4.1 Sphalerite 3.5 Diamond 3.4-3.6 Topaz	PbS (Fe, Mn)WO <sub>4</sub> SnO <sub>2</sub> CaWO <sub>4</sub> (Fe, Mn)O(Mb, Ta) <sub>2</sub> O <sub>6</sub> Fe <sub>3</sub> O <sub>4</sub> Fe <sub>2</sub> O <sub>3</sub> (Ce, La, etc)PO <sub>4</sub> ·ThO <sub>2</sub> Y PO <sub>4</sub> Ba SO <sub>4</sub> Zr Si O <sub>4</sub> FeTiO <sub>3</sub> TiO <sub>2</sub> (MgFe)O(Cr, Al, Fe) <sub>2</sub> O <sub>3</sub> ZnS C (AlF) <sub>2</sub> SiO <sub>4</sub>	Pb: 86.6 W: 60.6 Sn: 78.6 M: 85.9 Nb, Ta: variable Fe: 72.4 Fe: 70 H.E.: ThO <sub>2</sub> : 70 Y: 45.3 BaO: 65.7 Er: 50 Ti: 31.6 Ti: 40 Cr: 46.2 Zn: 97.1 C: 100 Gem: variable	3.0 4.5-5.5 6.0-7.0 4.5-5.0 6.0-6.5 5.5-6.5 5.5-6.5 4.5 4.5 2.5-3.5 7.5 5.0-6.0 6.0-6.5 5.5-6.5 3.5-4.0 10.0 8.0
3.0 2.9 2.8 2.7 2.6 2.5	2.8-2.9 Dolomite 2.7 Calcite-Aragonite 2.65 Quartz	CaMg(CO <sub>3</sub> ) <sub>2</sub> CaCO <sub>3</sub> SiO <sub>2</sub>		3.5-4.0 3.0-4.0 6.0

Figure 2. Some physical and chemical data of placer minerals.

- if there is little or no water, dredging is not possible.
- the largest throughput consistent with the size of the deposit is usually the most economical.
- dredging is not possible on steep surface inclines,
- if dredging is possible, it is always more economical than any other method.
- dredging requires more capital investment than dry earthmoving or gravel pumping, and thus requires larger deposits and longer mine life for amortization of equipment.
- gravel pumping is a low investment method but has a significantly higher operating cost per ton produced.
- dry earth moving equipment is normally standard equipment, and can either be purchased or rented on term contracts, so investment can be kept low, but operating costs are high.

These, and many more factors should be considered in any feasibility study together with a forecast of the sale of the mine product during the lifetime of the mine.

Some pre-dredging open cast mining practices are shown in Figure 1; a monitor - gravel pump mine and the use of belt conveyors in a tin mine.

The great advantage of these open cast mines is that the bedrock is visible, enabling efficient clean-up. Therefore these mines can have a R/E (Recovery/Evaluation) factor of 1.3, while dredging averages an R/E of 0.9 only.

However cost wise, the cost/unit throughput parameters of dredging, gravel pumping and dry earth mining roughly compares as 1 : 2 : 4.

### 3. Mineral Dressing

No matter which mining method is selected the next step in the operation is always the separation of the valuable mineral from the matrix material. The in-situ mineral content of the deposit may vary from less than 1 ppm to several thousand ppm, and it is therefore necessary to upgrade this valuable content as close to the deposit as possible to minimize transportation cost of material to the refineries where the mineral is produced in the purity required by the market.

Some, if not most deposits, contain a mixture of valuable minerals, one of which is the main target of the exploitation. The accessory minerals however, may be worthwhile to recover and sell to separate markets. The separation of the individual minerals often requires sophisticated equipment and close process control, neither of which are compatible with the relatively rough process of earth moving, whatever the method.

Therefore the on-site separation is primarily an upgrading process, using non-sensitive equipment and aiming at discarding as much of the matrix material as is possible.

Fortunately the valuable minerals have a significantly higher specific gravity than the matrix material, which is mostly quartz. (See Figure 2 for list of principal

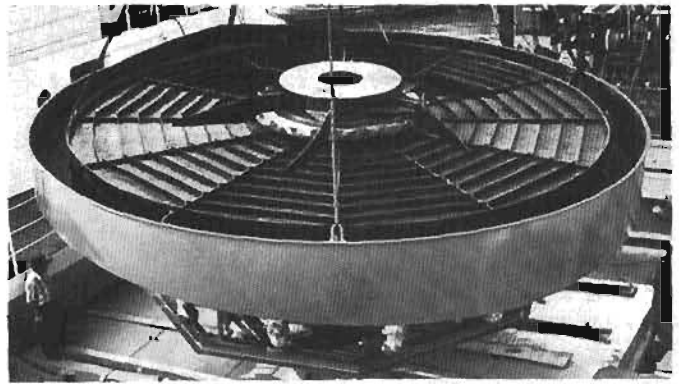


Figure 3. IHC's largest jig, the 12 cell, 42 cubic meters, type 25.

placer minerals). All methods use the 'Gravity separation' principle and require some preparation of the material such as screening, addition of water and control of feed flow.

The principal types of separation equipment can be characterized as follows:

- sluices: simple and low cost, they require a high amount of water, periodic cleaning, have varying efficiency, are relatively high polluting, and are not sensitive to feed conditions.
- thin film separators such as trays, cones, spirals: very sensitive to feed conditions, require fine screening, close slurry control, low capacity per unit, average water consumption, suitable for low specific gravity minerals. The variety in these types of separators is staggering. Just to mention a few proprietary names: Van Bergen strake, Lovegreen jet separator, Kower separator, Kyna whirlpool process, Bartless-Mozley concentrator, HY-G concentrator, and Knelson concentrator etc. besides the initially indicated devices

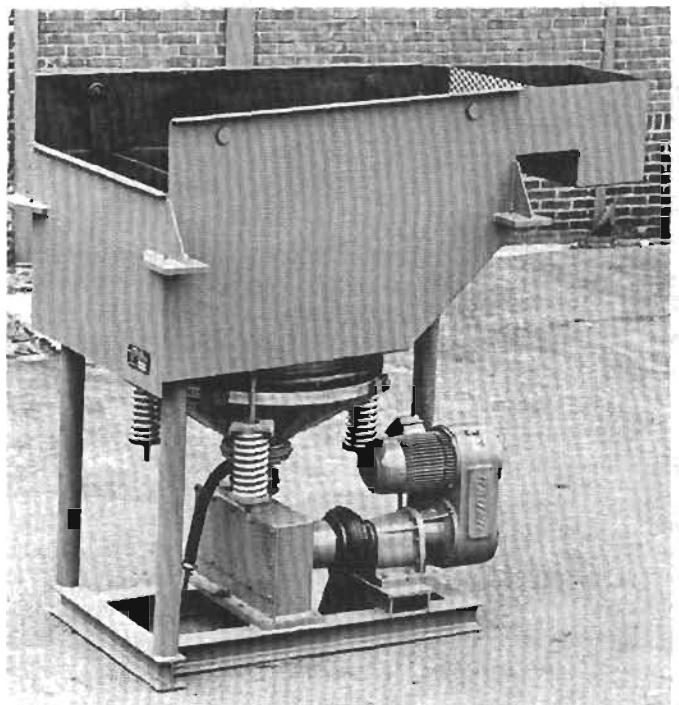


Figure 4. The IHC Mini-module jig.



with brand names as Wright tray, Reichert Cone and Humphrey Spiral.

- jigs: pulsating thick bed separators, relatively insensitive to feed grain size and slurry density, insensitive to variations in feedrate, relatively high capacity per unit, simple staging, high efficiency, little maintenance, high upgrading possible.

Of specific interest to this audience will be the development of the IHC jig, a large capacity ore concentration machine which has found wide acceptance in the alluvial mining industry, specifically in tin and gold mining.

Figures 3 and 4 show two of the IHC jig types (largest and smallest) available, while Figure 5 shows our jig on a mining dredger. It is also interesting to note that we have a full size module type jig for testing purposes, located at the University of Technology in Delft.

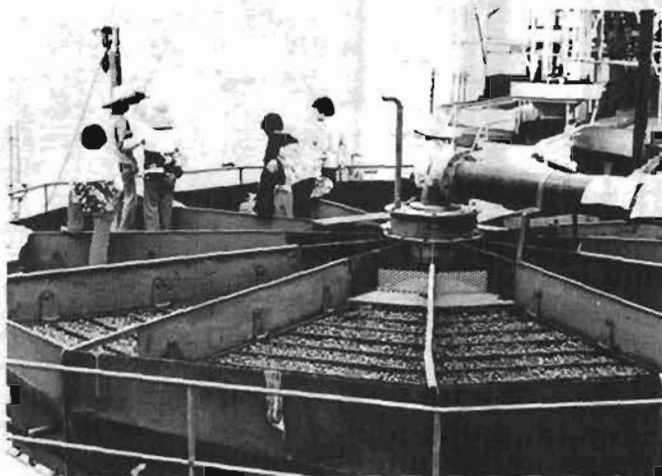


Figure 5. 12 module IHC Jig mounted on a dredge.

The deposit's characteristics determine which equipment is most suitable for a particular application. A jig plant, despite its higher cost and complexity compared with a sluice installation seems a good solution for many Alaskan gold operations because of its water economy and its high recovery efficiency. The possibility of designing and building a self contained plant of reasonable capacity for an acceptable investment, which can be skidmounted to follow the earth moving operation makes it an attractive alternative.

We will now describe such a plant, which is planned to be operational in the 1984 season. It will be used at the GDM operation, which we understand is typical for a large number of Alaskan operations.

## 4. Description

IHC will deliver to GDM a skid-mounted mobile treatment plant for alluvial gold mining with a separate diesel-driven power unit.

The plant is composed of two main sections, each 35 ft. long, 11 ft. 10 in. wide. The bottom section is 11 ft. high and the top section 10 ft. high. Both sections weigh less than 32 metric tons. In addition, there is a small stacker belt and a tailings launder. A basic feature of the plant is its low water consumption, thus reducing environmental pollution.

The treatment plant is designed to handle a feed of 200 cu. yds/hr (Figure 6). This feed is delivered by an owner-supplied track feeder and belt conveyor to a hopper, with a Vibro-barsizer to scalp +12" boulders. The grizzly is set at approximately a 20 ft. height, so as to ensure a maximum gravity feed inside the plant, minimizing pumping requirements. The hopper feed is delivered to a revolving scrubber/screen trommel to wash the feed and screen off the oversize.

The undersize is gravity fed through a screen collecting box to a three-stage jiggling plant, concentrating and reducing the gold-bearing solids. Oversize material from the trommel screen is discharged to a stacker belt conveyor.

The primary jig tailings are gravity discharged into a tailing tank. A tailing pump draws from this tank and discharges through a dewatering cyclone, which is fitted at the tail end of the upper frame. The cyclone overflow is directed into the headertank, thus reducing the quantity of new water needed. Cyclone underflow is discharged into the tailing launder. The primary jig product is gravity discharged to a middling tank. From there the product is pumped to the secondary jig.

The secondary jig tailings are recirculated to the primary jig feed. The secondary spigot product gravitates to the tertiary jig. Tertiary jig tailings are recirculated to the middling tank. The final concentrate,

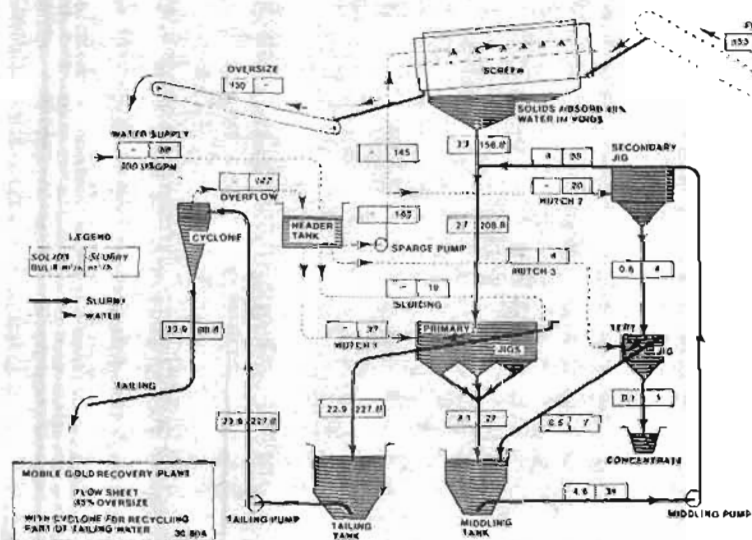


Figure 6. Flowsheet of the GDM mobile gold recovery plant.



recirculated to the middling tank. The final concentrate, discharged by the tertiary jig spigot, can be collected in owner-supplied buckets.

Jig hutch water supply to primary and tertiary jig is from a header tank, which is kept filled by cyclone overflow and make up water. Hutch water supply to the secondary jig is by means of a branch on the sparge pump discharge line.

Feed conditions may vary over a certain range. The plant is designed to handle a full feed rate of 200 cu yds/hr, containing an oversize (+3/8") percentage between 70 and 90%. For this reason the maximum stacker conveyor belt capacity is 180 cu yds/hr and the maximum jig capacity is 60 cu yds/hr plus recirculation products.

## 4.2 Principal Particulars

### a) Treatment plant design criteria:

slope of revolving screen .....	1 in 12
slope of distribution and collecting chutes .....	1 in 6
slope of tailing chutes .....	1 in 12

### b) Road transport dimensions

NOTE: Weights are the net construction weights, excluding jig ragging.

The plant will be sectioned as follows:

- one bottom section:
 

length .....	10.4 m (34.2 ft)
width .....	3.8 m (11.8 ft)
height .....	3.35 m (11 ft)
approximate weight .....	32 tons metric
- one top section:
 

length .....	10.4 m (34.2 ft)
width .....	3.6 m (11.8 ft)
height .....	3.5 m (10 ft)
approximate weight .....	26.5 tons metric
- one stacker belt section:
 

length .....	12.3 m (40.5 ft)
width .....	1.5 m (5 ft)
height .....	1.5 m (5 ft)
approximate weight .....	2.5 tons metric
- one tailing launder section:
 

length .....	5.5 m (18 ft)
width .....	0.4 m (1.4 ft)
height .....	0.5 m (1.7 ft)
approximate weight .....	0.9 tons metric
- a separate diesel-generator set to be mounted on a truck with dimensions:
 

length .....	3 m (9.8 ft)
width .....	1.5 m (4.9 ft)
height .....	2.3 m (7.5 ft)
approximate weight .....	3500 kg (7700 lbs)

### b) Approximate weight of the plant in operating condition:

Nett construction weight of plant .....	52.9 tons metric (138,800 lbs.)
Diesel generator set .....	3.5 tons metric (7,700 lbs.)
Small mounting materials such as bolts etc. ....	0.1 tons metric (200 lbs.)
ragging .....	4.0 tons metric (8,700 lbs.)
water and slurry .....	18.0 tons metric (40,000 lbs.)

In total 88.5 tons metric (195,400 lbs.)

## 5. Gold Mining Dredging

The first gold dredger in the Yukon was started on the Lewes River in 1899 and in 1914 there were 42 dredgers operating. Therefore it may be of interest to give some information on a medium sized gold dredging operation, which uses modern dredgers with an integrated gold recovery plant in Northern China, where the climate conditions are similar to those found in Alaska.

The equipment was designed by us, the components and prefabricated steelwork were shipped to the minesite. Construction and assembly were carried out by the owners with our assistance in 1980.

### 5.1 Design Parameters

The mining dredger is an inland 300 litre bucket dredger with treatment plant for the recovery of gold from deposits in the sub-arctic region.

The solids dredged by the bucket line are delivered into a drop chute leading into the primary treatment plant through a revolving screen. Oversize disposal is from the screen via a stone chute. Tailing disposal is partly by gravity through tailing launders, the other part is discharged through a tailing pump via a cyclone after the chute. With this system the oversize material will be covered by fines which will enable re-solling.

The treatment plant is comprised of a three stage jiggling system. The tertiary jig concentrate is further upgraded by a hydraulic classifying process in the concentrate tank.

The dredger and its equipment are designed for continuous operation 24 hours a day.

The dredger is fitted with a diesel driven power plant, the power system being 380 Volts A.C., 50 c/s (3-phase). The top tumbler is electric motor driven thyristor controlled variable speed. The ladder hoisting winch, the headline winch and the side winches are hydraulic motor driven, with the hydraulic oil being supplied by electric motor driven power packs.

The dredger is designed for the following conditions:

- a rated dredging capacity of 243,000 cu. m/month at 600 dredging hours per month at 75x average bucket fill and 30 buckets per minute

- a maximum dredging depth of 11 m below water level

- typical soil analysis:

particle size mm	weight percentage
+100	4.78
100 - 50	14.74
50 - 25	14.80
25 - 16	8.09
16 - 10	6.9
10 - 4	12.69
4 - 2.5	5.6
2.5 - 1	5.96
1 - - 0.1	19.24
-0.1	7.2

- typical grain analysis of the gold:

particle size mm	weight percentage
+2.5	0.7
2.5 - 1	7.8
1 - 0.5	19.3
0.5 - 0.25	54.41
0.25 - 0.15	16.33
0.15 - 0.1	0.75
-0.1	0.68

- gold content average 0.316 grams/cu.m
- maximum face 2 m above water level and a average face height of 1.50 m.

- depth of the deposit below water level is max. 10.2 m, min. 3 m, average 6.16 m.

The alluvial from top to bottom consist of: humus, clay, upper sand and gravel, lower sand and gravel, and gravel.

The gold is mostly concentrated in the gravel. The bedrock is decomposed granite.

The top soil freezes up to a depth of 2.8 m below the surface while permafrost lenses occur at 4-6 m depth for 60%.

These permafrost lenses are defrosted two years prior to dredger operation. Surface is marsh land with grass with scattered bushes and small trees.

Silt content is as follows:

- upper sand and gravel ..... 3 - 10%
- lower sand and gravel ..... 9 - 15%
- gravel ..... max.20%

Specific gravity of the soil in situ is 2 tons/cu. m.

Swell factor of the soil is 1.16

Accessory heavy minerals of the gold are ilmenite and garnet.

Stones of over 200 mm in size are found in clay 1.33%, in upper sand and gravel 1.17% and lower sand and gravel 2.28% and in gravel 3.79%. Minimum water flow is 0.312 cu.m/sec. There is a big river 10 km from the mine site.

## Gold Recovery with Sluice Boxes

Will Godbey, Graduate Student

The recovery of gold from placer deposits is one of the oldest mining technologies known to man. The use of sluice boxes to recover gold is as old as man's known history and is still in use today. The idea for the sluice box came from nature itself. The first miners probably used the method of ground sluicing to recover the gold. This method does not recover the fine gold, but in areas where nature has created coarse gold pay streaks this method is satisfactory.

Figure 1 shows a profile of a typical placer stream. Since bedrock in a stream behaves much the same as in a sluice box, some direct analogies can be drawn. The high energy or upper section of a stream has a high gradient and contains the largest gravel sizes. It is here that most of the coarse gold will stay while the fine gold is carried away.

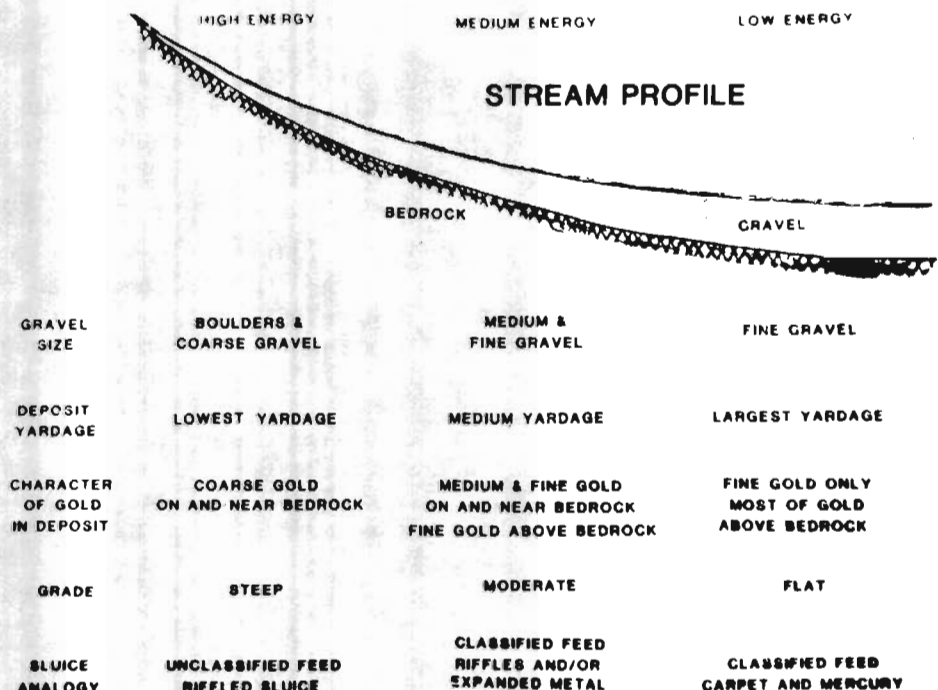


Figure 1. Stream Profile.

The same will happen in a sluice box that has an unclassified feed. In the stream, the medium and fine gold do not begin to drop until the coarse gravel has been left behind, i.e. the gradient decreases. It is in the medium energy area that the problems with sluice boxes begin. A sluice box having a classified feed will be able to catch medium and some fine gold, but a lot of fine gold will get away. The fine gold gets away because the water velocity is too high to allow it to settle.

In the low energy environment of the stream the fine gold is able to settle out but unfortunately the gravel bed is not loose enough to allow it to drop to bedrock. The same thing happens in a sluice box. For fine gold to settle, the water velocity must be reduced. Unfortunately this allows the sluice bed

to pack and thus the gold is unable to penetrate.

With these basics understood, a flow sheet can be developed that will show a sluice box doing the same things that nature does in her streams, only better. Figure 2 shows this flow sheet.

First, rocks larger than the largest nugget you expect to find must be screened out. Then the gravels are put through a nugget trap to get all the large gold out of the gravel. The gravel is screened and put through sluices to recover medium and some fine gold. The sluice tails are again sized to get rid of all but the fine gravels and gold. This feed is then processed through some type of fine gold recovery unit. This paper will not discuss the use of devices other than sluice boxes and little will be said at this time about fine to very



Figure 3. Moganson Sizer.

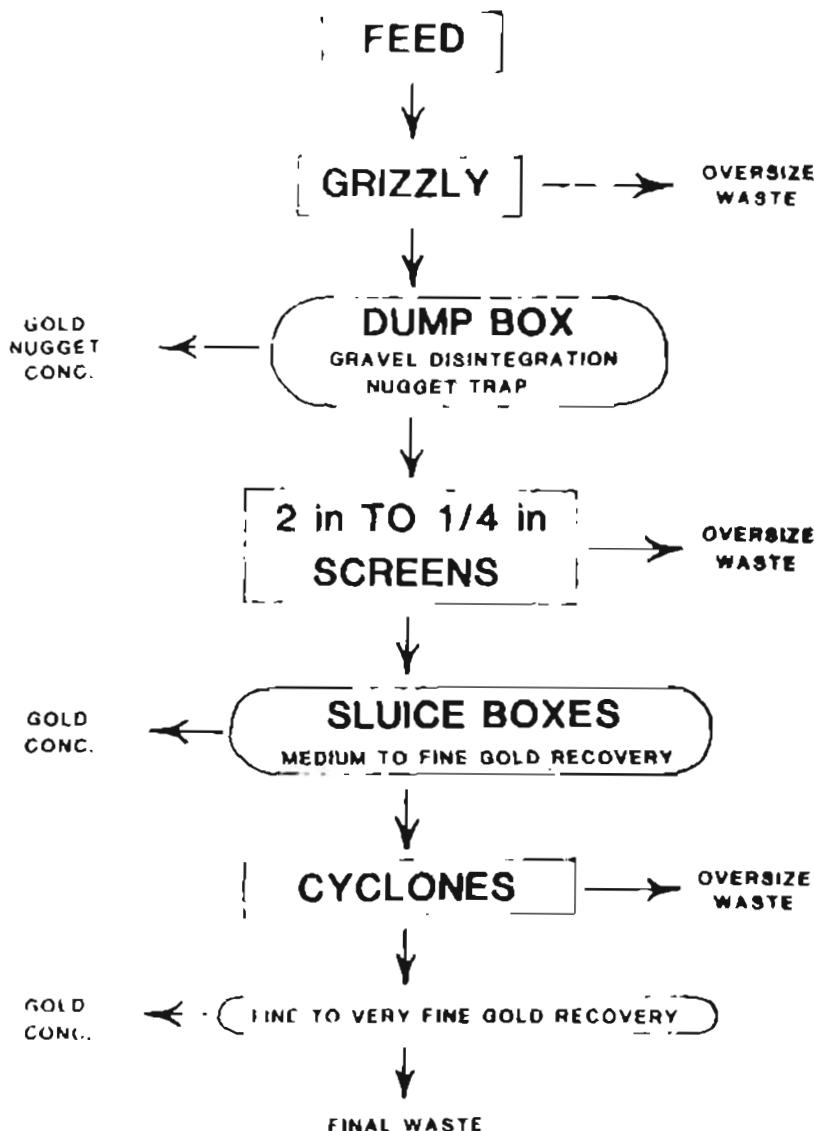


Figure 2. Flowsheet for gold bearing placer gravel processing.

fine gold recovery units.

Most operations use some type of grizzly to remove the large boulders. Few operations can run all their ground straight through a box but those that can and do are losing a lot of gold. Figure 3 shows the Moganson (German Co.) Sizer. In the area I've been working there is so much glacial material with flat boulders that it tends to hang up in the grizzly. Most people are now either picking out the boulders one at a time or just dumping them all in a sluice box and putting up with it, causing tremendous wear. The Moganson sizer has a three dimensional screen. On this grizzly the bars diverge not just laterally, but vertically also. The result is that you can get a greater spacing from the top of your bars to the bottom of your bars. Not only that, but these bars vibrate, reducing hang ups. In the area I'm working, the clay on the boulders allows them to wedge in so solidly that you can't get the boulders out, no matter what you do. Some miners have been using their backhoes, to remove boulders, ripping their grizzly apart.

Once the gravel passes through the grizzly it usually drops into a dump box. It is here that the gravel should be disintegrated and the nuggets extracted before the undercurrent screens are reached. Many operations use the undercurrent screens first and then the oversize

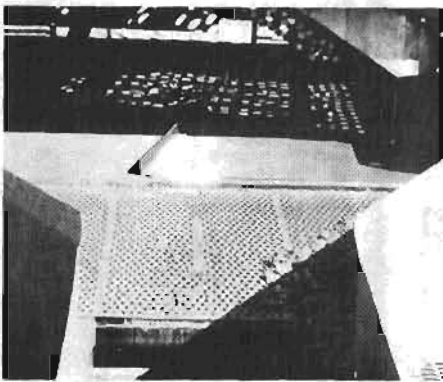
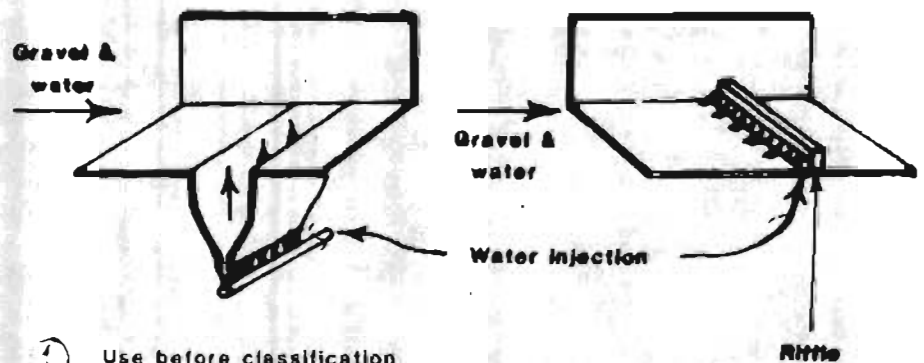


Figure 4. Sluice punch plate.

goes to a large sluice box which is used as a nugget trap (Figure 4). This method is not as efficient and results in greater losses of gold. If the nuggets are caught before the undercurrent is reached, the fine material in suspension makes it easier to concentrate the nuggets. Figure 5 shows an example of two types of nugget traps. When fine material is present in the sluiced pulp, the density of the resulting slurry, or pulp, is greater than that of water alone. Using a specific gravity for gold of 17 and a specific gravity of 3 for the gravel, then the ratio of effective specific gravities is 15 for an unclassified feed and 8 for gravel which has had the fines removed. This means that coarse gold can be separated more efficiently in a sluice box or nugget trap which has both coarse and fine gravel running through it, compared to one that processes only coarse gravel. Another problem exists when putting the undercurrent screen before the coarse gold trap. In order to move this material through the sluice box a great deal of water at a faster flow is required. This means that most of the water goes over the undercurrent screen and not through it. This results in most of the fine gold also going over the undercurrent screen and almost all is lost. Only when all of the water goes through the undercurrent can you be sure the fine gold has also gone through.

Although gold is very dense, this does not mean it will not move in a sluice box. Looking back to Figure 1 (stream profile) we can see that in nature the gold particles which are finest and also flattest, will travel further down a stream valley. The same thing happens in a sluice box.



① Use before classification

Fine material increases density of water (pulp) and makes it easier for nuggets to settle

② Use after classification

Gold nuggets much cleaner  
Less volume to handle

Ratio of effective specific gravities

$$\frac{\text{SpG Au} - \text{SpG pulp}}{\text{SpG Gravel} - \text{SpG pulp}}$$

### EXAMPLE

No classification

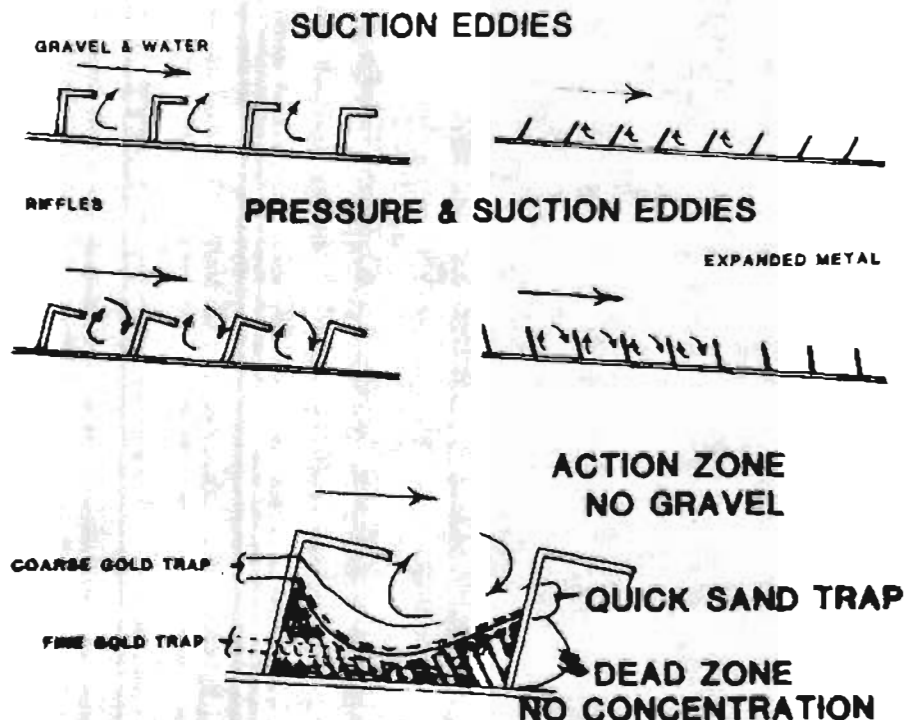
$$\frac{17 - 2}{3 - 2} = 15$$

Classification

$$\frac{17 - 1}{3 - 1} = 8$$

Figure 5. Nugget traps (above).

Figure 7. Riffle action (below)





The coarsest gold particles will tend to settle out quickly and seldom move while the very fine gold particles will settle out only with great difficulty and will be flushed from their resting places very easily. Figure 6 graphically shows the ability of gold to travel through a sluice box. Coarse gold has a very long travel time, measured as the amount of time it takes coarse gold to travel one foot down a sluice box.

Medium gold has a shorter travel time and some of this gold will be lost out of the box in a matter of minutes. The flatter gold particles have the shortest travel time. If you can recover most of your flat medium gold in the head of your box, then you have increased the travel time of this gold enough to keep it in your box till clean-up.

Fine gold has a short travel time and is very difficult to trap at any point in the sluice box much less at the head where you want it. A small amount of fine gold will have a long enough travel time that there will be some concentration at the head but most will make its way down the box. Once this gold starts leaving the box, the amount leaving is almost equal to the amount being fed into the box. Once this condition is reached, the amount of fine gold recovered will not change much no matter how many yards are sluiced.

Very fine gold has such a short travel time that almost no concentration occurs in the sluice box. In other words just a few seconds after this very fine gold enters the box it leaves again. Upon clean-up the only very fine gold recovered is that which was in the last few yards sluiced.

Travel time for gold is gauged not only by the size of the gold but also other factors such as velocity of the water, surging of the feed, clay content of the gravel, etc., however, gold size is a major factor. You cannot change the size and shape of the gold but you can control the other factors to some extent.

A miner might wonder if there is any hope after reading this far. With sluice boxes, there are good recovery possibilities for medium and fine gold but very poor possibilities for very fine gold. In order to achieve these good recoveries an under-

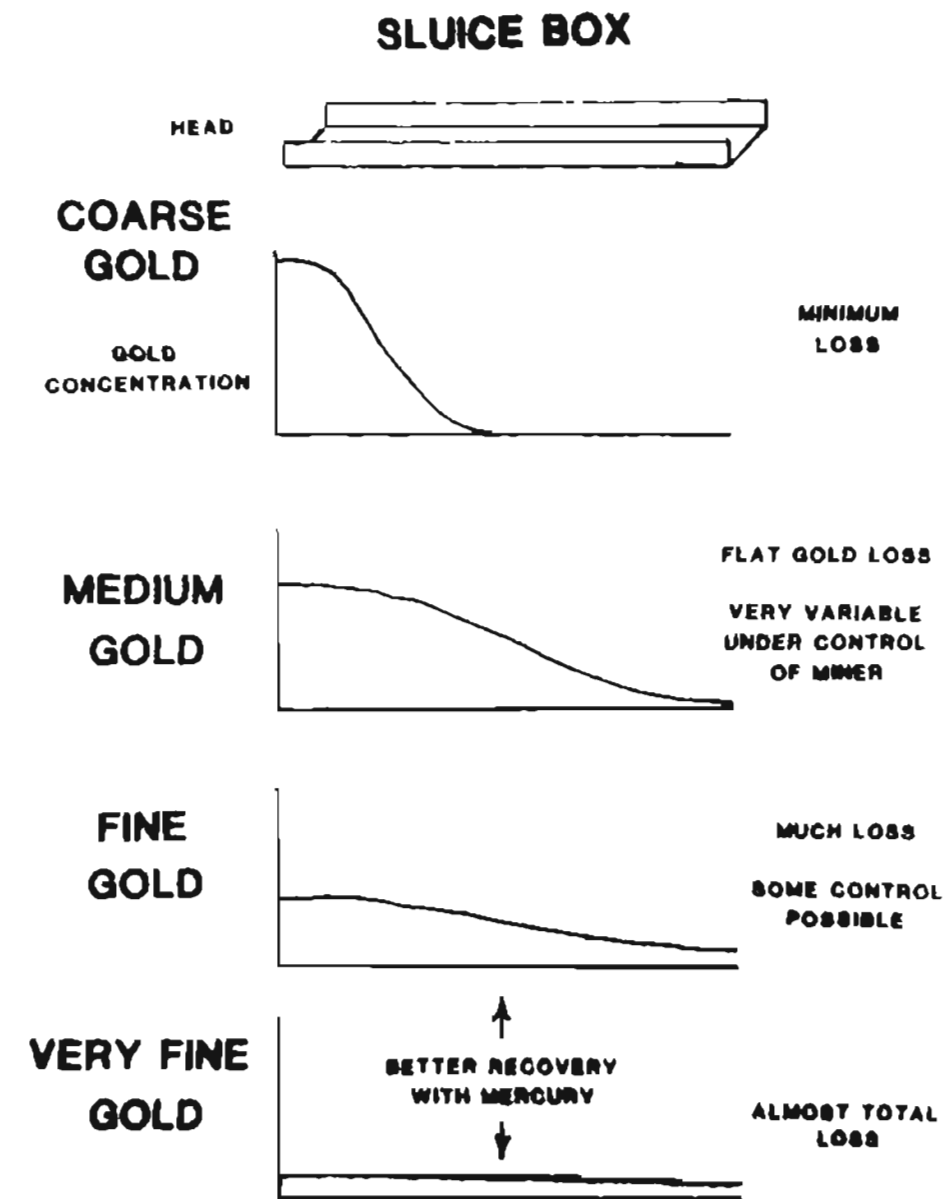


Figure 6. Gold travel time in a sluice box.

standing is needed of how a sluice box trapping mechanism works. Figure 7 shows the workings of a riffle and expanded metal arrangements. In a riffle there are three zones. The first one is the action zone where the gold and gravel swirl around and either drop down into the second zone or are rejected. The second zone is the quicksand trap. It is here that the gold particles are trapped by displacing the lighter sands. Finally the third zone is the dead zone in which the gravel is so well compacted that the gold is not able to penetrate and consequently no concentration occurs.

The second zone, the quicksand trap, is not the same for all sizes of gold. The larger sizes of gold need a

thicker quicksand trap and the smaller sizes a much thinner trap located much lower in the riffle. This quicksand trap does not stay in the same place but moves up and down according to material feed rate and water velocity. A very high feed rate or low water velocity will cause the quicksand trap to rise, perhaps even above the riffle surface, which is the case of sanding up of the riffles. On the other hand, a low feed rate or high water velocity will lower the quicksand trap, possibly even to the bottom of the box. It is at this point that all the fine gold present in the quicksand trap will be flushed out. If the water velocity becomes extremely high some of the coarse gold itself may even be re-

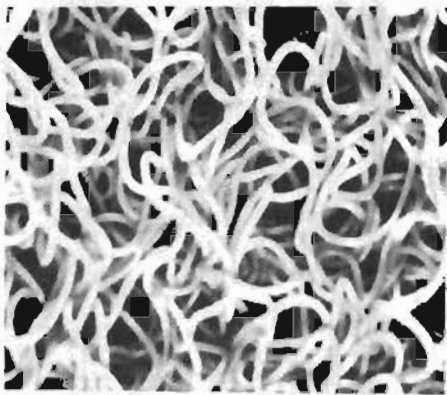


Figure 8. NOMAD® carpet.

jected. Fluctuation in the height of the quick sand trap is very detrimental to fine gold recovery. Inducing contact between the fine gold and the quicksand trap is the second major problem.

Figure 7 shows the type of action one gets with riffles and expanded metal. With riffles put in flush or expanded metal put in the usual way, the quicksand traps are created by only suction forces. However, if the riffles are tilted or expanded metal is put in backwards, one gets not only suction forces but pressure forces as well. With both forces present, the quicksand trap becomes thicker because more energy is available to create it. This can cause a problem with riffles in that it is easier to drop the quicksand trap down due to booming and thus lose fine gold. However, this extra boiling action gives the fine gold greater access to the trapping medium. The case with the expanded metal is just the opposite. In the standard orientation with only suction eddies present it is easier to lose the gold and bottom out the quicksand trap than it is when the expanded metal is reversed, causing the eddies to be more violent. This is because the pressure eddies drive the material down and keep it down. This results in the expanded metal bed always being full and looking like it is not working but in reality it is working very well and the quicksand trap is protected from quick movements up and down. This is the case only when two or more layers of expanded metal are used. Fine gold also has very good access to the quicksand trap because of the pressure eddies forcing fine material through the expanded metal.

Carpet works for the same reason. Quicksand traps are created in it just the same as with riffles. The reason fine gold is trapped is because the pore spaces in carpet are too small to allow large gravel in thus only fine gold quicksand traps form (Figure 8). These traps allow easier access for fine gold and most importantly these traps fluctuate very little and the gold is not easily flushed out of the carpet. Carpet essentially screens the material running over it and creates many small traps which can hold the fine gold dropping close enough to access these traps.

Figures 9 and 10 show NOMAD® carpet and expanded metal together. The expanded metal creates the large quicksand traps for the coarser gold while also screening out the larger gravel so only the fine gravel can get access to the carpet. This not only results in longer life for the carpet but better access for the fine gold to the carpet traps.

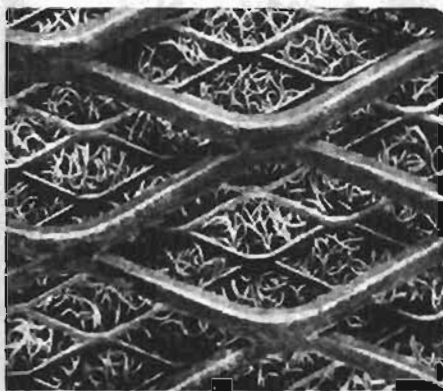


Figure 9. NOMAD® carpet overlain by two layers of expanded metal.

Figure 11 shows a system of screening which gives the greatest chance for gold to work its way through the punch plate and still leave enough water on top to transport the oversize material. This punch plate has a layer of Linacled rubber on top to keep the rocks bouncing so the punch plate will stay clean. This system was designed and used with great success by Jim Wallis of Atlin, British Columbia. His screen was around 70 feet long and the entire area under it was covered with heavy duty NOMAD® carpet with a layer of expanded metal over it. The resulting action from the punch plate and the flow of

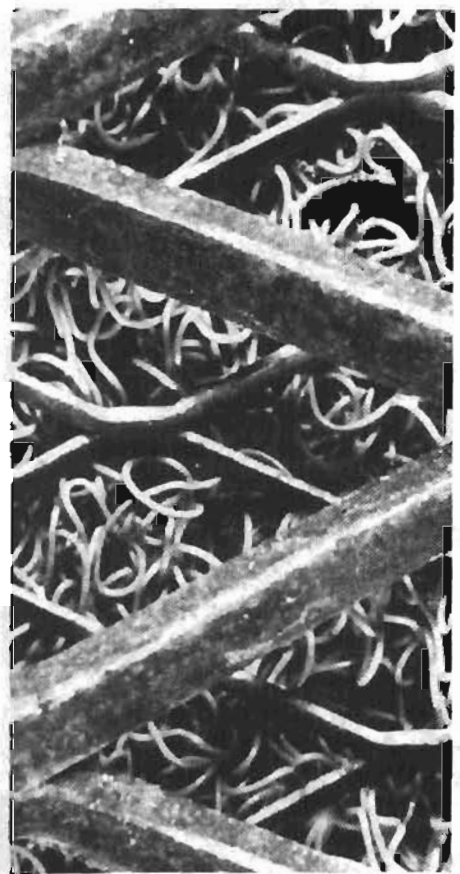


Figure 10. Close-up view of Figure 9 (NOMAD® carpet overlain by two layers of expanded metal).

material over and under the wooden blocks gives the fine gold tremendous access to the carpet quicksand traps. This action also keeps the quicksand traps in the carpet alive. All the material that works through the punch plate eventually goes to side sluices (undercurrent boxes). Jim told me that the total width of these boxes was 40 feet compared to 4 feet for the punch plate box. The action in the punch plate section was so good that approximately 80% of the gold was caught here and only 20% in the side boxes.

This undercurrent is vastly superior to any other I know. It not only helps the gravel to disintegrate but gives fine gold many chances to pass the punch plate. It also makes use of the area under the screen for catching gold instead of wasting it like most boxes do. This area under punch plates or under trommel screens (Figure 12) gives fine gold the greatest possible access to quicksand traps if heavy duty carpets are used. NOMAD® carpet seems practically indestructible and creates the

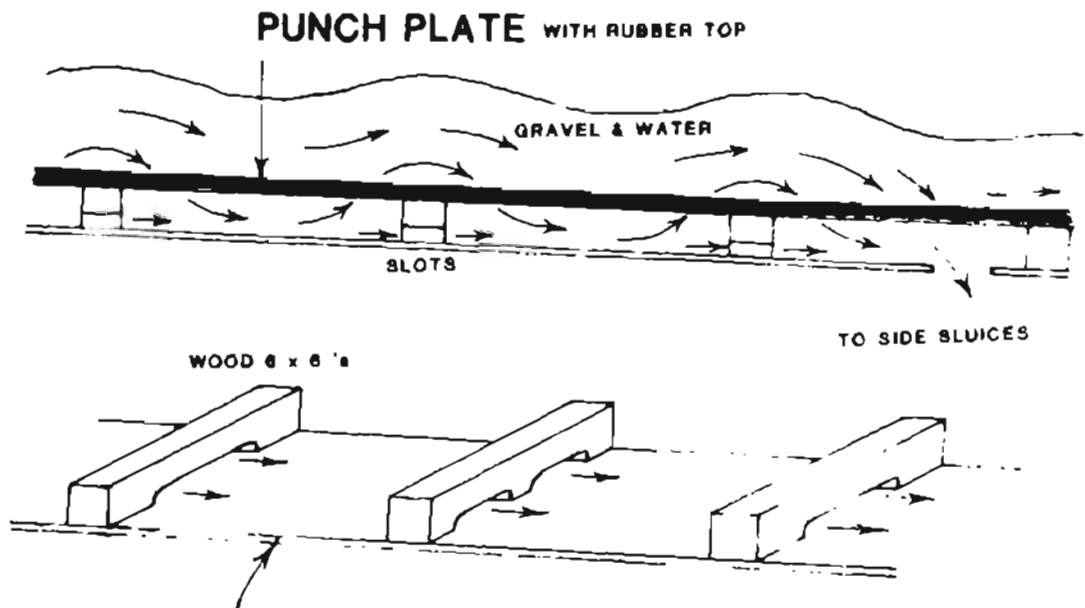


Figure 11. Fine gold recovery design for a sluice box.

greatest number of small quicksand traps.

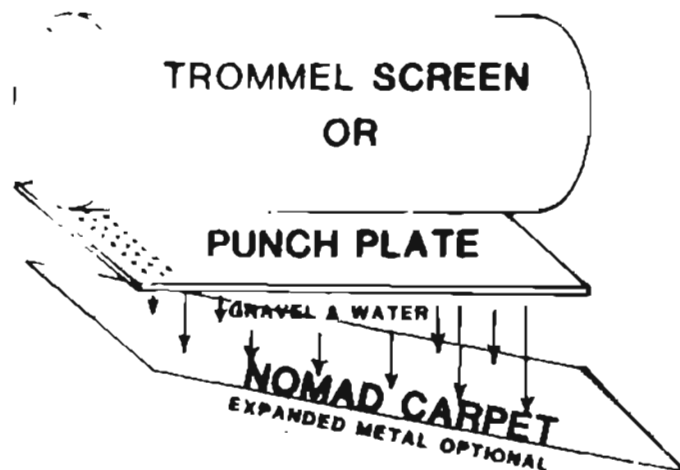
Carpets which have only vertical pile are much more susceptible to scouring and thus to a loss of fine gold. Scouring causes the action zone to drop to the bottom of the carpet, ejecting the captured gold.

Vibration of sluice boxes helps increase recovery by allowing one to slow the velocity of the water and gravel without losing quicksand traps. This lower velocity allows the finer gold to settle. One way to get vibration is by suspending boxes with chains. Once the gravel is screened to -2 inch, it is more economical to construct your sluice boxes out of wood since wood is lighter, cheaper, and does not freeze as easily as steel. For this reason, wood boxes can extend your season up to 2 weeks.

Finally, a word about the importance of sluice boxes. Half of the world's supply of tin comes from placer mines where hydraulic monitors are used to break and move gravel. Large pumps move the -6 inch material to wooden sluice boxes. The other half of the world's tin supply comes from 3/4 of all the mining dredges in the world. This numbers into the hundreds, with most of the dredges having over half a million cubic yards per year through-put capacity.

Figure 12. Advantages of placing carpets beneath trommel screens or punch plates.

### **NOMAD HEAVY DUTY CARPET WITH ONE LAYER OF EXPANDED METAL**



**CARPET SCREENS OUT OVERSIZE**

**BOUNCING ROCKS KEEP QUICK SAND  
TRAPS IN CARPET FLUID**

**ALL GRAVEL HAS ACCESS  
TO TRAPPING MEDIUM**

**SURFACE AREA / CONC. VOLUME VERY  
HIGH. BEST FOR FINE GOLD**

**DEAD ZONES VERY SMALL**

**VERY EASY TO CLEAN SO DAILY  
CLEANING CAN BE DONE**

# Excavation of Late Pleistocene Mammoth Remains at Colorado Creek, Alaska

Robert C. Betts

University of Alaska Museum  
Fairbanks, Alaska 99701

## Introduction

In the late summer of 1982, miners working a placer claim on Colorado Creek which is approximately 45 miles north of McGrath, Alaska, discovered two tusks projecting from a cut bank on their claim (Figure 1). The effort to expose the tusks more completely revealed that both were still attached to the cranium. Associated skeletal elements including vertebrae, a tibia and rib fragments, along with what appeared to be mammoth hair, indicated that the site could be of major scientific interest and the University of Alaska Museum was notified of the find.

After an initial field investigation by museum staff, an agreement was reached between the museum and the Rosander family, owners of the claim, to permit transportation of the skull to the museum where it would be stabilized and placed on display. In September of 1982 a museum field crew led by R. Dale Guthrie placed a protective plaster cast around the skull and moved it three miles by truck to the Colorado Creek Airstrip (Figures 2, 3 & 4). Aircraft logistical problems and adverse weather conditions made it impossible to transport the skull to Fairbanks until the following spring and the museum crew returned with only the smaller skeletal elements collected by the miners. One of these bones, a lumbar vertebra collected from near the skull, produced a collagen fraction radiocarbon date of 15,090  $\pm$  170 B.P. (Beta-5691).

The excellent preservation of the bones and the possibility of organic preservation of softer body parts in the frozen muck deposit from which the skull was recovered led R. Dale Guthrie and Robert M. Thorson to submit a proposal to the Office of the Vice-Chancellor for Research and Advanced Study at UAF to fund an excavation to attempt to recover additional skeletal elements in an undisturbed context from which paleoenvironmental data could also be obtained. No

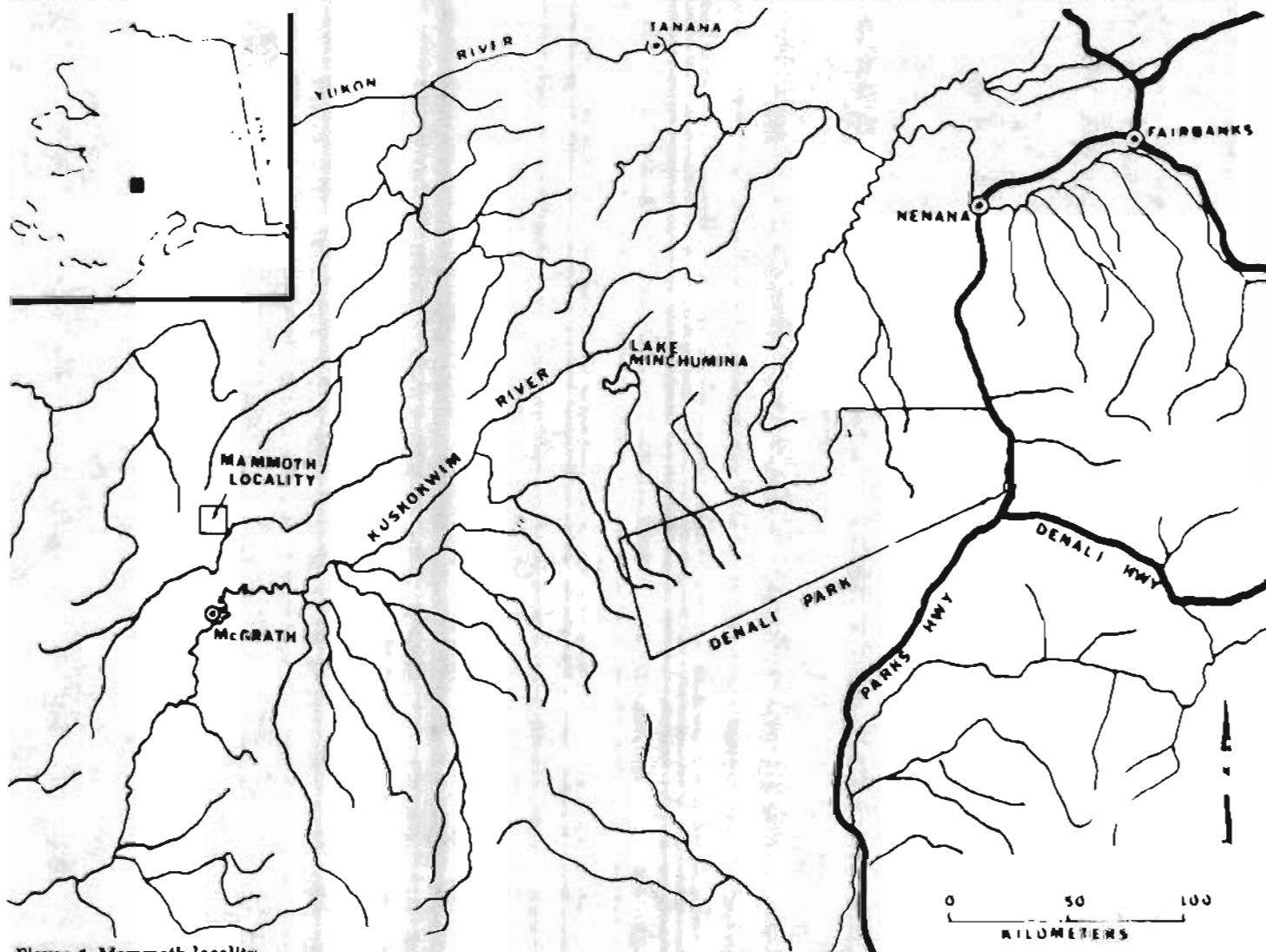


Figure 1. Mammoth locality.





Figure 2. Applying a plaster cast.



Figure 3. The mammoth skull awaiting transport.

previous major systematic excavation of in situ mammoth (*Mammuthus primigenius*, Figure 5) remains had previously been conducted in Alaska and the Colorado Creek discovery provided the first opportunity to recover paleoenvironmental data in direct association with Pleistocene mega-fauna in Alaska.

Because of the late radiocarbon date from the vertebra and the possibility of associated cultural material, the proposed excavation was designed as a rigorously controlled and multidisciplinary project involving paleontologists, geologists and archaeologists. Funding was received from both the Vice-Chancellor's Office and the University of Alaska Museum and field work began in early June of 1983 under the supervision of Robert C. Betts. Gary Selinger from the museum paleontological staff took part in the excavation and Robert M. Thorson joined the field team in late June to measure and describe stratigraphic sections at the site once they had been revealed by excavation.



Figure 4. The mammoth skull arriving at the UAF Museum.



Figure 5. *Mammuthus Primigenius*.

## Methodology and Field Procedure

Before excavation the mammoth locality was photographed, gridded in two meter squares with a transit, and mapped with a plane table at a scale of 1:80 with a contour interval of 50 cm (Figure 6). An arbitrary site elevation of 100m was established at a datum point located at N100 E100. All site elevations were taken in relation to this datum. The frozen muck deposit presented a major problem to the systematic excavation of the site because of the tendency of the sediments to thaw and 'flow' downslope once the insulative vegetative cover and overlying sediments had been removed. Concrete reinforcement bars (ribars) 5/8" in diameter and 46" long were sharpened and used to establish a grid point for which ground and ribar elevations were taken. Slight movements of ribar grid stakes were detected by periodic transit checks and ribar stakes could be repositioned and elevations recalculated during the course of the excavation.

Due to the limited time allowed for fieldwork (three weeks) rapid removal of the overburden was critical in order to reach the mammoth horizon as quickly as possible so that the frozen ground would have time to thaw and allow excavation of the remaining skeletal elements. As soon as the grid system was established, removal of the surface vegetation from all grid squares was completed. Removal of thawed ground well above the mammoth horizon was accomplished rapidly without screening.

The stratigraphic position of the base of the skull (removed the previous fall) was evident from remaining plaster fragments, a mat of coarse hair 1-2 cm thick a few centimeters below the 'plaster horizon' and photographs of the skull taken while it was in situ. By estimating the depth of the mammoth horizon based on this information, excavation of the overlying sediments could proceed quite rapidly without risk of encountering mammoth bones or cultural material unexpectedly (Figure 7). Once excavation had proceeded to within an estimated 50 cm of the mammoth horizon the technique of skim shoveling with square ended 'scoop shovels' was employed and random screening was conducted as a check to make sure no faunal or cultural material was being missed. Once the depth of excavation had reached 15-20 cm above the mammoth horizon, excavation was conducted with trowels and all sediments were dry screened using a 1/4" mesh screen. When bone was encountered it was excavated with a wooden 'tongue depressor' to prevent trowel marks on the faunal material. Wet screening through a 1/8" mesh screen was done selectively at all stratigraphic levels when concentrations of organic peat were encountered. Identifiable mammoth bone was pedestaled and left in situ to be recorded, photographed and drawn prior to removal (Figures 8, 9 & 10). Concentrations of small mammal bones, scat and most of the mammoth hair was collected as 'bulk samples.' These samples of hair included soil matrix, seeds, rodent remains, insect parts, and fragments of what appeared to be mammoth skin. Each specimen or bulk sample was recorded sequentially and assigned a field catalog number. All mega-fauna bone

left in situ was protected from direct sunlight, which helped reduce the rate of drying and limit cracking of the bone. Other than shading, the bone required no stabilization or protective casting.



Figure 6. Gridding and mapping the excavation area.



Figure 7. Progressing excavation.

During excavation 50 cm wide balks were left in place. Tephra, pollen and radiocarbon samples (peat and wood fragments) were collected primarily from these balks by Dr. Thorson after a measured stratigraphic section had been drawn and stratigraphic unit designations had been assigned.

Once frozen ground had been exposed, the maximum rate of thawing achieved was about 10 cm a day. As the excavation proceeded, it became more and more dif-



Figure 8. Pedestaled bones.

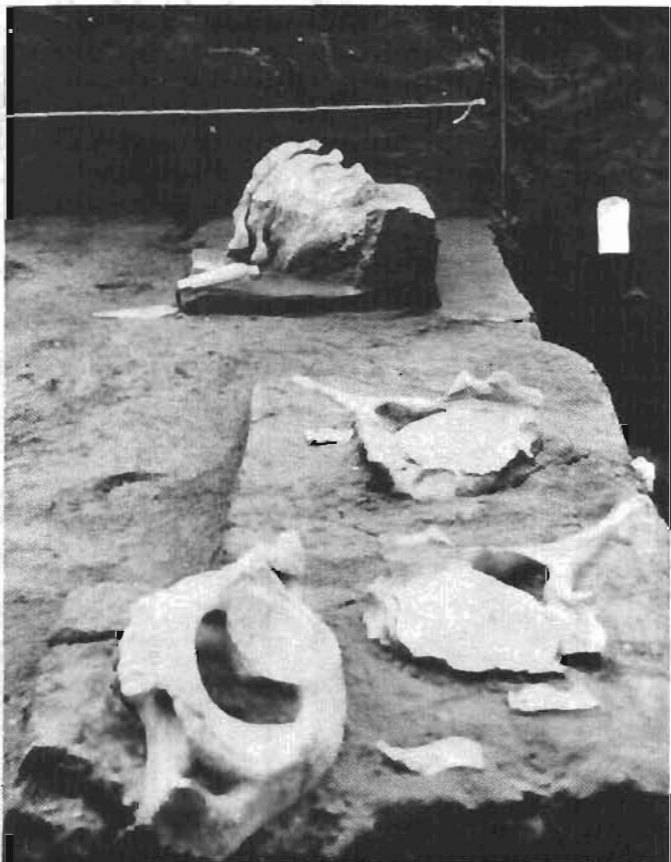


Figure 9. Pedestaled bones.

ficult to keep the grid system intact. The melting of both permafrost and ice lenses created a quagmire of mud in the lower portion of the site and undercut some of the grid walls and balks causing them to collapse. The simultaneous drying out of the upper portions of the site caused cracking and crumbling of the upper walls which began collapsing, endangering any bones still left in situ. Because of possible damage to the bones, we were forced to remove them early, rather than leaving them in place until the end of the excavation. A total of 59 sq. meters were excavated within the grid system of which 50 sq. meters were excavated to and below the level of the mammoth bone concentrations.

The presence of placer gold a few meters below the mammoth bones and the planned mining activities at the site limited our work at the locality to a maximum of three weeks and insured the total destruction of the site by mining activities very shortly after the excavation was completed. Because of this, the decision was made to hydraulically wash the slope at the termination of the excavation in order to recover any bones missed either because they were outside the grid system or because they were frozen in permafrost below the maximum depth of excavation in squares where frozen ground prevented reaching the mammoth horizon. A Mark III pump was used during the last three days at the site to remove thawed ground for a large area around the grid system and to cut into the frozen ground both inside and outside the grid system (Figure 11). The warm creek water rapidly thawed the permafrost and allowed the

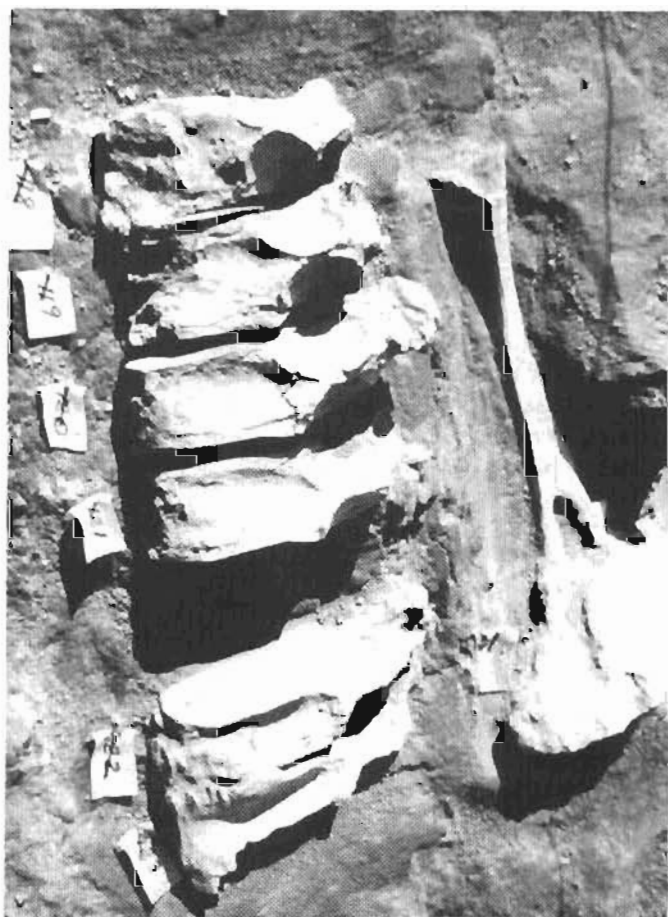


Figure 10. Mammoth Thoracic Vertebrae.



removal of sediments which could not have otherwise been removed in the time remaining. The hydraulic washing of the site was accomplished 'systematically' working upslope, beginning outside the grid system and working around the perimeter of the grid before moving inside the excavation area. Once inside the grid one or more grid squares were washed within the framework of the grid so that at the minimum it was possible to identify the grid square from which a bone was washed. Very few additional mammoth bones were recovered during the hydraulic operation. Of these, all but one were spotted when first exposed by the water and were recovered while still in situ. The hydraulic washing worked quite well because the long pointed 3/8" rebar driven into the permafrost withstood the force of the water while the surrounding thawed and frozen sediments were washed away. The grid system remained intact for the most part throughout the hydraulic operation allowing bones exposed by the water to be recorded in relation to the grid system. Once a bone had been exposed by water it was excavated and recorded using standard excavation methods.

### Mammoth Remains Recovered

Skeletal elements of at least two mammoths (*Mammuthus primigenius*) were recovered at Colorado Creek, along with hair, probably skin fragments and possible mammoth dung or intestinal contents. Initial excavation in grid sq. N86 E96 directly below the skull location revealed a 1 to 2 cm thick mat of coarse dark reddish brown hair covering almost the entire square. A cross section view of this hair lens revealed that it sloped slightly downhill towards the creek (Figure 12). The first mammoth bones found (apparently in situ) were excavated from immediately upslope from the skull location. These bones included the atlas and two thoracic vertebrae recovered from the Sw quad of square N88 E96 and another thoracic vertebra from the NW quad of this square. The articulated axis (2nd), 3rd and 4th cervical vertebrae were also recovered from the SE quad of N88 E96. All of these major bones were lying flat with basal elevations between 97.12 m and 97.28 m. These bones, together with two centra, a mandible and one scapula comprise the larger bones directly associated with the skull and mat of hair.

The above mammoth bones and associated faunal elements have been referred to as the 'upper mammoth horizon.' The mat of hair extended under all of the mammoth bone in this horizon with the exception of the mandible. Numerous samples of small and large carnivore scat containing fragments of mammoth hair, mammoth bones and microtine bones were collected in direct association with this hair mat. Several samples of organic matter in an otherwise silt matrix were collected. These may prove to be dung or intestinal contents from a large herbivore, possibly mammoth. Because of the continuous mat of hair, the horizontal orientation of the larger mammoth bones, the similar basal elevation of the major mammoth bones and the associated carnivore scat it appears that there has been

only minor if any post depositional disturbance and that these bones are essentially in what can be considered primary context. There is some evidence of post depositional disturbance of the remains in the upper mammoth horizon as the bones were separated from the mat of hair by several centimeters of silt. The geomorphic processes involved in the burial of the mammoth remains are not yet fully understood and the sequence of depositional events can only be reconstructed clearly



Figure 11. Using hydraulics to excavate the area.

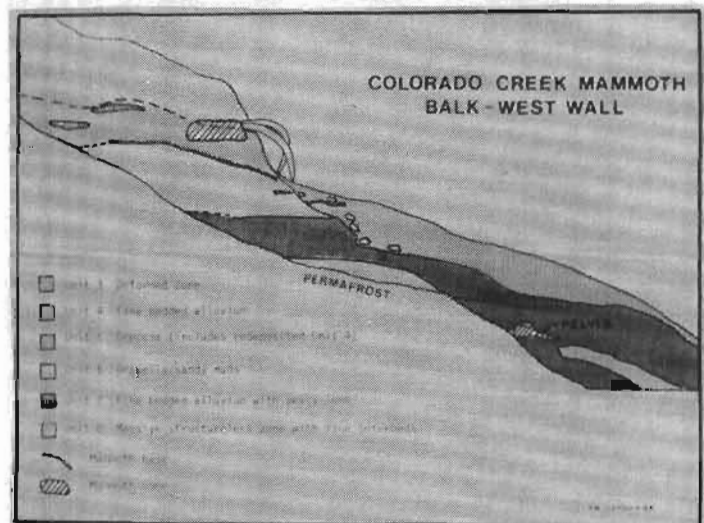


Figure 12. Generalized stratigraphic section of excavation.



with additional radiocarbon dates on both bone and peat lenses.

In addition to mammoth remains, caribou (*Rangifer tarandus*) bones were discovered in direct association with the mammoth remains in the upper mammoth horizon. These elements include a phalange and a spirally fractured distal humerus fragment (V-48-135) exhibiting polish near the tip and along the shaft. This humerus fragment was excavated from 2 cm above the mat of mammoth hair in N96 E96. Many of the mammoth bones also exhibit slight polishing. This could probably be attributed to natural geomorphic processes.

During the excavation of a 1 m wide test trench from the maximum extent of the grid system, downslope to the level of the creek bed, additional mammoth bones were discovered approximately 2 m lower in elevation than the upper bone horizon. The grid system was expanded to grid south and the additional bones were excavated from grid sq. N82 E 96. This new discovery was referred to as the 'lower mammoth horizon.' A complete articulated pelvis and sacrum were recovered from N82 E96 along with seven thoracic vertebrae, six of which were articulated. In expanding the excavation into N84 E906 a second mandible was discovered in the lower mammoth horizon. This mandible, smaller than the one associated with the upper mammoth horizon, was located at approximately the same elevation as the in-nominate (95.09 to 95.24 m) and approximately 1 m to the grid NE. Also associated with the lower mammoth horizon were several lumbar vertebrae and centrum recovered from N84 E94 during the hydraulic operation. All of these lumbar vertebrae except one were recovered by excavation after initially being exposed by the water. The basal elevations on these vertebrae were between 94.82 and 94.93 m and they were still in anatomical position and partly articulated. An *Equus* right calcaneum (V-48-174) and *Rangifer* tooth (left p4), were recovered 25 cm above these lumbar vertebrae. No mammoth hair was recovered from the lower mammoth horizon. While many of the bones in the lower mammoth horizon were articulated, their basal elevations varied much more than those in the upper mammoth horizon.

The presence of two distinct concentrations of mammoth bones at two different elevations and a thin peat lens which appeared to separate the two horizons suggests that the bones were buried at different time intervals and represent separate depositional events. The discovery of a second mandible associated with the lower mammoth horizon immediately ended the controversy among the field crew as to whether the remains of more than one mammoth were present.

However, as the excavation proceeded and no further clear duplication of skeletal elements occurred, the second mandible became more and more of an enigma. Unfortunately the peat lens which appeared to separate the upper and lower mammoth horizons terminated at an ice lens and it was impossible to trace it laterally below the upper mammoth horizon. Other structural evidence in the site stratigraphy does indicate that the two horizons are distinct stratigraphic units and that the lower mammoth bones were buried before the upper bones.

The laboratory discovery of a 'fit' between a bone flake (V-48-159) excavated in direct association with the mat of hair in the upper mammoth horizon and a mammoth rib fragment (V-48-124) recovered directly below the mandible (V-48-152) in the lower mammoth horizon clearly indicates the faunal elements in the two horizons are related and presents a major stratigraphic and taphonomic problem. We are presented with two stratigraphically distinct mammoth horizons with what appears to be articulated elements of the same mammoth occurring in each. We have an extra mandible but no other clear duplication of skeletal elements. Any depositional process presented as an explanation for the distribution of the mammoth remains will have to account for the preserved articulation of the bones, the stratigraphic separation yet clear relationship of the two mammoth horizons, and the role of scavengers in the overall taphonomic process. There is no question that the rib fragment which was recovered, as was the 'lower' mandible from frozen ground below the seasonal thaw depth, is not part of recent surface slumping of sediments at the mammoth locality. Radiocarbon dating of both mandibles should eventually demonstrate whether or not they are contemporaneous and peat dates from the site should help establish the sequence and rate of deposition. Laboratory analysis of the faunal material recovered has not yet been conducted and may eventually show duplication of other mammoth skeletal elements.

## Site Stratigraphy

As the first large scale excavation of a frozen muck deposit, the Colorado Creek excavation presented new and special problems in excavation methodology and stratigraphic interpretation. The homogenizing effect of the redepositional processes associated with muck deposits resulted in highly gradational contacts between most stratigraphic units and soft sediment deformation within units. Because Colorado Creek has undercut the mammoth locality in the recent past, removing an unknown amount of sediment from below the site, there is an unconformity immediately above the gravel of the creek bed. Ten stratigraphic units were identified by Dr. Thorson at the mammoth locality (Table 2).

Table 2.

### Colorado Creek Mammoth Locality Stratigraphic Units.

Unit 1	Peat with pockets and blebs of possible tephra
Unit 2	Massive muds
Unit 3	Deformed zone (soft sediment deformation)
Unit 4	Fine bedded alluvium (upper mammoth horizon sediments)
Unit 5	Breccia (includes redeposited Unit 4)
Unit 6	Gravelly/sandy muds
Unit 7	Fine bedded alluvium (lower mammoth horizon)
Unit 8	Massive structureless zone with fine interbeds
Unit 9	Woody silt
Unit 10	Fluvial gravel

While the mammoth bones associated with Unit 4 seem to be largely in situ there is considerable evidence of downslope movement, minor slumping and soft sediment deformation in the micro-stratigraphy at the mammoth locality. Some of the evidence for redeposition of sediments includes 1) pockets and blebs of tephra, 2) deformation of horizontal bedding in Unit 3 apparently from the weight of overlying sediments, 3) discontinuous organic lenses, 4) discontinuous and 'stepped' lens of mammoth hair in Unit 4, 5) small slip faults with downslope displacement of sediments and 6) inclusions of Unit 4 within Unit 5 (breccia). Because of the gradational nature of most contacts between stratigraphic units the depositional history and relationships between units were extremely difficult for the non-geologists to interpret.

The upper mammoth bones are within the finely bedded alluvium of Unit 4, clearly fluvial sediments that appear to have accumulated fairly rapidly. This unit contains pockets of pebble silt (possibly fossil rodent burrows) and sandy lenses which may be the result of rill wash. Above the upper mammoth horizon in Unit 4 are numerous lenses of fine organics including identifiable plant macrofossils. Some of these organic lenses appear to be characteristic of organic material deposited by shallow standing water. Other organic lenses are made up entirely of larger sticks oriented parallel to the present valley slope.

The lower mammoth horizon was also associated with finely bedded alluvial sediments (Unit 7). The grain size and bedding characteristics of Units 4 and 7 are very similar as are the massive structureless sediments which underly both of these units (Units 6 and 8). The lack of evidence for a major slip fault in the stratigraphy at the mammoth locality refutes the hypothesis that the difference in elevation between the two concentrations of mammoth bones can be due to significant slumping of the lower portion of the site. Such slumping is evident today along Colorado Creek where muck banks have been undercut by the creek but evidence for this is lacking at the mammoth locality (R. M. Thorson, personal communication). Until a detailed geological report on the stratigraphy at the site is available and additional radiocarbon dates have clarified the relationship between the two mammoth horizons, stratigraphic inferences remain largely speculative.

### **Paleoenvironmental Data Recovered**

A wide range of paleoenvironmental data was recovered in direct association with the upper mammoth horizon at the base of Unit 4. It was from this level that miners dug out the lumbar vertebra which produced a collagen fraction radiocarbon date of 15,090  $\pm$  170 (Beta - 5691). Additional radiocarbon dates associated with the mammoth locality are presented in Table 3.

In addition to mammoth (*Mammuthus primigenius*) several other large mammal remains were recovered, including horse (*Equus* sp.), bison (*Bison* sp.) and caribou

(*Rangifer tarandus*). Of these only caribou was excavated in direct association with the mammoth remains in Unit 4. Each of these large mammals except *Mammuthus* is represented by only a few skeletal elements and the *Equus* and *Bison* elements recovered from Unit 7 have probably been redeposited. All of the large mammal remains represent herbivores with a grazing adaptation and point strongly to the presence of a significant grassland habitat.

Small mammals are more sensitive environmental indicators because their home ranges tend to be more restricted and because of their rapid evolution and universal occurrence in the Holarctic (Guthrie, 1968b). A large number of small mammal remains were recovered in direct association with the mat of mammoth hair in Unit 4. In several instances the articulated remains of small rodents were recovered directly from the mammoth hair and it appears that these rodents may have burrowed down under snow cover to nest in the mammoth hair. Many of the small mammal bones were found in carnivore scat. Initial analysis of the microtine faunal remains by Steve McDonald at the UAF museum indicates that collared lemming (*Discrotonyx torquatus*), brown lemming (*Lemmus sibericus*) and arctic ground squirrel (*Citellus undulatus*) are present.

The present range of *Discrotonyx torquatus* includes the Brooks Range and northeastern Alaska. It is not presently found in the Colorado Creek area. *Discrotonyx* is usually associated with ecotone communities and prefers non-forested, well drained areas (Steve McDonald, personal communication). *Discrotonyx* has also been associated with rocky tundra and dry upland areas but does occur in damp tundra in some locations (Guthrie, 1968b). The collared lemming is also associated with rock uplands or areas where the soil and vegetative mat are broken by forest action (Guthrie, 1968b).

The brown lemming (*Lemmus sibericus*) is widely distributed throughout Alaska but prefers open tundra and wetter areas. Guthrie (1968b) states that "The general conclusion of most studies of the brown lemming is that it prefers wet meadows. Also, it is almost completely dependent on a diet of sedges and grasses."

The arctic ground squirrel is found today in alpine areas with well-drained soils. Fossil arctic ground squirrel nests are common in the muck deposits around Fairbanks although *Citellus undulatus* does not presently occur in the Yukon-Tanana upland (Guthrie, 1968b).

Together, these microtine faunal elements suggest an open treeless (possibly alpine) zone with well-drained soils and nearby wetter areas. This mosaic pattern would seem to fit well with the geological interpretation of the stratigraphy at the mammoth locality which suggests that the mammoth remains were buried fairly rapidly near the base of a slope by alluvial sediments of an aggrading floodplain. (Robert Thorson, personal communication).

Carnivore activity at the mammoth locality is evident from both the gnawing of bones and from preserved scat directly associated with the upper mammoth horizon. Both large and small carnivores are represented by the

scat which often includes mammoth hair, mammoth bone fragments and small mammal bones. Much of this scat was recovered immediately adjacent to the hair mat and it is possible that carnivores were 'marking' their territory (R. Dale Guthrie, personal communication).

Insect remains, primarily beetles, were found inside some scat specimens. Other insect parts were recovered during laboratory inspection of organic samples recovered during wet screening. Insect pupae were discovered in the porous parts of some of the mammoth bone fragments and around the molars of one of the mandibles (V-48-137). These egg cases all appeared to be empty. Two feathers, not yet identified, were found in direct association with the mammoth hair mat. They may have come from a bird feeding on scraps from the carcass or perhaps from rodent activity at the site, having been carried underground as nesting material.

Plant macro-fossils were collected from all stratigraphic levels of the site as a result of wet screening of organic lenses. Larger wood samples were collected for identification and C14 dating. A huge quantity of seeds have been preserved in the mammoth hair. To date these seeds have not been identified. Numerous pollen samples were collected from balks at all stratigraphic levels. In addition, pollen samples were taken from the occlusal surfaces of molars in both mandibles.

Perhaps the most interesting specimens recovered are the isolated organic 'lumps' excavated from the fine silt matrix of Unit 4 at and slightly above the upper mammoth horizon. Two of these organic lumps came from the same level as the hair mat but outside the extent of the hair. Microscopically they appear to be compressed plant matter which on excavation resembled herbivore dung. Laboratory analysis has not yet been conducted on any of the specimens recovered and it is not yet certain just what these organic specimens represent. All of the soil samples, possible dung and scat specimens, and pollen or radiocarbon samples have been placed in frozen storage at the University of Alaska Museum until analysis can be conducted.

### **Speculative Reconstruction of the Death and Preservation of the Colorado Creek Mammoth**

The Colorado Creek Mammoth, a male about 40 years old (R. Dale Guthrie, personal communication), died near the base of a gradual slope, probably near where it intersected the floodplain of Colorado Creek (R.M. Thorson, personal communication). Carnivore gnawing of the articulated cervical vertebrae (V-48-92 to 94) is limited to the right transverse foramen and suggests that the mammoth may have been positioned on its left side at death with only the right side accessible to scavenging. The body which evidently lay exposed for some time after death attracted scavengers who disarticulated portions of the skeleton and crushed or carried off most of the long bones and ribs. At some point the skull became disarticulated and rolled downslope (perhaps undercut by slope wash) coming to rest upside down. The mandible may have become disarticulated

when the skull rolled and remained upslope of the skull and cervical vertebrae. The axis and 3rd and 4th cervical vertebrae remained articulated and in place when the skull rolled so that the tusks pointed down. These may have stabilized the skull from further movement. The atlas (1st cervical vertebra) was disarticulated (perhaps still attached to the skull when it rolled) from the other cervical vertebrae and eventually wound up 1.5 m to the grid west of the articulated cervical vertebrae in the vicinity of the location of the base of the skull. The relationship of the lower mammoth horizon bones to the upper mammoth horizon is still not clear. The distribution of bones at the site is probably a result of both carnivore activity and limited redeposition. Most mammoth bones appear to represent a single animal (except for the enigmatic mandible in Unit 7.)

After the skeleton had been scavenged, but presumably while some scavenged meat and cartilage were still present, insects deposited egg cases in many of the exposed porous areas of the bones. The skeleton continued to remain exposed allowing these pupae to hatch leaving only the egg casing behind. Within a relatively short time (a few years at most) and while cartilage articulated many of the bones, the skeleton was buried by alluvial sediments. These sediments may have been overflow sediments from the aggrading floodplain. Crossbedding of sediments in Unit 4 indicates a deeper channel was present for at least part of

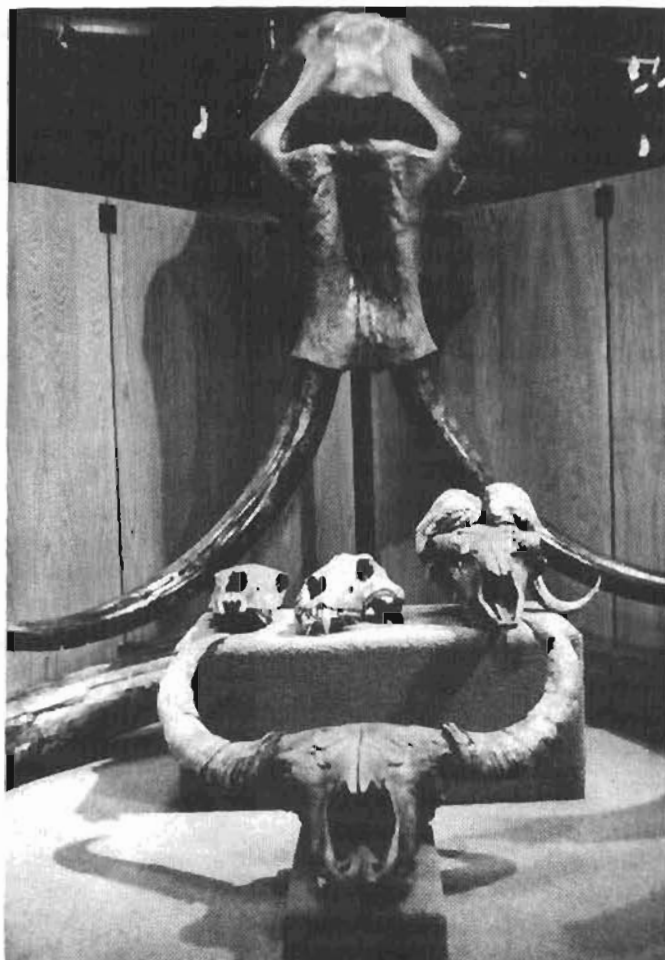


Figure 13. Mammoth skull on display at UAF Museum.



the time of the accumulation of Unit 4 (R.M. Thorson, personal communication). Some colluvial slope processes may have also been involved in the burial of the skeleton. The fine bedding of the silt in Unit 4 and Unit 7 (Fig. 3) suggests that burial resulted from a series of seasonal deposits which would be characteristic of overflow floodplain sediments.

Inclusion of the fragmentary remains of other large mammals (*Equus*, *Rangifer*, *Bison*) suggests the mammoth locality was a location where bones were likely to concentrate as a result of depositional processes and the presence of the second mandible may be a chance occurrence not directly related to the rest of the mammoth remains. Only radiocarbon dating of both mandibles will produce a clear answer to their temporal association.

The mammoth remains probably went through a series of yearly freeze/thaw cycles with some possible downslope movement of skeletal elements until sedimentation and insulative plant cover accumulated to the extent that the sediments containing the bones remained frozen below the active permafrost layer. Any redeposition or displacement of the bones downslope must have occurred within a short time after death and prior to the time the sediments became permanently frozen. The preservation of hair and skin associated with the skeletal elements indicate the bones remained frozen until present erosion by Colorado Creek exposed them.

No evidence of associated cultural material with the mammoth locality was discovered during the course of the excavation. Two possible specimens of bone, a mammoth bone flake (V-48-159) and a spirally fractured and polished distal caribou (*Rangifer tarandus*) humerus (V-48-135), both discovered in association with the mat of mammoth hair in Unit 4, have been discounted as culturally modified bone and are believed to be the result of carnivore activity at the site. The bone flake does not exhibit tooth marks or other evidence of gnawing and it would have been difficult to determine how it had been produced had not the rib fragment with which it articulated been found in Unit 7. The bone flake had been snapped from the rib fragment and not percussion flaked as from a core. Extreme caution should be used with interpreting redeposited 'bone tools' because the Colorado Creek excavation has shown that at least two types of modified bone frequently presented as evidence for extreme antiquity of man in North America (flakes made from mammoth bone and spirally fractured and polished caribou bone) can occur as a result of scavenging activities of predators at mammoth sites.

## Sediment after Recovery

*Dr. Ernest Wolff, Retired Professor*

*School of Mineral Engineering  
University of Alaska, Fairbanks*

This paper is based on a report to the U.S. Bureau of Mines on the effects of placer mining on the environment in interior Alaska. The results of this study have been published in MRL Report No. 48. We studied the Tolovana District which is Livengood and a part of the Circle District. In the course of looking at the effects of Tolovana mining we had to take a close look at what happened to the muck that emptied out of the Fairbanks District. A drive around Fairbanks will show that a lot of muck went out. I want to know where it went. I asked Dan Higgen the other day how much muck there was, and he said nobody knows, but it was at least a 100 million cubic yards and could have been several hundred million cubic yards. That's a lot of dirt.

Figure 1 shows a profile through a placer mine. This is the most common type of mining we have where they build up a little ramp in the cut and push to it. The upper grade of 7% refers to the virgin ground. I know you don't like to have 7% to deal with. I just picked it cause I was on one creek that did run that steep. The sluice will run about 15% and then of course you have a drain to get rid of the water and that might run 2% and then you get back to the natural slope of the creek again which is 7%. The point here is that anything that will get out through that drain will go on down the creek. Because a grade of 2% can transport smaller material than a 7% grade.

Figure 2 shows a very simple concept that's helped me a great deal. If you put on the left side of the balance of stream erosion, the diameter of your sediment and the quantity of your sediment and on the other side the slope of the stream and the quantity of water, they must balance. Not numerically, but they will balance each other because if you disturb any one of them, the other one, two or three will adjust to bring the system back into equilibrium. A very simple statement of the theory of a graded stream is that the stream will adjust its gradient so that it can just transport the load being delivered to it. That's what the miner does when he sets his sluice box at a steeper grade than a stream. He has to move more and larger material through in a shorter

Profile through a placer mine

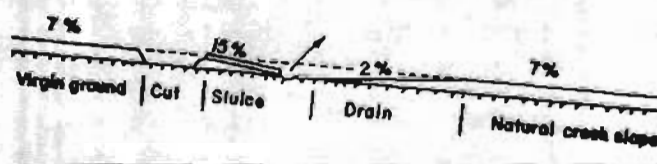


Figure 1. Profile through a placer mine.



### Balance of Stream Erosion

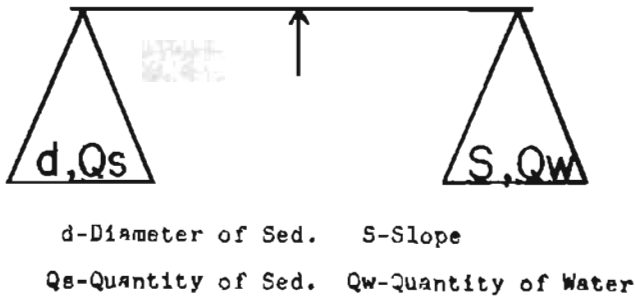


Figure 2. Balance of stream erosion.

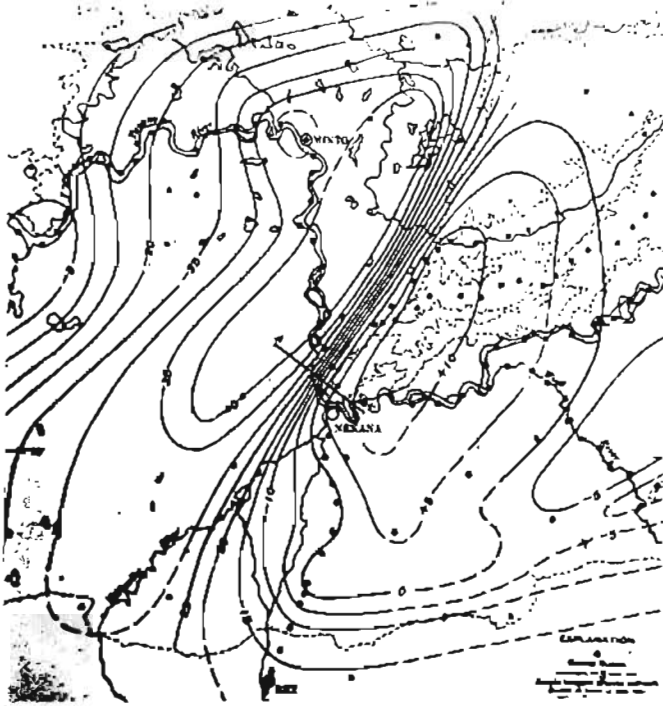


Figure 3. Gravity contour map of the Minto Flats.

time. So he uses a steeper grade and more water. It will be useful for you to keep this in mind while we're going through some of these points.

About 50 miles or less to the west of us are the Minto Flats. It just so happens that the Minto Flats are rapidly subsiding. All of the major streams in this part of the country head for the Minto Flats because they're low and getting lower all the time. There are a concentration of lakes along the east side of the Flats, also a concentration along the north. I'm paying a lot of attention to the Minto Flats because this is where the mud from the Tolovana District ends up. It's the only place we found significant changes due to the sediment coming out of a mining district. Figure 3 shows a gravity map of the Flats. I'm not an expert on gravity measurements, but I think anybody can see that it appears to be subsiding on the east side where the lines are close together. Figure 4 is a hypothetical section that has been constructed by the U.S. Geological Survey showing the subsidence along the east side. There is also subsidence along the north side. Streams entering the Flats came from quite a

wide area and they all headed for the Flats like a homing pigeon. Goldstream Creek used to flow through one of those lakes and out to the Chatanika. When that mud started arriving in 1929, the stream became overloaded and sluggish and started to fill in its bed. Remember the balance of stream erosion. The stream attempted to increase its capacity for transporting solids and migrated sideways. Some of them migrated and hit lakes. Goldstream became so clogged that Little Goldstream captured its drainage and the lower end of former Goldstream is completely plugged. You can't see it from an airplane today. Figure 5 shows an aerial view of a portion of the Minto Flats.

I think you can see that this country is just awash. The base level of erosion is practically the water level. There isn't a lot of room for mud to go. However fine materials coming down are still able to flush through the Tolovana River and out to the Tanana River. Once it gets into the Tanana, I don't care if it ever was mud as John Miscovich said, "You've got the finest settling pond there is and it's the Bering Sea."

Some lakes were filled up. They were the settling ponds for the Fairbanks district and to some extent for the Tolovana district. I might add that anybody who had suggested that the Fairbanks Exploration Company's mining program be stopped in the 1920's, when it was started, because they might fill in some lakes, would have been lynched.

The north side of the Flats shows a distribution of lakes. Minto was on the contact between that lake area and the uplands. The wide river that flows past Minto is the Tolovana, flowing turbid with muck from the Livengood district. What happens is periodically the Tolovana overflows its banks and any sediment in the Tolovana is going to go into these lakes and they're going to become settling ponds and are in fact natural settling ponds and the process goes on whether there's mining or not. Mining just makes it faster. We wanted to be scientific so we made all kind of screen analyses to see if we could prove that streams coming from the mined areas had larger proportions of finer sediments. We did some trace elements analyses to see if we could trace something back to Livengood. I want to say there's absolutely no way you can correlate where that mud came from with any of these measurements.

Anybody who would say no mud comes out of a placer mine is either a fool or a liar. It's one of the facts of life of mining. Some of you have seen when Birch Creek seems to be running solid with mud from all of those mines on Harrison Creek, Eagle Creek, and upper Birch Creek but it doesn't seem to accumulate. The next year it's gone.

I won't say much about our study of the Circle Mining District except to mention Medicine Lake. Most of you know the streams in the area. The ones that go out through Crooked Creek, about six or seven of them with their tributaries, are all heavily mined, in fact a large proportion of the gold coming from the interior every summer is coming from the Circle district. Figure 6 is a very interesting aerial photograph of Medicine Creek. Notice the north half of the lake seems to be pretty well filled in, just about half of it. Crooked Creek, to the north of it does not flow through the lake. What this tells me is

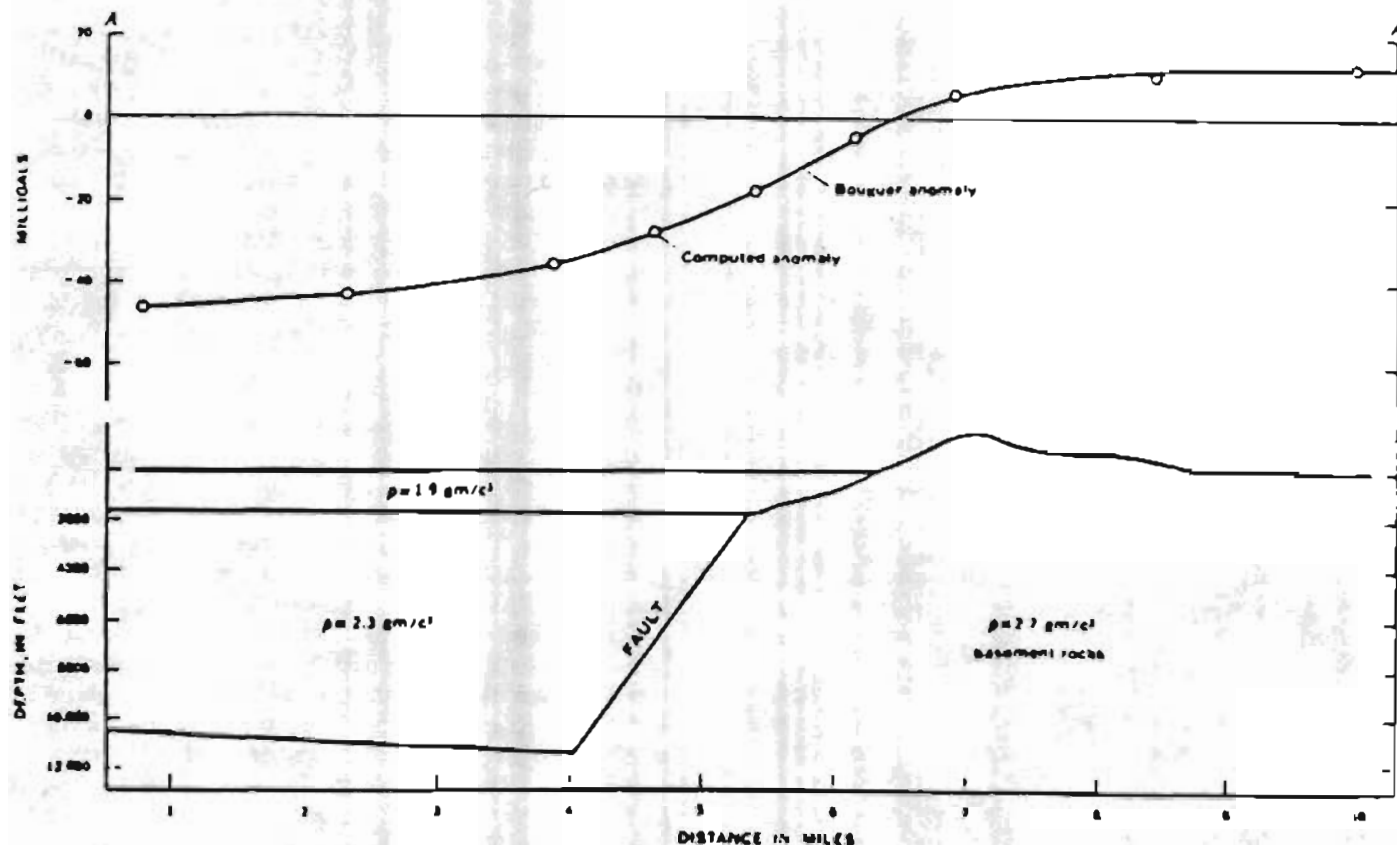


Figure 4. Hypothetical section of the Minto Flats.

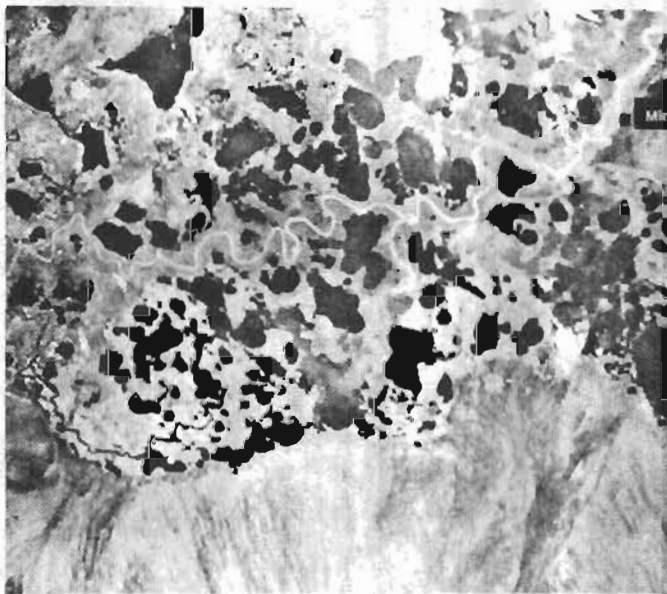


Figure 5. An aerial photograph of the Minto Flats.

that periodically Crooked Creek overflows its banks and puts sediment into this lake. Now this is prehistoric sedimentation. Nobody's observed this since there's been mining around there in the last 75 years. This indicates that the process goes on naturally. This lake is going to be filled in because it can't get away from Crooked Creek and it can't get away from those sediments.

Part of this study was to look at the beneficial effects of mining. I did a little calculating that if it takes 100

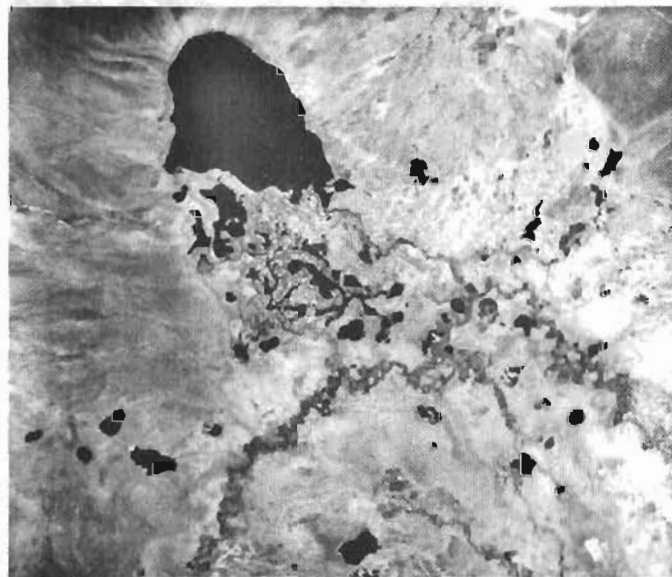


Figure 6. Aerial photograph of Medicine Lake - Medicine Creek area.

ounces to support a family for a year, there's at least a 100 families supported directly from the Circle district and about 70 families from the Tolovana district. Now you can use your own multiplying factor, but this might mean that 3 or 4 hundred families have been supported every year by the Circle district. That's not insignificant when you figure out how hard it is to support a family these days. This is just one of the beneficial effects that we noted from the products of erosion from a placer

mine. Mine tailings also benefit many as a good building foundation in the Fox, Alaska area. Many subdivision roads are also built from tailings.

Mining seems to be the base from which everything else came. There's never been a case in Alaska I know of where a road was built before the mining started. Mining opened up the country and all subsequent activity has been based upon that.

This isn't the first time that mining sediments have been in the forefront. During the first gold boom, which was mostly a hand mining boom, in the spring when they were sluicing the winter dumps, Livengood Creek and the Tolovana were bank to bank with mud. But it only lasted, say for six weeks. During the second gold boom, late twenties to late fifties, every creek in the country was running bank to bank with mud. You can imagine what Goldstream must have looked like when it was carrying all that muck.

The effects of placer mining on the environment are not amenable to quantitative analysis. I found that out in trying to pin something down that we could attach a number to. There are too many variables. If anybody tells you that he's got scientific proof of the effects of placer mining on the environment ask him how many variables he looked at. I can find positive or negative correlations with the salmon catch. I can find a correlation between the price of copper and the amount of mud in a stream, because usually when based metals are good placer mining is down.

How about the fish of Minto? Some people say that the fishing is poorer now than it was ten years ago. But Minto moved to its present location about 12 or 15 years ago. Gill netting was introduced. People that lived on salmon in the past are now living on pike. I don't think that we can say a word about the effect of placer mining on the pike population. Fairbanks has grown. Roads have been constructed to Minto. There's nothing you can say about the environmental effects of mining except that a lot of mud came down the streams and rivers in the past.

Yesterday we heard a lady stand here and completely demolish the idea that turbidity has any relationship to the potability of water or the study of the quality of water. I think I can do the same thing to the idea of a scientific study of this subject. You can correlate one thing with one other thing and that's all. All I want to say is that this proves that the equilibrium principle is still operating. This is the most universal principal of all. If you change any one thing in the universe, conditions are going to have to change so that a balance is maintained. If you change something on a stream, the conditions are going to change so equilibrium is restored. If you heat up a chemical reaction the conditions will change so that the reaction moves in the direction which is more in equilibrium. It's such a broad principle that it's hard to apply but it's been a very useful one to me.

Finally, I'd like to say that I think we could clean up a lot of mine tailings and we could do much toward reclamation if we had easier patenting laws.

## **Geological Factors Governing the Formation of the Gold Placer Deposits of the Fairbanks Mining District, Alaska**

**Abstract**

**P.A. Metz**

*Assistant Professor of Economic Geology  
School of Mineral Engineering, University of Alaska, Fairbanks*

The Fairbanks mining district includes an area of 400 square miles and is located in the northwestern portion of the Yukon-Tanana Uplands Schist Terrane of central Alaska and Yukon Territory. Gold was discovered in the Fairbanks district in 1902 and since then the area has produced 7,500,000 troy ounces of placer gold and 250,000 troy ounces of lode gold. In addition, the district has produced several thousand tons of antimony and several thousand short ton units of tungsten. Although it has been the single most important placer district in Alaska, the major controls of placer formation are only now being recognized. In this paper, new evidence is presented on the bedrock sources of the placer gold, bedrock structural control of stream drainage, and surficial depositional controls of placer formation. Of the major controls of placer formation, the alteration of stream drainages by basement structures leading to stream capture, stream reversal and sediment resorting is the most important control.



## **Education and the Mining Industry**

**James A. Madonna**

*Assistant Professor of Mining Extension, UAF*

The objective of this presentation today is to ask and hopefully, with your assistance, obtain answers to two questions of educational importance. (1) Is the School of Mineral Engineering within our Land-Grant College performing as it was originally intended? and (2) Are we, the residents of the State of Alaska and the mining community, supporting our Land-Grant College in its educational mission? Before we answer these two questions, perhaps we should take a quick look at the historical development of the Land-Grant College concept.

I understand that some of you here are aware of the function of a land grant college. Nevertheless, for those who are not entirely familiar with the land grant story, perhaps a review of some of the essential historical facts might be enlightening as well as beneficial. Two major crusaders are credited with the development of



the land grant college concept: A Vermonter by the name of Justin Smith Morrill and an Illinois educator by the name of Jonathan Baldwin Turner. It was Jonathan Baldwin Turner, in 1851, who planted the seed of the concept, but it was left up to Morrill to nurture it and bring it to full fruition. Now Morrill left school at the relatively young age of 15. Despite his lack of education, Morrill became a successful businessman and ultimately was elected to Congress. Evenso, throughout the years, Morrill felt handicapped by his lack of education, and it was this that led him to introduce a bill in Congress which would grant for each congressional seat from each state 30,000 acres of federally owned land to be sold with the stipulation that the proceeds be used to develop education on a college level, such education to "promote the liberal and practical education for the industrial classes and the several pursuits and professions of life."

Interestingly, in the 1800's, the industrial classes included just about everybody who worked for a living and were distinguished from the elite who pursued the purely classical education being offered by the colleges of the time. In the United States, education in the 1800's patterned itself closely after the classical European style which educated a few men in law, medicine and theology, clearly ignoring the education needs of the majority of people who of course, were the industrial class.

The United States of America in the 1800's was a young, vibrant, energetic country with a vast untamed wilderness containing a tremendous amount of natural resources. Farsighted people began to recognize the need of coupling science and technology with human need and further, with development. It became clear that the prevailing educational system did not meet the vibrant needs of this young country and the aspirations of the common man in politics, technology, and most of all, natural resource development. Growing criticism then resulted in the acceptance of the Morrill Act of 1862 and subsequently the development of the land grant college system. Again, a college whose primary mission was then and is today to promote the liberal and practical education of the industrial classes and several pursuits and professions of life.

The development of a land grant college in Alaska began in the early part of this century. On March 4, 1915, the Congress of the United States granted the Territory of Alaska a site for an Agricultural College and School of Mines. In addition, they also provided 100,000 acres of federally owned land to be sold for the benefit of the college. Subsequent territorial legislation created a corporation in the name and style of the Alaskan Agricultural College and School of Mines. Upon certification by the Governor of the Territory of Alaska stating that a land grant college had been established in accordance with the laws of the United States, on the day of its opening, September 22, 1922, the Alaska Agricultural College and School of Mines began receiving funds provided by the Morrill and Nelson Act for land grant colleges. Finally, on March 12, 1935, the University of Alaska was established with all the provisions of the first act of March 4, 1915.

Keep in mind that without ignoring higher level education and scientific research, the primary mission

of a land grant college was to develop programs which would educate and benefit the industrial classes. When we examined the curricula here within the School of Mineral Engineering at the University of Alaska, we found that indeed it did have well established higher level degree programs solidly in place. Furthermore, the Mineral Industry Research Laboratory is a well staffed, well equipped facility, actively pursuing higher level scientific research. However, when we examine our primary mission or programs which would benefit the industrial classes in mineral exploration and mining, we have to address a couple of questions:

(1) What is the current mining activity going on within Alaska today? (2) What mining activity is being developed and will be blossoming in the near future and will it have practical educational needs which the University could address by initiating programs today? (3) With the present and future mining activities in mind, what will be the practical educational needs of the people in Alaska and is the University of Alaska developing programs to meet these needs?

The answer to the first question is, that aside from fossil fuels, there are two major mining affiliated activities currently in this state. One of them, of course, is mineral exploration, and the other as you well know is the mining of gold placers. The State Geological and Geophysical Survey has a list of scores of people in mineral exploration, exploring not only for placer but for lode deposits. These people are willing to and commonly do hire University students as assistants. However, when we examine the curricula here at the University of Alaska, we find that aside from a few scattered classes spread in the various departments around the University, there is not at this time a coherent package or program designed to benefit the techniques of mineral exploration. Further, the industry that is the major metal mining industry within the State of Alaska, is, of course, the placer gold mining industry, an industry supplying 250 million dollars to Alaska's trickle down economy each year. Furthermore, they either directly or indirectly, provide jobs for thousands of people. When we examine the curricula here at the University of Alaska, we find that aside from this placer miners conference and perhaps the mining extension program which has been teaching practical classes throughout the towns and villages in the State of Alaska for the past 50 years, there is not one practical class on campus, much less a full program, directed at benefiting the placer mining industry.

In answer to the second question, there are many new mines being developed at this time. We have the U.S. Borax molybdenum property near Ketchikan, Alaska, Noranda's Green Creek silver, lead, zinc property on Admiralty Island, and we have Cominco's Red Dog property on the Seward Peninsula. Several others are being developed. When these mines come on line, they are going to need educationally well rounded work forces in addition to personnel with higher level degrees. They are going to need technicians, lab assistants, geological assistants, mill technicians, and perhaps even people in lower level supervisory positions. It is clear that the University of Alaska is capable of supplying these higher level degrees. However, it does not have a pro-



gram developed that can address the needs of the new industries' technical support positions.

Finally the last question. I am sure you have heard this many, many times before, that the State of Alaska is roughly 1/5 the size of the coterminous United States and within the state's borders there are roughly 600,000 people. Half of these people reside in the Anchorage area, another 100,000 people in Fairbanks, Juneau, Ketchikan, Adak and the remainder, roughly a quarter of a million people, live in small towns and villages throughout the State. Aside from Fairbanks and Kenai which have some mining programs in place, and of course the mining extension program, there is little opportunity for these people in rural Alaska to obtain practical education in mining and mineral exploration. Furthermore, few of these people have the funds or care to spend the four to five years necessary to come into the University here in Fairbanks to pursue a higher level degree. However, some would come to the University for a semester or a year or perhaps even two years if they were assured that they could obtain practical education that would benefit them in their private mining operations or would benefit them in obtaining elevated positions within the mining industry at present or which is being developed.

I will conclude by saying that although there are several scattered classes around the different departments here at the University, there is no solid program that supports the mineral exploration industry. There are no classes here which provide the practical knowledge necessary to benefit the placer mining industry. There is no practical program being developed to benefit the future mining industry and finally, we have not addressed the practical educational needs of our people in rural Alaska, so that they may obtain higher level jobs in industry, jobs with avenues for promotion and perhaps futures which they could be proud of.

Just as the United States was a young, vibrant, energetic country in the 1800's, the State of Alaska is now a young, vibrant, energetic state. It too has a vast relatively untouched wilderness and a tremendous amount of natural resources. Perhaps we have overlooked the educational needs of the mining industry in the State of Alaska and perhaps the mission of the University in educating the industrial classes has reverted back to that classical European style of ivory towers. The question here then, is what can we do to fill this educational gap?

I propose we develop a two year technical program, which might be called the Department of Mineral Exploration and Mining Technology. First, the major goal of the program would be to educate students so they may enter into the elevated technical positions of industry. The second mission would, of course, be to provide classes which could be taken by the current people of the mining industry to improve their mining ability.

The program would consist of two year technical certificate programs encompassing seven areas: Laboratory technology, which is designed to educate people for assay labs, private as well as government labs; Research Technology, designed to help people entering government positions, perhaps educational positions; Mineral

Exploration, designed specifically for the mineral exploration industry; Placer Mining Technology, to benefit the placer mining community in Alaska; Oil Technology, for those interested in petroleum; Geological Engineering and Mining Engineering designed for people entering mining and milling techniques. Of course, under this structure, we would also have the public service mining extension program, which as many of you know, has for the past 50 years, served the various towns and villages throughout the State of Alaska with practical education in mineral exploration and mining. But even more, the function of this public service program would be to inform people in the various towns and villages throughout the state of the facilities at the University of Alaska and hopefully stimulate some to come to the University in search of higher level degrees.

The two year programs would be designed to help students enter into the technical positions available. Even more, the program would be designed to help people who are entering government positions to better understand the needs of the mining community in Alaska. Conversely, there would be courses available to help educate people in the mining community to better understand the role government must play in mining. Hopefully, through education, we can open lines of communication. The overall goal would be to improve the mining industry and benefit the people of the State of Alaska.

There are more benefits than this. Occasionally, students who come in from rural Alaska in search of a degree in earth science find that although they are genuinely interested in the earth sciences they do not have the ability to take all the support classes necessary to obtain that higher level degree. Perhaps, if these people had the opportunity or the option of a two year technical certificate rather than a drop out status, they might have the incentive to go forward into the mining industry. Conversely, some people may come into the University for a two year degree, find they are well adapted to education, and go for the higher level degree. The classic example is that of a person taking a class for self improvement and getting so enchanted over the entire idea of education that they go on to earn the higher level degree. So what we have here is a two way filtering system. (1) We eliminate much of the attrition taking place and (2) we obtain a higher quality student at a higher level.

## Water Quality Concerns

*Richard Neve, Commissioner*

*Dept. of Environmental Conservation*

It's a pleasure to be here to address this Sixth Annual Conference on Alaskan Placer Mining. Governor Sheffield sends his regards and best wishes for the success of this conference and hopes that indeed it will be productive to all concerned. I'm pleased to see the large number of people in attendance. You now have exceeded the enrollment of any previous conference.

I want to thank the School of Mineral Engineering and the Alaska Miners Association for inviting me to present some thoughts I think will be useful to all of you placer miners, and things which need to be said by my agency, which is a regulatory agency, and in some aspects we're looked at as the bad guys. To quote Senator Murkowski's telegram, "I hope that we will be in a spirit of cooperation. I'm hopeful that this conference will result in a well balanced and well reasoned conservative effort to solve the problems facing the industry."

We're not necessarily always the bad guys and I don't think you are necessarily always the bad guys. Hopefully we'll get into a spirit of cooperation and solve some serious problems in the placer mining industry. As you may know, there is an advisory group which has been meeting for over a year and we're finally making some progress. In conjunction with the Department of Natural Resources (DNR) and Fish and Game we're going to present and develop our policies, so that you know where you stand with us. I'd like to give you an outline of the coming year's schedule.

In April, we're going to look at permits. The permit that you have from EPA now is a draft. There will be public hearings on April 3rd and 5th and we intend to provide input to make this more of a working document. There are some seriously weak points in it, which you're aware of, I'm aware of and so is EPA. In mid-April we're going to be looking at the EPA effluent limits. There will be some economic and engineering reports available. The national rules on placer mining discharges will be announced for critique and review. Again in mid-April we open the records for review on turbidity, placer mining use category, and reclassification, with that process continuing until December. During this period we're going to be out in the field collecting our own data. EPA will also be collecting data. I can't emphasize enough the necessity for your cooperation. It's absolutely essential in acquiring this data. I intend to spend considerable time in the field this summer. I'll be going with John Reeves, whom many of you know, and hopefully an additional three, maybe four people.

By the end of May it will be DEC's responsibility to take some action on certification of the EPA discharge permit. Hopefully we'll have a more well defined and documented enforcement policy at that time.

On June 1st, I understand from EPA, the discharge permit will be issued. During June, July, August and

perhaps into September, there'll be two teams. EPA will have an enforcement team out and we will too, but our thrust is data collection. EPA, I understand, will have three two-man teams in the field looking for those people without settling ponds, those who don't have permits, and those who are not operating under compliance orders. These are the rules by which they have to operate. (I'm going to touch on what we have in mind in terms of our enforcement policy later.) We're going to be looking at recycling, its effect on gold recovery, discharge characteristics, and mixing zones. We want to collect data on stream flows and their quality as affected by mine discharge flows, so that we can define better permit limits. We are interested in settling pond performance, so we're going to be studying several well operated settling ponds to determine what the proper limits should be. By September, and this isn't absolute, we will have collected an adequate amount of information to send to EPA in order to help them modify their effluent guidelines and permits.

By October we hope to go public on the issues of turbidity, placer mining use category and reclassification and fulfillment of our three year commitment to water quality standards modification. We hope to be on time and have the data in hand.

Into January and February and March of 1985, we'll be looking at reclassifications. Perhaps I need to make myself clear on stream reclassification. I'm not interested in reclassifying streams of high drinking water quality, but I am interested in those streams which are highly silted, glacial type streams, which I think, would lend to reclassification. We'll be looking at some trial reclassification of streams and also at a basin plan approach for proposed regulations.

Hopefully by March 1985, we'll be able to address you on mining practices which really relate to good mining. Finally we will present this information for approval by the EPA.

Now let me be a little more specific in terms of what I think DEC's responsibilities are. We look at streams in terms of damage to the water quality. Fish and Game looks at this slightly differently. They look at the sensitivity of the stream. Sensitivity in terms of fish. So I'll take this moment to explain some things with regard to turbidity.

We do not look at turbidity as a measure of toxicity. The real damage from turbidity is the disruption of the effect of light on plant growth and the algae which is necessary for the support of aquatic life. At 25 NTU's you get light scattering and do not have adequate light for proper plant growth so you have no survival of fish in those streams. If you have a long stream and a number of mining activities, and siltation is there, Fish and Game gets quite concerned because the zone is disrupted. Siltation is not an instant kill. You kill the food then you have a slow death of the biomaterial. We're concerned with those actions which are wholly unnecessary, such as dumping overburden into a stream, or unnecessary destruction of a stream bed. We don't think that's necessary under any condition, and we intend to enforce that. Secondly, we are concerned with damage caused by failure to construct settling

ponds. This has been measured by the settleable solids in streams or in discharges to streams. If the settling pond is in place, is it really operating? That's the third category. Damage caused by failure to properly operate settling ponds as measured by settleable solids in stream or in discharges to streams. Recycling in some areas is good.

Before we get into the enforcement of properly operating ponds, those of you who have had experience with John Reeves know that he's been very helpful to anybody who's ever asked him. John's article in the DEC's program manual is excellent and I highly recommend that it be read, plus the articles by Fish and Game and DNR, Joe Sullivan in Natural Resources, and Al Talsan in Fish and Game, along with Jack Winters. John Reeves also put together a settling pond manual. So we are attempting to work with you as well as regulate.

In terms of Fish and Game, we're looking with them at priority waters, priority systems. Streams that have their attention are the Chatanika, Chena, Salcha, Bear Paw and Hogotsa.

Though there's never enough to do the total job, there will be state funding for our field work. We hope to get a program going that isn't just a regulatory issue. We'll try to work with you so you can succeed in your mining efforts and we can succeed in our mandate to protect the quality of the water.

## Placer Mining Controls in the Yukon Territory, Canada

*Jack Nickel*

*Regional Manager, Water Resources*

The purpose of this presentation is to summarize the environmental controls applied to the Yukon placer mining industry over the past ten years and to show the direction these controls are taking today.

I'll begin with a review of legislation and the way in which this legislation has been applied. I'll then outline the reaction these proposals have received. Finally, I'll attempt to describe the situation in Yukon today.

Before I discuss the legislation governing placer mining I think it is important that you understand that the Canadian Federal Government owns and administers the water, fish, land and mineral resources in Yukon placer areas. There are three main parts of federal legislation affecting placer mining. First is the Yukon Placer Mining Act (1906) which provides for the allocation of mineral and mining rights.

Second is the Northern Inland Water Act (1970) which provides for the discharge of effluents and the use of water, either by regulation or by a Water Use License issued by the Yukon Territory Water Board (YTWB). Until very recently, all Yukon placer mines operated under Water Use Authorizations issued by the Controller of Water Rights pursuant to regulations under the Northern Inland Waters Act. The Federal Court recently declared these authorizations to be invalid.

The third and perhaps most demanding law is the Canada Fisheries Act passed in 1867 and amended in 1977. This amendment prohibits the discharge of substances deleterious to fish (and prohibits alteration or destruction of fish habitat). The term "deleterious," as it relates to placer mining, has not been defined. If this act were to be enforced there would be very few placer mines operating in the Territory.

Now, how have these laws been applied? In the early 1970's the YTWB began to receive applications for water use in placer mining. The Board chose to hold general public hearings on placer mining in 1973 to determine how the applications should be handled. They concluded that their licensing process was too cumbersome and time consuming for the rapidly growing number of applications and recommended that such use be permitted through authorizations issued by the Controller of Water Rights. The Board again held hearings in 1974 and 1975 and in late 1975 they developed Placer Mining Operating Guidelines for use by the Controller of Water Rights in the issuance of authorizations. These guidelines were first used in 1976 and continued to be applied through 1983.

The 1975 Guidelines required that all operations provide, where practical, effective settling facilities to the satisfaction of the Controller. They also stated that stabilization of tailings and stripped areas would be required. Fish passage and fish screens were to be provided where it was critical that fish stocks be sustained. Minimum assured flows and enhanced settling were to be provided where downstream users were affected. A list of designated creeks was developed. (These are traditional placer creeks deemed not to be critical for the maintenance of fish stocks.) where few restrictions applied. Fisheries concerns were incorporated through an application referral and joint inspection system.

In 1983, 313 authorizations for placer mining were issued. Of these, 25 applicants did not operate, leaving 288 active placer mines. Of the 288 active operations 225 had settling facilities discharging to receiving waters or about 80% of the industry. The remaining 20% consisted of:

- 3 total recycle operations
- 17 testing programs (no discharge)
- 5 suction dredging operations (working within enclosed bars) We haven't permitted floating down a river.
- 11 hand mining operations
- 26 operations with no settling, either because they used a downstream common settling pond or because they did not have land available to construct settling facilities and it was deemed impracticable to provide it. During this same period, the Board issued 4 licenses for placer mining.

The authorization process was efficient and flexible. It was also highly discretionary and led to a great deal of uncertainty for both the miner and the inspector. Not long after the Water Board issued its Guidelines to the Controller it became apparent that they were inadequate in many areas. Inspectors needed defined design and effluent standards to be assured that his obligations would not change from day to day. Also, many fisheries related aspects had not been incorporated in the Guidelines (restrictions on diversions, leave strips, ef-



### Summary of Proposed, Required Site Specific Mining Practices

Reach Classification	Water Acquisition	Ultimate Suspended Solids Effluent Standard	Diversions	Leave Strips
A Salmonid Spawning (Salmon, lake trout)	Taken by pumping only. Screening required.	0 mg/l suspended solids. No toxic discharge.	Not permitted	30 meters wide both sides of stream. A berm may be required.
B Salmonid Rearing	Taken by pumping only. Screening required.	100 mg/l suspended solids. No toxic discharge.	Not permitted	15 meters wide both sides of stream. A berm may be required.
C Other Fish Grayling & Whitefish	Screening required	100 mg/l suspended solids. No toxic discharge	Must contain one in ten year flood. Provision of fish passage Open during spring freshlet	One bank to remain vegetated
D Not Important for Fish Use	Screening required	100 mg/l if to A, B, C or D. 1000 mg/l suspended solids if flowing into a Major D. No toxic discharge.	Must contain one in five year flood. Fish passage if A, B or C upstream	Not required
X Not important for Fish Use	Screening required if fish present	100 mg/l if to A, B, C or D. 1000 mg/l suspended solids if flowing into a Major D. No toxic discharge.	Must contain one in five year flood.	Not required

fluent standards) and the Fisheries Department began to question their involvement in a joint permitting process so, in 1979 the YTWB again held hearings on changes to their guidelines. They concluded that they could not address the variety of issues involved and requested the Minister of DIAND to provide policy of legislation guidance. Placer studies were begun in the fall of 1979 on waste treatment tech, biological impacts of mining, and mine site and stream recovery. In 1980 the three involved federal departments (DIAND, DFO & DOE) began the development of a new set of placer mining guidelines. They were released for public review in early 1983. Figure 1 is intended to give a more detailed, site specific, view of these proposals.

Four background reports were prepared in support of the proposed guidelines. They were:

- (1) A rationale for the classification of rivers, streams and lakes
- (2) A rationale for the suspended solids standards
- (3) The attainment and cost of placer guidelines
- (4) Socio-Economic impact assessment

Also, stream classification maps were drawn up for all placer areas. A review committee was struck to hear the government proposals and public reaction to them. They held hearings in various Yukon communities and heard over 150 presentations. Many miners felt they could not meet the proposals. Their recommendations were filed in January of this year.

The review committee concluded that:

- (1) All operations should file development plans
- (2) Rehabilitation should occur progressively
- (3) Some form of financial security should be required to ensure rehabilitation is carried out
- (4) Stream diversions should be allowed in all cases where mitigative measures for salmon protection are feasible
- (5) That the proposed design standards for diversions were excessive
- (6) That leave strips should only be required where salmon presence has been proven
- (7) That in principle, the stream classification system was sound
- (8) That the proposed suspended solids effluent standards were appropriate for the protection of fish and fish habitat

Due to doubts about the impact of imposing the effluent standards the committee felt existing industry should be exempt for a period of 12 years, unless they were on salmon creeks, in which case financial assistance or compensation should be provided.

New operations were to meet the standards from the start. The three federal departments are presently reviewing the report but have not yet decided how they will proceed.

What about the 1984 mining season? As I mentioned earlier, authorizations were recently declared invalid. All miners wishing to mine this year must now either operate within regulations (50,000 G/day but no waste discharge) or apply to the YTWB for a license; a process which requires published notice of application, a public hearing and the Minister's signature on the license. The YTWB presently has 93 applications scheduled for public hearing with about 100 more to come and less than 2 months to process them. The objectives for effluent control the Board will use for 1984 are 0 and 100 mg/l suspended solids for salmon creeks and a settleable solids effluent quality of 0.2 to 0.5 ml/l with variation for site specific constraints for all other creeks. Each application will be determined separately and operating requirements imposed as the Board sees fit. The Department of Fisheries has not yet decided how they will enforce the requirements of their law in this year.

That summarizes the situation in Yukon today. I believe you can see that our problems are as complicated as your own. I believe solutions to these problems will be found but we are still a long way from achieving them.



## Water Quality Concerns

*Ernesta Barnes*

*Region 10 Supervisor, EPA*

I am glad to have been invited and I think that it is a sign of good faith that I came today. I am happy to be here but as I start to speak, I think of a Chinese proverb which goes basically, "Don't insult the crocodile until after you have crossed the river." I'm not sure I am across the river yet.

I'm going to try to be as polite as I can and yet I am afraid that I'm not always the bearer of good news when I come to talk about placer mining. I have had to have quite a crash course in placer mining, since I've only been with EPA since last June. I am a political appointee, Mr. Ruckelshaus selected me for the dubious honor of representing national environmental laws in Region 10 which includes the wonderful State of Alaska. However, in my 9 months of opportunity to study this industry, I have read, talked, listened, and learned a great deal and I am impressed by a number of things that I share with you today.

The concern over the independence and viability of mining, gold mining and all mineral development in this country, has a long tradition. That tradition reflects both the size of the men and the machines and the huge scope of the mining operations in the United States. There have been many forecasts, one after another, of the impending collapse of the mining industry and all to date have proven wrong.

Numerous government and trade association analysts have generally concluded that even though there are problems in mineral management, we will find solutions and a way to cope with them. It is interesting to read the suggested remedies of over 30 years of national mineral management policy development because these suggested remedies do not change from year to year, from metal to metal, or from mine to mine. They are in no particular order: to ease the restriction on access to federal lands, to gain substantial relief from environmental regulations, to improve hydrogeological surveys and ore mapping, to provide financial incentives to miners, to provide greater government aid in mining methods research. These are always there, not just with respect to placer mining in Alaska, but with respect to all mining. One of the suggested remedies (usually in a poorly defined way) is to achieve a greater national recognition of the valuable role played by the miners themselves in the cultural wealth of America.

With these traditional remedies in mind, my remarks today will be neither technical nor detailed. To prove that, let me start by stating my premise which is very unscholarly and is simply a personal observation. This is that the current debate over the future of the placer mining industry in Alaska is at dead center, which is to say we are engaged right now in a standoff. What's more, in my opinion, we are destined to stay right where we are, engaged in a standoff, unless those of us par-

ticipating in this debate shed our ideological armor and start to listen to one another. It's time to look at the facts, to agree on what they are, and to work together.

The real issues in placer mining are not difficult to enumerate and they have been talked about by many of the speakers here yesterday and today. They are the costs and benefits of the placer mining activities, both to the state and the state's economy and to the national economy and to the miners themselves, to you, and the relation of gold mining to other community objectives and water quality impacts. Until now the debate over these issues has been conducted in a highly adversarial form. Each side of this debate claims to be in possession of truth and accuses the opponents on the other side of the debate of various sins. Principal among these sins are stubbornness, unresponsiveness, disregard for one another's rights and finally, the worse accusation of all is bad faith. It is the accusation of bad faith which most clearly denotes the breakdown in trust, and the rebuilding of trust is going to be the key to movement off dead center in this debate.

The opposing camps are well known to me. I hear from each of them daily, the public record on the proposed permits which are underway right now includes not only the very vociferous input from your community which we heard in Anchorage and Fairbanks last week but also written input from the environmental community. Heard in abundance here is one side of the polarization of this issue. The phrase that I use to summarize that side of the debate is, "You are locking up free enterprise, you are locking it out of the last frontier." The phrase that I use to characterize the other side of the debate which you will not hear today because I doubt there are many environmental extremists present is, "The placer miners are ripping up Alaska's entire stock of stream beds." Each of these represents a level of silliness which does not reflect the real world and is not likely to settle regulatory policy. What this debate does do, however, is extremely effectively poison the atmosphere in which we attempt to regulate and in which you attempt to do business. There are no signs today that the level of intensity, or more sadly, the level of litigation is dropping off.

I am very pleased that you gave me an opportunity to come here today and place these issues in the perspective as I see them. For I am not a member of either of these camps. I am neither a mining rights fundamentalist nor am I an environmental extremist. I am not an engineer nor a biologist, nor a fisherman, nor a politician. I am, however, responsible for the orderly, legal, rational administration of national environmental law in Alaska. And I intend to carry out that trust in spite of the posturing and challenges from both sides of this debate. In the mid-60's, environmental awareness added a new dimension to the agenda of public concerns over mining. The National Material Policy Commission reporting to Congress in 1973 added a new mandate to an old, very familiar one, which you are well aware of. The time honored mandate which has been prevalent in mineral management in this country for the last century was basically, "get it out of the ground cheaply." The new mandate which has been with us for the last 15

years and was clearly articulated in the 1973 commission report to Congress was, "get it out of the ground cheaply but leave the ground fit for others to use."

In the subsequent 10 years, we have struggled to understand what that means, to understand what is adequate protection for the environment. What is a base line of environmental condition which we should seek to maintain in territory that was not occupied 10, 20, or 25 years ago? What future uses should we protect for this land and these rivers?

There are some useful facts which I want to share with you as we consider this debate and dilemma. They might explain the isolation I feel, and perhaps you feel, and the frustration in trying to achieve a broader national attention and focus or even a minimal national understanding on the problems we have here in Alaska. Non-energy minerals such as gold are a relatively small factor in the United States aggregate production of goods and services. We are not talking about a large piece of the American pie. In 1980, metallic and non-metallic output at the mine was valued at \$25 billion for all metallic and non-metallic minerals. For metallic minerals alone, which include gold, it was \$9 billion. This compares to \$100 billion worth of oil produced in this country, \$30 billion of natural gas, and \$25 billion of coal. If we look at the metals alone, the \$9 billion worth of metals produced in 1980, iron and copper both represented \$2 1/2 billion, molybdenum, \$1.2 billion, gold only \$600 million. That's as much as the oil consumed in the United States in a single day. There is no national or international agreement on which of these minerals should be labeled as critical or strategic or what is the difference between a critical and a strategic metal and which should be specially protected. In the economy of world markets, this is an even smaller piece of the pie. Aggregate trade in 1980 in ore concentrates and in scrap metal were less than 1 percent of all world trade. Here in Alaska the economics are different.

Placer mining and the economics of placer mining are a far more significant percentage of Alaska's economy than gold mining is to the nation. In 1982, the value of gold production in the State of Alaska was \$70 million which is almost 28 percent of the State's 2.6 billion dollar income and represents almost 10 percent of the total national production of gold. It is helpful to keep these facts in mind.

We are parties to a debate here in Alaska over the future of placer mining. We can glean from this one very important thing. That is, that we, here in this room today, have a far bigger stake in resolving this conflict than anyone else in the country. Nobody cares as much as we do and therefore we should not invite outsiders into this debate. Every time we fail to cooperate and end up in litigation, those outsiders come in again in the form of judges and they do not have the stake in resolving this as we do. We are currently in an era of expanding domestic mineral production and that includes the expanding pressure which I have felt and which you feel to permit placer mining.

The timing of this meeting is fortuitous for EPA, for it falls very conveniently between the workshops which were held two weeks ago and the public hearings which

we will hold in Anchorage and in Fairbanks next week to discuss the proposed permits with which I am sure you are all familiar. We have obtained valuable information from you during the March workshops and in our subsequent correspondences. Bud Laiselle, which many of you have met, has been giving out a fact sheet which summarizes what we learned from you in the workshops and the proposed changes which we hope to be able to incorporate in the drafted permits. We have been getting good cooperation from you. We have over 300 applications for permits for the 1984 season, but there is clearly still a strong opposition to the fundamental premise of EPA proposed permits, i.e. compliance with the state water quality standards.

The Federal Clean Water Act clearly requires every state to establish water quality standards and clearly requires that those water quality standards be met. Water quality standards protect streams for fishing, drinking water, and recreation as well as for commercial use. They also protect streams used by creatures other than man. All of these uses exist to some degree or another throughout the State of Alaska. It is a fact that traditional placer mining methods degrade water quality and deny these other uses that are protected by Alaska state water quality standards. A recent 3 year study conducted by the University of Alaska shows that the plants and animals which are at the bottom of the food chain are reduced by over 50 percent when turbidity exceeds 200 NTU. These algae and insects are essential food for fish, and fish are essential food for others.

The EPA goal is not to close down the placer mining industry. However, EPA and national regulations are not the only obstacles which your industry faces. The Alaska State Department of Commerce estimates that there has been a 20 percent decline each year in placer mining operations. Data which you submitted to us shows that a large number of your mines continue to operate on a negative cash flow. This speaks very highly of the initiative and determination that keeps each of you in business. It also raises questions about how future environmental controls and purchases of modern equipment will be financed.

As it now stands, our proposed permits will require most of the mines to conduct major recycling in order to meet state water quality standards. However, there may be other technology that will achieve those standards; there are ways to use less water, ways to capture more fine gold. Some of the new machinery is here on display and I have asked the operators to tell me about it. We have asked for your ideas on what's possible so that we may incorporate them into future permits.

For our part, we have an obligation to you. We have pledged to work more closely with the Alaska Department of Environmental Conservation (ADEC). We have pledged to remove the drinking water use, in other words to reclassify your streams if high natural arsenic and turbidity will not allow drinking water in any event. We have pledged to help reevaluate the turbidity criteria and to look around the country for examples of turbidity criteria which will be easier for you to meet. We have agreed to help reevaluate the mixing zones definitions to provide technical assistance to miners, to

jointly with ADEC, monitor operations this summer and collect data for future permits, to improve geological surveys and mapping so that only productive gold bearing areas will be mined in the future.

We will issue permits by June 1 of this year. Those permits will ease the monitoring burden but we intend to enforce them. We will conduct a serious enforcement and compliance effort this summer. We will work directly with individual miners and we have asked Bud Laiselle to be stationed here in Fairbanks from the first of May throughout the remaining 1984 mining season. We have explained to you that we will negotiate with any one of you who applies to us to extend their compliance schedule, so that you will have the time that you need to purchase the equipment and install it.

We are faced in this regulatory exercise with a classic production versus environment tradeoff. Traditionally mineral resources have been assumed to out value any other natural resources wherever the two are found together. In other words, traditionally a rich gold deposit has been thought to outweigh non mineral resource values such as canoeing or fishing. However, there is a strong national tide giving increasing value to non-mineral resources and the activities which they support. Ignoring the rapidly growing national constituency for balancing water quality and mining values leads inevitably to frustration and has led to the unproductive controversy characterizing the debate over placer mining in Alaska. Instead of continuing to ignore the inevitability of regulation, I urge you and the regulators to share ideas on how, with adequate controls, placer mining can coexist with fishing, recreation, and drinking water uses of rivers and streams in Alaska. I urge you to accept the fact that national law and state water quality standards have a strong and binding constituency and to acknowledge the progress that we have made together in regulating placer mining rather than prohibiting or eliminating it as has happened already in some states and is inevitably going to happen in others. I urge you, in summary, to get the debate off dead center so that we can proceed with the 1984 mining season without the necessity of enforcing our laws against people who willfully do not comply.

## **Technical Approaches to Turbidity Reduction at Placer Mining Sites**

*David R. Maneval, Professor*

*Department of Mining and Geological Engineering  
University of Alaska-Fairbanks*

### **Introduction**

The placer mining industry of Alaska has been faced in recent years with the requirement to remove not only silt size and settleable solids, but to further reduce the suspended solids resulting from their mining operations. The future strength of the placer mining industry depends in large measure on the regulatory climate with regard to water quality standards. Within the framework of existing law, state and federal agencies by vigorously enforcing regulations could shut down the placer mining industry in Alaska. In this paper the various techniques available to reduce turbidity will be discussed in survey form. At the outset it will be useful to define some of the necessary terms. In the mechanical analyses of soil, silt according to international classification, has a grain size between 0.002 and 0.06 mm. Sand, on the other hand, is considered to have larger size particles and clays are considered to have finer smaller size particles. It is the clays or the subsilt sizes which are not readily settled by conventional settling ponds.

For the purpose of this paper certain assumptions will be made without which this presentation will only be argumentative. It is assumed for the purpose of this presentation that: 1) the mine operator has done as much dry land stockpiling of overburden as possible in order to minimize silt and sediment in the operation; 2) effective routing of the water has taken place to use that which is necessary for optimum operation of the mine and washing plant, but that other natural flow and rain runoff has been diverted away from the mining operation; 3) the current stream classifications now in place continue to stand; 4) the turbidity standards now on the regulations continue to stand and no allowance be made for dilution; 5) silt removal will be performed using the Best Practical Technology (BPT); 6) improved gold recovery will result from 'clean' processing water; 7) suspended solids at placers are similar to those at other mines both in terms of size and minerals (For example, clay mines, lignite mines, phosphate mines); and finally 8) equal enforcement will be performed on all mines.

### **Possible Approaches - Pros and Cons**

There are basically four approaches for the removal of suspended solids. These include polishing ponds, coagulants, filters centrifuges and hydrocyclones. The advantages of polishing ponds are that they can generally be constructed with existing earth moving equipment and



with minimum expenditure for additional supplies and materials. One of the disadvantages of polishing ponds is that if they are to have any reasonable chance of successful operation they must be well engineered, perhaps to a greater degree than is available with existing mine management, especially with small operations. Coagulants are known to be extremely effective in most all applications for sediment removal. Among their disadvantages are the difficulty of providing uniform feeding of the chemical to the solution to be settled and the unavailability at many sites of electrical power for such operations. In addition, the cost of flocculants is considered to be excessive in some cases. Filters and centrifuges are extremely effective in removing ultra fine mineral particles and are widely used in many sections of the mining industry. The principle disadvantage of these devices is their high initial capital cost and the highly skilled man power necessary to assure their operation at optimum conditions. Hydrocyclones are known to be extremely effective for classification. Because of this phenomenon these devices again are considered to be extremely effective in many mining applications, for example, the phosphate and the clay industry. Among their disadvantages is the necessity to provide electrical power for the pumps required in most cases to give an adequate head for the optimum operation of the device. In addition, as a general rule, the finer the size of the material which must be removed the smaller the cyclone should be, necessitating in many cases multiple small size units in order to handle the throughput from the mine. Another option available for removal of ultra fine particles is to use a combination of the devices in processes listed above. This process of using multiple units can sometimes capitalize on the strong points of several devices and work to an economic advantage for the operation. In order to explore the potential for these turbidity reducing procedures a detailed examination of each follows.

## Polishing Ponds

Assuming the mine operator has used a competent engineer in developing his primary settling pond or 'rougher' water clarification pond, approximately 90% of the silt and sand size particles from the operation will have been removed. The challenge then is to design a 'polishing pond' which will remove the remaining 10% of suspended solids without use of chemicals. Any design must be made using well known construction procedures for settling ponds including compartmentalization of the pond floor, adequate baffles to prevent short circuiting, adequate riprapping of pond sides to prevent rein troduction of solids, a well designed down comer or drainage system and of course, the inclusion of an emergency spill way to accomodate anticipated rainfall. As a general rule it has been found that warmer waters permit the settling of fine solids at a faster rate than colder waters. This is in keeping with the theoretical concepts of Stokes law and has been repeatedly demonstrated. This warmer temperature can be achieved by using large shallow polishing ponds in lieu of deep ponds. However, to accomodate the necessary

detention times, multiple ponds are sometimes required and need more frequent clean out. The ponds must be cleaned out in season if they are small. A useful technique adopted by many mine operations, including small producers, is to have two polishing ponds, while pond one is gathering clay size material, pond two is being cleaned out. Efforts must always be made to permanently dispose of the clay sized dredgings so that they do not become resuspended and recycled or drained back into a receiving stream. Ponds must also be designed so that water is not removed by excessively high velocity which causes bottom scour. A well know phenomenon is that freezing breaks up colloidal suspensions. This will 'miraculously' result in clear water in a polishing pond in the spring, whereas it was filled the previous fall. An alert operator can take advantage of this phenomenon, drain the pond early in the spring, clean out the bottom, consolidate sediments and start the mining season with a clean full capacity polishing pond. Following completion of the mining operation, primary rougher ponds and secondary polishing ponds should be backfilled and reclaimed using equipment available at the site. Stream channels should be restored so that postmining difficulties are eliminated at least from this source.

## Coagulants

Coagulants are known to be most effective in accelerating the rate of settling colloidal and clay size particles. Voluminous literature exists which demonstrates that properly chosen coagulants can reduce suspended solids concentrations by factor of ten. Because many of the streams in the gold mining regions of Alaska are clean with the exception of the suspended solids from the mining operation, and they therefore contain little or no 'buffering,' a small amount of acid can be useful in increasing the rate of coagulation and accelerate the settling. Very simple reagent feeders are available which could meter small quantities of acid to the inlet end of a settling facility. Such control of acidity or pH is readily accommodated. Extensive literature is available concerning the choice of chemicals and it is not the purpose of this paper to discuss the variations in the choices available to the operator. A great number of commercial entrepreneurs will be more than happy to test your particular suspended solids and make the necessary test and recommendations for appropriate coagulants for your setting. This approach has been widely adopted by the coal mining industry and to some extent by the metal mining industry and the clay mining industry. You will recall that we have assumed that the size and mineral composition of those materials which create the turbidity problems in Alaska are the same or nearly the same as those encountered by other portions of the worldwide mining industry. It must be remembered that once a coagulant is added to the suspension, adequate time must be permitted and space allowed for the larger particles to settle out. The admonitions noted previously with regard to polishing ponds are to remain for such settling facilities. A common problem noted by operators is the difficulty of uniform addition of



coagulants in remote locations. Many small electrically operated peristaltic feeders have been devised which will pump small increments of the required coagulant in liquid form into the turbidity containing stream. In addition, devices have been created which will add dry flocculants or chemicals to receiving discharges based on the turning of a paddle wheel which in turn operates a star feeder, thereby admitting dry chemicals to the discharge. Whether mechanical or electrical, equipment is available at a generally modest cost for the addition of both liquid and dry reagents to the turbidity containing stream. It should be noted that the capital equipment cost is much the same for small and medium size operations. This fact works to the advantage of large operators who will produce a much larger amount of gold product and process a much larger volume of wash water, but will have the same capital cost for their water treatment equipment as a small operator who will only be producing a small amount of gold.

## Filters and Centrifuges

Centrifugal dryers are machines used to create high gravity forces for the purpose of dewatering fine solid particles. Centrifuges have been developed that are consistent, uniform and easily handled. Properly operated centrifuges are generally used to dewater coarse materials but have also been used for extremely fine particles. There are three principal types of perforate basket machines: 1) one basket without transporting device; 2) basket with positive type discharge; 3) vibrating basket type. The vibrating basket machine is most often used in new plants. A special type of device is used for extremely fine underflows from settling basins called a solid bowl centrifuge. The treatment of extreme fines, .6 mm  $\times$  0 has been routinely accomplished with the solid bowl type centrifuge. It should be noted that addition of chemical flocculants to solid bowl feeds tends to increase solids recovery. The improvement is often substantial. A related technology, also mechanical, is the use of filters. Filters process a suspension through a path of cloth screening or other membranes in order to remove particles. A vacuum is applied below the surface so that the water and solids are drawn to it. Data from many sources indicate that extremely fine particles can be removed by filters. As the extreme fine content of the feed liquor increases, the permeability of the filter cake is reduced and there is a resulting decrease in filtration rate and an increase in cake moisture content. Most of the manufacturers suggest that when extremely fine colloidal materials are to be filtered, a special type of filter known as a precoat filter should be used which will allow significant throughput without blockage of the membrane - filtration surface. The filter in these devices is coated prior to immersion in the solution containing the ultrafine particles with a more granular material which allows a buildup directly on the cloth or membrane underneath the colloidal size filter cake.

It should be obvious that the operation of either variety of mechanical equipment noted in this section, that is filters or centrifuges, is extremely costly. As a first ap-

proximation of cost, it can be assumed that the operation of these devices is somewhat similar to that of tailings dewatering using dewatering thickeners. In these cases, the capital cost for tailings dewatering is \$150  $\times$  10<sup>3</sup> per 100 metric tons per day of feed. The operating cost for a similarly sized plant would be as follows: supplies including electric power and some flocculant would be \$29.00 per/day, labor based on \$7.95 per/hr would be \$24.00 per/day. Equipment operation including repair parts and lubrication would be \$7.00 (all based on a thousand metric tons per day of waste material). It can be seen from these estimates based on a 1978 U.S. Bureau of Mines publication that the capital and operating costs of either of these mechanical devices would be high, especially for a small operator. The technique then, although well established and having the advantage of state-of-the-art equipment and full development, may be excessive for the small transient placer operation.

## Hydrocyclones

Cyclones are of proven use for the removal of suspended solids from a feed stream. As a general rule, the smaller the particle size of materials to be removed, the smaller the size of the cyclone. In some of the Florida phosphate operations, for example, cyclones are being used that are no bigger in diameter than a man's thumb. A large battery of such cyclones must be used to handle a large throughput. On a more practical tack, hydrocyclones may be effective in reducing the turbidity to meet the current limitations, especially in areas where there is a problem of limited space for polishing ponds. Researchers at the University of Alaska have shown the effectiveness of hydrocyclones for the treatment of wastewater in gold placer mining and have shown that the use of hydrocyclones would also permit water reuse. Miners who are interested in learning more about this possibility are encouraged to contact the Mineral Industry Research Laboratory (M.I.R.L.) and review report No. 53. Cyclones which operate at a high head pressure require necessary pumps for the movement of feed through the devices and also for circulating purposes. In the absence of electric power, generator sets may be required as auxiliary equipment to run the motors, to drive the pumps, and to provide the required head pressure for hydrocyclones.

Recent work performed by the staff of M.I.R.L. and several graduate students, has shown the Compound Water Cyclone to be useful for the concentration of fine gold. The use of a cyclone proposed in the present context is for a standard configuration cyclone operated as a classification device for removal of clay sized particles. The economics of a classifying hydrocyclone are considered to be similar to that noted above for the centrifuge and filter processes.

## Combined Systems

A combination of one or more of the possible turbidity removal procedures briefly described previously, may be the most technically sound and economically feasi-

ble solution. Possible combinations might involve the use of a classifying hydrocyclone and the use of flocculants. Another possibility would be the use of a simple polymer flocculation in conjunction with settling ponds. The pretreatment of turbidity containing water in a settling pond and the final filtration of the pond effluent might be feasible. Other mixes and matches of equipment and procedures may be the least cost technically feasible solutions recommended for any particular site. These combinations would have to be considered and evaluated on a case by case basis.

## Summary and Conclusion

In conclusion there are a number of possible approaches, all of which have good technical support for their efficiency. For the removal of clay size particles from mining operations they rank in order of priority (in terms of economic practicality): 1) polishing ponds, 2) coagulants, 3) hydrocyclones, and 4) filters-centrifuges. These technically attainable procedures have been demonstrated to be effective in other mining situations. This assumes that at least as far as size consists, the turbidity causing elements of placer mining water are similar to those in other mining operations. The suggested techniques should be readily transferable and applicable to the Alaska situation. Each individual miner will need to consider how he would best be able to achieve required water quality. A system which has been used successfully in other mining circumstances in this country and abroad is to treat all mining effluents to a feeder stream in one treatment facility. The treated (specification quality) water is then discharged into a major stream. If arrangements could be made with state and federal authorities to approve this technique, then many miners, all operating on the same stream would only need to contribute to the cost and operation of a central treatment facility for the combined effluent into a given water shed. This enables each operator to realize the economies of large volume treatment and facilities and the expertise and technology available with a large central treatment facility. Such schemes have been used in this country in several locations, including the State of Pennsylvania, and in Europe, for example, with the Emschergergenossenschaft and Lippeverband.

Along similar lines a procedure, which involves operator cooperation, has also been practiced several places in the mining area of this country. This involves having all the miners in a given area or water shed contributing a fee to a common fund to secure services - engineering advice and know-how, which none of the individual operators could afford separately. Sometimes these arrangements are conducted through a formal 'cooperative' or sometimes through a regional or area miners association. The consultant or engineering firm hired could then provide the expertise and advice in order to design and operate treatment facilities. This would likely be better designed than one done individually, since the mine operator is most knowledgeable on mining and mineral processing but as a rule

does not have great expertise in water treatment. These suggestions are long run solutions rather than short run answers. A decision is necessary whether to operate alone with the best technology available or whether a group of nearby mine operators could combine their efforts in order to achieve required water quality standards. In the latter case, there is a history of acceptable and successful joint efforts, both insofar as it relates to engineering and to the co-treatment of mine discharges. A single utopian panacea solution which would achieve required turbidity specifications and simultaneously low and insignificant cost is not immediately apparent to the author. However, the technical approaches to turbidity reduction at placer mining sites is an open subject with many possible avenues pointing to the achievement of this goal.

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Following are listed a variety of suggested readings and references all of which pertain in one way or another to the technical achievement of turbidity reduction, to the definition of the problem, to the solution of these problems reached by others, or for appraisal of the capital and operating cost of such turbidity reduction procedures. Other readings and references on this widely studied subject are available from libraries of the U.S. Bureau of Mines, consultants, or the University of Alaska.

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## U.S. Geological Survey Alaskan Gold Project

John C. Antweiler, John Cathrall and Richard Tripp  
U.S. Geological Survey, Denver, Colorado

What are the precise details of the formation of gold placer deposits? Why do nuggets commonly occur on or near bedrock? Where and how might additional gold deposits – placer and lode – be found? In an attempt to answer these and other questions of interest to placer miners, the United States Geological Survey has begun a state-wide study of Alaskan gold deposits. This study should culminate in a synthesis of considerable new scientific information on the origin of placer deposits. The immediate goals of the study are to determine the relationship of gold in placer deposits to possible primary sources, to determine how nuggets form, to contribute to existing knowledge of principles for prospecting for placer deposits, and to determine if minerals associated with placer deposits might suggest important deposits of other metals.

The project started two years ago with a study of placer mines in the Brooks Range. The miners there provided samples of gold and associated heavy minerals from their sluice concentrates. These samples have been analyzed in the Survey laboratories, and miners have been informed of the results obtained on their samples. Gold of unusually high fineness was found in many deposits. Trace elements within the gold varied from one deposit to another. Arsenic was found frequently in gold from the Lake Chandalar area, but antimony was more abundant in samples from the Wiseman Quadrangle. Other elements of interest in some samples included zinc, cobalt, chromium, nickel, platinum, tin and

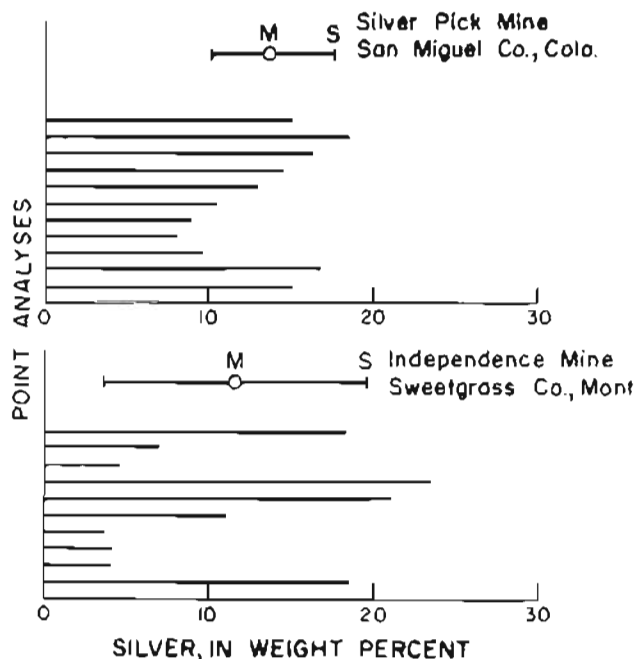


Figure 1. Electron microprobe analyses of lode gold from mines in Colorado and Montana showing point-to-point variation in silver content of different grains.

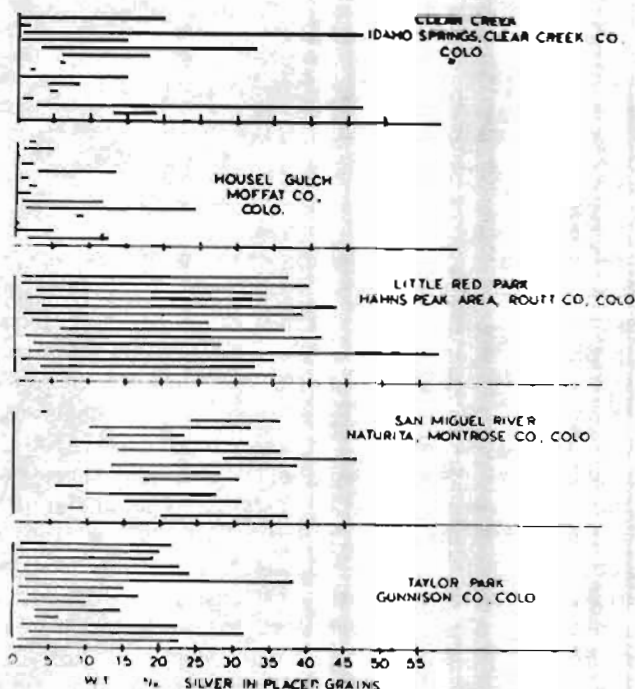


Figure 2. Electron microprobe analyses of placer gold from mines in Colorado showing variation and range of silver content of different grains.

### Gold Signatures from Gold Ore Deposits (2)

Location	%Au	%Ag	%Cu	Au/Ag	Au/Cu	Characteristic Trace Elements (in order of abundance)
Cable Mine, Mont. (Pyrometasomatic)	97.5	2.3	0.23	42.4	425	Bi, Pb, Te, Zn, Sb
King Solomon Mine, CO (contact Metamorphic)	89.1	10.9	0.056	8.3	1,600	Bi, Pb, Zn, Te
Round Mountain, NV (Epithermal)	75.5	24.4	0.0027	3.1	28,000	Pb, Sn, Sb, As
Dixie Mine, CO (supergene enrichment of Mesothermal veins)	80.7	19.2	0.0012	4.2	67,000	Pb

Figure 3. Signatures of gold from different types of hydrothermal deposits.

### Gold Signatures from Gold Ore Deposits (1)

Location	%Au	%Ag	%Cu	Au/Ag	Au/Cu	Characteristic Trace Elements (in order of abundance)
Diana Mine, WY (Hypothermal)	92.5	7.4	0.05	12.5	1,850	As, Bi, Ni, Pb
Little Jonny Mine, CO (Upper Mesothermal)	89.6	10.3	0.025	8.7	3,600	Bi, Pb
Seafoam Mine, ID (Lower Mesothermal)	77.6	22.3	0.0165	3.5	4,700	Pb, Bi, Sb
Hahns Peak, CO (Epithermal)	66.8	33.3	0.0017	2.0	40,000	Pb, Sb

Figure 4. Signatures of gold from hypothermal, mesothermal and epithermal deposits.

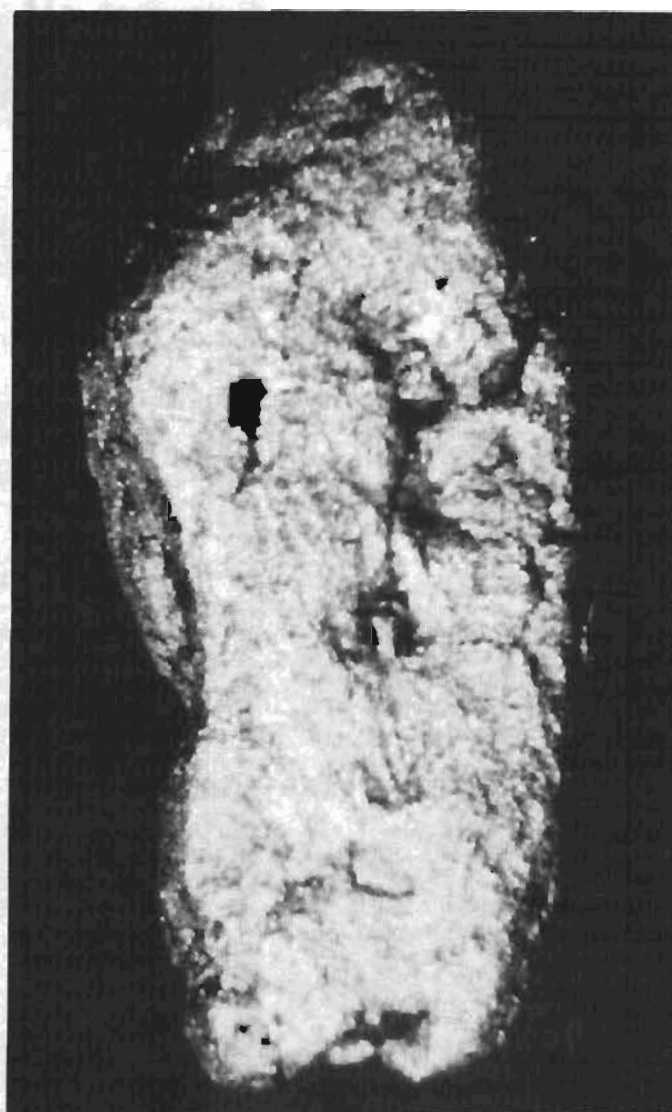


Figure 5. Typical, well-rounded nugget from a placer deposit in Montana.

tungsten. Mercury, copper and lead occurred in variable amounts in nearly all samples. In the mineral concentrates, several minerals, including cinnabar, galena, chalcopyrite, arsenopyrite, stibnite, scheelite and powellite may have implications of economic interest.

Nearly 300 individual compositional analyses (Mosier, 1975) were made on gold from about 50 mines and prospects. The natural variation in gold composition is so great that several analyses must be made to establish confidence that the data reflects the true composition of the gold. Gold of unusually high fineness (up to 980) occurs in the Koyukuk district, but its signature (proportions of gold, silver, copper and content of trace elements) does not fit patterns of compositional data for high fineness gold from deposits elsewhere (Antweiler and Campbell, 1982). Gold from the pyrometasomatic deposit at Cable, Montana, for example, or from the hypothermal deposits of the Atlantic City - South Pass district, Wyoming, contains considerably more copper than do the samples from the Brooks Range. Moreover, antimony and arsenic occur more frequently in the





Figure 6. Delicate crystalline gold from Sheep Creek, Koyukuk District. Magnification 8X. (Gold courtesy of Jules Wright.)

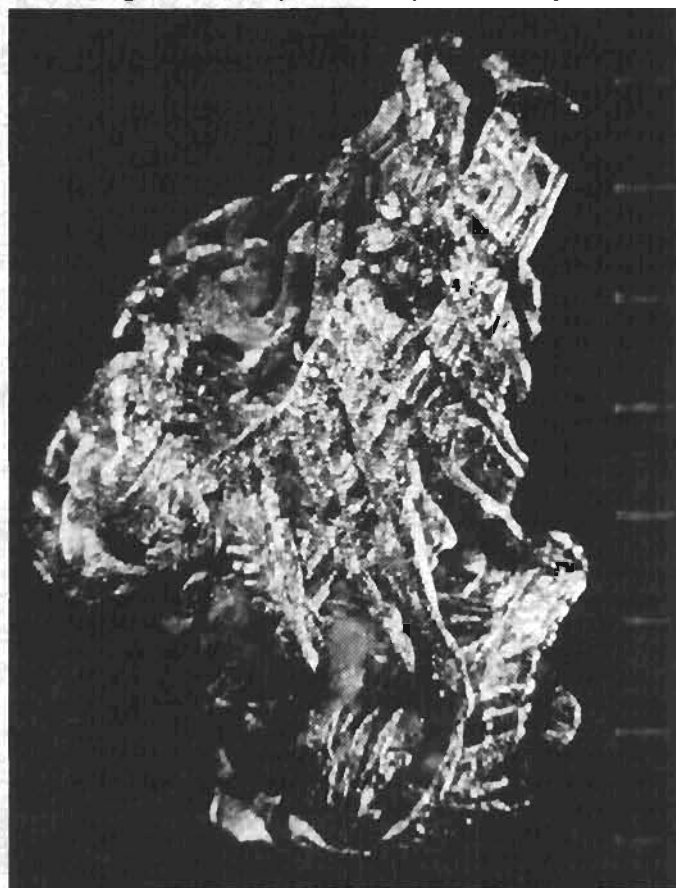


Figure 8. Very beautiful, delicate crystalline gold from Yellow Pup, Kantishna District. Magnification 6.4X. (Gold courtesy of Barry Donnellan.)



Figure 7. Colloform nugget showing little abrasion or wear, obtained from Sheep Creek, Koyukuk District. Magnification 8X. (Gold courtesy of Jules Wright.)

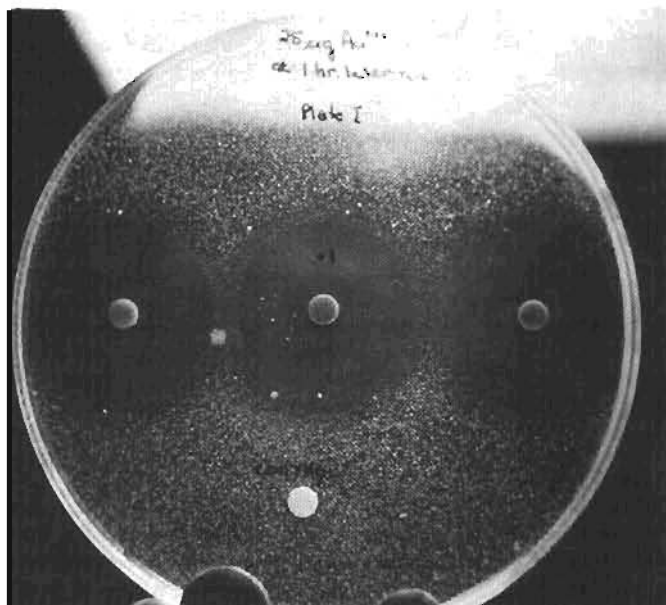


Figure 9. Gold chloride - impregnated cellulose discs immersed in solution containing colony-forming units of *Bacillus cereus*. Bacteria migrated to the discs, where their spores collected gold. Subsequently the spores were recovered and washed in ion-free water until free of gold chloride. (Experiment courtesy of John Watterson, U.S. Geological Survey.)

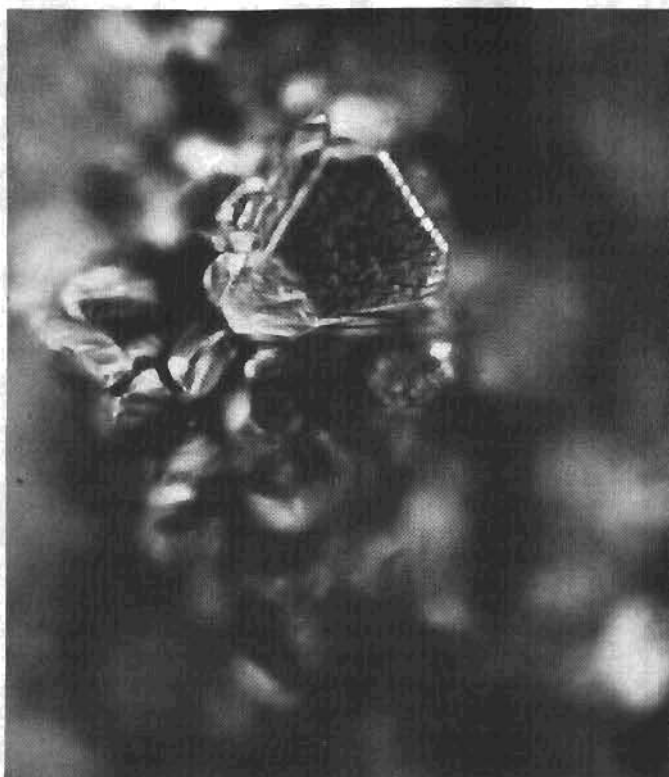


Figure 10. A crystal of gold on a strip of clean aluminum placed in a stream near Placerville, California. This gold crystal is similar to that in the preceding photograph, and suggests that gold in solution could have been precipitated by bacterial spores on the aluminum strip.

Brooks Range samples than in samples from Montana, Wyoming and Colorado.

The exteriors of placer gold grains commonly contain less silver than their interiors, as first noted by McConnell (1907). Either silver is removed by processes of oxidation and ground water leaching as grains travel from a lode to a placer deposit, or gold is precipitated from solution onto a detrital gold grain. Both processes evidently occur. We made compositional analyses on both the plus 35-mesh and minus 35-mesh fractions of gold from several placers. The plus 35-mesh fraction from some deposits contained smaller amounts of silver, copper and trace elements than did the minus 35-mesh fraction; thus, for those samples, higher purity gold most likely resulted from processes of gold accretion. For other deposits, smaller particle gold was of higher purity, thus suggesting that silver and trace elements were removed by leaching from the exterior of the grains by atmospheric and ground agents during transport and deposition in a placer deposit.

Analyses of water samples collected upstream from placer deposits showed they contain appreciable quantities of gold either in solution or in the colloidal state. The most notable of the samples so far analyzed was water percolating through a sulfide-rich zone in the Mikada lode in the Chandalar district, which contained 26 parts per trillion (ppt) gold. Elsewhere, the content of gold in waters ranged from less than 1 ppt to 20 ppt.

Finely disseminated gold which occurs in schists, veins, stringers and blebs in many Alaskan gold fields can be dissolved by several agents. These include cyanogenic compounds in organic materials, organic acids in the layer of humus-rich muskeg over permafrost and bedrock exposures, and sulfuric acid with traces of arsenic and antimony in pyrite-rich zones. In addition, various microbiological processes may contribute to the solubilization of gold.

Other recent work had suggested several promising avenues of research. Gold, although the noblest metal, is soluble under a wide combination of naturally occurring physical, chemical, biological and electrical conditions. For example humic and fulvic acids in the soil under tundra and above permafrost, particularly when concentrated by annual freezing cycles, not only dissolve basic rock minerals, but also gold. The high electromotive forces accompanying freeze-thaw cycles assist in the process as well. Some species of bacteria and microfungi are capable of solubilizing gold, and other species can precipitate gold from solution. Indeed, small nuggets of crystalline gold were produced in the Denver laboratory on spores of bacteria.

The U.S. Geological Survey is anxious to utilize the knowledge and experience of Alaskan miners in this project. An initial step is to obtain a small amount of gold (0.025 to 0.1 dwt, or about \$0.50 to \$2.00 worth of gold at \$400 per ounce) and associated black sand from active mining operations. In exchange for the gold and heavy minerals, the U.S. Geological Survey will determine the fineness of gold and the impurities and trace metals in the gold; and will also determine the minerals present in the heavy-minerals concentrate.

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## **Water Quality: Question and Answer Period**

*Jeff Burton, Chairman*

Dr. Maneval has presented an innovative idea of a common down stream settling pond. This idea has been presented before. One miner mentioned to me earlier today that the state should reconsider building the Rampart dam and have it serve as a settling pond for the whole upper Yukon drainage. It might flood the Yukon Flats, but it would certainly solve part of the problem.

We now have about 23 minutes for questions and answers. Again I encourage you all to give your name and affiliation and a one-issue, one-point question. There will be students at the corners of the auditorium with pads and pencils available so you can rephrase your questions. A number of questions have been submitted already and it's necessary that I read all questions over the P.A. system so that the people in the back can hear as well as be recorded for the transcription of the proceedings.

I've talked with many miners in the last few days about the water quality problems and specifically the EPA permit. Many miners have complained that recycling is required under the EPA permit yet recycling has not been proven as a viable technique. The first question has been submitted by Karl Hanneman, a miner in the Manley District. I know it addresses a question many miners have. First Karl wants to present two facts and then pose the question.

Fact No. 1 - The data collected by EPA during the 1983 season from the 7 high rate recycling mines show that 6 out of 7 mines sampled met the settleable solids standard of 0.7 milliliter per liter. But none of the 7 mines met the turbidity standard of 25 NTU. In fact, they range from 800 to 3400 NTU. These turbidity levels were as high, or higher, than those from mines which had only settling ponds.

Fact No. 2 - The results of a study done by EPA on the economic feasibility of proposed wastewater controls on the placer mining industry indicate in Appendix 2, page 28, that there is a direct economic loss to the industry of 26 million dollars if high rate recycling is imposed. Using the economic multiplier for mining, this would be a negative impact to the state's economy of over 76 million dollars.

Given the above facts No. 1, that water quality of the discharge from high rate recycled mines is not any better than that from settling ponds, and No. 2 imposing the high rate recycling would cause severe economic hardships, the question is: On what basis does EPA justify imposing high rate recycling on any segment of the industry? Would you care to answer that, Ernesta?

**Ernesta Barnes:**

I can't answer it because I can't verify the facts but I'll comment on his observations. It is difficult not having the material in front of me, but let me work from the bot-

tom up. The second part of the question was the economic burden to the State of Alaska and given the computed burden, on what basis do we justify the cost of recycling. I'm rephrasing the question. Our proposal was a proposal on which we hoped we would hear comments. Our economic analysis was prepared on the basis of data prepared by you. We need accurate economic data. We do not do anything particularly complicated or mysterious with your information. What we did to satisfy our federal requirement that the technology be affordable and achievable was to hypothesize about ore concentrations. In our workshops you verified that our guess about the ore concentrations was correct. But assuming ore concentrations, assuming different sluicing capacities, and assuming the cost of the equipment necessary to move that much dirt, we were able to generate theoretical cash requirements for mines operating at different levels of sluicing capacity. Based on the theoretical concentrations which in large part you verified to be correct, and based on the price of gold, it was not hard to estimate the revenue from different size mining operations. We knew what the ore concentrations were. We knew what the price of gold was. It's not hard to figure out how much equipment is required to move the dirt to get the gold, and therefore to figure out how much money should be left over after paying for that equipment. Based on those assumptions, the recycling equipment and the pumps should be achievable within the ranges we designated to be the larger mines. If we are wrong we need to know that. We need to know that our economic analysis was wrong if the ore is not present in the concentrations we assumed, or if you can't sell it at the price of gold in the free market, or if the equipment is costing you twice as much as we assumed. Whatever is true, we need to know the facts. It is not our responsibility to look at gross economic impact, it is our responsibility to look at net economic impact. Therefore I distinguish between the total cost to Alaska of supporting recycling and the individual burden on each of you. If in fact our regulations are not economically affordable by a hypothetical mine, then we should not impose them. But nothing we have presented to you to date, will prove that our economic analysis is wrong.

The first part of the question had to do with the questioner's given fact that evidence showed recycling operations resulted in turbidity ranges which exceeded those of settling ponds. I can neither verify nor deny that, and I'm looking at Ron Kreizenbeck and Bub Laiselle, my two staff members who are here. Do either one of you want to come up and comment on that or shall we ask for five minutes to figure out what it is he's referring to?

**Ron Kreizenbeck:**

Well I'm not sure exactly what it is he's referring to.

**Jeff Burton:**

I believe his point was that the effluent from operations using recycling was essentially the same quality as operations that were using just settling ponds. Carl's question is, with the economic burden placed on the in-



dustry from recycling, why was recycling required if it does not improve water quality?

**Ron Kreizenbeck:**

I don't think I have a good answer for that.

**Ernesta Barnes:**

The recycling alternative is chosen with the allowance for the inevitable linkage in what I guess we're calling blow down. Recycling should achieve the lowest effluent into the stream. Again if our data is wrong, the people who can prove it are you. What I suggest is that Karl Hanneman confer with Bub and/or Ron for a few minutes before I leave the stage. I'm not trying to slip the question, I just don't understand the form of the question. Bub is sitting in the middle of the room and if the questioner would see him and clarify exactly where either I'm confused or the questioner is, then we can answer this a little better.

**Jeff Burton:**

Thank you. We have a question for Dr. Nevè concerning the reclassification process. It's from Rose Rybachek who's the President of the Tolovana Mining district. She would like to know why the reclassification process has been stopped and under what regulatory and statutory authority?

**Dr. Nevè:**

As far as the state is concerned, we have not stopped the reclassification process. I reclassified Nolan Creek and I was over ridden in recent decisions by EPA. I feel the position of EPA is that any reclassification action I take is likely to be overridden. I'm assuming, and perhaps Randy Bayliss or John Reeves can help me, that the authority to stop stream reclassification lies within the Clean Water Act.

**Jeff Burton:**

Thank you. We have another question for Ernesta Barnes from Roger Burgraff, a miner in the Fairbanks District. It is Roger's understanding that the #309 administrative order can be obtained to allow individual placer miners to operate during the next two years in violation of the NPDES Permit conditions, provided settling ponds are included and a reasonable effort is made to obtain best available technology. The question is can the #309 order be requested before the final NPDES Permits are issued on June 1, 1984? Most miners will be in the field by June.

**Ernesta Barnes:**

The #309 order, just to clarify what it is, doesn't allow you to operate in violation of your permit. It allows you to operate in compliance with your permit over a period of time. It is what we call prosecutorial discretion. The #309 order gives us an opportunity to give you time to come into compliance so that you are operating legally. I know many of you will be moving into the field by June, when our final permits will be issued. By the end of the public hearing period, it will be obvious to almost all of you what the terms of the final permit will be. In order

to apply for a #309 order or for us to give you one, we need to hear specifically from you, exactly with what provisions in the permit you cannot comply and how long it will take you to be able to comply with them. Some of those terms you know already, and some you can guess. So the answer is yes, you can begin your preparation and you can probably have your material complete and available to us before you leave town. Bub Laiselle will be stationed in the federal building within two weeks. As soon as he has a phone connected, we'll try to get the word out however we can to you. I suggest you see him and talk with him if you're going to apply for a #309 order.

**Jeff Burton:**

Thank you and I concur with that encouragement. The time to start is now, because we are fast approaching the field season.

I have a question for Dr. Nevè from Barbara Truit of the Midnight Dream Assoc. Why does the Dept. of Environmental Conservation insist that 25 NTU harms aquatic life when the EPA green book says that adverse effects begins only at 100,000 NTU's?

**Dr. Nevè:**

I think there's some misinformation here. The facts that I have are that 25 NTU's disrupt aquatic activity. 100,000 NTU is a difference by comparison that is way out of context. I don't think that figure is correct at all.

**Jeff Burton:**

If I can address the question for a minute, I believe that aquatic habitat effects start at lower NTU levels than the fish effects. The fish can live with the higher turbidity levels whereas the algae and the benthic invertebrates cannot. I believe that is the difference between the numbers.

**Dr. Nevè:**

That's correct. Fish will migrate away from high turbidity but the aquatic life is not as mobile as the fish. Some of it does move, by drifting. You have fiber plankton in the water which will drift depending on current movement.

**Jeff Burton:**

Thank you. I have another for Ernesta Barnes. We can see who the popular people are today. The question is from Helen Warner, a miner on Porcupine Creek.

The question is, have OMB and EPA done a cost benefit study on the cost of enforcement of the water quality standards for the Alaskan placer mining industry?

**Ernesta Barnes:**

It's very expensive to enforce anything in Alaska. The helicopter rental rates are very high. No, we do not do a cost benefit study on enforcing any of our laws. It is our mission to enforce them equally whether it be the steel industry or the mining industry or the paper industry or any other. We would choose not to have to enforce a wide percentage of any industrial community. It is our



experience that in most other parts of the country, if we enforce aggressively against the obvious violators, a fairly high percentage of the industry will voluntarily comply and we do not have to involve ourselves in massive enforcement actions. I suspect that will be the case in Alaska also. Our targets for enforcement are people who willfully, intentionally, and blatantly do not even attempt to comply with the law and that is where we will begin next summer.

**Jeff Burton:**

Thank you. I have another question for Dr. Nevè from Jim Smith, student here at the University of Alaska.

Turbidity is the major problem miners face and the major objection to turbidity is the deterioration of algae and insect population in streams. Has any work been done on rejuvenation of algae-insect population after discharge of turbid water into the affected stream?

**Dr. Nevè:**

I don't know of any. John, Randy, do you know of any studies? No.

**Jeff Burton:**

I think that addresses a very important point. Scientific data is clear that turbidity does have an impact on aquatic habitat. But the question is the duration of that impact. Does it last just until the cessation of mining or does it last for many decades afterwards? I believe the record shows that there are rivers such as the Salcha, dredged many years ago, which now support high fish populations. So this is an area that may well deserve a detailed scientific study.

The next question is for Ernesta Barnes. It's from Larry Wilmar, a miner.

History has shown that fish from silty water has been a food source for miners. If we use flocculants or coagulants, recommended by the chemical industry to settle out particles in the water, is there evidence to verify that the miner may still eat the fish without harmful side effects?

**Ernesta Barnes:**

I don't think the question deserves an answer.

**Jeff Burton:**

I'm not so sure that it doesn't. What is the environmental impact of these flocculants and coagulants? If excessive amounts are required, there could very well be a severe impact to the environment.

**Ernesta Barnes:**

If they are carcinogenic we won't recommend that they be used.

**Jeff Burton:**

Dr. Maneval would you like to respond to this question?

**Dr. Maneval:**

I'd like to make a note about one of the flocculants that I mentioned. We all know starch isn't harmful to human

life and it's a widely used coagulant. One of the more modern ones, recommended by the U.S. Bureau of Mines, is polyethylene oxide. Excruciating testing with the Food and Drug Administration has shown it is not harmful.

**Jeff Burton:**

Thank you, Dr. Maneval.

**Dr. Nevè:**

May I make a comment. Some of these coagulants in question need Food and Drug Administration impact statements. If it's an edible material then the U.S. Food and Drug Administration has direct oversight. The bottom line again is that many of these things need some research efforts to investigate their effects. It's an expensive program.

**Jeff Burton:**

Thank you. Is Earl Beistline in the audience? Would you like to come forward please? Karl have you received a response to your question?

**Ernesta Barnes:**

Do you gentlemen wish to come forward or have you agreed upon an answer?

**Karl Hanneman:**

We've agreed. We disagree, but we do agree on some things.

**Ernesta Barnes:**

Interested persons can group around them when this is over and find out what they've agreed to.

**Ron Kreizenbeck:**

It is impossible to get a detailed analysis at this hearing. My only . . .  
(the balance of his statement was inaudible)

**Ernesta Barnes:**

What he said is that the data is supportable and apparently comes from our site investigations. If Karl will present this on the public record then we can use it. Thank you.

**Jeff Burton:**

Thank you. It's 4:15 p.m. now and I'd like to turn the program over to Earl Beistline, the President of the Alaska Miners Association. The speakers may step down from the panel. I'd like to thank all the speakers for attending, particularly those who have attended from out of state.

## Conference Summary

Earl H. Beistline

President, Alaska Miners Association

A detailed conference summary is impossible because of time restraints. In the final analysis, each of you will summarize the conference in your own mind. Thus, each individual will have his or her appraisal of the success of the Sixth Annual Placer Mining Conference in meeting their desires for:

- Receiving technical information.
- Viewing new equipment and supplies.
- Having the opportunity to discuss matters of common interest with fellow miners and others.
- Become informed on current and proposed regulations and laws.

Consequently, my summary remarks are general. However, I do have some comments on points brought out during the conference.

1. As of noon today, conference statistics for the 1984 conference compared to the 1983 conference are:

	1984	1983
Registrants	560	450
Exhibits	55	28

This year, a number of individuals and companies had requested booths for exhibits but space was just not available.

2. The technical papers presented were excellent and covered all facets of placer mining:

- Placer Geology
- Exploration
- Mining Methods
- Recovery Units
- Government Regulations
- Education

Speakers formed a composite international and national group with many coming from excellent backgrounds in Alaska placer mining and having considerable placer mining experience. Topics were:

- Historical in nature
- Current operations
- Proposed Operations
- Surface and Sub-surface

Creative and innovative ideas were expressed and offer a challenge to people in the audience to pursue various facets of interest.

3. Education - Mining, minerals and me program.

The program is being prepared for elementary school classes for the purpose of having our young generation become familiar with the importance and economic value of minerals to the state and nation. The Alaska Miners Association is the initial sponsor of the program. Currently, a fund raising drive is underway to support the program.

4. All members of the congressional delegation have indicated their interest and action to solve the problems now confronting the placer industry - letters from Don Young, Frank Murkowski, and Ted Stevens.

5. On Tuesday afternoon, the board of directors of the Alaska Miners Association held a meeting to conduct essential business and clear up some essential routine matters in furthering the efficiency of the operation. Much time was used to further refine the organizational structure of the statewide association and to allow more effective cooperation and coordination with other groups. Thus, statewide and branch committees will be working to carry out the assigned responsibilities of their particular areas.

A formula that I visualize stating objectives of the Association is: Accomplishment of Association Objectives = C<sup>3</sup>VS

C = Communication

Coordination

Cooperation

V = Speak with one voice

S = Service to the industry and its members

6. Most satisfying is the number of mineral organizations that have conducted business during the conference period. Certainly this type of action is conducive to the various groups working in harmony.

An outstanding presentation made at the Wednesday evening conference banquet was by Dr. Wood who spoke on "Mining in Alaska Today."

His sound, creative, forward-looking thoughts point to a direction that the mineral industry could well follow to better our days in the future.

"In any game requiring wit and skill, it pays to learn the fundamentals, master them, and use them consistently when the stress is greatest. For the mineral industry game in Alaska, look at these three: 1) from time immemorial the two basic sources of new wealth for mankind have been, and are, agriculture and mining: (The button given me yesterday reads, 'if it can't be grown, it has to be mined'). 2) Unused or underutilized resources - people, renewables, and non-renewables - inevitably deteriorate, ultimately to the point where they cannot be afforded by any people, tribe, community, state, or nation; (this was originally referred to in manpower studies as 'the theory of idle resources') and 3) To see one's self as a victim leads to deeper frustration, but to perceive one's self as a part of the problem can be the wellspring of hope. (Perhaps Pogo summed up today's situation for the Alaska Mining fraternity in the comment, 'We have met the enemy, and they is us').

And then Dr. Wood stated, "The consumer of products directly and indirectly dependent upon the Mineral Industry of course, is everybody, everyday in a thousand ways."

Dr. Wood also referred to the political implications of voting strength where the mineral industry is 1/2 per-

cent or less, the tip at the very bottom of the structure. This analysis led him to say,

"As President Heinze, President of Arco Alaska and others have advocated, it's time to build a coalition. In the process, let there be no fighting within the mining fraternity, no matter how independent anyone may claim to be. This is an interdependent world, inescapably so in the worldwide mineral industry."

This same thought was studied by Mayor Bill Allen of the Fairbanks North Star Borough in his conference welcome statement, "Form a coalition." Similar expressions have been made by the Resource Development Council of Alaska. Informal discussion with other natural resource groups point to the desirability of all concerned.

Mayor Allen in a brief discussion after his welcome statement stated the desirability of having an appropriate meeting of resource persons in Fairbanks to initiate such a program. Senator Stevens has indicated a similar approach.

What is the purpose of a coalition composed of representatives from diversified resource areas? First of all, a coalition will bring together a group of people who have a common objective--that of developing resources for the good of the community, the state and the nation. By initially having a rather small group of representatives from each area sitting down together, identifying restraints and then using these as a basis for common action will provide a true direction for accomplishing objectives. In addition, there is the possibility that new ideas will be forthcoming by viewing what others are doing, even though it may not seem appropriate at the time to a particular area.

Dr. Wood also stated, "There is no quick and easy way out of the tunnel, but there are leads to follow in seeking the sunlight of a new day for Alaska's mineral industry. Take a step or two today that will make a difference tomorrow."

Through Pete Nelson, Vice President of the Alaska Miners Association, I am asking our executive director, Jim Jinks, to move toward setting up a coordination meeting with groups in the near future, working toward developing an appropriate resource coalition. This, of course, first involves contacting units and explaining the idea and then following through with appropriate action.

By way of conclusion, I remind you of the short courses that will be held tomorrow and Saturday. Again, the sponsors of the conference express our thanks to all who have worked so diligently with dedication to make this conference most successful. And to each of you, the conference participants, thanks for coming and best wishes for a stimulating and successful 1984 mining season.