RECLAMATION RESEARCH AT A MINE SITE IN NORTH COASTAL BRITISH COLUMBIA - A FIVE-YEAR PROGRESS REPORT [1/]

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The Mine and Townsite

Kitsault Molybdenum Mine is an open pit mine situated on the north coast of British Columbia near the Alaska border, about 100 miles northeast of Prince Rupert, at latitude 50°25' N., longitude 129° 25' W. at the head of Alice Arm, a small fiord off Observatory Inlet.

This is a remote wilderness location, more than 600 air miles from Vancouver and the only access is by amphibious aircraft or weekly coastal boat. The pit itself is located five miles from tidewater in rugged, mountainous country at an elevation of 2,500 feet. When the mine was in production, a townsite at tidewater housed approximately 500 people. This isolated community was self-contained and well developed with a four-room school and kindergarten, a resident doctor and nurse, a well-serviced store and a bank. A community centre, complete with four sheets of curling ice, bowling alleys, theatre, library and lounges provided recreational facilities.

The mine was in production from 1967 to 1972 when falling molybdenum prices led to closure. It will be reopened when economic conditions permit. Meanwhile, the sole residents are a caretaker and his family and occasional work crews.

Mining was by standard open-pit methods with a thirty-five foot bench height. Ore-bearing rock was trucked to a primary crusher at the mine site and the rock dump was alongside the pit.

On completion of mining the pit was projected as being 500 feet deep with an area of 280 acres, the projected waste dump of 80 million tons of coarsely broken rock was to cover 600 acres; additional is the area occupied by the mine plant.

The Environment

The terrain is the usual rugged topography of coastal British Columbia with mountain peaks to over 4,000 feet elevation. Two creeks drain the mine area, flowing through almost vertical canyons. A five-mile road from

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the townsite provides access to the mine. Previously, access was by helicopter only, or a full day on foot by an experienced man.

The climate is typically coastal with high precipitation, well distributed throughout the year, including 120 inches of snow in the pit area. Usually there is more than 3 inches minimum precipitation each month; winter temperatures occasionally drop to 30° F. Growing seasons are short and extremely variable. In two of the five years that the mine has been under observation there has been intermittent snow fall at the mine site as late as July. Along the Inlet, snow has lain in sheltered places down to 500 feet at the beginning of August. The typical Kitsault day is misty, wet or snowy, but on clear days the scene is one of unsurpassed beauty.

Because of inaccessibility there has been no logging in the area except in the immediate foreshore and tidewater area. Tree cover is principally hemlock and amabilis fir. These stands are degenerate. Trees are grossly over-mature with many dead snags. The bulk of the timber is unsound.

There is very little wildlife in the immediate mine area because of the unfavourable terrain. Large mammals are few, with the notable exception of black bear. The occasional wolf has been seen. There are seasonal waterfowl on the tidal flats and a salmon run that brings commercial fish boats into the Arm. Seals and killer whales follow the salmon.

Reclamation Requirements

It is insufficient for reclamation concern to be directed only to the pit area - it must encompass the whole site.

There are four areas of environmental concern:

1 - the development of Kitsault townsite and its treatment after abandonment;

2 - the disposal of tailings;

3 - the treatment of the minesite and roads;

4 - the treatment of the waste dumps.

Initial proposals were based on dependence on natural processes. This was justified on the basis of the remote and inaccessible nature of the mine. These proposals were not acceptable to government and a revegetation program was required under the provincial reclamation regulations. However, the period of disuse has allowed valuable observations to be made regarding natural revegetation possibilities and it is clear that considerable areas of disturbance will revegetate naturally.

A two-phase reclamation strategy has been adopted. One phase is to determine the extent to which natural revegetation can be reasonably expected to succeed in the northwest coast environment, the other is directed toward increasing knowledge of artificial reclamation.

Early denudation along Observatory Inlet

Twenty miles from Kitsault there is the site of a once flourishing community, Anyox. To a previous generation Anyox was a town of 2,700 people with a thriving community life, an underground mine and the largest copper smelter in the British Empire.

All that survives are a few charred remnants where dwellings once stood, a drinking fountain in the midst of the bush, fire hydrants, a number of concrete shells that once housed the concentrator and smelter, two large chimneys, a cemetery and a hole in the side of the mountain.

Anyox contributed materially to the economic prosperity of British Columbia. During the operation of the smelter from 1914 to 1935, 140,000 ounces of gold, 8 million ounces of silver and 700 million pounds of copper were produced. But the operation left its mark along many miles of the upper reaches of Observatory Inlet. Gross atmospheric pollution resulted in extensive areas of fume-killed timber all along the Inlet during the 1920s and 1930s. Effects were felt for a distance of sixty miles while trees were reported killed for twenty-five miles. One hundred and twenty-seven million board feet of timber was killed; additional were immature timber and trees below the merchantable sizes of that time.

Subsequently, at least four fires through the fume-killed timber completed the destruction along Observatory Inlet and destroyed Anyox itself.

Thus the process of natural revegetation has been subjected to a most severe test. Probably no area on the Pacific Coast has been subjected to such harsh treatment.

The area immediately adjacent to the smelter was by far the most severely damaged. Recovery here has been slow but is progressing. The townside has been occupied by willows, alder and hemlock, but the smelter waste and other toxic deposits remain bare. Further from Anyox, but still in the fume-affected region, a new forest has developed under the snags of the killed timber.

To provide information of reclamation potential at Kitsault, an ecological study has been made of the Anyox denudation and recovery. This has been reported in detail in a Ph.D. dissertation by Errington (1975).

The Town Site

Regrettably,when Kitsault townsite was established, all vegetation was stripped from the site. The stark appearance of the bare slopes contrasted with the grandeur of the surrounding scene of fiord, ice fields and tree-covered mountain sides.

Considerable effort has been expended in making good this ill-considered clearance. Residents developed their house surrounds. Under the impetus of the reclamation program, plans for landscaping were prepared and a gardener employed. Soil was hauled in to cover exposed gravel ridges, advice was sought as to suitable trees and shrubs for ornamental planting and raw banks fertilised, seeded to grass and/or planted to trees. Ornamental flower beds were planted. Although there is little horticultural knowledge or experience relating to north coast conditions, by the time the mine closed the raw appearance was much ameliorated. In a very few years Kitsault would have been a well-established, attractive township with a stable community that would have done much to reduce the problems of high labour turnover that is a major difficulty in such northern mines.

With the closure of the mine, the people moved out. Seeded slopes and natural regrowth of alder and willows have benefitted from the absence of human pressure. A considerable amount of tree planting, particularly of lodgepole pine, was done during the last months before closure and these trees are now well established with good colour and growth and strong leading shoots. Re-invasion of, particularly alder, but also willow and western hemlock, has been significant. Thickets of alder eight to ten feet tall have developed on bare areas within the townsite and individual saplings are growing in houseyards and along roadsides. Growth is rapid. In the absence of human intervention it seems clear that the townsite will rapidly revert to its prior forested condition. When the mine is re-opened, considerate handling will allow the rapid development of an attractive community.

The Kitsault case indicates that the barrenness characteristic of many such wilderness mines need not be.

On final closure, minimal treatment to speed up natural processes only will be necessary to reclaim the townsite.

Tailings Disposal

During the operation of the mine, spent crushed rock, or tailings, were discharged into a creek at the minesite and thence into Alice Arm. The creek ran white and the discharge coloured the inlet for a distance of several miles. Shoreline marine life disappeared and the mud flats at the head of the Arm were barren. There were indications of adverse effects on the salmon run.

With the closure of the mine, discharge of tailings ceased. Recovery has been rapid. The creekbed was flushed clean by the first spring run-off. Tidal action has rehabilitated the shore line and mud flats. Within one season, large numbers of small barnacles and sea wrack colonized the previously bare rocks at the entrance to the creek. The tidal flats are green with marine weed and tidal marine life is plentiful.

It is unlikely that the previous surface discharge will be permitted when the mine is brought back into production.

The Mine Site

The mine itself cannot be seen from the shore of the inlet or, indeed, from any vantage point other than the surrounding inaccessible mountain peaks.

Because of the nature of the mine, which must progressively increase in circumference as it increases in depth, progressive reclamation is impossible. The pit in its final configuration will comprise a series of rock terraces, extending to the pit bottom, with a core of untouched rock forming an island in the centre of the pit. The final appearance may be likened to a huge amphitheatre with a central hub and terraces ascending the mountain on the upper side.

On completion of mining, proposals are to divert a small watercourse to flood the workings, thus forming a lake. The walls that will remain above the surface of the water cannot be revegetated artificially. They will consist of natural rock surfaces and, especially in the case of the walls, are unlikely to provide a suitable media for planting or seeding. Under the extremely humid conditions some natural growth may establish itself in the rock fissures. On the terraces, ripping should allow a suitable medium for plant growth. An alternative will be to blow the walls to destroy the mine configuration and bring detritus down onto the terraces.

The access road is unlikely to long remain open once maintenance ceases. Indications are that there will be invasion of hemlock and alder. These are prolific on roadsides and fill slopes, particularly on the lower portion of the road.

The Waste Dumps

Natural Revegetation

It is hoped that under the humid coastal conditions natural processes may provide for revegetation over considerable portions of the dumps. Colonization of natural rock slides also provides evidence in support. The question may well be determined by the length of time that we are prepared to wait upon natural processes in such remote situations and the extent to which the slopes

are left at the biological rather than the physical angle of repose. Long-term ecological studies are intended to clarify the probable course of succession and provide some indication of the time sequence.

In 1970, while the mine was still in production, a level area of freshly tipped waste rock 100 x 200 feet was reserved for long-term study. Observations are made at intervals. After five years progress has been slight. One plant of rye grass, Lolium perenne, appeared in 1972 and remains today. Subsequently, one patch of moss originating from bear faeces has extended to about eighteen inches. During summer, 1975, a single stem of fireweed, Epilobium, and a small group of Rubus spp. seedlings forming a 9-inch diameter circle, also originating from bear faeces, were noted.

In other parts of the mine site naturally seeded plants are appearing. These plants are still few in number, but the significance of slope is becoming apparent. Speculating, it may be that revegetation of slopes may be more easily obtained through slope modification alone than through attempts at artificial establishment of vegetation on steep unmodified banks.

Despite the absence of plants, interesting observations can be made on the rate of weathering and breakdown of the waste rock. A clear relationship is apparent between the physical condition of the rooting medium and revegetation -- the finer the "soil" the more likelihood of natural invasion. It has also been found that the superficial surface layer, apparently unchanged other than the breakdown of pieces of shale, often comprises a thin surface pavement little thicker than one layer of rock fragments with disintegrating material below.

1970 Seeding Trials

These trials comprise 400 sub-plots on a level 200 x 100-foot area of spoil. Seed, fertiliser and muskeg peat applications were made in late July, 1970. There are four site treatments that each received seven seed mixtures comprising 25 different grass and legume varieties.

Treatments

Treatment A - Broken unweathered rock, as dumped from the pit, levelled.

Treatment B - Broken unweathered rock, as dumped from the pit, levelled. 13-6-10 (N.P.K.) commercial fertilizer at 500 lbs./acre.

Treatment C - Broken unweathered rock, as dumped from the pit, levelled. Muskeg peat spread uniformly at 6 cubic feet/40 square feet.

Treatment D - Broken unweathered rock, as dumped from the pit, levelled. Muskeg peat spread uniformly at 6 cubic feet/40 square feet. 13-6-10 (N.P.K.) commercial fertilizer at 500 lbs./acre.

Seed Mixtures

Mixture #1:
30% Perennial rye grass
20% Creeping red fescue
20% Chewing's fescue
20% Poa trivialis
5% Red top
5% White Dutch clover - - - - - - - Sowing rate 71 lbs/1000 sq.ft.

Mixture #2:
20% Annual rye grass
25% Creeping red fescue
20% Chewing's fescue
15% Kentucky bluegrass
15% Canada bluegrass
5% Highland bent - - - - - - - Sowing rate 71 lbs/1000 sq.ft.

Mixture #3:
20% Double cut red clover
18% Alsike clover
15% New Zealand perennial rye grass
10% Climax timothy
5% H 1 rye grass
10% Tall fescue
5% Red top
12% U.S. perennial rye grass
5% New Zealand wild white clover- - Sowing rate 100 lbs/acre

Mixture #4: Reed canary grass

Mixture #5: Legume mixture - 50% Sainfoin
50% Birdsfoot trefoil

Mixture #6:
30% Timothy
20% Perennial rye grass
30% Meadow fescue
10% Red top
10% Alsike clover

Mixture #7:
33.3% Spring rye
33.3% Barley
33.3% Winter vetch

All legumes were double inoculated. Observations have been made at

intervals since establishment. There have been no subsequent fertilizer applications or other treatment.

Distinct differences are apparent between seeds mixtures in speed of establishment, survival and total leaf production.

It has been shown that commercial grass mixtures can be grown on unweathered fragmented rock, with the addition of fertilizer or organic material. Fertilizer and peat applications, when applied separately, result in a significantly better plant cover, but in combination are poorly productive. Organic material or "soil" is not an essential concomitant for successful seeding. The annuals, rye, barley and winter vetch perform well in the first year but are not self-seeding. Mixtures containing legumes perform significantly better than do grasses alone. With heavy-leafed grasses and legumes, an appreciable accumulation of organic material can occur after the first year with a full stand of grass and an organic mat over large rocks and complete cover of bare surfaces after the second season. A most significant observation is the contribution that the clovers, particularly birdsfoot trefoil, after a slow start, have made to the grass stands.

1974 Observations

Treatment A - Broken rock, no additives. Vegetative cover minimal, visually estimated between 1-5% cover. Creeping red fescue and red top have established and persisted, but sparsely.

Treatment B - Broken rock, plus fertilizer. Mixtures #3 and #5 excellent and Mixture #1 good, with full sward and build-up of organic layer. The main species are creeping red fescue, red top, timothy, orchard grass, blue grass, alsike clover, red clover, white clover, birdsfoot trefoil and a lesser proportion of sainfoin. In Mixture #3 there is an estimated 60% grass and 40% clover cover.

Treatment C - Broken rock, plus peat. Mixtures #1 and #5 excellent and Mixture #6 good, with full sward and organic build-up. Mixture #6 has been invaded by other species and is strong to timothy, creeping red fescue and red top. Mixture #1 is excellent as to grasses, with creeping red fescue, red top and white clover predominant, but the clover is in very small percentage. Mixture #5 is very vigorous and strong, particularly birdsfoot trefoil. Sainfoin observed.

Treatment D - Broken rock, plus peat and fertilizer. Very poor growth and generally poor. It would appear that some interaction between the peat and the fertilizer has resulted in the immobilization of the fertilizer.

Some invasion of alsike clover, white clover, birdsfoot trefoil, timothy, orchard grass and Canada blue grass has occurred in small areas one foot in diameter where trees have been planted and failed. The invading grasses have found favourable seed beds in the rocky "tilth" resulting from filling of planting holes with finer rock fragments.

Other species noted but not mentioned above because they were not dominantly strong are reed canary grass and perennial rye grass. A single plant of alfalfa was found and it looked extremely healthy and vigorous. This plant probably originated as a crop contaminant in the seed mixture, but is certainly a species worthy of record.

Observations made in August, 1975 show the relative success of individual treatment applications to be unchanged. However, the impression was obtained of an over-all reduction in vigour. It is understood that growth was slow in starting because of the late season. Certainly the grasses were poorly advanced compared to previous visits, with flowering not started in most instances. It may be that this adverse impression is merely the result of the vagaries of the northern climate, which present problems in making comparative annual assessments.

The seeded plots show significant development of moss between the rock fragments. This moss appears to be associated with the build-up of organic material. Naturally seeded hemlock germinants are now appearing in the moss. Speculating, it might well be that the long-term benefits of the treatments will result less from the establishment of a grass sward that may or may not be permanent, but from the provision of conditions that allow reversion to an early natural successional stage of vegetation establishment.

1975 Seeding Trials

The initial trials were on level ground. In August, 1975 two series of grass/legume trials were set out on waste rock slopes within the dump area.

The slopes were of coarse rock fragments, as dumped, and at the natural angle of repose.

The following seed mixtures were applied:

Mixture A -	Grass species	- red top creeping red fescue timothy Canada blue grass, orchard grass, tetraploid perennial rye grass.	In equal proportion by weight. Rate of application, 50 lbs./acre.

Mixture B - Legume species -	alfalfa birdsfoot trefoil sainfoin white clover alsike clover	In equal proportion by weight. Rate of application 75 lbs./acre.
Mixture C - Legume/grass mixture: (1)			
	10% red top 15% timothy 15% Canada blue grass 20% birdsfoot trefoil (inoculated) 25% sainfoin (inoculated) 15% alsike (inoculated)	Rate of application 75 lbs/acre.
Mixture D - Legume/grass mixture: (2)	15% tetraploid perennial rye, 15% orchard grass 10% alfalfa (inoculated) 20% white clover (inoculated) 20% cicer milk vetch (inoculated)	Rate of application 75 lbs/acre.

Ten plots,each 20 feet wide and running from top to bottom of the dump slopes,were laid out on southeast and northwest aspects. The southeast slope was 100 feet and the northwest 200 feet long. There was no modification of the surface. N.P.K. fertiliser was applied at a rate of 333 lbs./acre.

Slope stability

On both sites slopes are extremely unstable. The sheering effect of even slight surface movement can have a major influence on revegetation prospects. To obtain some indication whether there is surface movement, three paint bands, each fifteen feet long, were painted across the slopes alongside the seeded plots. Some indication of movement will be provided by any discontinuity in these bands.

Tree Planting

In October, 1970, Sitka spruce, western hemlock, amabilis fir and lodgepole pine were planted in the two-feet separation strips between the grass/legume plots. The trees were bare rooted 2 + 1 transplants. A pick was used to prepare planting holes, no soil was introduced and the trees were planted directly into the waste rock. Holes were filled with relatively smaller rock fragments from the immediate surface. A handful (approx. 2 oz.) of commercial 13-16-10 N.P.K. fertilizer was spread around each tree. Half of the trees died during the first year, probably consequent on poor supervision of unskilled planters and a subsequent dry summer.

An assessment in July 1974 showed that all species had survived

when planted carefully, but that lodgepole pine was by far the most vigorous, with good colour, growth and strong leading shoots; under all conditions it had performed best of the species tried. Hemlock was established; amabilis fir was, in the main, healthy, but had shown little growth; Sitka spruce was of very variable condition. But with the exception of lodgepole pine all species tended to be chlorotic and without vigour.

A strong interaction with the legumes was observed. All species showed enhanced vigour and good colour wherever trees were in proximity to seeded plots with strong clover components.

In contrast to the 1975 grass/legume assessment, a favorable change was noted in the performance of the tree species. As noted previously, only lodgepole pine had been vigorous and in good health. The other species were merely surviving with little or no growth and poor colour. In August of this year almost all the trees looked healthy, were of good colour and showed significant leader growth. It may be that after five years their root development is sufficient to bring them out of check. To date it can only be said that lodgepole pine has proved itself during the five-year period, is well established and growing vigorously, and that the desirability of growing it in association with nitrogen-fixing species has been established.

Conclusions

Reclamation and field scale rehabilitation at Kitsault is in the initial stages only, but useful insights have been obtained.

With the mine closure, the absence of operating personnel has limited the scale of the enquiry already begun, but the absence of human pressures has permitted the natural colonization of much bare ground.

Under the extreme conditions of the waste dumps the practicality of establishing a plant cover on level waste rock deposits has been demonstrated. It remains to be shown that equal success can be obtained on the steep slopes of these dumps.

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