Proceedings of the 5th Annual British Columbia Mine Reclamation Symposium in Cranbrook, BC, 1981.
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NATURAL REVEGETATION OF EXPLORATION TRENCHES IN THE STILLWATER COMPLEX OF THE BEARTOOTH MOUNTAINS, MONTANA

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ABSTRACT

In 1971 and 1972 Anaconda Copper Company reclaimed a series of mineral exploration trenches located in the Beartooth Mountains of Montana, Custer National Forest. The work was done following U.S. Forest Service prescriptions and resulted in backfilling the trenches and extensive seeding of exotic species of three grasses and one clover. From an examination of photographs taken 1971 to 1975 and subsequent site inspections, it is apparent that the initially high cover of exotic species has declined, and native plants from surrounding areas have begun to colonzie the reclaimed trenches. A study was conducted during 1979 to 1980 to identify those native species.

The trenches are located in the basal zones of the Stillwater Mineralized Complex at elevations ranging from 2,500 meters to 2,835 meters. Surrounding vegetation types include *Abies lasiocarpa-Pinus albicaulis/Vaccinium scoparium, Pinus albicaulis-Abies lasiocarpa, Pinus albicaulis,* and dry alpine.

Colonization on the trenches was found to be positively correlated with the surrounding undisturbed vegetation types. There was an assemblage of native species that were mainly restricted to colonizing trenches that extend into or through the dry alpine and timberline habitat types. There was another aggregate of species that were associated with the *Abies lasiocarpa-Pinus albicaulis/Vaccinium scoparium* habitat type. Successful colonizers which are locally abundant should be used as seed sources for subsequent reclamation of disturbances in the Complex and in other areas of similar habitat type. Further studies should be conducted to develop seeding recommendations for other habitat types throughout Montana.

INTRODUCTION

Disturbances due to mining can be environmentally damaging in any area, but in mountains the disruption is greatly increased. Mountainous areas with steep, unstable slopes, shallow soils, and high winds and precipitation are not only very susceptible to erosion, but the erosion rates after comparable disturbance are greater than in lowlands (Ives 1979).

Not just the aesthetic, recreational, wildlife habitat, grazing, and watershed values of the mountains suffer, but also areas of erosional deposition, far from the original disturbance, are affected (Brown et al 1976, Ives 1979). Some means of reclaiming these mining disturbances should be found to mitigate the loss of the inherent values of mountainous areas. In most cases, the establishment of plant cover is the primary means of reclaiming these disturbed areas (Brown and Johnston 1978).

When revegetating mining disturbances, the primary concern is plant establishment and survival with minimal maintenance (Kenny and Cuany 1978). This goal is already difficult to attain in the harsh environment of mining spoils, but the problem is compounded at high elevations where most of the commonly used, commercially available, non-native plants are close to, or beyond, the limits of their environmental tolerance. It has been shown that using adapted, native plants is the most effective way to meet this challenge (Monsen 1975, Brown et al 1976, Billings 1978, Brown and Johnston 1978, Wagner et al 1978). Native plants that are best adapted for revegetation, are those pioneer species that are most active in colonizing the disturbed areas (Brown et al 1976, Billings 1978, Brown and Johnston 1978). Planting these pioneer species should then increase the rate of subsequent natural succession by a process referred to as "nucleation" (Yarranton and Morrison 1974). These pioneer, or "nuclei", species act as centres of propagule dispersion, and succession proceeds as an increase in size of these patches of persistent species until they coalesce to form a more continuous vegetative cover. Environmental modification resulting from this cover then promotes further succession toward a climax vegetation. This is essentially what is meant by the term "natural revegetation". Revegetating an area consistent with, and thereby speeding up, natural succession.

Gates (1962) conducted one of the early studies on high altitude revegetation in Idaho. His first seeding attempts were made using commercially available, non-native grasses, and mulches of sawdust and conifer boughs. Despite an excellent initial establishment, nearly all seedlings had succumbed to the rigorous environment by the middle of the second growing season. Further seeding attempts were made using a mulch made from native hay, containing viable seed, that was cut from surrounding areas. Again, initial establishment of grasses was good, but by the end of the growing season, nearly all introduced grasses were dead and only native grasses from the seed in the mulch had survived. These native grasses not only survived, but "...appeared to be well established and thriving." In addition, other native plants from the surrounding vicinity had begun to colonize the mulched plots. Gates concluded that "...the native species appear to be much better adapted to the environmental extremes of the site and become established where exotic species fail."

Brown et al (1976) conducted revegetation studies at the McClaren mine on the Beartooth Plateau, using both native colonizers and commercial seed mixtures. At the end of the first growing season introduced grasses were taller, had higher production levels, and generally were more vigorous than native grasses. However, by the end of the third growing season the productivity and vigor of the introduced grasses had declined. The native grasses were much more vigorous, had greater productivity, and had even begun to invade plantings of introduced grasses. When transplanting native and introduced grasses in the same area, Brown and Johnston (1978) found that the native plants had an average first year survival rate of 75%, whereas the introduced species had only 39%. Also the native species had a higher level of productivity.

In February of 1971, representatives of the Custer and Gallatin National Forests met with officials of the Anaconda Copper Company to discuss ways to minimize environmental impacts due to mineral exploration. A direct result of this meeting was that Anaconda voluntarily agreed to reclaim disturbances in the Beartooth Mountains (Anaconda Copper Company 1975). The disturbed sites were surveyed and mapped in the summer of 1971. The following summer, the sites were graded to approximate original contour, and subsequently seeded using U.S. Forest Service technical assistance and advice. The seeding recommendation used consisted of commercially available, non-native grasses and a clover.

As a part of their reclamation procedures, Anaconda produced a pictorial review of the revegetation work starting in the summer of 1971 and continuing through September of 1975 (Anaconda Copper Company 1975). From these pictures and a current inspection of the trenches, it is readily apparent that the results are similar to the findings of Brown et al (1976) when using seed mixtures of introduced grasses. At the end of the first growing season, most of the trenches supported a lush growth of grasses. Since then, the vigor and productivity of the seeded vegetation has declined. Native grasses, herbs, and trees are now colonizing the trenches from the surrounding undisturbed areas.

The purpose of this study was to identify those native plants that are best adapted for revegetating high elevation exploration trenches in the Stillwater Complex of the Beartooth Mountains, Montana. Successful adaptation of a species to the disturbed environment of the trenches would be indicated by that species having high colonizing frequency. Identification of colonizers that are locally abundant could then be used as the basis for recommending seed sources to be used in subsequent reclamation, thereby improving the chances of effective revegetation of these and other mining related disturbances (Bell and Bliss 1973, Greller 1974, Brown et al 1976, Wali and Kollman 1977, Billings 1978, Brown and Johnston 1978).

STUDY SITE

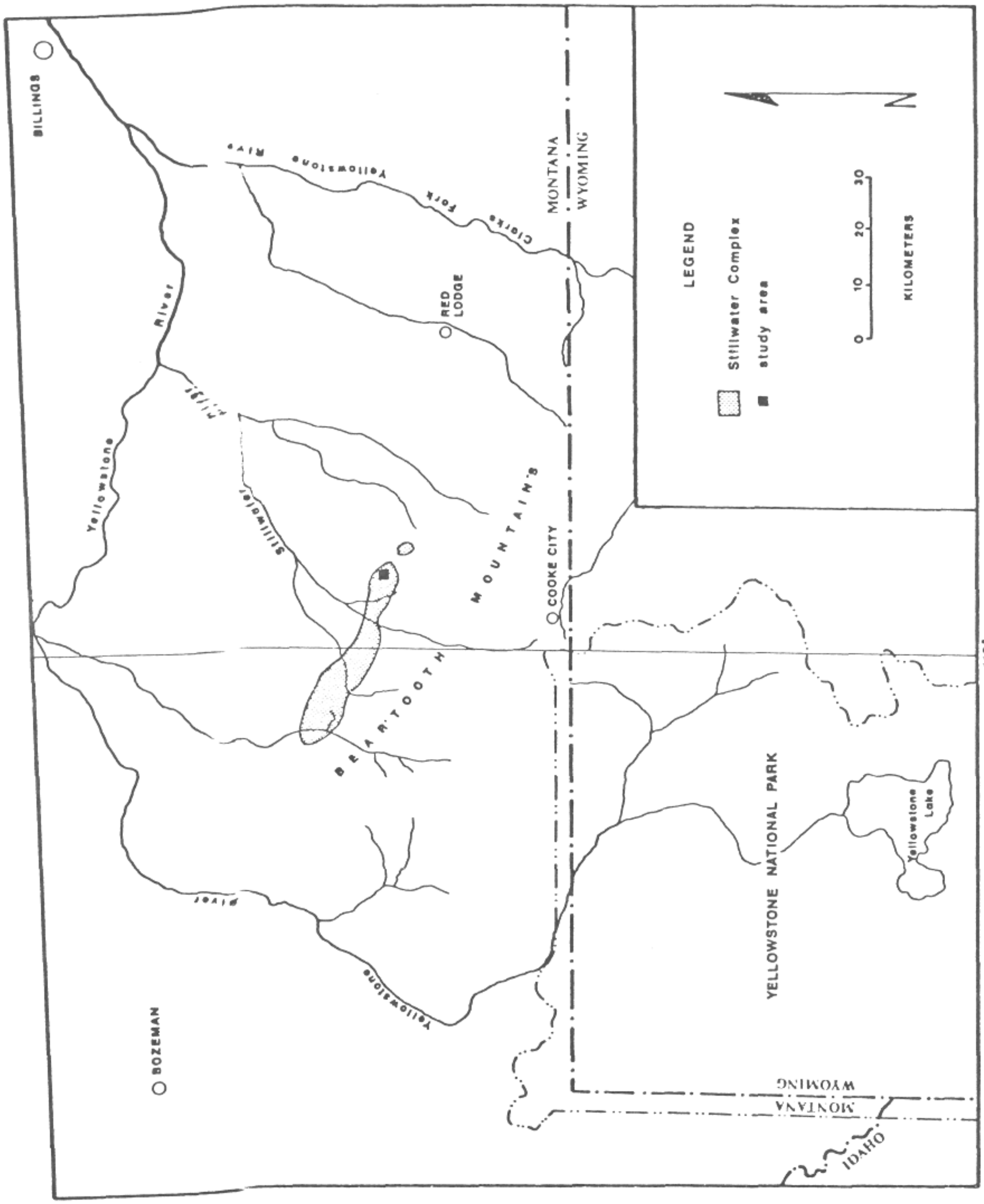
The Beartooth Mountains, a front range of the Rocky Mountains, are located in southern Montana and northwest Wyoming. The range is about 130 km long and 50 km wide. The mountains extend southeasterly from the Yellowstone Valley near Livingston, Montana to the canyon of the Clark Fork of the Yellowstone River, 50 km northeast of Cody, Wyoming. They rise from the Great Plains at 1550 m to almost 3960 m, with a major plateau about 3050 m. The range consists primarily of an uplifted pre-Cambrian granitic block, with numerous basic intrusions and diabase and pegmatitic dykes (Bevan 1923, Loverling 1929).

Climatically, the Beartooth Mountains are similar to other high altitude regions in the Rocky Mountains (Baker 1944, Johnson and Billings 1962, Thilenius 1975, Brown et al 1976). There is a short growing season of 60 to 70 days with high solar radiation loads and cool summer temperatures, with the possibility of frost at any time during the year (U.S. Forest Service 1978). Average maximum and minimum temperatures range from O^0C to -13^0C in January, and from 24^0C to 9^0C in July (National Oceanic and Atmospheric Administration 1971). Annual precipitation is estimated between 115 cm and 152 cm, with most falling as snow in the winter months, September through June (Brown et al 1976, NOAA 1971).

The Stillwater Complex is a highly mineralized zone about 50 km long that lies in a band along the northeast face of the Beartooth Mountains (Figure 1). The Complex is of igneous origin and is separated into a

FIGURE 1

REGIONAL SETTING OF THE STILLWATER COMPLEX, INCLUDING THE STUDY SITE



succession of extensive sheets lying one on top of the other. This layering can be divided into four basic zones: a) the Basal Zone (approximately 70 m thick) of medium grained noritic rocks; b) the Ultramafic Zone (1200 m to 1800 m thick) repeating layers of bronzitite, granular harzburgite, poikilitic harzburgite, and chromitite; c) and d) the Banded and Upper Zones (in aggregate approximately 4200 m thick) layers of norite, anorthosite, troctolite, and gabbro (Jones et al 1960, Sullivan and Workentine 1964).

The exploration trenches in this study were dug in the basal zone of the Stillwater Complex by U.S. Steel in the late 1950's and early 1960's. The claims containing these trenches were later transferred to Anaconda Copper Company. The trenches are located just to the south of the Benbow chromite mine in Custer National Forest. There is a total of 20 reclaimed trenches following, and usually dug perpendicular to, the basal zone. The trenches are between 6 m and 12 m wide, and up to 120 m long. The trenches begin at 2500 m elevation and progress up the side of a mountain and across a plateau with an elevation of 2835 m. Slope aspect is generally southeast.

METHODS

A reconnaissance was made in the summer of 1979, to gain familiarity with the flora and vegetation types of the study site. This reconnaissance indicated several vegetational variables to be considered during the course of the study. Undisturbed vegetation surrounding the trenches could easily be divided into two obvious categories: an unforested alpine area and a subalpine forest. Further variation of the subalpine forest was shown by the change in dominance from *Pinus contorta* at lower elevations, to *Abies lasiocarpa* and *Pinus albicaulis* at higher elevations, to dominance solely by *Pinus albicaulis* at the highest elevations.

Vegetation on disturbed trenches showed similar variation. There were several plants that were common on trenches in the alpine area and rare in the subalpine forest. Conversely, there were other plants common on trenches in the forest that were infrequent in the alpine. Also, *Pinus contorta* was restricted to the lower elevation trenches. A sampling plan was devised to elucidate this vegetational pattern, and also to demonstrate any possible correlation between the species composition of a particular trench and the species composition of undisturbed vegetation surrounding that trench.

Sample plots in the undisturbed vegetation were evenly distributed around and between the trenches (Figure 2). Plots were therefore situated so as to demonstrate the vegetation types that may be influencing colonization. The sampling method used was the releve method of the Zurich-Montpelier school of phytosociology (Becking 1957, Meuller-Dumbois and Ellenberg 1974). This method uses sample plots that require the following: 1) Plots are variable in size, but large enough to contain most species belonging to the plant community as defined by the minimal species/area criterion; 2) The habitat is uniform within the plot; and 3) The plant cover is homogeneous within the plot. After the releve was established, species were listed by tree, shrub, and herb layers. Categorical visual estimates of cover-abundance were then made for each taxon. These estimates have not only been proven effective through utilization by the releve method (Whittaker 1962), but also by Lyon (1968) who tested various methods of sampling shrub density (roughly analogous to cover-abundance) on a plot with a known number of shrubs. He concluded that:

> "...the most reliable density methods tested require a virtually prohibitive sample to attain barely acceptable precision for a statistical test which may fail to detect density differences that are probably obvious on visual inspection... it appears that categorical visual estimates or ranking might be just as reliable as more objective samples."

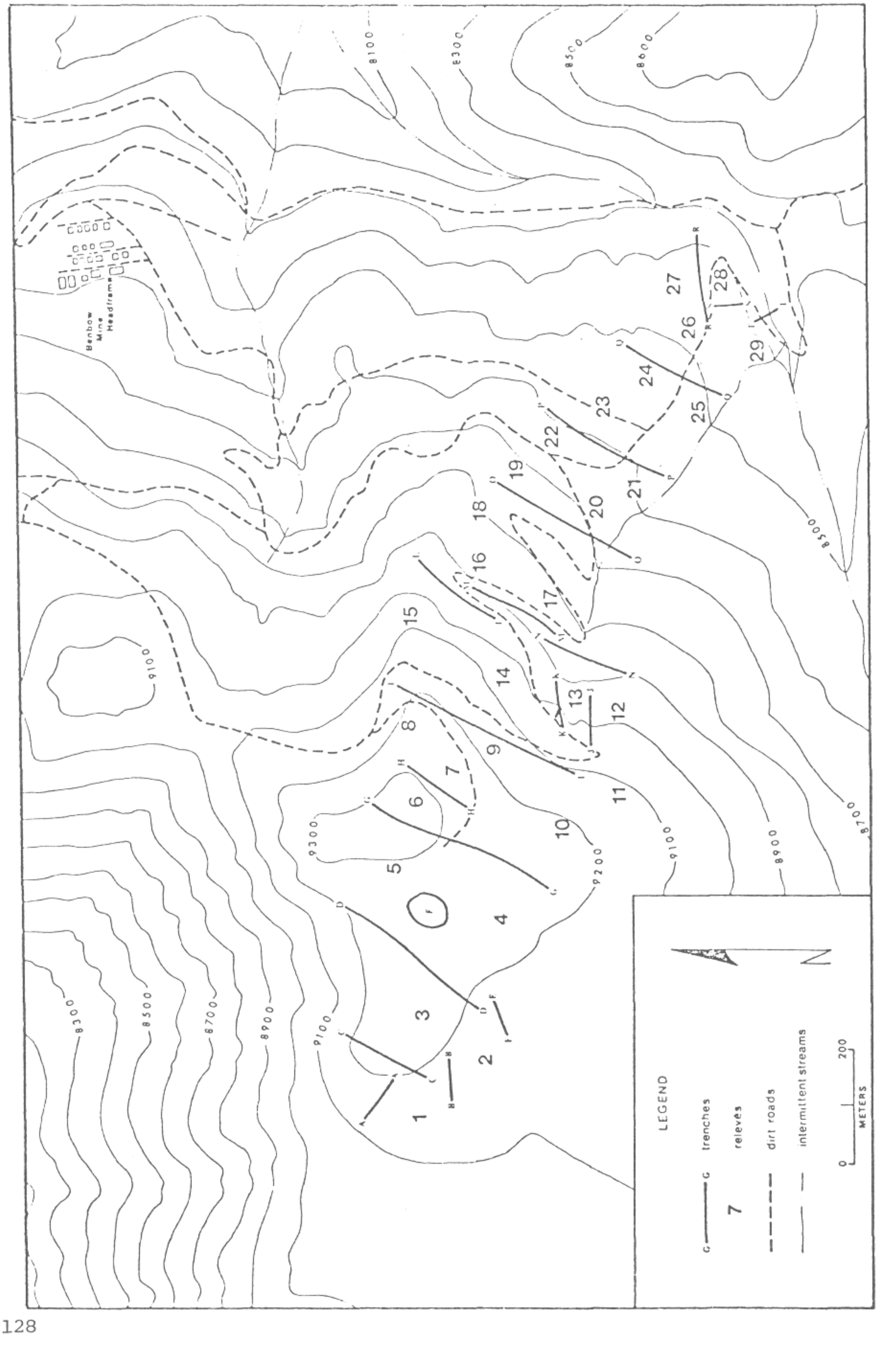
Trenches were sampled with a slight modification of the releve method. Each trench was considered as a single sample plot since its area was small and easily defined.

The cover-abundance scale used during releve sampling was modified from the Braun-Blanquet (1965) scale. Reconnaissance of the trenches indicated that more discrimination was needed in the lower end of the scale where plants were abundant but had low cover. The resulting scale is:

7 - Any number of plants, 75 to 100% cover
6 - Any number of plants, 50 to 75% cover
5 - Any number of plants, 25 to 50% cover
4 - Any number of plants, 10 to 25% cover
3 - Any number of plants, 5 to 10% cover
2 - Any number of plants, 1 to 5% cover

FIGURE 2

STUDY SITE SHOWING LOCATION OF TRENCHES AND RELEVES



1 - Abundant, but with low cover
+ - Scattered
r - Solitary or rare

Trees were aged on two of the lower trenches to determine whether colonization was episodic or an ongoing process. *Pinus contorta* was used since it is the dominant colonizer of the lower trenches, and the age of each tree was easy to determine. Trees were aged by counting the number of internodes on the main stem. To substantiate this method, trees of varying ages were cut and growth rings were counted. If a tree was damaged and its age was not easily determined, it was not sampled.

Voucher specimens were collected of all taxa found on sample plots. Identifications were made using local and regional floras (Hitchcock and Chase 1950, Hitchcock et al 1964, Booth and Wright 1966, Hahn 1977, Hermann 1970). Identifications were verified, and specimens deposited at Humboldt State University Herbarium (HSC).

RESULTS

Tabular analysis (Meuller-Dumbois and Ellenberg 1974) of the data from sampling the undisturbed vegetation indicated that there are four distinct habitat types in this study, a dry alpine habitat type and three forest habitat types. This conclusion agrees with classifications developed by Pfister et al (1977) and South et al (1971).

Pfister compiled a comprehensive classification of the forest habitat types in Montana. Application of this classification to the study area was quite effective. The forest habitats were readily identified using the keys and descriptions. According to this system, the forested areas in this study represent three of the upper subalpine habitat types of the *Abies lasiocarpa* series. The most abundant habitat type is the *Abies lasiocarpa-Pinus albicaulis/Vaccinium scoparium* (Abla-Pial/Vase) habitat type, which surrounds a majority of the trenches.

The Abla-Pial/Vasc habitat type is characterized by *Abies lasiocarpa* as the indicated climax dominant; *Pinus albicaulis* as a long-lived serai dominant; *Picea engelmannii* as a codominant on more moist sites; *Pinus contorta* as a major serai species at lower elevations; and *Vaccinium scoparium* as a dominant in the undergrowth. Once disturbed, regeneration is expected to be difficult, and growth will be slow for this habitat type (Pfister et al 1977).

The other two forest habitats are both timberline types, the *Pinus albicaulis* (Pial), and the *Pinus albicaulis-Abies lasiocarpa* (Pial-Abla) habitat types. Both of these habitat types are classified by the dominant tree species only, since the understory vegetation can be quite variable. Common trees, in order of importance, are *Pinus albicaulis, Picea engelmannii, and Abies lasiocarpa.* The Pial-Abla habitat type differs from the Pial in that it more often assumes the krummholz shape, and has greater accumulations of snow. Regeneration of this habitat type is also considered to be very slow, and in some cases disturbances may be permanent if they are not rehabilitated (Willard and Marr 1971, Habeck 1972, Klock 1973, Pfister et al 1977).

South et al (1971) describe two similar forests, classified as a "subalpine forest ecosystem" and a "krummholz ecosystem." The subalpine forest ecosystem is equivalent to the Abla-Pial/Vasc habitat type. The krummholz ecosystem best coincides with the Pial-Abla habitat type. South describes the timberline habitats as having an understory similar to that of the nearby alpine vegetation. This contention is supported by my data.

Unforested alpine areas are not covered by Pfister's classification. The alpine area in this study is similar to South’s description of a "dry alpine ecosystem." Characteristic vegetation is composed of low growing cushion and turf-forming plants. Again, re-establishment of vegetative cover after disturbance is expected to be very slow (Brown et al 1976, Brown et al 1978, Brown and Johnston 1978, Billings 1979).

Data collected while sampling the trenches indicates a definite correlation between the colonizing species and the surrounding habitat type. There are a few plants that are found colonizing nearly every trench regardless of the surrounding vegetation, there are some plants that are mostly confined to colonizing trenches surrounded by Abla-Pial/Vasc habitat type, and there are several other plants that mainly colonize the trenches surrounded by the alpine and timberline habitat types. There is some variation in colonization among the Pial, Pial-Abla, and the dry alpine habitat types, but it is slight in comparison to the difference between the Abla-Pial/Vasc and the other habitat types.

The sampling method used worked very well for the determination of plant cover found on the trenches. The modified cover-abundance scale gave needed emphasis to small herbs that were abundant but had low cover.

Using each trench as a single sample plot provided some assurance that scattered and/or rare plants were consistently found and reported.

Both of the trenches sampled for tree colonization showed that trees began establishing themselves immediately following disturbance. The number of trees in each age class decreases with increasing age since reclamation. The maximum number of trees were in the one year age class. Colonization has occurred each year, and presumably will continue to do so (Figure 3).

DISCUSSION

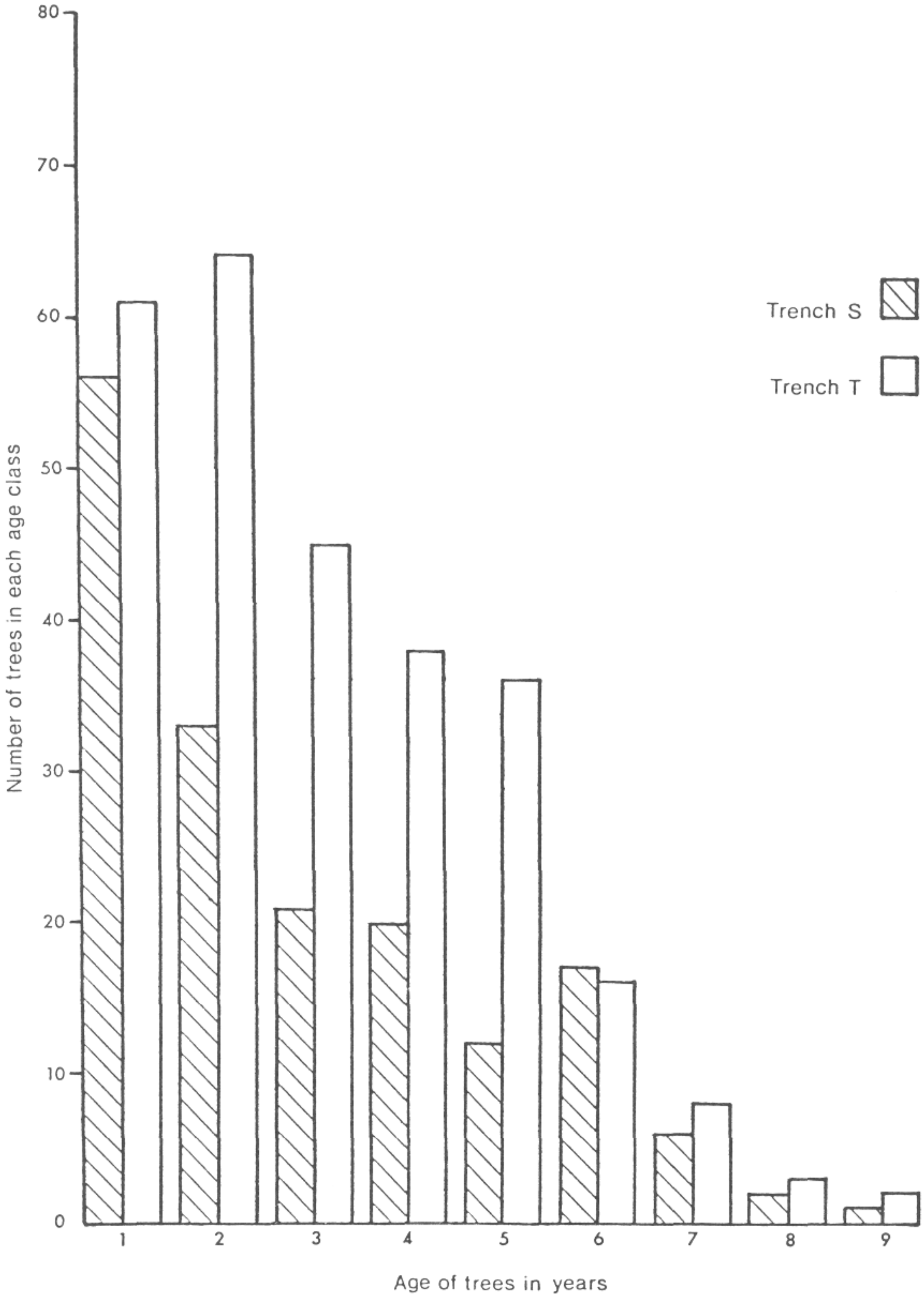
Colonization of *Pinus contorta* on the lower trenches suggests that there is no problem establishing native vegetation. Environmental conditions have been suitable for the establishment of trees each year for the past nine years since disturbance. From the number and abundance of species present on the trenches, it is safe to assume that environmental conditions have not been limiting the establishment of herbs either. Therefore, the limiting factor to colonization appears to have been the availability and dispersal of seed from the surrounding vegetation. Sowing adapted native seed during reclamation should mitigate the effect of this limiting factor.

The best adapted species for planting on the trenches are the most active colonizers on the disturbed areas. Seeding recommendations for revegetating the trenches should involve two different mixtures. There should be one mixture for use on the trenches surrounded by the Abla-Pial/Vasc habitat type, and another mixture for use on the trenches surrounded by the treeline and dry alpine habitat types. There are differences in colonization between the Pial, the Pial-Abla, and the dry alpine habitat types, but the differences are slight. The areas to be seeded are also small enough, so that using different seed mixtures would not be practical.

The species selected for revegetating the exploration trenches were chosen for their high frequency and high cover-abundance values on the trenches. Ease of collection was also taken into consideration when making the recommendations listed in Table 1 . Planting these naturally occurring pioneer species should establish a self-sustaining vegetative cover that is successional to the surrounding vegetation types.

FIGURE 3

NUMBER AND AGE OF *PINUS CONTORTA* COLONIZING ON TWO OF THE LOWER TRENCHES



The undisturbed vegetation on the area of study is typical of the regional pattern of vegetation. The same habitat types are found in other mountainous areas of Montana, and perhaps throughout the northern Rocky Mountains according to Pfister (1977) who developed a comprehensive classification scheme for the forest habitat types found in Montana. These reoccurring habitat types are based on the climax vegetation type, and are easily recognizable and identifiable, even seral stages. Colonization of disturbances in the forest by native plants is directly correlated to the surrounding habitat type. Therefore it should be possible to conduct similar studies in other habitat types to arrive at a list of native species that are adapted for revegetating disturbed areas in any of the habitat types found in the State of Montana. Once these lists have been compiled, work can begin toward making these adapted native plants more readily available on the commercial market. Then reclamation work can get away from the use of ineffective exotic species, and turn toward a more effective program of natural revegetation.

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TABLE 1

SPECIES RECOMMENDED FOR REVEGETATING THE BENBOW TRENCHES BASED ON HIGH FREQUENCY AND COVER-ABUNDANCE VALUES FOR COLONIZERS

ALPINE MIXTURE (PlaI, Pial-Abla, dry alpine)	SUBALPINE MIXTURE (Abla-fMal/Vasc)
Grasses	Graminoids
X Agrositanion saxicola	Carex phaeocephala
Calamagrostis Purpurascens	Phieum alpinum
Poa interior	Sitanion hystrix
Herbs	Herbs
Antennaria umbrinella	Achillea millefolium
Campanula rotundifolia	Aster foliaceus
Geum rossil	Campanula rotundifolia
Lupinus leucophyllus	Epilobium angustifolium
Polygonum bistortoides	Lupinus leucophyllus
Senecio canus	Microceris nigrescans
Solidago multiradiata	Polygonum bistortoides
	Senecio canus
	Senecio pauperculus
	Solidago multiradiata
Shrubs	Shrubs and Trees
Artemisia campestris ssp. borealis	Pinus albicaulis
Potentilla fruticosa	Pinus contorta
	Potentilla fruticosa

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