68-71

GEOLOGICAL SURVEY OF CANADA

DEPARTMENT OF ENERGY, MINES AND RESOURCES

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BOTANICAL INVESTIGATIONS AT THREE KNOWN MINERAL DEPOSITS

(Report, 3 tables and 5 figures)

Lily Usik

CANADA

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Price: $1.50 Catalogue No. M44-68-71

Price subject to change without notice

The Queen's Printer
Ottawa, Canada
1969

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ABSTRACT

Identification and systematic investigations of the distribution and morphological features of about 165 plant species at two copper properties and one molybdenum property in British Columbia did not reveal the presence of any plants indicative of ore minerals. Distribution of plant species and the general vitality of the growth of the plants were related to qualities of site, i. e. drainage, soil, relief, and to region. Lupine concentrated molybdenum in much larger amounts than lodgepole pine. However, only the Cu:Zn ratio of the lupine outlined reasonably well the presence of copper-bearing rocks at one property. No relationship could be established between growth swellings in the trunks of alpine fir and the presence of mineralized rocks or any other environmental factor at the molybdenum property.

BOTANICAL INVESTIGATIONS AT THREE KNOWN MINERAL DEPOSITS

INTRODUCTION

Botanical prospecting for mineral deposits uses some feature of the vegetation that is related to the presence of higher than average amounts of elements in the growth substrate and, hence, in many cases indicative of a nearby mineral deposit. The presence of ore-bearing material may be reflected in the plants in several ways: Plants can absorb and concentrate abnormally high amounts of an element from the soil. These accumulator plants show no outward visible effects and can only be differentiated by careful chemical analysis of their ash. This method is commonly known as the biogeochemical method and has received much attention in Canada by Warren and his workers (1948, 1949, 1955a, 1955b), and in other countries (Marmo, 1953; Malyuga, 1964).

A high concentration of elements in the soil can, however, be toxic to some plants and, consequently, effect the absence of a species, a community of species, or the total plant cover from the site in which it is otherwise normally present. On the other hand, some plant species or plant communities are known to prefer, or to be dependent on, an area where there is a high concentration of some element. High concentrations of elements may also produce changes in the morphology (size, shape, colour) and physiology (reproductive process, i.e. flowering, seed production, etc.) of a plant. These are outward effects and are usually readily detected by visual observations. The geobotanical or indicator plant method, as it is known, has also received considerable development and application in the U.S.S.R. (Malyuga, 1964) as well as in the United States (Cannon, 1960). In Canada, an attempt at systematic geobotanical investigations is contained in a recent report (Usik *in* Fortescue and Hornbrook, in press).

This paper reports on systematic geobotanical investigations made at three known but relatively undisturbed mineral deposits in British Columbia. The investigations consisted of: (1) the identification of plant cover types and plant species present or absent over the known mineralized areas in comparison to those in the surrounding nonmineralized areas, and (2) the examination of the morphological features of the plants for abnormal variations indicative of ore-bearing rocks. The latter was done by examination of the plants in the field and of collected, dried, and pressed plants in the office. Examination and comparisons of growth features of individuals of the same species growing in similar and in different sites (e.g., moist ravine, dry exposed slope, rocky ledge, etc.) from both mineralized and nonmineralized areas were made. Difficulty in the identification of the lower plants, i. e. mosses, lichens, and fungi allowed only limited investigations of these plants as well as of the taxonomically difficult grass and sedge species.

Project Number 630040
Manuscript received 18 September 1968

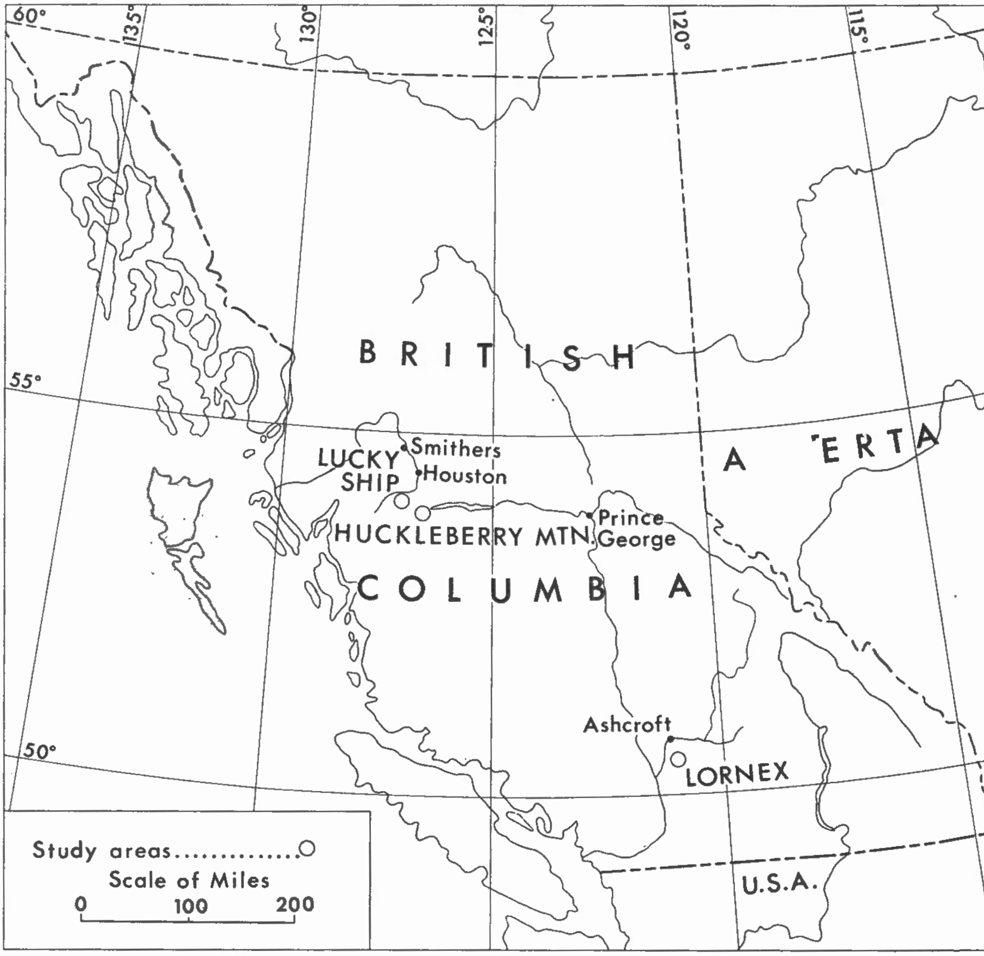

Figure 1. Index map.

Acknowledgments

The writer sincerely thanks the companies for granting permission to work on their properties and especially their field personnel for help, encouragement, and accommodation during the field work. The enthusiastic help of D. Clark in the field, the ashing of the plant material by E.H.W. Hornbrook and assistants, and the analytical work by J.J. Lynch are gratefully acknowledged.

LORNEX COPPER DEPOSIT

The Lornex property is in Highland Valley in south-central British Columbia and is about 30 miles by road from Ashcroft (Fig. 1). The region consists of rolling uplands and dissected valleys with elevations from 4,000

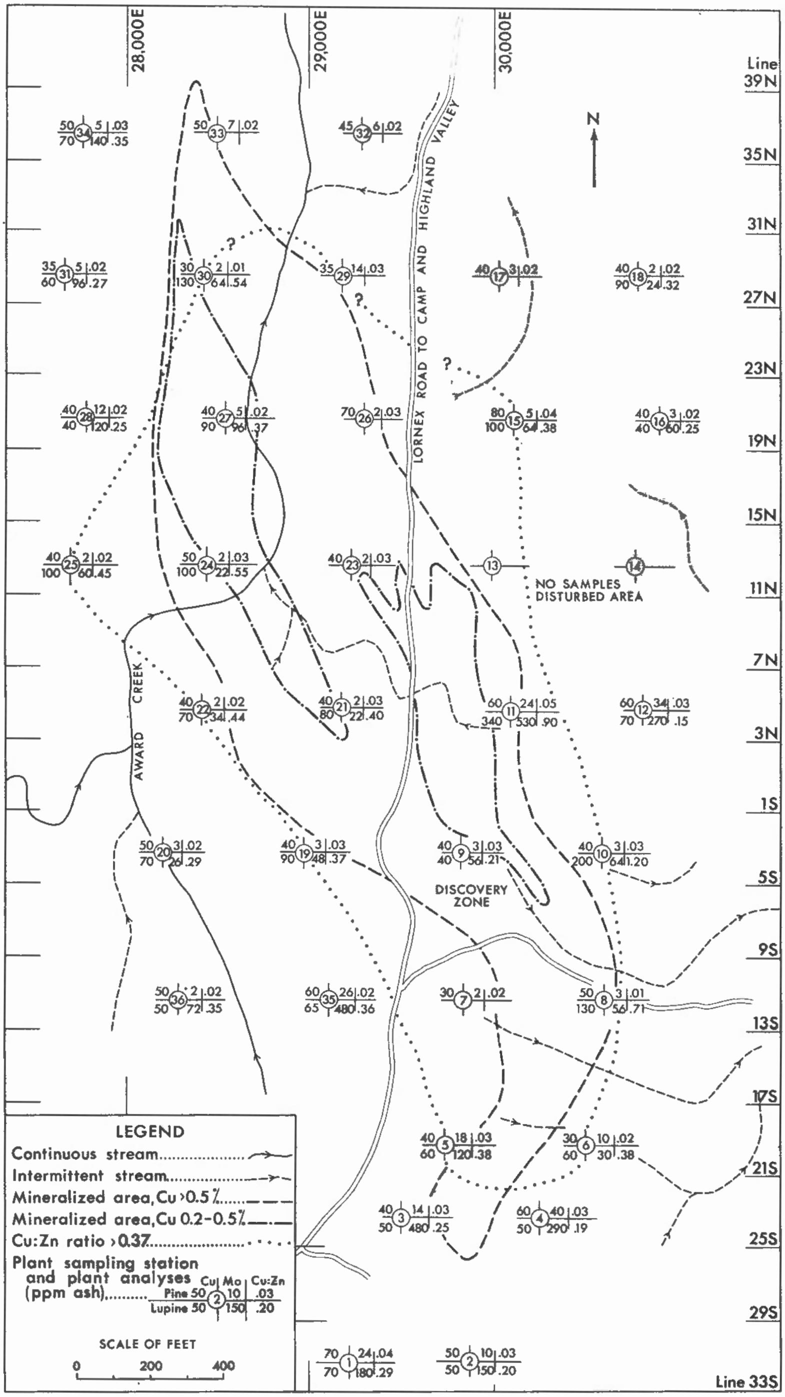

Figure 2. Cu and Mo content (ppm ash) in pine (bark) and lupine (leaves), and Cu:Zn ratio anomaly in lupine for Lornex area.

to 6,000 feet. Highland Valley is underlain by the Guichon Batholith composed of quartz diorite and granodiorite rocks (White et al., 1957). Glaciation has covered the region with till and sandy well-drained loam, developed from till, is the principal soil type in the region.

Copper-bearing rocks at Lornex occur along the northwest slope of a rounded hill and extend into the valley of Award Creek between elevations 4,800 and 5,200 feet. The mineralized area (carrying 0.2% Cu) is approximately 5,000 feet long in a southeasterly direction and in places is as much as 1,000 feet wide, giving an areal extent of about 0.22 square mile (Fig. 2). Two zones of higher grade copper averaging 0.5 per cent Cu have been outlined within the larger lower grade zone. Surficial deposits vary in depth from 250 feet over the mineralized zone in Award Creek valley to about 25 feet in the southeast Discovery Zone.

The Lornex area is situated in the Douglas fir zone of the Interior Plateau where fir (Pseudotsuga menziessi) is predominant at lower elevations grading into spruce-fir (Picea-Pseudotsuga) forest at higher elevations and in moist valleys. However, due to various disturbing factors, particularly past forest fires, large portions of the region are now dominated by other tree species. The most important of these is lodgepole pine (Pinus contorta).

An examination of aerial photographs revealed that the Lornex area and most of the surrounding terrain is covered predominantly by lodgepole pine forest of different age stands related to past forest fires. Relict or re-established stands of spruce (Picea glauca var. engelmanni) and spruce-fir, however, are present usually on isolated slopes and in valleys and depressions. Black spruce (Picea mariana) occurs only in peat bogs.

Ground botanical investigations at Lornex were made along east-west traverses within the undisturbed intervals between the east-west cut lines. Investigations were made in both the mineralized and nonmineralized areas between lines 31S and 39N and approximately 1,000 feet east and west beyond the delineated mineralized area (Fig. 2). Plant species were identified, their relative frequency (i.e., dominant, co-dominant, abundant, common, or infrequent), their morphological features, and general vitality were noted along each traverse line in relation to mineralized zones and nonmineralized zones and to variation in local site qualities such as moisture regime, drainage, slope aspect, relief, elevation, shading, and soil characteristics. Samples of all herbs, shrubs, and trees, and of the most conspicuous species of moss, lichen, and grass and sedge plants were collected from each site type along each traverse and then pressed and dried and later examined and compared for morphological variations in relation to mineralization. Table 1 lists the plant species identified and morphologically examined for the Lornex area and summarizes their relative frequency over mineralized and nonmineralized zones. Site affinities of the species are also noted.

Examination of plant cover types from aerial photographs and detailed ground and laboratory botanical studies revealed no indicator plant associations, plant species, or morphological features that can be related to the presence of copper. The Lornex and surrounding areas are covered predominantly by a lodgepole pine forest with ground and understory species that vary mainly with the local site qualities of elevation, drainage, moisture, relief, soil, slope aspect, and presence and severity of past forest fires. Lodgepole pine occurs in relatively evenly distributed and open-canopied stands from 20 to 100 years old, which average 15 to 60 feet in height respectively, over and around the Lornex area. Wood cores taken from the trunks (at a standard breast height of 4.5 feet) of 20 randomly selected trees from the mature stands revealed an average age of 100 years. Charred logs and stumps, fire scars on standing trees, and the absence of almost all surface humus in the soil under the pine stands are evidence of past fires in the area. Younger stands (about 25 years old) in the northern end of the Lornex area are evidence of recent fires of local extent. Detailed plant-soil ecological investigations are required to determine the effect of the fires on the physico-chemical conditions of the soil and, hence, on the plant-mineralized rock relationships. Until this information is available, areas disturbed by fire may not be favourable for geobotanical investigations of mineralized rocks.

Relicts of the original fir and fir-spruce forests are found at Lornex. A few large Douglas fir with diameters exceeding 3 feet are present mainly as isolated individuals on inaccessible rocky ledges at the top of the Lornex hill. Small stands of white spruce occupy damp depressions and occur on the slopes of Award Creek and other drainage courses. Both fir and spruce are present as seedlings under the mature pine stands.

Other tree species are present and their distribution is related to site quality. For example, black spruce is present only in a peat bog area at the southwest end of the property. Populus tremuloides occurs infrequently over the area and is confined mainly to the heavily burned over and exposed lower slopes. Populus trichocarpa is found only along Award Creek valley. Willows (Salix bebbiana?) occur as tree height (over 25 feet) individuals both in dry and damp sites but more frequently in moist water courses. Both alder (Alnus) species are present but only Alnus sinuata reaches tree height in Award Creek valley.

When present, the understory vegetation (5 to 15 feet) consists of seedling fir and spruce and alder shrubs. Both alder species form thickets in wet, poorly drained depressions and along water courses. Salix is frequently associated with the alder in the thickets.

Shrubs less than 5 feet tall consist of numerous species whose distribution and general growth vitality can only be related to site factors such as moisture regime, drainage conditions, sunny or shady and rich or poor rocky soil, and severity of past forest fires. For example, Lonicera involucrata and Ribes lacustre occur in moist but well-drained sites, usually shaded, and in rich humus soil conditions whereas species such as Sorbus and Spirea are present more frequently in dry exposed thinly humified soil sites. Shepherdia canadensis occurs frequently as a co-dominant with Ledum and Lonicera species in both moist and dry sites. Although Ledum is more frequently associated with poorly drained or wet sites, at Lornex it occurs in both wet and dry sites under open pine stands. Its growth, however, in the moist shady sites (usually under spruce or fir) is conspicuously more luxuriant than that in the dry, open-canopied pine stands. In the latter it is associated with Vaccinium scoparium and Hypnum moss species (Calliergonella) whereas in the former, it is associated mainly with Linnea borealis, Lonicera involucrata, Ribes lacustre and a generally richer herb flora. Vaccinium membranaceum is a conspicuous ground shrub element in the Pine-Vaccinium-Ledum-Moss association. Rosa nutkana is abundant over the entire area in both moist, shaded, and dry sunny sites but grows taller and more luxuriantly and is found to blossom only in the moist, shaded sites.

No indicator plants of copper-bearing rocks could be established for ground shrub species less than 2 feet in average height, for the herb species, or for the lower plant species. For these various species distribution and growth vitality could only be related to site quality. Vaccinium scoparium and lupine are the dominant ground species over most of the area and form Vaccinium-Moss or Lupine-Vaccinium associations under the forest stands. The Pine-Lupine-Vaccinium association occupies the moister sites whereas the Pine-Vaccinium-Moss association covers the more exposed drier sites and usually the heavily burned-over areas where there is almost no surface humus in the soil profile. Arctostaphlos uva-ursi and Cladonia lichens are conspicuous ground elements in the Pine-Vaccinium-Moss association. Herb species also showed affinities to factors of site. For example, Heracleum, Petasites, Thalictrum, and Dryopteris are found only in the moist, shady, rich soil sites along the banks of Award Creek, whereas Arennaria, Achillea, and Pyrola secunda are present in dry sunny sites with thin or rocky soils.

For the Lornex area two plant species were selected for chemical analysis to determine if the copper and molybdenum concentrations in their ash could be related to the zones of copper and molybdenum mineralization. Lodgepole pine and lupine were selected because of their widespread and usually dominant or co-dominant distribution over the area in almost all site types. Also, both species were noted to have conspicuously long root systems which should enable them to sample the deep soil horizons. For example, the excavated root system of one pine was 7 feet deep and for several excavated lupine roots the average was 5 feet.

Samples of pine bark from about 4.5 feet above ground and of lupine leaves and petioles were collected in self-sealing paper bags at each 800-foot station within the undisturbed intervals between lines 33S and 39N (Fig. 2). The stations covered both mineralized and nonmineralized zones. Lupine was collected only when present within a 100-foot radius of the selected pine tree; thus, no samples were collected at stations 17, 23, 26, 29, 32, and 33. No pine or lupine were sampled for stations 13 and 14 because of almost complete removal of the vegetation in this area. The plant material was dried, ashed, and then colorimetrically analyzed for Cu, Mo, and Zn at the Geological Survey laboratories in Ottawa.

The data of Table 2 suggests that lupine is a concentrator of molybdenum and perhaps a weak concentrator of copper in comparison to pine. The average copper and molybdenum contents of pine are 46 and 10 ppm respectively; for lupine the contents are 80 and 150 ppm respectively.

No relationship, however, could be established between the copper or molybdenum contents of the plants and the delineated mineralized zone (Fig. 2). However, there is some indication of a rise in molybdenum, and occasionally in copper, in the lupine only as the mineralized zone is crossed. Correlation appears weak on some lines, e.g. 27, 19, and 11N because of lack of samples but is strong on others, e.g. 3N. Downstream drainage courses are anomalous especially in the southeast part of the area. This may reflect more fracturing in this locality which may be correlative with the geology. Also, overburden here is shallow being about 25 feet deep compared to depths of 250 feet along Award Creek valley.

The higher concentration of molybdenum by lupine than by pine may be explained by the fact that lupine belongs to the legume family of plants (Leguminosae) which are known to have a greater capacity for accumulation of molybdenum than any other plant species (Vinogradov, 1943). Furthermore, molybdenum appears to be involved in both the reduction of nitrates and in the fixation of elemental nitrogen by the nitrogen-fixing bacteria in the characteristic root nodules of the legume species (Stiles, 1961). The above illustrates how a basic physiological knowledge of plant growth may be helpful in interpreting the results of biogeochemical investigations.

Several authors (Warren et al., 1949; White, 1950) have reported on the use of the Cu:Zn ratio of plant ash for delineating anomalous areas of mineralization. There is some correlation between the Cu:Zn ratios greater than 0.36 for lupine and the zone of mineralization at Lornex (Fig 2). Except for the low value at station 9, a Cu:Zn ratio greater than 0.36 approximately outlines the mineralized area.

LUCKY SHIP MOLYBDENUM DEPOSIT

The Lucky Ship property is in north-central British Columbia about 50 miles by road west of Houston (Fig. 1). The area lies in the eastern slope region of the Coast Mountains. The relief is mountainous with elevations from 4,000 to 6,000 feet. Broad U-shaped valleys form basins for a series of long narrow subparallel lakes draining eastward. The region consists mainly of sedimentary and volcanic rocks of the Hazelton Group (Duffell, 1959). Glaciation resulted in a complex series of deposits, mainly till. Characteristic of the region are parallel ridges and intervening grooves.

The Lucky Ship molybdenum deposit lies on the steep southeast slope of the ridge between Morice Lake and the Nanika River valley. Mineralized rocks occur along this slope between elevations of approximately 3,400 to 3,900 feet. Outcrops are present throughout the area but are more common at the top of the ridge; talus is frequent along the upper slopes. Hammer seismic work revealed that overburden varies in thickness from zero to about 50 feet downslope towards the Nanika River. In general, the overburden is less than 15 feet over the area (G. D. Hobson, pers.comm.).

The ore mineral is molybdenite in quartz veins in a quartz porphyry pluton. It is concentrated in a zone immediately peripheral to the contact of the granitic plug. A soil geochemical survey outlines the molybdenum halo associated with the ore zone and the granitic plug as a whole (Fig. 3).

At the Lucky Ship deposit investigations were made of the plant cover types and plant species distribution. Studies were also carried out on the relative frequency and appearance of the plants and on a tree-ratio method in relation to anomalous and nonanomalous molybdenum areas. The major forest cover types over and surrounding the Lucky Ship area are fir (Abies lasiocarpa), pine (Pinus contorta) and fir-pine (Abies-Pinus). Lodgepole pine occurs in association with fir alone, or with aspen (Populus tremuloides). The fir and aspen occur mainly in burned-over areas. White pine (Pinus albicaulis) replaces lodgepole pine at the higher elevations particularly on exposed, steep, rocky and talus slopes. The lower slopes, towards the Nanika River on the southeast, and towards Morice Lake on the northwest, are covered predominantly by spruce-fir or spruce-pine-fir forests for the former and by fir-pine forest for the latter. No relationship between forest cover type and the presence of molybdenum could be established for the Lucky Ship area.

Plant species and their relative frequency were mapped and their morphological appearance noted at each 100-foot station for each of four

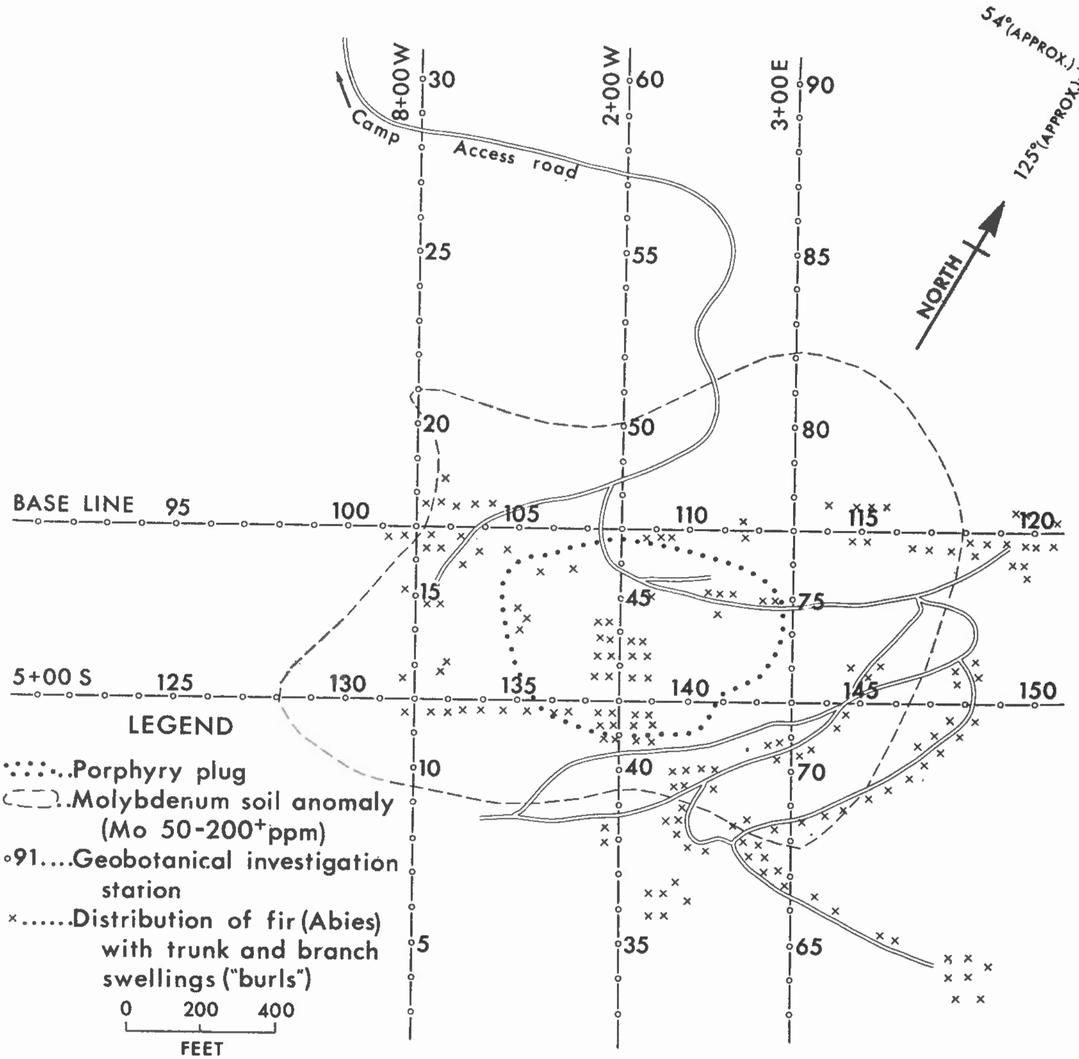

Figure 3. Lucky Ship molybdenum mineralization; geobotanical investigation stations and distribution of fir (Abies lasiocarpa) with trunk and branch swellings.

selected lines extending across and beyond the mineralized zone (Fig. 3). This procedure permitted botanical comparisons not only of mineralized and nonmineralized terrain but also of the variations in site type occurring within each of these areas. Samples of all the identified species from different site types from the mineralized and nonmineralized zones were collected, dried, and pressed, and later examined and compared for morphological variations in size and shape. In the Lornex area species distribution and general growth vitality (e.g. stature and luxuriance) could only be related to site qualities. Of the 115 species identified for the Lucky Ship area 63 were also present in the Lornex area (Table 1). Similar site affinities for species common to both areas were found. For example, Sorbus, Antennaria, Spirea, and Sedum species are found mainly in dry exposed sites on thin or rocky soils. Alnus, Ribes, Gallium and Heracleum, also common to both areas, are found in the usually rich soil of moist, shady sites. Lodgepole pine is the dominant tree in the burned-over areas in both locations replacing Douglas fir or white spruce at Lornex and Alpine fir or white spruce in the Lucky Ship area. Vaccinium membranaceum and Arctostaphlos are the conspicuous and most abundant ground cover elements under the pine and fir-pine forests in the Lucky Ship area while in the Lornex area they are Vaccinium scoparium and Arctostaphlos. Other similarities of site affinities for common species are noted in Table 1.

In the Lucky Ship area one conspicuous botanical feature was noted that at first appeared to be present only in the mineralized area. This was the presence of rounded swellings or distortions on the stems, branches, and trunks of fir (Abies lasiocarpa) which were locally called 'burls' or cankers. Trees of all ages were observed to be affected. An investigation was made to see if the distribution of the affected trees could be related to the zone of anomalous molybdenum. Figure 3 shows the distribution of 'burled' trees observed by ground survey along cut lines and roads over the area. No relationship could be established between the distribution of affected trees and the presence of ore minerals.

J.H. Ginns of the Forest Research Laboratory at Victoria, British Columbia, kindly examined samples of the burls and suggested that the growth distortion was probably caused by a bacterium. It is known that a similar growth distortion is caused by a bacterium in Douglas fir (Pseudotsuga). He explained that as yet no case was known of such a condition caused by a high concentration of particular elements in the soil.

Chemical analyses of the growth swellings showed no anomalous concentration of molybdenum compared to other parts of the affected tree or to unaffected trees (E. Hornbrook, pers. comm.). An indirect effect of molybdenum mineralization on the growth distortion in the fir is, however, a consideration to be taken into account. Also, Sutherland-Brown (1966) found a mercury halo associated with the molybdenum mineralization. However, nothing is known at present about the relationship between mercury and plant growth. Therefore, whether a relationship, direct or indirect, exists between the growth swellings in the fir and molybdenum mineralization at the Lucky Ship deposit can only be established by (1) further reports of similar occurrences and (2) by controlled physiological experiments where the abnormal 'burl' growth is shown to be induced by high molybdenum concentrations, or by other physico-chemical conditions related to or induced by molybdenum concentrations.

The tree-ratio method for mineral exploration was investigated in the Lucky Ship area. This method was successfully used by Kleinhample and Koteff (1960) in the United States to define the most favourable areas containing uranium. Briefly, the method consists of determining the ratio of the two co-dominant trees for different sites over an area. For the Lucky Ship deposit the tree-ratio study was made for lodgepole pine and alpine fir. Tree counts of each species were made at each 100-foot station along the base line and along lines 5 + 00S, 2 + 00W, and 3 + 00E. The nearest 10 live trees (with a diameter over 5 inches) around one randomly selected tree were tallied as to species.

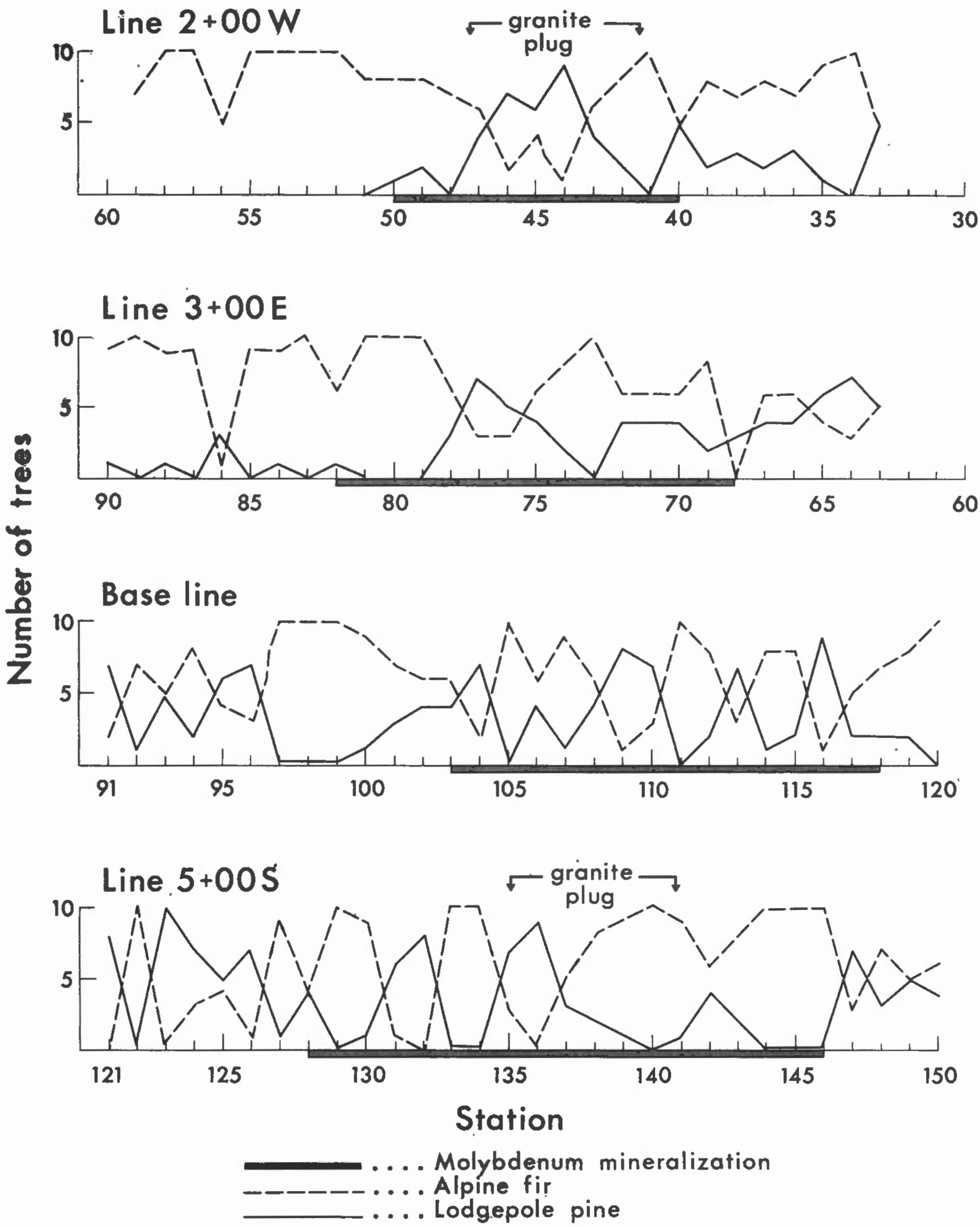

Figure 4. Distribution of lodgepole pine and alpine fir over anomalous and nonanomalous molybdenum areas for Lucky Ship deposit.

Table 3 and Figure 4 show no relationship between pine-fir tree-ratios and the anomalous molybdenum zone of the area of the granitic plug. A relationship between the distribution of pine and elevation is suggested for lines 2 + 00W and 3 + 00E (Fig. 4). Above station 50 on line 2 + 00W and 80 on line 3 + 00E pine is absent or only infrequent. Here lodgepole pine is replaced by white pine (Pinus albicaulis). The slope above stations 50 and 80 is more exposed, steeper, and rocky with an elevation change of approximately 200 feet in a ground distance of 1,000 feet. Under these conditions white pine is co-dominant with fir.

The limitations of the tree-ratio method are apparent from the above observations. An area for tree-ratio study must be homogeneous for only two co-dominant species. Furthermore, site factors such as elevation, slope, soil characteristics, drainage, and moisture all affect tree growth and tree distribution and may mask any diagnostic tree-ratios related to the presence of mineralized rocks. The effective application of this method, therefore, requires an area of relatively homogeneous environmental conditions for the growth of two indigenous tree species.

HUCKLEBERRY MOUNTAIN COPPER DEPOSIT

The Huckleberry Mountain copper deposit is also in north-central British Columbia just southeast of the Lucky Ship deposit and approximately 80 miles by road west of Houston (Fig. 1). It is about 3,500 feet above sea level on the southwest slope of Huckleberry Mountain about 5 miles east of Tahtsa Lake. Relief, landforms, glaciation history, soils, and geology are in general similar to those of the Lucky Ship area.

The ore minerals at the Huckleberry Mountain deposit consist of copper (and molybdenum) in and around a chalcopyrite-bearing diorite stock that appears as a prominent hill. The metallic minerals are concentrated at the periphery of the stock, particularly in a crescent-shaped area along its eastern border (Fig. 5). Hammer seismic work done over the area revealed that overburden varies from 6 feet over the top of the stock to about 68 feet on the northeastern flank (G.D. Hobson, pers. comm.).

Botanical investigations of plant cover types were made from air-photos, and plant species distribution, relative frequency, and appearance were studied on the ground. The ground survey was made at each 100-foot station along four lines crossing anomalous and nonanomalous copper zones (Fig. 5). Site affinities of the plants identified were noted, and plant samples were collected from each representative site community along the lines. Comparison of morphological features of the plants were made in the field and from the pressed samples.

No indicator plant cover type or plant species could be established as indicative of the anomalous copper mineralization at the Huckleberry Mountain deposit (Table 1). Plant cover types over and around the mineralized area were mapped also in 1965 and reported on briefly by the author in Fortescue and Hornbrook (in press). The presence of lodgepole pine stands indicates past fires in this region also. Examination of the age of the pine-fir stand over the mineralized hill area suggested a fire 60 years ago. The severity of the fire over this area was evident by the almost complete absence of a surface humus layer in the soil profile.

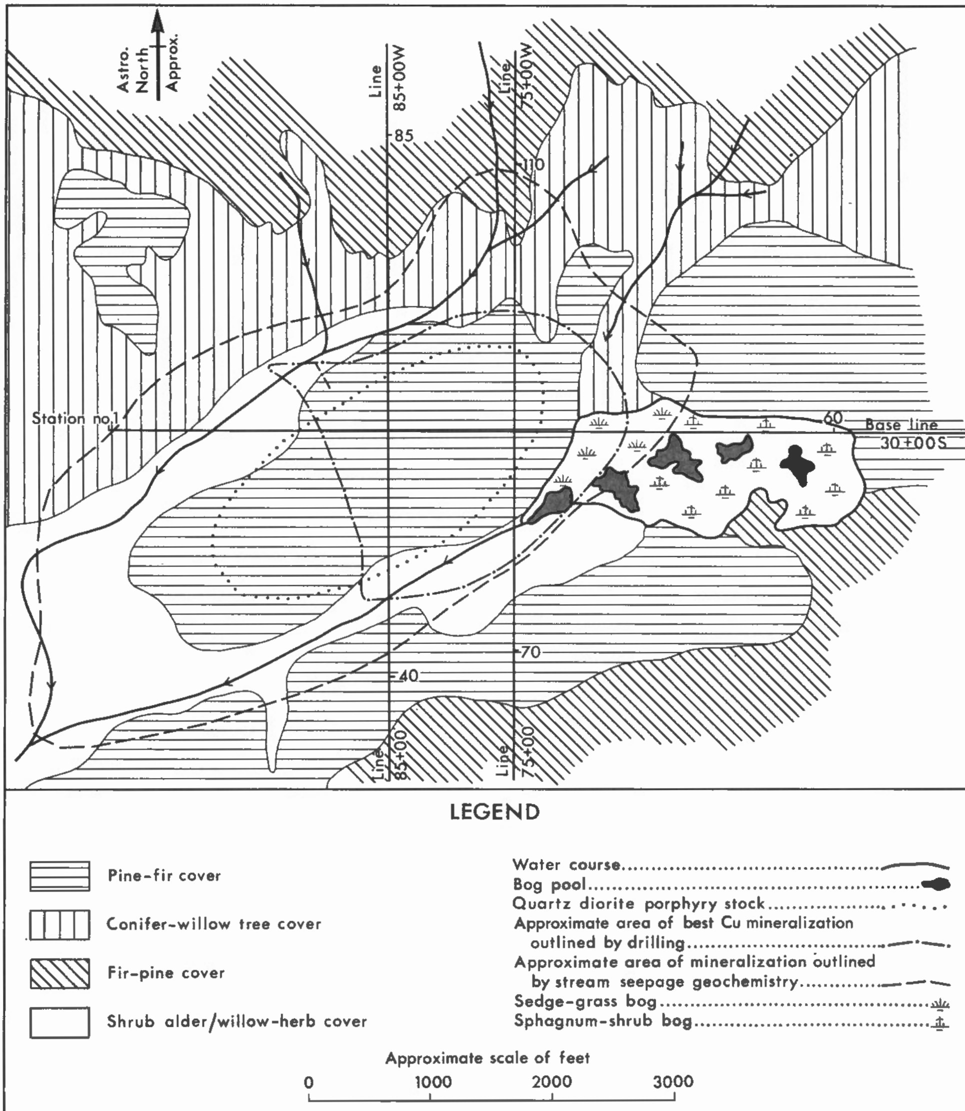

Figure 5. Huckleberry Mountain copper mineralization and plant cover types.

Surrounding the pine-fir hill area to the north and west is a low moist drainage area covered by a willow-alder-herb community. The soil particularly along the banks of the creek and in depressions has a thick organic surface layer and supports a rich herb flora of Heracleum lanatum, Valerian sitchensis, Thalictrum occidentale, Athryium felix-femina, Montia parviflora, and Parnassia fimbriata. Scattered throughout this area are large living fir (Abies lasiocarpa), spruce (Picea glauca), and shiny poplar (P. trichocarpa) as well as very large dead standing trunks, relicts of past fires. North of this area, up the slope of Huckleberry Mountain, is a dense mixed conifer-willow forest with a dense alder understory and a rich herb ground cover. Fir (with abundant lodgepole pine) is co-dominant with tree-sized willows (Salix bebbiana (?)) which occur in conspicuous clones. The ground flora consists of species such as Thalictrum, Actaea, Heracleum, and Epilobium alpinum in the damp, shaded, rich soil areas and of Pachystima, Castilleja, and Cornus on the more exposed slopes with thin or rocky soils. Although the conifer-willow association appeared to be present only in this area along the south slope of Huckleberry Mountain, its relationship to the mineralized rocks or to any other site factor could not be established. Further examination of the plant cover types over a broader area surrounding the Huckleberry property would be required to determine the uniqueness or commonness of the fir-willow association and of its site relationships.

Above the fir-willow area is an open pine-fir cover over the exposed rocky and talus slopes towards the summit of the mountain. White pine becomes abundant at higher elevations and on the rocky and talus slopes.

The ground cover, when present, consists predominantly of Vaccinium membranaceum, Arctostaphlos uva-ursi and Pachystima myrsinites similar to that under the pine-fir cover over the mineralized hill. Associated conspicuous species are Rosa, Sorbus, Salix (shrub), and Pentstemon.

Mention should also be made of the complex bog sites to the east of the hill. In general two main bog types are present: a sedge-grass-herb bog immediately at the base of the hill, and a low shrub - Sphagnum bog area farther east. The former is dominated by species of Carex, Luzula, Scirpus, Juncus, Potentilla, Agrostis, and Equisetum; the latter by Empetrum, Phyllodoce, Kalmia, Ledum, Vaccinium, Eriophiorum, Drosera, Sphagnum mosses, and lichens. Scattered pine and hemlock (Tsuga mertensiana) are present in the Sphagnum-shrub bog.

The variability and adaptability of plant species to environmental conditions are well illustrated by the distribution of Tsuga. Not only is it present in the wet, acidic, rich organic bog site, but it is also found growing on the dry, thin, poorly humified soils of the pine-fir hill area. Similar observations were made for the shrub Empetrum nigrum. A possible explanation is the common high acidity condition characteristic of the sphagnum bog and caused by burning of the vegetation and humus over the hill area.

Time did not permit detailed botanical-ecological studies of the bog areas in relation to the presence of mineralized rocks. It is proposed that such areas may be especially suitable for geochemical and geobotanical methods of prospecting because of their characteristic hydrological, physio-chemical, and botanical conditions. For example, peat bog areas are usually drainage basins for surface or underground water from the surrounding rocks and soils, which are most likely to be influenced by nearby mineralized rocks, and their presence may be expressed in the physico-chemical conditions of the bog waters, of the peat, or in the nature of the plant species composition and growth. Investigation of the last may be done primarily by visual observation on the ground, by air surveys, or by chemical analyses.

SUMMARY AND CONCLUSIONS

No plant indicators could be established for the copper-bearing rocks at the Lornex and Huckleberry Mountain properties. Chemical analysis of lupine, which was a dominant element in the vegetation cover at the Lornex property, confirmed the known fact that members of the Legume family to which it belongs concentrate relatively higher amounts of molybdenum than any other plants. Neither the copper nor the molybdenum contents of the lupines nor their areal distribution were found to delineate the zone of known mineralized rocks. Both the Lornex and Huckleberry Mountain properties contain appreciable molybdenum in association with the copper. It is known that the presence of molybdenum counters the effect of copper toxicity in vegetation. This may help to account for the absence of any plant indicators or morphological toxicity symptoms.

In both areas soil geochemistry was not found to delineate accurately the location of the orebody beneath the overburden. Cu:Zn ratios greater than 0.36 for lupine did, however, approximately outline the area known to be mineralized at Lornex. Soil geochemistry at both places showed conspicuous anomalies in the soils along the water courses. More detailed and careful geobotanical investigations are, therefore, recommended for these sites in future work.

Both the Lornex and Huckleberry Mountain areas have been subjected to repeated and severe fires resulting in the establishment of after-fire plant species and communities. Until the effects of fire upon the soil-plant ecosystem are known, burned-over areas may not be suitable for geobotanical investigations.

No botanical indicators were established for molybdenum at the Lucky Ship deposit. Whether the mineralized rocks or associated soil conditions at Lucky Ship caused the abnormal growth swellings in the trunks and branches of fir cannot be determined without detailed physico-chemical studies of the soils and of other ecological factors or without controlled experimentation on the effects of different molybdenum concentrations (under similar environmental conditions as at Lucky Ship) on the growth of fir.

The use of the tree-ratio method for delineating the molybdenum mineralization in the Lucky Ship area was found to have several limitations. Variations in environmental factors, such as elevation appear to affect the tree-ratio observations. The effective application of this method requires, therefore, an area of relatively homogeneous environmental conditions and of two co-dominant tree species.

The systematic geobotanical investigations for the three areas revealed that a variety of environmental site conditions existed in each area that were related to plant species distribution. Species common to the areas showed similar site affinities. Whereas the Huckleberry Mountain and Lucky Ship deposits were situated within 100 miles of each other in north-central British Columbia, Lornex was 350 miles farther south and also farther inland. Elevations, however, were comparable for the three properties. Thus, of a total of 165 different species identified for the three areas, 53 species, or about 30 per cent were present in all three areas and showed similar site affinities particularly moisture, drainage, soil, elevation, and relief and exposure (sunny or shady). The two northern areas, Lucky Ship and Huckleberry Mountain, although differing in the type of mineral deposit present, had 88 species or about 80 per cent (of a total 138 identified for the two areas) in common whereas Huckleberry Mountain and the Lornex copper area had only 59 species or 40 per cent (of a total 153 identified) in common. Geographic and regional as well as local site factors must, therefore, be taken into account in interpreting species distribution.

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APPENDIX

Tables 1-3

TABLE 1

SUMMARY OF PLANT SPECIES IDENTIFIED AND EXAMINED, AND THEIR RELATIVE FREQUENCY DISTRIBUTION OVER ANOMALOUS AND NON-ANOMALOUS MINERALIZATION FOR LORNEX, HUCKLEBERRY MT., AND LUCKY SHIP PROPERTIES

Relative frequency

d - dominant; c - common; co-d - co-dominant; i - infrequent; a - abundant

Species	Lornex deposit (COPPER)		Huckleberry Mt. deposit (COPPER)		Lucky Ship deposit (MOLYBDENUM)		Site habitat
	Anomalous area	Non-anomalous area	Anomalous area	Non-anomalous area	Anomalous area	Non-anomalous area	
Overstory (trees)							
Abies lasiocarpa	i, co-d, d	i, co-d, d	co-d, d	co-d, d	i, co-d, d	i, co-d, d	widespread
Alnus crispa (sinuata)	i		i, c	i, c			wet
Picea glauca	i, d	i, c	i	i		i, co-d	moist site, middle altitudes
Pinus albicaulis			i to co-d	i to co-d	i to co-d	i	open slopes, higher altitudes
P. contorta	c, co-d, d	c, co-d, d	a, co-d	a, co-d	c, co-d, d	c, co-d, d	mainly burned-over site
Populus tremuloides	i,	i, a			i	i, co-d	
P. trichocarpa	i		i, c	i			moist valley
Pseudotsuga menziessi	i	i					rocky, gravelly
Salix (bebbiana?)	i	i	i to co-d	i to co-d		i	moist
Tsuga mertensiana			i, c	i		i, c	well-drained and bog
Understory (shrubs <5' avg.)							
Alnus crispa (sinuata	i, c	i, c	c, d	c, d	i, d	i, d	wet, poorly-drained

Relative frequency

d - dominant; c - common; co-d - co-dominant; i - infrequent; a - abundant

Species	Lornex deposit (COPPER) Anomalous area	Lornex deposit (COPPER) Non-anomalous area	Huckleberry Mt. deposit (COPPER) Anomalous area	Huckleberry Mt. deposit (COPPER) Non-anomalous area	Lucky Ship deposit (MOLYBDENUM) Anomalous area	Lucky Ship deposit (MOLYBDENUM) Non-anomalous area	Site habitat
A. tenuifolia	i	i	i,	i,	i	i	"
Amelanchier alnifolia	i	i	i	i, c	i, c	i, c	open
Salix sp.	i	i	i, a	c, a	i, c	i, c	moist to dry
Groundstory A. Shrubs (<5' avg.) Arctostaphlos uva-ursi	i to co-d	i to co-d	i, c	i to co-d	i, c	i, c	dry, sandy, rocky
Aruncus sylvestris					i	i	damp shaded
Cassiope lycopodiodes			f	f			wet Sphagnum bog
Cladothamnus pyrolaeflorus			i to co-d	i, c		i, a	moist forest
Empetrum nigrum	i, c	i, c	i to co-d	i to co-d			wet Sphagnum bog; dry acid soil
Juniperus communis	i, c	i, c	i	i	i	i	woods and open slopes
Kalmia polifolia			c to co-d	c to co-d			wet Sphagnum bog
Ledum groenlandicum	i to a	i to a					wet
L. palustre *			c to co-d	c to co-d			wet Sphagnum bog
Linnaea borealis	i, c	i, c	i, c	i, c	i, c	i, c	moist shaded forest
Lonicera involucrata	i, c	i, c	i	i	i	i, c	moist
L. utahensis	i, c	i, c			i	i	open slope

Menziesia ferruginea			i, c	i, c	i	i, c	shady moist forest
Oplopanax horridus					i, c	i, c	shady moist, rich soil
Pachystima myrsinites	i	i	i to co-d	i to co-d	i, a	i, a	well-drained conifer forest
Phyllodoce empetriformis			i to co-d	i to co-d		i	wet Sphagnum bog; rocky slope
Potentilla fruticosa	i	i					open slope
Ribes lacustre	i, c	i, c	i, c	i, c	i, c	i, c	wet
R. viscosissimum	i	i					moist shaded forest
Rosa nutkana	i, c	i, c	i, c	i, c	i	i, c	widespread
Rubus ideaus	i	i					shaded forest
R. parviflorus	i	i	i	i, c	i, a	i, a	fairly open forest
R. spectabilis			i	i	i, c	i, c	moist forest
Sambucus melanocarpa			i	i	i	i	moist
Shepherdia canadensis	i to co-d	i to co-d	i, c	i, c	i, c	i, c	slopes, dry sandy soil
Sorbus scopulina	i	i	i	i	i, c	i, c	widespread
S. sitchensis	i	i	i, c	i, c	i, c	i, c	open dry slope
Spirea densiflora		i			i, c	i	moist thickets
S. douglassi			i	i			bog
S. lucida	i, c	i, c	i, c	i, c	i, c	i, c	thin woods; open slope
Vaccinium caespitosum	i	i	i	i			moist rocky slope

Relative frequency

d - dominant; c - common; co-d - co-dominant; i - infrequent; a - abundant

	Lornex deposit (COPPER)		Huckleberry Mt. deposit (COPPER)		Lucky Ship deposit (MOLYBDENUM)		
	Anomalous area	Non-anomalous area	Anomalous area	Non-anomalous area	Anomalous area	Non-anomalous area	Site habitat
V. membranaceum	i, c	i, c	c to co-d	c to co-d	i to d	i to d	dry conifer forest
V. ovalifolium			i, a	i, a			conifer forest
V. oxycoccos			c	c			wet *Sphagnum* bog
V. scoparium	i to co-d	i to co-d	i	i	i	i	conifer forest
Viburnum edule	i	i	i	i	i		moist shaded forest
B. Herbs							
Achillea lanulosa	i	i	i	i		i	disturbed areas along cut lines, roads
Achillea sp.					i	i	disturbed areas along cut lines, roads
Actaea rubra	i	i	i, c	i, c	i, c	i, c	shaded forest
Agoseris sp.	i				i		open slope
Agrostis sp.			c, a	c, a	c	c	damp depressions; (fresh water)
Anaphalis margaritacea			i, c	i, c			dry rocky
Antennaria racemosa	i	i			i, c	i	moist woods
A. rosea					i	i	open well-drained slope
Apocynum androsaemifolium		i					conifer forest

Aquilegia formosa	i	i				i	rocky slope
Arennaria capillaris	i	i					open slope
Arnica amplexicaulis	i, c	i, c	c	c	i, c	i, c	moist
A. cordifolia	i, c	i, c	c	c	i, c	i, c	forested
Aster conspicuous	c	i, c					open forest
A. foliaceus			i, c	i, c	i	i	moist site, creek banks
A. modestus			i, c	i, c	i	i	moist thickets; bog
Athryium felix-femina			i to a	i to a	i	i to a	moist rich soil
Calamagrostis canadensis			c, a	c, a	c, a	c, a	moist woods; depressions
Calamagrostis sp.			i	c	i	i	widespread
Calamagrostis rubescens	i	i, c					open woods; moist slopes
Carex buxbaumii			c				sedge-herb bog
C. richardsonii	i, c	i, c					dry sunny
C. sitchensis			c, a	c, a			bog
Calochortus macrocarpus	i	i					dry slope
Calypso bulbosa	i	i					shaded conifer
Castilleja miniata	i	i	i, c	i, c	i, c	i, c	widespread
Cerastium sp.	i	i			i	i	moist
Chimaphila umbellata	i	i			i	i	dry
Clintonia uniflora			i, c	i, c	i to a	i to a	moist forest
Corallorhiza striata	i	i					conifer forest
Cornus canadensis	i, c	i, c	c, a	c, a	c, a	c, a	widespread
Coryadalis sempervirens					i		open forest or slope

Relative frequency

d - dominant; c - common; co-d - co-dominant; i - infrequent; a - abundant

	Lornex deposit (COPPER)		Huckleberry Mt. deposit (COPPER)		Lucky Ship deposit (MOLYBDENUM)		
	Anomalous area	Non-anomalous area	Anomalous area	Non-anomalous area	Anomalous area	Non-anomalous area	Site habitat
Cryptogramma crispa					i, c	i, c	rocky slopes and crevices
Cypripedium montanum					i	i	moist forest
Drosera rotundifolia					a	a	<u>Sphagnum</u> bog
Dryopteris austriaca		i					moist
Elymus canadensis					i to a	i to c	sandy well-drained
Epilobium alpinum			i, c	i, c	i	i	wet rocky slope
E. angustifolium	i, c	i, c	c, a	c, a	i, c	i, c	widespread; burned sites
Equisetum arvense	i, c	i	i, c	i, c	i, c	i, c	moist well-drained
E. scirpoides	i	i					creek banks
Eriogonum subalpinum	i	i	i, c	i, c	i	i	exposed, high elevations
Eriophorum angustifolium			c, a	c, a			bog
Gallium triflorum	c	c	i, c	i, c	i, c	i, c	moist, shaded
Geum macrophyllum	i	i					moist forest thicket
G. triflorum			i	i	i	i	dry, open
Goodyera oblongifolia	i	i				i	forest
Gymnocarpium dryopteris			i, c	i, c	i, c	i, c	moist, shaded
Habenaria dilatata	i	i	i	i	i	i	wet sites; bog open slope

Heracleum lanatum		c	c	c	i	i	rich soil, damp
Hieracium albiflorum	i	i, c			i to a	i, c	wooded
H. umbellatum	i	i, c			i	i	open forest
Juncus oreganus			i	i			Sphagnum bog
Leptarrhena pyrolifolia			c	c			rich moist soils along creek and bog sites
Lilium parviflorum	i	i					damp shaded woods
Listera cordata			i, c	i, c	i, c	i, c	damp mossy site; bog
Lupinus sp.	c to d	c to d	i, c	i, c	i	i	widespread except bog
Luzula parviflora	i, c	i, c	i, c	i, c	i, c	i, c	widespread
Lycopodium annotinum	i	i	c	c	c	c	moist forest
L. complanatum			c	c	i	i	dry thickets woods
L. sitchense			i, c	i, c	c	c	thickets open forest
Melica sp.			c, a	c, a	i	i	open forest
Mitella nuda	i	i	i	i	i	i	moist forest
Monotropa hypopithys	i	i	i	i	i	i	shaded damp conifer
Montia parviflora			i	i	i	i	moist rich soils
Myosotis sp.	i	i	i	i			moist high
Ozmorhiza purpurea			i	i			forested slope
Parnassia fimbriata			i	i			moist site; bog
Pedicularis bracteosa	i, c	i, c					moist forest
Pentstemon gracile	i	i					moist-dry open

Relative frequency

d - dominant; c - common; co-d - co-dominant; i - infrequent; a - abundant

	Lornex deposit (COPPER)		Huckleberry Mt. deposit (COPPER)		Lucky Ship deposit (MOLYBDENUM)		
	Anomalous area	Non-anomalous area	Anomalous area	Non-anomalous area	Anomalous area	Non-anomalous area	Site habitat
P. globosus	i	i					moist-dry
P. scouleri			i, c	i, c	i to a	i to a	exposed rocky slope
Petasites sagittarius	i	i					wet
Polystichium sp.					i	i	shaded; rocky slopes
Potentilla palustris			c	c			sedge bog
Potentilla sp.					i	i	moist
Pyrola asarifolia	c	c	i, c	i, c	i, c	i, c	moist forest
P. minor	i	i	c	c	i	i	forest
P. secunda	c, a	c, a	c, a	c, a	i to a	i to a	forest
Rubus pedatus			i	i	i to a	i to a	damp conifer forest
Sanguisorba canadensis			i, c	i, c			widespread
Saxifraga bronchialis					c, a	c, a	rocky soil
S. ferruginea			i	i	i	c	moist ledges and banks
Scirpus caespitosus			a, co-d	a, co-d			bog
Sedum douglassi					i	i, c	rocky slope
S. lanceolatum	i, c	i, c					open slope
Senecio triangularis	i, c	i, c	c, a	c, a	i to a	i to a	wet
Silene menziessi					i	i	moist
Solidago sp.	i	i					widespread
Solidago sp.			i	i	i	i	"

Streptopus amplexifolius	i, c	i, c	c	c	c, a	c, a	moist forest
S. roseus			i, c	i, c	c, a	c, a	moist forest
Taraxacum officinale	i	i	i	i	i	i	disturbed road sides
Thalictrum occidentale	i, c	i, c	i to a	i to a	i to a	i to a	moist rich soils
Tiarella unifoliata			i	i	i, c	i, c	moist forest
Valeriana sitchensis			i, c	i, c	i to a	i to a	wet
Valhodea atropurpurea			i	i			moist forest
Veratrum viridi			i, c	i, c	i to a	i to a	wet
Viola adunca	i	i					
V. palustris			i, c	i, c	i, c	i, c	wet
V. spp.	i	i					shaded
V. spp.			i	i	i, c	i, c	shaded, moist
C. Lower plants (moss, lichen, liverwort, fungi)							
Brachythecium spp.	i to co-d	i to co-d					pine forest
Calliergonella schreberi	i to co-d	i to co-d	i to a	i to a	i to a	i to a	conifer forest
Cladonia gracilis	i to co-d	i to co-d	i to a	i to a	i to a	i to a	"
Dicranum polysetum			i to a	i to a	i to a	i to a	"
Dicranum sp. (?)	i to co-d	i to co-d					"
Marchantia polymorpha	i, c	i, c	i, c	i, c	i, c	i, c	"
Other liverwort sp.	i, c	i, c					
Mnium sp.	i	i	i	i	i	i	wet-moist sites
Peltigera apthotha	i, c	i, c	i, c	i, c	i, c	i, c	conifer forest
Plagiothecum undulatum			i	i	i	i	"
Polytrichum juniperum	i, c	i, c	i	i	i	i	"
Rhytidiopsis robustus	i	i	i to a	i to a	i to a	i to a	"

Relative frequency

d - dominant; c - common; co-d - co-dominant; i - infrequent; a - abundant

	Lornex deposit (COPPER)		Huckleberry Mt. deposit (COPPER)		Lucky Ship deposit (MOLYBDENUM)		
	Anomalous area	anomalous area	Anomalous area	anomalous area	Anomalous area	anomalous area	Site habitat
Sparassis sp.			i	i	i	i	forest
Sphagnum spp.			d	d			bog
Tree lichens							
Letharia vulpina	i to a	i to a	i, c	i, c	i, c	i, c	mainly pine forest

TABLE 2

Cu, Zn, AND Mo (IN P.P.M. OF PLANT ASH) AND Cu:Zn RATIO IN PLANT ASH IN PINUS CONTORTA (BARK) AND LUPINE SP. (LEAVES) FOR LORNEX PROPERTY, BRITISH COLUMBIA

Station number	Cu		Zn		Mo		Cu:Zn Ratio	
	Pine	Lupine	Pine	Lupine	Pine	Lupine	Pine	Lupine
1	70	70	1800	240	24	180	0.04	0.29
2	50	50	1500	240	10	500	0.03	0.20
3	40	50	1300	200	14	480	0.03	0.25
4	60	50	2300	260	38	290	0.03	0.19
5	40	60	1300	160	18	120	0.03	0.38
6	30	60	1600	160	10	30	0.02	0.38
7	30		1300		2		0.02	
8	50	130	3200	180	3	56	0.01	0.71
9	40	40	1300	180	3	56	0.03	0.21
10	40	200	1300	160	3	64	0.03	1.20
11	60	340	1300	360	24	530	0.05	0.90
12	60	70	2300	460	34	270	0.03	0.15
13		no sample						
14								
15	80	100	2200	260	5	64	0.04	0.38
16	40	40	2000	160	3	60	0.02	0.25
17	40		2000		3		0.02	
18	40	90	2400	280	2	24	0.02	0.32
19	40	90	1400	240	3	48	0.03	0.37
20	50	70	2600	240	3	26	0.02	0.29
21	40	80	1600	200	2	22	0.03	0.40
22	40	70	1800	160	2	34	0.02	0.44
23	40		1200		2		0.03	
24	50	100	2000	180	2	22	0.03	0.55
25	40	100	2000	220	2	60	0.02	0.45
26	70		2400		2		0.03	
27	40	90	2000	240	5	96	0.02	0.37
28	40	40	1800	160	12	120	0.02	0.25
29	35		1200		14		0.03	
30	30	130	2100	240	2	64	0.01	0.54
31	35	60	2300	220	5	96	0.02	0.27
32	45		2100		6		0.02	
33	50		3000		7		0.02	
34	50	70	1500	200	5	140	0.03	0.35
35	60	65	2700	180	26	480	0.02	0.36
36	50	50	2300	140	2	72	0.02	0.35

TABLE 3

SUMMARY OF TREE COUNTS AND TREE RATIOS FOR PINE AND FIR ALONG FOUR DIFFERENT LINES IN RELATIONSHIP TO ANOMALOUS AND NON-ANOMALOUS MOLYBDENUM ZONES AT THE LUCKY SHIP DEPOSIT.

Anomalous Mo area

Line*	Lodgepole pine	White pine	Fir	Tree ratio: Lodgepole pine / Fir	Tree ratio: Both pines / Fir
2 + OOW	40	2	58	.69	.72
3 + OOE	35	12	93	.37	.50
Baseline	56	7	87	.64	.74
5 + OOS	48	10	122	.39	.45

Non-anomalous Mo area

Lodgepole pine	White pine	Fir	Tree ratio: Lodgepole pine / Fir	Tree ratio: Both pines / Fir
16	10	144	.11	.18
32	8	90	.36	.44
42	3	105	.40	43
57	4	49	1.2	1.3

*Stations common to two lines were counted only once.