000948 Pantelyev

THE CARMI Mo-(U) DEPOSIT, SOUTHERN BRITISH COLUMBIA

J.M. Kenyon (Vestor Explorations Limited)

R.D. Morton (University of Alberta, Edmonton)

ABSTRACT

The Carmi Mo-(U) deposit is situated in the Omineca Crystalline Belt 80 km south of Kelowna. Total drill-indicated reserves are estimated at between 24 and 34.5 million tonnes of 0.15% MoS_2 with associated but sporadic brannerite. Where drill-intersected, uranium averages 1.0 lb/ton U_3O_8.

The geochemical association of the two elements is common throughout a range of geological environments. In comagmatic igneous suites, U and Mo show preference for late-stage fractions and are commonly zoned.

At Carmi, rocks range in age from Precambrian to Tertiary but only the Jurassic Nelson batholith and the Cretaceous Valhalla intrusion are of importance. The Nelson rocks are predominantly biotite-granodiorites while the Valhalla suite is represented by a two mica granitoid. The Valhalla granitoid and its derivatives are intrusive into the Nelson, but the main body does not crop out.

Two mineralized breccia zones have been discovered to date (the "E" and "Lake" zones) and are localized within the Nelson unit. Molybdenite occurs in angular Nelson fragments and within the quartz-rich breccia matrices. Brannerite is restricted to the quartz matrix of a portion of the "E" zone.

Porphyry-type hydrothermal alteration includes pervasive propylitic alteration and quartz-sericite alteration largely confined to the breccia zones. A minor area of potassic alteration may be present in the "E" zone.

Because the breccia fragments show no milling effects, the zones are proposed to have been formed by collapse of the Nelson rocks into vapor-rich voids formed at the Nelson-Valhalla interface. Such voids might form from exsolved water released during injection and cooling of the Valhalla magma. Fluids from the Valhalla permeated the breccia producing the coeval mineralization, alteration and the quartz cement.

The recognition of the Mo-U association serves to illustrate the potential of many Mo-porphyry prospects and is important in the search for source-basements for sedimentary-hosted Tertiary U deposits. If metal zoning applies at Carmi, then the breccias may overlie a lower-level hypogene Mo-porphyry.

The Carmi Mo-(U) deposit is situated in the Omineca Crystalline Belt along the western margin of the Nelson batholith. The property lies 5 km north west of the hamlet of Carmi and 80 km south of the city of Kelowna. The Carmi claim group lies within a slightly undulating plateau bounded on all sides by deeply cut valleys. Relief on the plateau rises to 1360 m from a base elevation of 600 m in the West Kettle River valley. The climate is similar to the Okanagan Valley to the west, but receives more precipitation.

The Carmi area has been the target of intermittent mineral exploration since 1960, but not until 1974 has a concentrated effort been applied. Since 1974, some 9100 m of percussion and diamond drilling has confirmed the existence of two molybdenite-bearing mineralized zones, namely the "E" and "Lake" zone intrusive breccias. The presently drill-indicated tonnage and grade has been variously estimated at between 24 and 34.5 million tonnes of approximately 0.15% MoS_2, as a total of both zones. The associated uranium mineralization, represented by brannerite, (UTi_2O_6) is sporadic and at present of sub-economic quantities and restricted to a portion of the "E" zone. Drill-intersected uranium mineralization averages approximately 1 lb/ton U_3O_8 and that at surface in the order of 0.5 lb/ton U_3O_8.

Mo-U ASSOCIATION

The geochemical association of the two elements has been documented throughout a range of geological environments (Buntebarth 1976, Fischer 1970, Barsukov et al. 1971, Mel'nikov and Berzina 1973). It has been further determined that in igneous environments Mo and U show a common geochemical behavior in that they are enriched in late-stage, felsic, silicic and potassic members of comagmatic igneous suites (Bohse et al. 1974). Fluoride and chloride complexes are thought to be the dominant transport mechanism (Rekharskiy 1971). As U is more mobile, it will tend to migrate further in the hydrothermal system. A vertical zonation of deposition arises which is characterized by an increasing U:Mo ratio with decreasing temperature (Rekharskiy and Plyatt 1967). Wallace et al. (1968) report that brannerite is associated with quartz-sericite alteration above the molybdenum ore at Climax, Colorado.

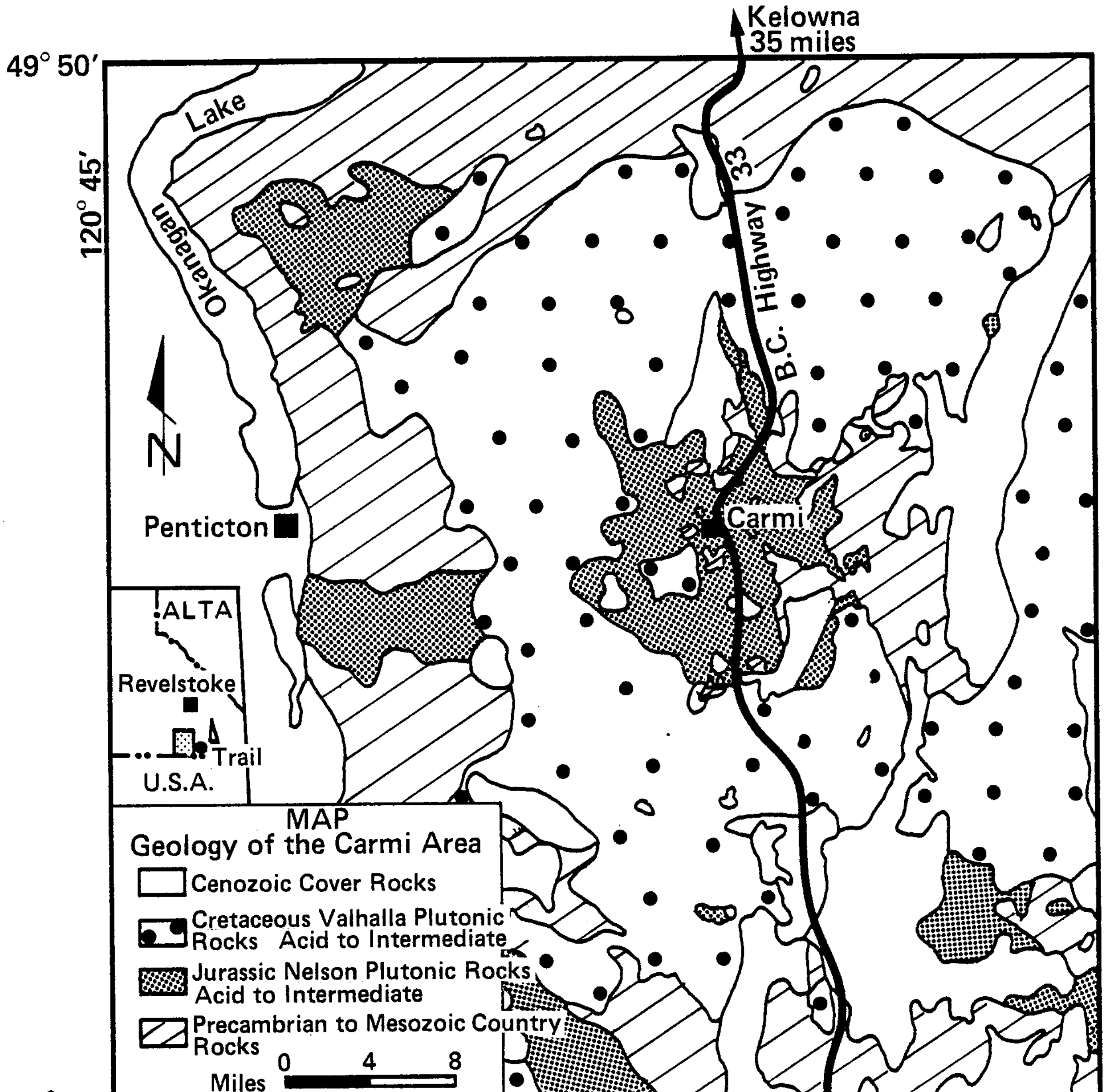
CARMI REGIONAL GEOLOGY

The regional geological map compiled by Little (1957, 1961) shows Precambrian to Tertiary sedimentary, metamorphic and igneous rocks exposed in the district (Map 1). The Precambrian sequences consist of low-to medium-grade metamorphic rocks of the Monashee and Chapperon Groups. Paleozoic rocks are represented by sedimentary, volcanic and low-grade metamorphic rocks, of which the Permian Anarchist Group metasedimentary/metavolcanic rocks predominate. Mesozoic and Cenozoic rocks mostly belong to the Jurassic Nelson intrusions, the Cretaceous Valhalla intrusion and the Tertiary, Coryell plutonic rocks. All major faults in the area appear to be radial or tangential to the major intrusions (Little 1960). Pleistocene glaciation, moving in a southerly direction, scoured the area below 2300 m elevation.

LOCAL GEOLOGY

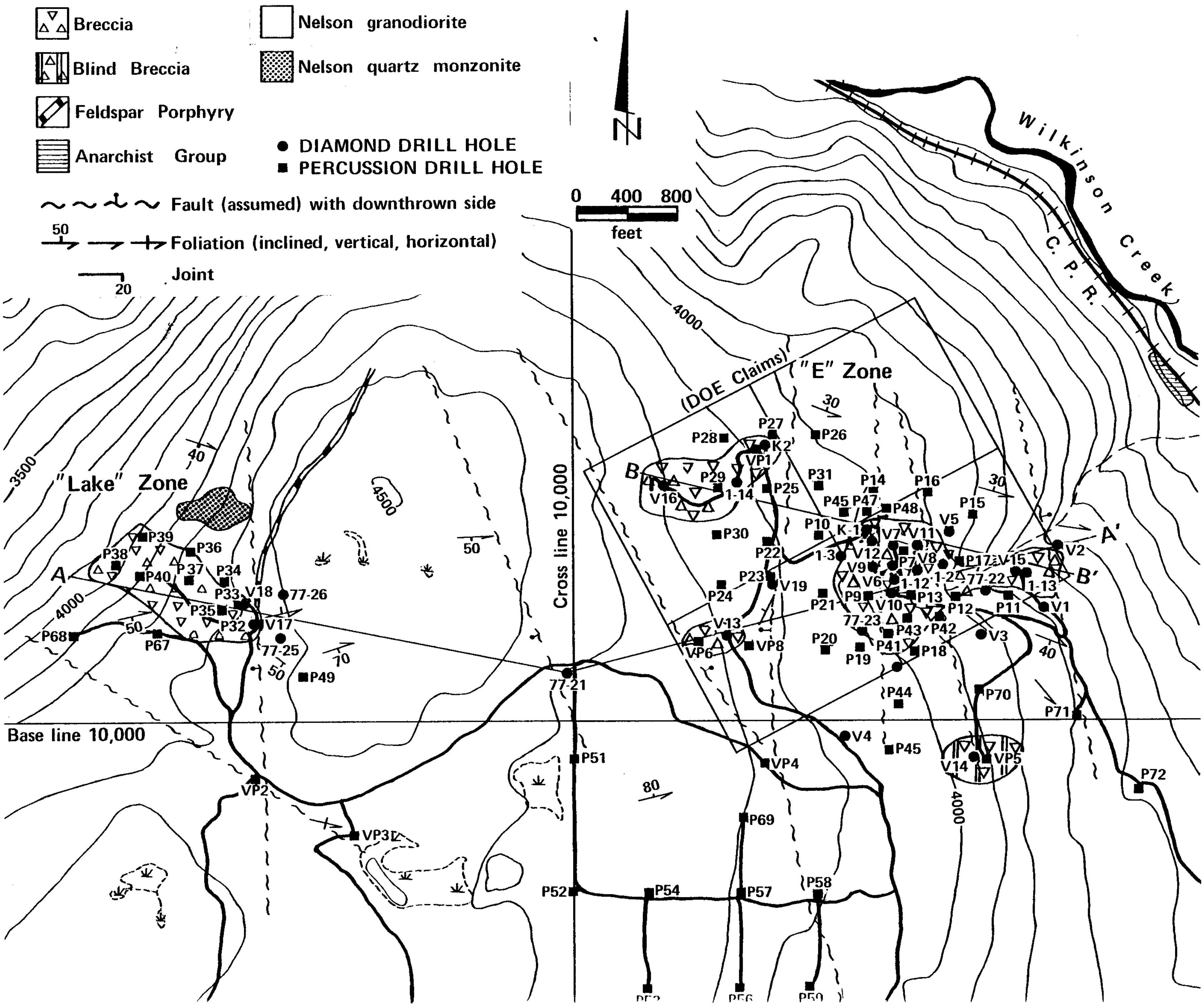
Locally, the Carmi area is dominated by the Nelson-and Valhalla-intrusions (Map 2). Anarchist Group rocks remain in part, as roof pendants within the Nelson intrusion and have been the site of small mining operations in the past (producing precious metals from mineralized shear zones).

At Carmi, the older Nelson rocks are predominantly melanocratic, medium-grained, foliated biotite-granodiorites. Smaller bodies of Nelson related quartz diorite and quartz monzonite have been observed, with the quartz monzonite displaying a cross-cutting relationship to the main granodiorite body. The main body of the younger Valhalla intrusion has not been observed in outcrop and its existence is known only from diamond drill intersection. It is a two mica granitoid and is massive and slightly porphyritic. Both plagioclase and less abundant potassic feldspar constitute the phenocrysts. The Valhalla intrusion is a muscovite-biotite-quartz monzonite and has several late-stage derivatives, including feldspar porphyry



(after LITTLE 1957, 1961)

CARMI B.C. GEOLOGICAL MAP



dikes and the cement of the mineralized breccia zones.

MINERALIZED ZONES

The two molybdenite-bearing mineralized breccia zones discovered to date, are elongate east-west in plan view and irregular in section (see cross-sections). They appear to be discrete bodies unconnectedat depth. From cross-section, the breccias appear as bodies localized within a thin fault-dissected cover of Nelson granodiorite and have been designated as the "E" and "Lake" zones respectively.

Within the breccias, rock fragments range from less than 3 cm to greater than 0.5 m across (with an average of 12-15 cm across). The fragments are angular and show no spalling or rounding of corners. They are chiefly composed of foliated Nelson granodiorite with minor Nelson quartz diorite and occasional fragments of Valhalla quartz monzonite. A considerable amount of rock, both laterally and vertically away from the breccias, has been affected by fracturing and/or shearing, but with no rotation of fragments.

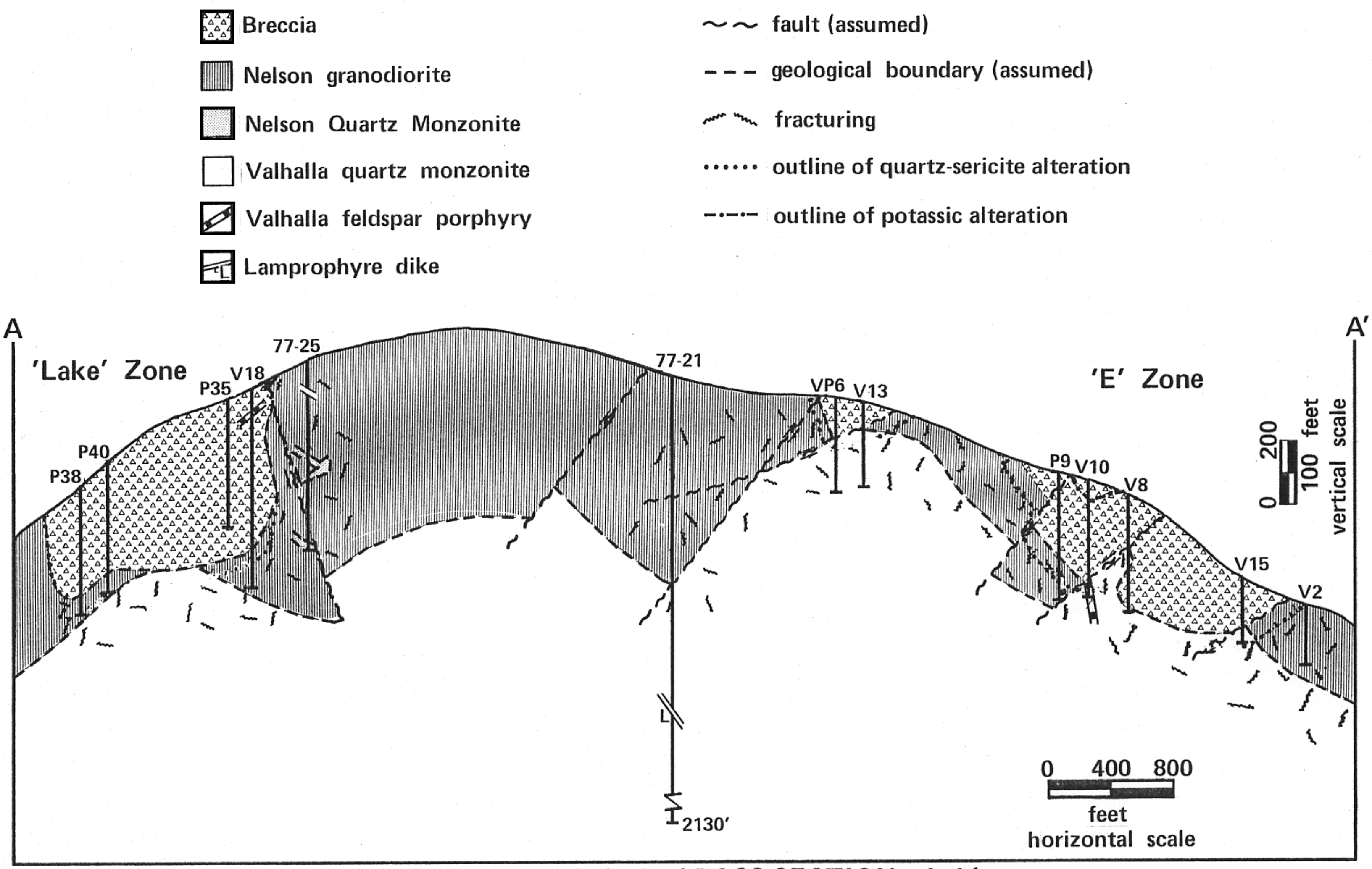
The breccia matrix consists of milky quartz, pegmatitic quartz-feldspar intergrowths and minor rutilated quartz, ranging from discrete, irregular patches between fragments to massive matrix containing discrete fragments. Within the "E" zone, minerals introduced with the matrix include pyrite, magnetite, fluorite, molybdenite, muscovite, biotite, chalcopyrite, brannerite and ilmenite in approximate order of decreasing abundance. Molybdenite occurs as rosettes within fragments, as thin lamellae on fragment/matrix boundaries and as discrete flakes within the matrix. Brannerite is restricted to the "E" zone and occurs entirely within the quartz matrix as prismatic crystals up to 6 mm long. Fluorite occurs within the matrix and has invaded fragments as has pyrite to a lesser degree. An increase in molybdenite content is accompanied by an increase in fluorite and pyrite abundance.

The mineralogy of the "Lake" zone is more varied. The breccia characteristics are chiefly the same but the fragments display a greater degree of hydrothermal alteration and the matrix is distinctly vuggy. Within the vugs (up to 5 cm across) euhedral crystals of calcite (2 phases), fluorite (2 phases), pyrite and rutile occur in decreasing order of abundance in addition to zeolites (stilbite and stellerite).

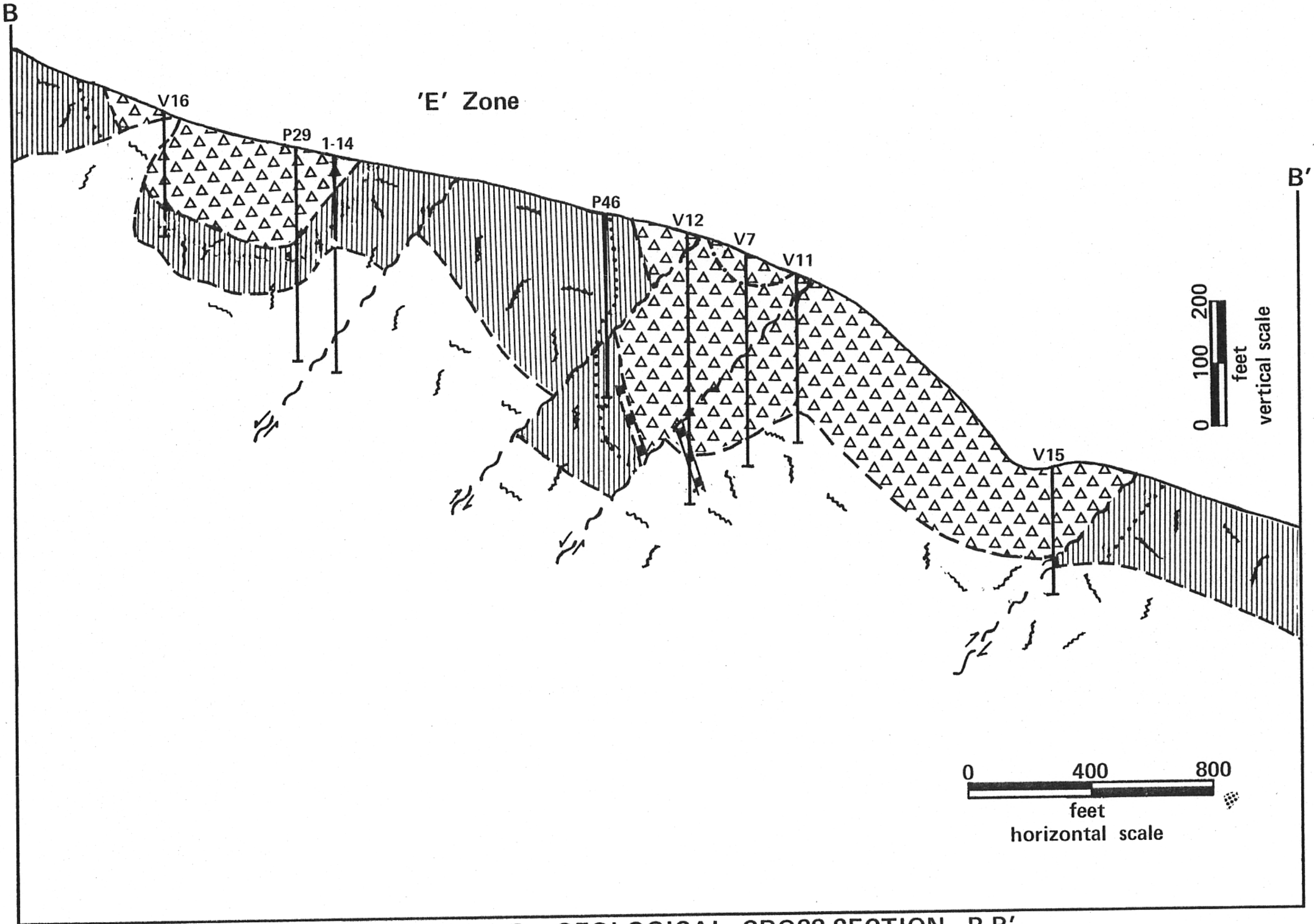
Accessory metalliferous mineralization from assayed sections includes trace to minor quantities of lead, zinc, gold, silver and rhenium. No lead-bearing minerals have been identified and only minor sphalerite has been noted. It is presumed that pyrite may be responsible for gold values, and the rhenium content (20 to 145 ppm), is of course attributed to molybdenite.

ALTERATION PHENOMENA

Porphyry-type alteration includes pervasive propylitic alteration, quartz-sericite (phyllic) alteration and minor potassic alteration. Propylitic alteration within the surrounding Nelson host may in part be due to low-grade greenschist facies regional metamorphism contributing in part to the development of epidote and chlorite. Quartz-sericite



CARMI B.C. GEOLOGICAL CROSS-SECTION A-A'



CARMI B' B.C. GEOLOGICAL CROSS-SECTION B-B' alteration is largely confined to the breccia bodies and varies in intensity within the breccias. The "Lake" zone is most intensely affected by quartz-sericite alteration which has in places, resulted in the complete destruction of fragments to coarse sericite/muscovite and quartz. A small halo of minor potassic alteration is localized within the central portion of the "E" zone. The lack of complete diamond drill information has made this latter assessment somewhat tenuous.

BRECCIA GENESIS

The generation of breccias associated with porphyry-type ore deposits has been the subject of much discussion and have been well-documented by Gilmour (1977). The most common breccias are pipes where the vertical dimension is many times greater than the horizontal dimension, and the matrix consists of new igneous material in association with comminuted host rock. Fragments characteristically show milling effects induced by fluidized systems.

At Carmi, the fragments do not show milling effects and the matrix is new material with no comminuted host rock. Considering these characteristics and the breccia zone shapes and dimensions, it is proposed that the Carmi breccias are the result of collapse into a void in a similar manner to a mechanism suggested by Norton and Cathles (1973) (Figure 1).

A void might form from exsolved vapor phases which collected at the contact of the Nelson and Valhalla intrusions during cooling of the latter. The collapse of the overlying Nelson rocks into the vapor void results during a subsequent decrease of hydrostatic pressure caused by piercement of the vapor phase into the Nelson. The ultimate size and shape of the resulting breccia would be a function of the size of the vapor void and the caving characteristics of the host rocks. The Carmi breccias were propagated upward to at least include, in part, the overlying Anarchist Group (as evidenced by the occasional metasedimentary fragment).

Due to their porosity, the breccias became hydrothermal channel ways which permitted the introduction of mineralization and alteration. A Pb^{206}/U^{238} date of a brannerite separate (H. Baadsgaard, Univ. Alta.), indicates the mineralizing event to be a late-stage Valhalla event at 62 my ($\pm$ 1). Table 3 illustrates the structural history of Carmi and Figure 2 relates stages of mineralization to periods of structural deformation. That the mineralization is Valhalla derived is supported by disseminated molybdenite in the Valhalla where it is unknown in unbrecciated Nelson. In addition, gamma ray spectrometric analyses of all rock types (Table 1 and 2) shows the Nelson to contain an average U content for granodiorites (2.65 ppm) while the Valhalla is depleted in uranium at 3.4 ppm (Clarke et al. 1966, Heier and Rodgers 1963).

CONCLUSIONS

The Mo- (U) bearing intrusive breccias of Carmi are perhaps variants of "Uranium Porphyries" as defined by Armstrong (1974). As such, they serve to illustrate the potentials

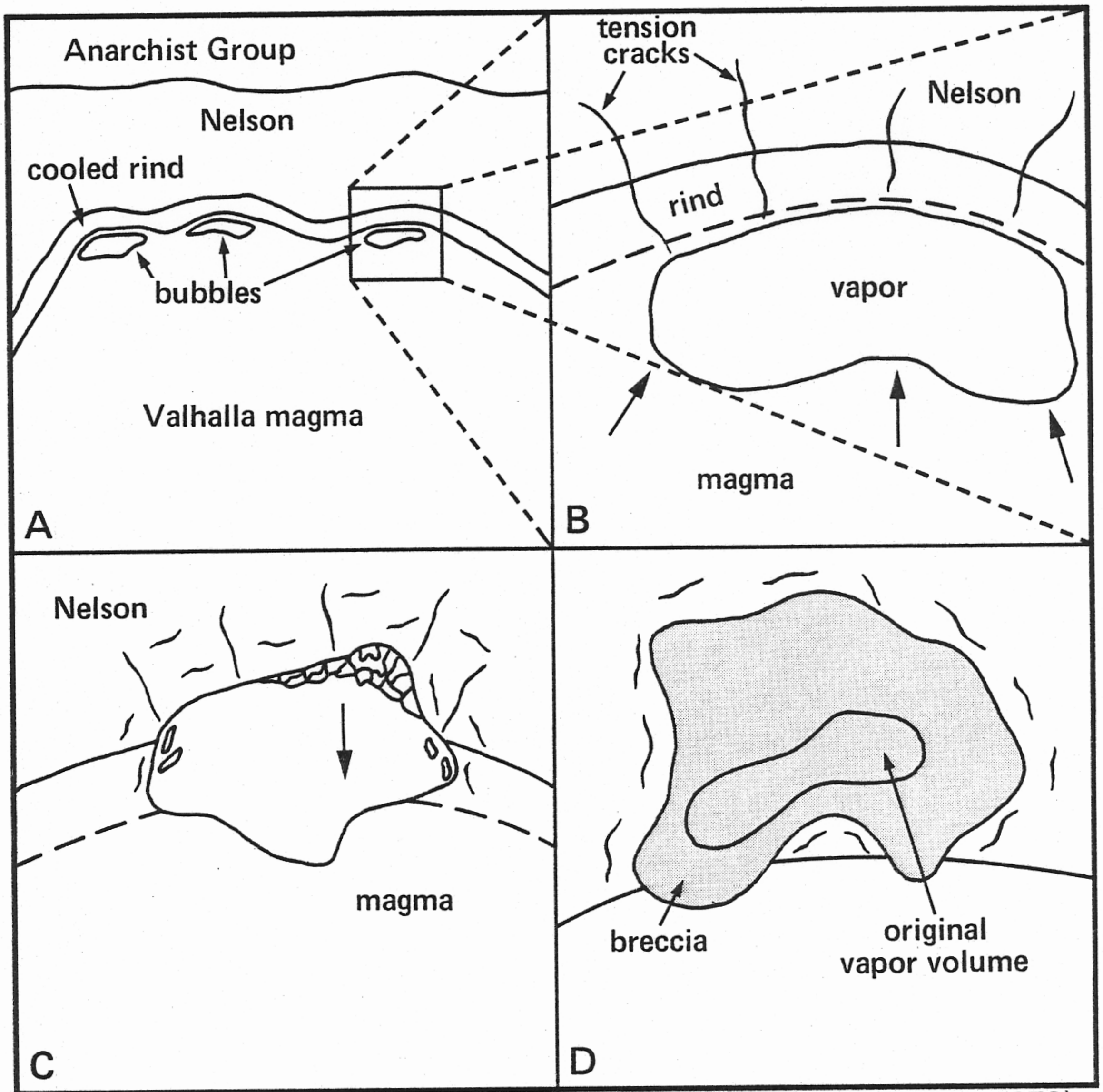


Figure 1

A. Exsolved magmatic water is trapped beneath cooled outer rind of intrusion.

B. Hydrostatic pressure fractures rind and vapor bubble begins to break through.

C. Resulting decrease in hydrostatic pressure starts brecciation by cavity filling through stoping and sheet fracturing.

D. Breccia body grows upward until cavity is filled and thus can support weight of surrounding rock.

TABLE 1

AVERAGED U CONTENT OF CARMI ROCK UNITS

	Uppm
Anarchist Group metasediments	2.5
Nelson granodiorite	2.65
Valhalla quartz monzonite	3.4
Valhalla feldspar porphyry	11.2
Nelson late-stage dikes	4.1
Nelson quartz monzonite	1.6

TABLE 2

AVERAGE U CONCENTRATIONS OF IGNEOUS ROCKS

	Uppm
Canadian Shield (Shaw 1967)	2.45
Granitic rocks (Heier and Rodgers 1963)	4.75
Granodioritic rocks (Clark et al. 1966)	2.60

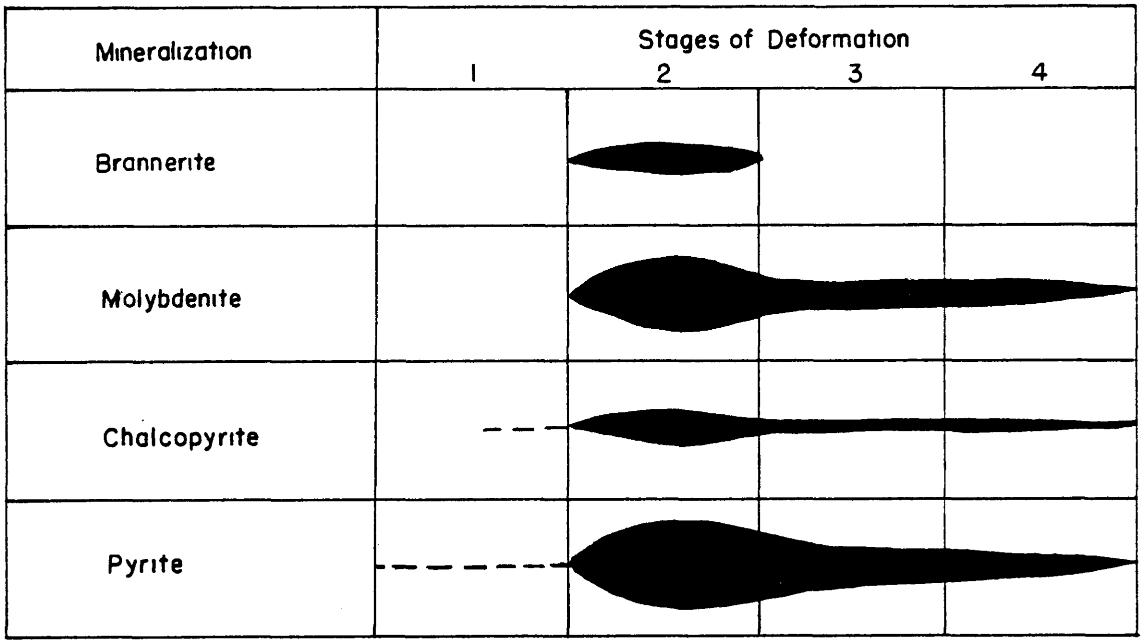


Figure 2. Stages of Hypogene Mineralization Related To Structural Deformation.

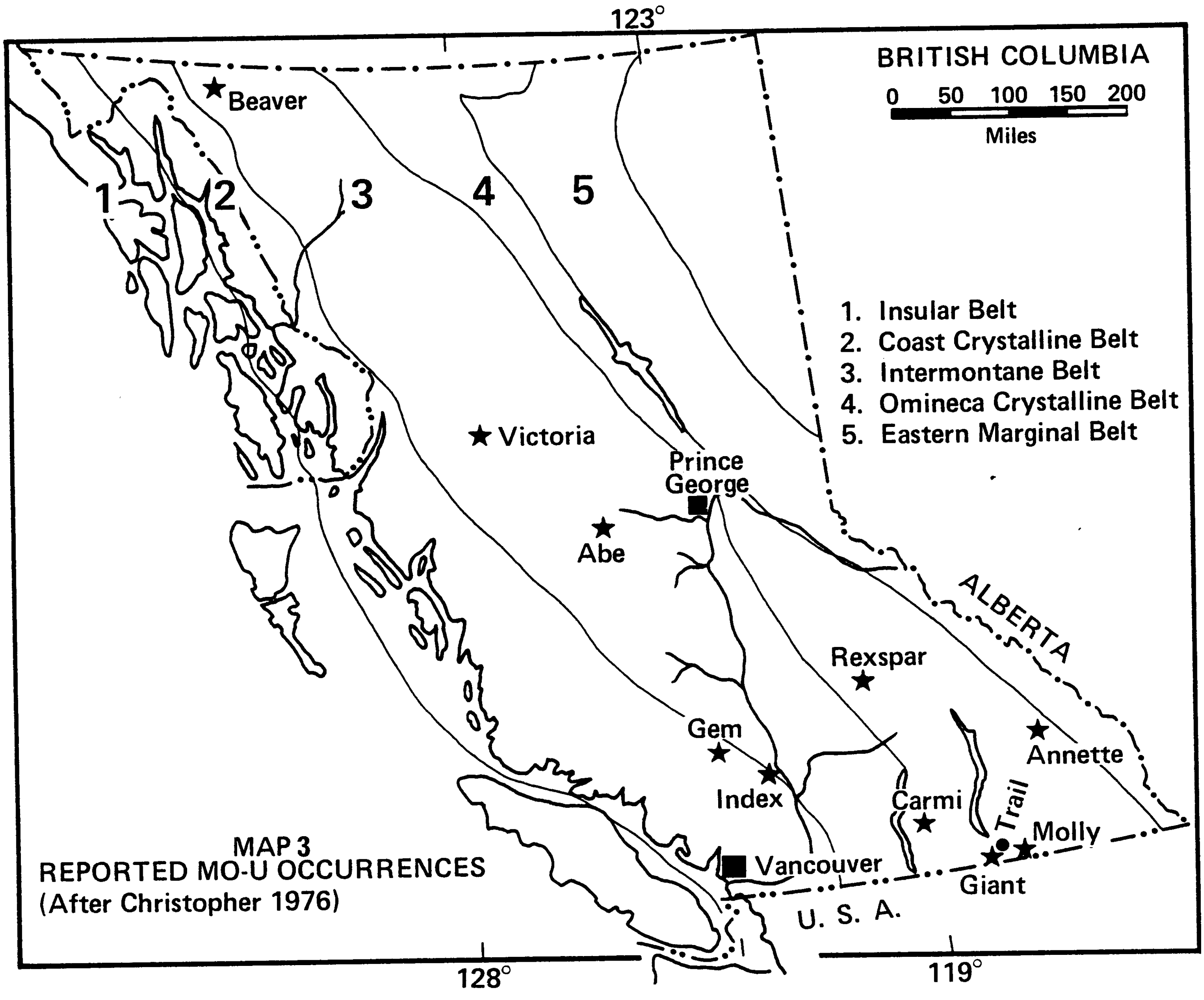
TABLE 3

CARMI STRUCTURAL HISTORY

stage 1:	foliation and minor shearing of the Nelson intrusion by regional orogenic events including initiation of the West Kettle River shear zone.
stage 2:	intrusion of the Valhalla quartz monzonite causing fracturing and shearing and brecciation of the overlying Nelson. Hydrothermal activity.
stage 3:	emplacement of inter-mineral feldspar porphyry dikes contemporaneous with mineralizing hydrothermal events.
stage 4:	development of horst and graben fault system and last pulse of hydrothermal event.

of many Mo-porphyry prospects in the Cordilleran as sources of nuclear raw materials. The association of Mo and U is not uncommon in British Columbia (Map 3) and has been mentioned previously by Soregaroli and Sutherland Brown (1976). It is also important to recognize such an association in the search for source-basements during prospecting for sandstone-and conglomerate-hosted uranium deposits within younger Tertiary intermontane basins of the region. The association of resistate titanium-bearing minerals (rutile) has recently been used as a prospecting indicator mineral in sedimentary-hosted uranium environments.

The Mo-(U) intrusive breccia association at Carmi seems to occupy a high level in the plutonic porphyry model of Sutherland Brown (1976) and if the data of Rekharskiy and Plyatt (1967) apply here, the association may be underlain by a hypogene zone wherein the Mo:U ratio increases, such that a normal Mo-porphyry association could occupy a lower level in the model.



MAP 3
REPORTED MO-U OCCURRENCES
(After Christopher 1976)

REFERENCES

Armstrong, F.C. 1975. Alternatives to sandstone deposits. in Mineral Resources and the Environment Supplementary Report and Resources of Uranium in the United States. Natl. Acad. Sci., Proc. Wash. D.C., pp. 99-118.

Barsukov, V.L., Sushcheveskoya, T.M., Malyshev, V.I. 1971. Composition of solution decomposing pitchblende at a U-Mo formation occurrence. Sov. Atomic Ener., 31, pp. 717-724.

Bohse, H., Rose-Hansen, J., Sorensen, H., Steenfelt, A., Louberg, L., Kunsendorf, H. 1974. On the behavior of uranium during crystallization of magmas -- with special emphasis on alkaline magmas. in Formation of Uranium Ore Deposits, Proceedings of a Symposium, Athens, Greece. I.A.E.A. Athens, 1974, pp. 49-57.

Buntebarth, G. 1976. Distribution of uranium in intrusive bodies due to combined migration and diffusion. Earth Planet. Sci. Lett. 32, No. 1, pp. 84-89.

Clarke, S.P. Jr., Peterman, Z.E., Heier, K.S. 1966. Abundances of uranium, thorium and potassium. Geol. Soc. Am. Mem. 97.

Fischer, R.P. 1970. Similarities, differences, and some genetic problems of the Wyoming and Colorado Plateau types of uranium deposits in sandstone. Econ. Geol. 65, pp. 778-784.

Gilmour, P. 1977. Mineralized intrusive breccias as guides to concealed porphyry copper systems. Econ. Geol. 72, pp. 290-298.

Heier, K.S., Rodgers, J.J.W. 1963. Radiometric determinations of thorium, uranium and potassium in basalts and in two magmatic differentiation series. Geochim. Cosmochim. Acta. 27, pp. 137-154.

Kenyon, J.M. 1978. Mo and U Mineralization With Special Reference To A Mo-(U) Deposit At Carmi, B.C. Unpub. MSc thesis, University of Alberta, Edmonton, Alberta.

Little, H.W. 1957. Geology - Kettle River (east half) map 6 - 1957. Geol. Surv. Can. Prelim. Ser.

__________ 1960. Nelson map-area, west half, British Columbia. Geol. Surv. Can. Mem. 308.

__________ 1961. Geology - Kettle River (west half) map 15 - 1961. Geol. Surv. Can. Prelim. Ser.

Mel'nikov, I.V., Berzina, I.G. 1973. Some characteristic features of the behavior of uranium in the formation of uranium-molybdenum deposits. Sov. Atomic Ener. 35, No. 1, pp. 615-621.

Norton, D.L., Cathles, L.M. 1973. Breccia pipes - products of exsolved vapor from magmas. Econ. Geol. 68, pp. 540-546.

Rekharskiy, V.I. 1971. Behavior of principal ore elements of molybdenum deposits during magmatic differentiation. Int. Geol. Rev. 14, No. 6, pp. 575-583.

Rekharskiy, V.I., Plyatt, N.D. 1967. Some experimental data on conditions in the formation of uraninite-molybdenite paragenetic association. Geol. rud. mestoroz. June, pp. 16-30 (in Russian).

Soregaroli, A.E., Sutherland Brown, A. 1976. Characteristics of Canadian Cordilleran molybdenum deposits. in Porphyry Deposits of the Canadian Cordillera, Sutherland Brown, A. ed. Can. Min. Metall. Spec. 15, pp. 417-431.

Sutherland Brown, A. 1976. Morphology and classification. in Porphyry Deposits of the Canadian Cordillera, Sutherland Brown, A. ed. Can. Min. Metall. Spec. 15, pp. 44-51.

Wallace, S.R., Muncaster, N.K., Jonson, D.C., MacKenzie, W.B., Bookstrom, A.A., Surface, V.E. 1968. Multiple intrusion and mineralization at Climax, Colorado. in Ore Deposits of the United States, 1933-1967, Vol. I. Am. Inst. Min. Metall. Pet. Eng. Inc. pp. 605-640.