GEOLOGY OF THE BRENDA MOLYBDENUM COPPER DEPOSIT

by

E. P. Chapman, Jr.

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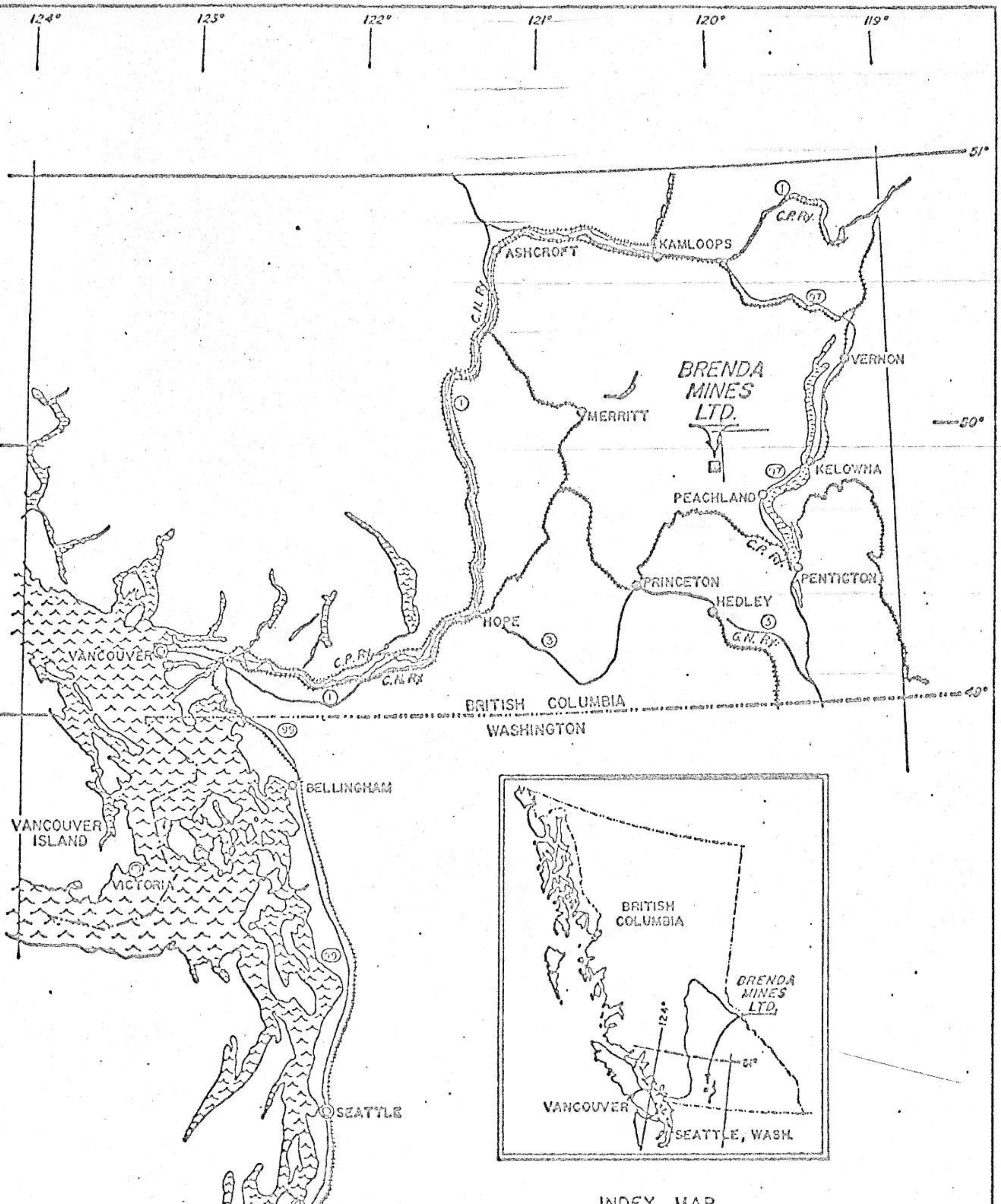

INDEX MAP

BRENDA MINES LTD.

OSOYOOS MINING DIVISION
BRITISH COLUMBIA

20 10 0 40 80
SCALE IN MILES

C.W.& G. LTD. *DRWG. NO. 590*

FEBRUARY, 1967.

GEOLOGY OF THE
BRENDA MOLYBDENUM COPPER DEPOSIT

The Brenda Copper-Molybdenum deposit, currently being prepared for production at a rate in excess of twenty thousand tons per day, is classed as a bulk type, low grade primary sulphide deposit.

Situated in south central British Columbia, Brenda lies approximately 150 airline miles east of Vancouver on the western edge of the Okanagan Valley (see Index Map).

During the past decade an increasing wealth of statistical information has become available relative to characteristics common to a large number of so-called porphyry deposits. Results of detailed studies, with particular emphasis on the great orebodies of the southwestern United States, have provided a great deal of information on a number of parameters which, since they are found in association with a great majority of such deposits, appear to be important criteria in making an early assessment of the economic possibilities of a potential porphyry. Among such parameters cited in "Geology of the Porphyry Copper Deposits, Southwestern North America" the University of Arizona Press, 1966, are the following:

I. Structure

1. Relationship to major regional and continental tectonic features.

2. Structural intersections, especially triple or more complex intersections.

3. Fracturing, shattering and brecciation.

II. Rock Types

1. The presence of intermediate to acidic intrusive rock types, even though they may not themselves form the host for mineralization.

2. The presence of a porphyritic textured phase of such rocks.

III. Alteration

1. Potassic alteration in the ore zone.

2. Argyllic and/or propylitic alteration as a halo.

3. Silicification.

In this paper, geologic conditions at Brenda are described initially on a local basis, then in relationship to the regional setting and finally, and with much speculation, an attempt is made to fit them into a continental pattern.

The author has drawn freely on published information and private communication from many authorities. He is particularly indebted to Harold Jones, Ross Vogan and Charles S. Ney for specific data on the Brenda Deposit; to J. M. Carr and W. H. White for regional correlation and to the late Harrison A. Schmitt for continental concepts.

LOCAL GEOLOGY

The Brenda deposit occupies the western margin of an intrusive mass of Jurassic age and of batholithic proportions near the contact with Triassic volcanics and sediments. The orebody, as presently known, is roughly circular in shape, has a diameter of approximately 3000 feet, and extends to a depth of at least 1000 feet. Since mineralization is almost entirely confined to fracture filling, fracture density is a major factor in grade control. Fracture patterns and frequency were studied in detail and described in an unpublished company report by Charles S. Ney dated June 1958.

Mineralization is present principally as chalcopyrite and molybdenite associated with very minor amounts of pyrite, pyrrhotite, bornite and galena. Ross Vogan, a former Brenda geologist, has estimated that 20 to 30 percent of the ore is contained in hairline fractures less than one millimetre in thickness. An additional 25 percent is present in zones of intense shearing in conjunction with faults, chloritization and other characteristic forms of argyllic alteration. The balance is present in fractures of from one millimetre to as much as six feet in thickness, generally accompanied by quartz and K-feldspar with calcite occasionally present. The average fracture thickness is in the range of from 3 to 5 millimetres. Molybdenite is clearly later than chalcopyrite and there is little if any mixing of these two minerals. This is a very important factor in the amenability of Brenda ore to concentration by flotation into clean and separate molybdenum and copper products.

The fractures related to mineralization at Brenda have three predominant strike directions:

1) N0°-20°E
2) N55°-75°E
3) N45°-55°W

All three sets are steep to vertical in dip. Where prominently developed, a pronounced columnar structure results. Figure 1, showing stereoscopic interpretation superimposed on a Canadian Government air photo, demonstrates the macro fracture pattern which reflects the micro network of mineralized veinlets.

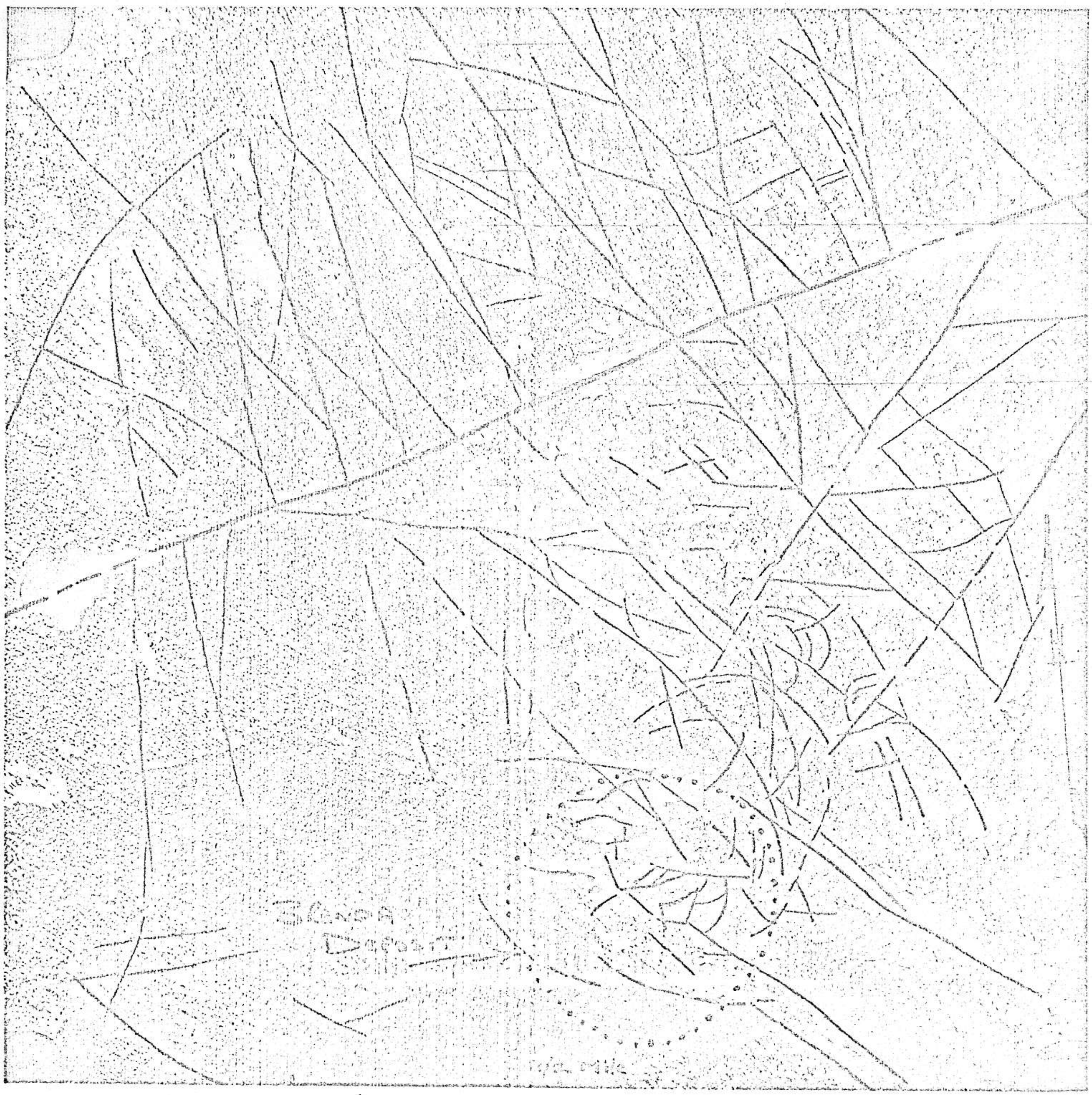

FIG. 1. BRENDA DEPOSIT AREA

Outline of Brenda deposit and photogeological interpretation by P.H. Blanchet, P.Eng.

-- Canadian Government Photography
Department of Energy, Mines and Resources

The host rock is medium grained phaneritic to porphyritic in texture and probably has the composition of a granodiorite. The rock is remarkably fresh and unaltered with the alteration patterns normally associated with "porphyry" type deposits present but almost entirely confined to fractures and rarely extending more than a few centimetres into either wall. The alteration is described by Vogan as being of three classifications.

1) Potassium Feldspar-Kaolinite
2) Quartz-Epidote-Sericite
3) Epidote-Chlorite

The first is by far the most prevalent and potassium feldspar content appears to increase with depth. Computer developed trend surfaces show that molybdenum content decreases and that copper grade increases with depth.

The portion of the Okanagan intrusive containing the Brenda orebody is characterized by a higher content of mafic minerals (hornblende and biotite) than is present in the exposed portions of the remainder of the batholith. Dr. William White of the University of British Columbia has carried out potassium-argon age studies on samples taken from both within the orebody and from the host intrusive distant from the zone of copper-molybdenum mineralization. While results from the two locations were identical, Dr. White reports an indicated age of 180×10^6 years for hornblende and for biotite an apparent age of 148×10^6 years. Although there can be no definite conclusions made on the basis of this information on the time of emplacement of economic minerals at Brenda, it seems clear that the host intrusive dates back to the lower Jurassic and that a major event occurred some 32 million years later near the boundary commonly placed between Jurassic and Cretaceous time. It seems reasonable to suppose that the late event might have included the period of potassic alteration which in turn may have shortly preceded or been contemporaneous with the deposition of chalcopyrite and molybdenite. Certainly it appears highly improbable that the Brenda orebody could be associated with the Laramide period assigned to many "porphyry" deposits.

The tonnage and grade present in the Brenda Deposit is for the most part a function of the cut-off grade used in ore reserve estimation. In the feasibility study completed in March 1967 by Chapman, Wood & Griswold Ltd., cut-offs used were based on net realized value per ton in Canadian dollars. This figure is dependent upon several variables, the most important of which are metal prices, metallurgical recovery, transportation cost and smelter charges.

To determine mineable reserves two cut-off grades were used:

(1) Grade A was required to meet estimated mining and milling costs and provide suitable profitability.

(2) Grade B was required to exceed estimated milling costs by an adequate margin, but would only be mined if within the projected pit path.

Mining cost per ton of feed to the concentrator is itself a variable dependant not only upon wage rates and prices for services and supplies but also upon the quantity of waste which must be mined and moved to recover that ton. With so many variables involved, an almost infinite number of possibilities in pit design and production rate can be examined in the attempt to settle upon the ore reserve estimate that will produce the optimum profitability upon ultimate exploitation. For this type of complex analysis the computer has become an almost indispensable tool.

Ore reserves at Brenda, as calculated through a computer program developed at the University of California, Berkeley, are tabulated below together with the conditions upon which they are based.

Type of Reserve	1000's of Tons	Cu %	MoS_2 %
Geologic	167,770	0.19	0.087
Mineable	145,750	0.20	0.092

Basic Conditions

Copper price	-	36 cents per pound (Canadian)
Molybdenum price	-	$1.75 per pound contained Mo (Canadian)
Recovery	-	As indicated by six months pilot plant operation
Tonnage	-	Figures combine Grades A and B for year by year open pit operation at 20,000 tons per day concentrator feed
Waste	-	48,833,000 tons
Ore to waste ratio	-	1:0.33

These figures reflect only one of the many combinations of conditions examined.

REGIONAL GEOLOGY

The Brenda deposit is on the southwestern edge of the British Columbia interior plateaus and on the eastern flank of an eugeosyncline that received great quantities of volcanics with some sediments throughout a span stretching from Permian through the Cretaceous. Local studies of black and white air photographs do not suggest major linear intersections at Brenda (figure 1). However, examination of various geologic plans shows that embayments into the Okanagan batholith at Peachland and south of Penask Lake have an alignment that passes through the deposit and that this line, if extended to the northwest and to the southeast, conforms to a number of geologic boundaries and other features, including the Yalakom Fault system west of the Fraser Fault. Furthermore, inspection of infrared airborne photography (figure 2) shows two strong linears intersecting near the centre of the Brenda Deposit. One of these has the general N60°-65°W direction mentioned above. The second strikes approximately N55°E and is approximately parallel to fault offsetting Okanagan Lake near Kelowna. A third, less prominent linear crosses the deposit at a bearing of approximately N45°W and is apparently offset several hundred feet by the northeast system.

The significance of these features in connection with the mineralization at Brenda is conjectural. It is interesting to note that inspection of infrared photography covering approximately 25 square miles around the Brenda Deposit (figure 3) reveals only one other triple intersection of linears having the same strike direction as those meeting at the Brenda orebody. This intersection lies about 1.5 miles north of the Brenda pit site, has a much less prominent photo expression and is in an area within which copper and molybdenum have been found. The mode of occurrence is similar to Brenda but grades are apparently sub-economic.

CONTINENTAL ASSOCIATIONS

In a paper titled "The Porphyry Copper Deposits in Their Regional Setting" (ref. 4(a)), the late Harrison A. Schmitt speculates on the relationship between the porphyry deposits and major continental orogens, which he defines as belts of deformed rocks. He notes the great cluster of bulk deposits in Arizona, New Mexico and Northern Mexico which lies on the southern flank of the Colorado Plateaus and within the area of intersection of the NW-SE Texas lineament and the N-S Wasatch-Jerome orogen, and observes that ore districts and clusters of ore districts are concentrated at orogen and fault zone intersections. He suggests that these major rifts may have tapped the earth's lower crust or even the mantle at various times throughout geologic history and thus provided access to the higher base metal content inferred for these zones.

Figure 4 shows some of the features cited by Dr. Schmitt for the western and southwestern United States with extensions and features in the Northwest and British Columbia drawn from many sources, but principally

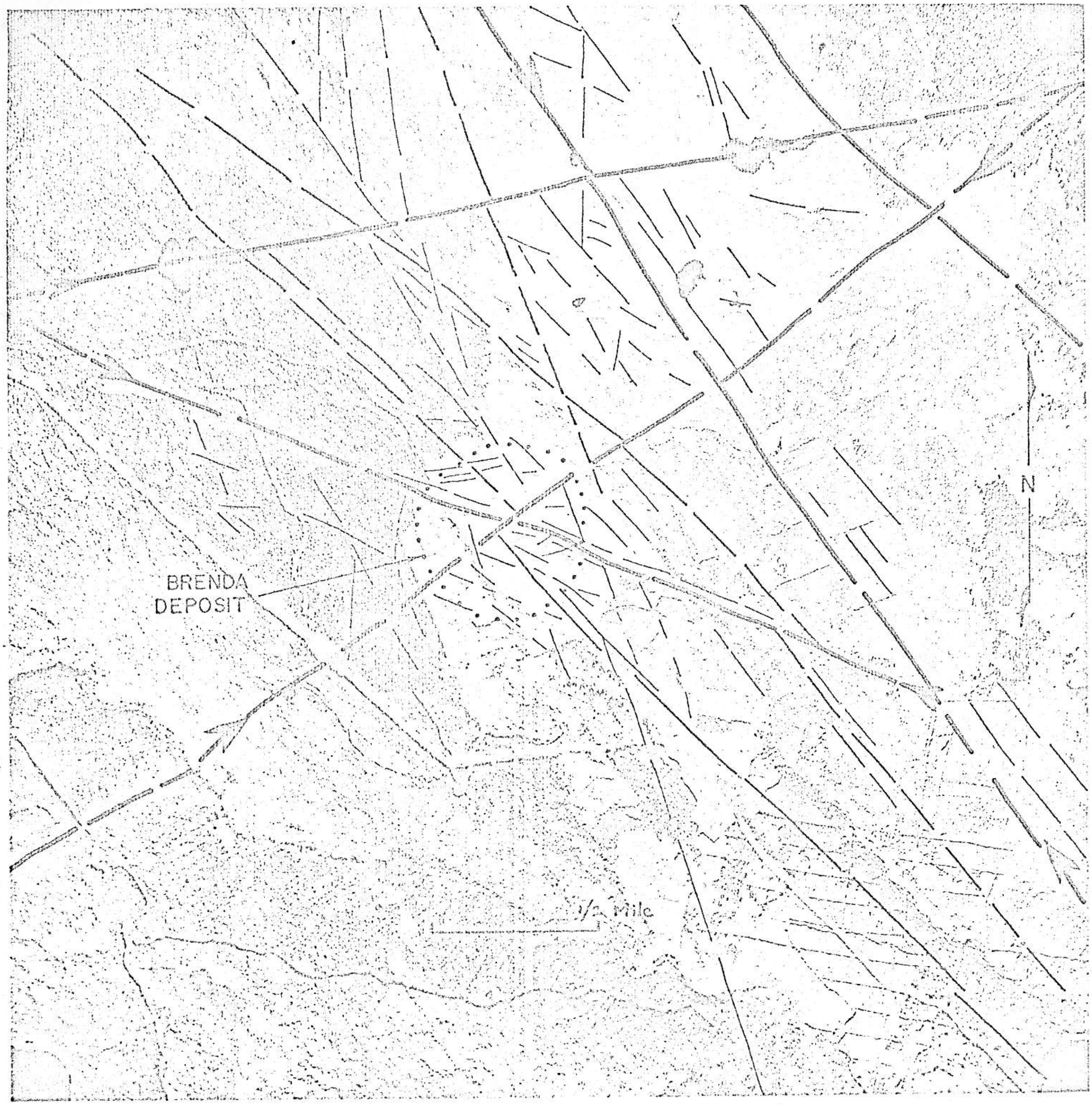

FIG. 2. BRENDA DEPOSIT AREA

Outline of Brenda deposit and photogeological interpretation by P. H. Blanchet, P. Eng.

-- Infrared Photography
Furnished by and used with permission of
Co-ordinate Aerial Surveys Ltd.
Burnaby, B.C.

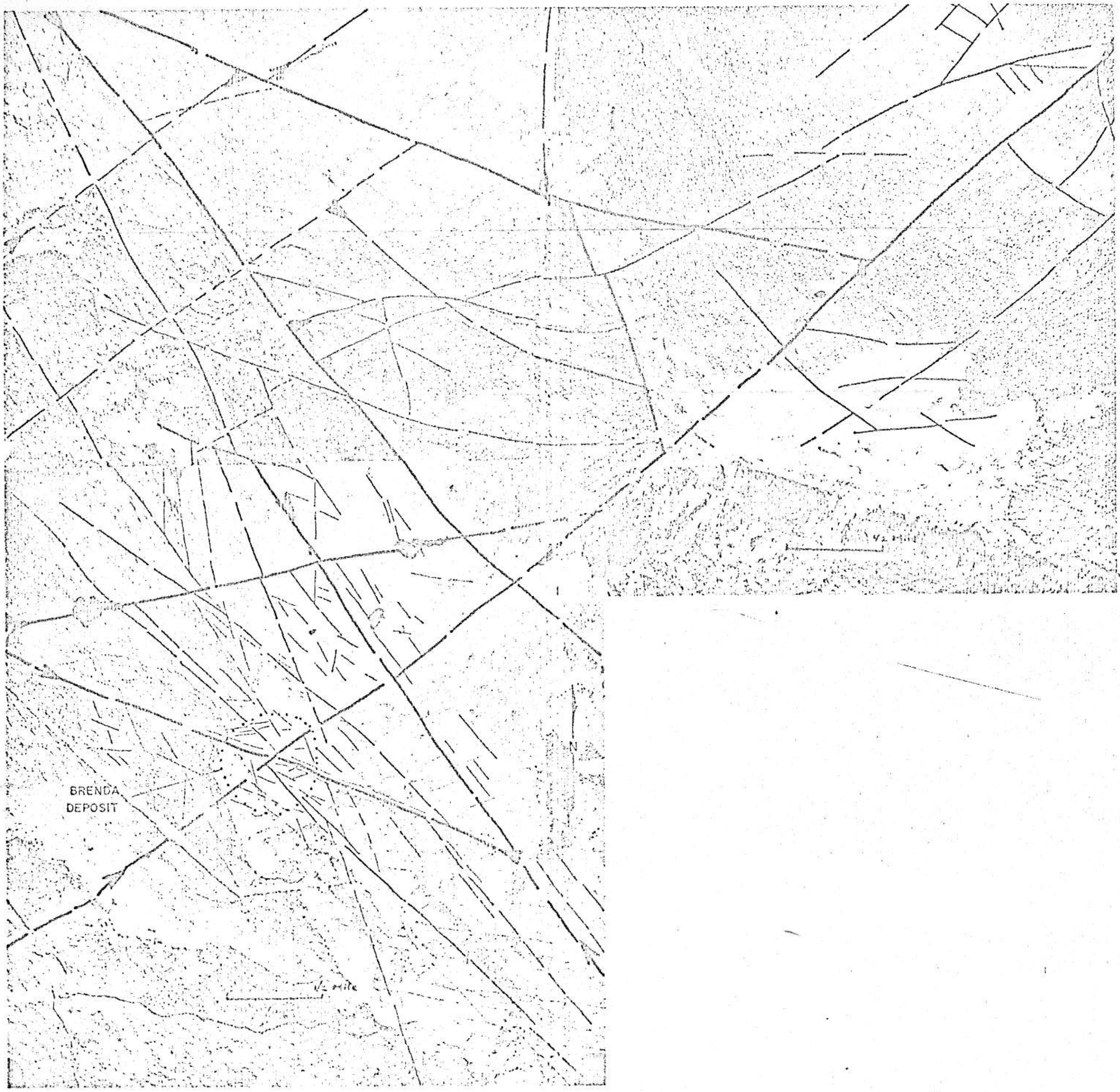

FIG. 3. LAYDOWN MOSAIC OF BRENDA DEPOSIT AREA

-- Infrared Photography
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Co-ordinate Aerial Surveys Ltd.
Burnaby, B. C.

from C.I.M. Special Volume No. 8 (ref. 6). At the risk of overemphasizing local and regional features to make them fit into a theoretical continental pattern based on very tenuous information, it is suggested that the upper edge of the Butte and/or Little Belt orogen might be as far north as Brenda and that extensions of the well known fault systems could result at Brenda in the type of complex intersection described by Dr. Schmitt.

Regardless of the validity of this speculation, it seems clear that as our knowledge of world-wide structural patterns increases--through the continued detailed geologic studies now in progress, assisted not only by relatively new photographic and geophysical techniques from conventional aircraft but also by the tremendous aerial scope provided on pictures taken from satellites--that the correlation between local, regional and continental geologic data will be an increasingly useful tool in the search for and discovery of bulk type ore deposits.

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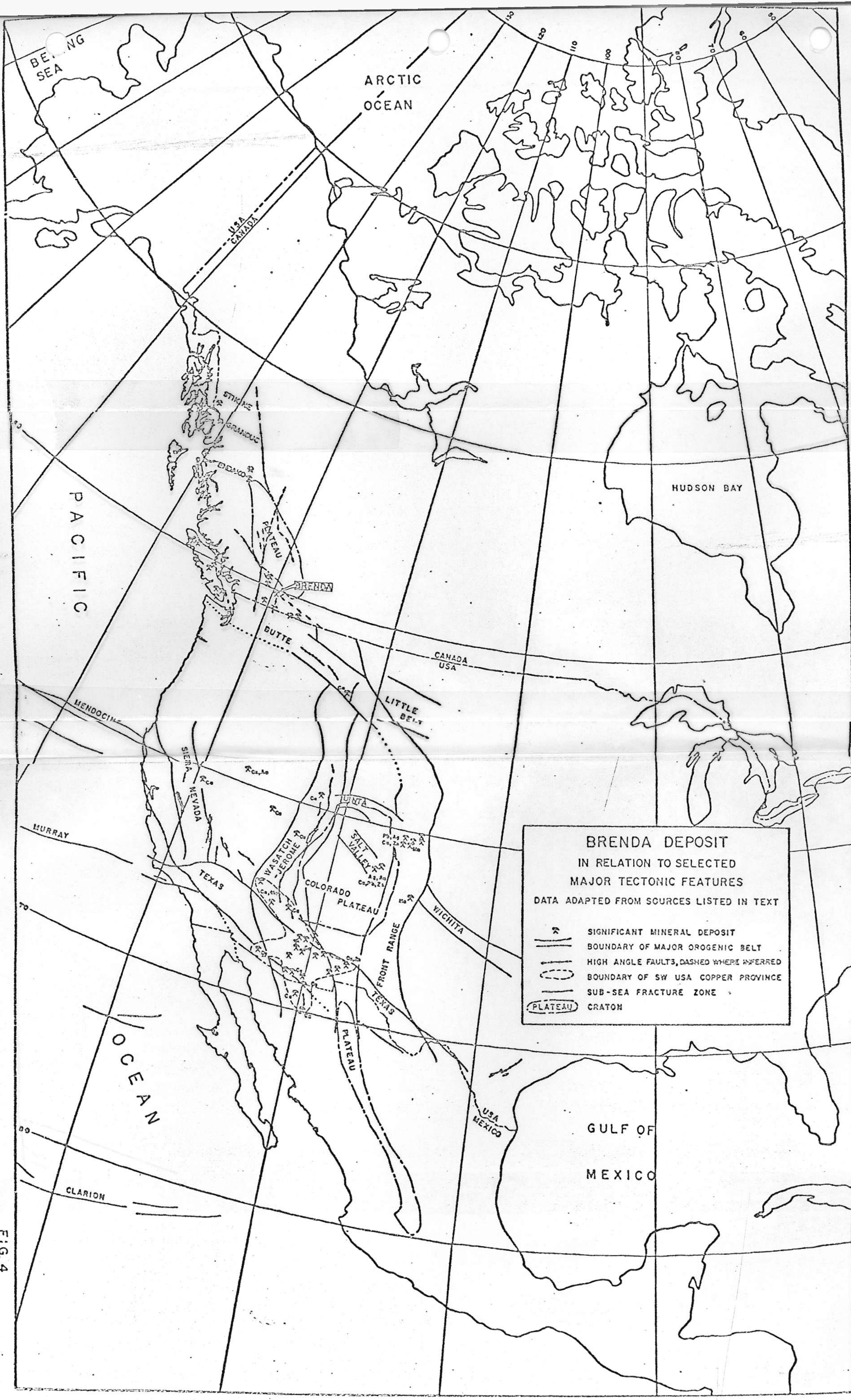
BERING SEA
ARCTIC OCEAN
USA
CANADA
HUDSON BAY
PACIFIC
OCEAN
STIKINE
GRANDUC
PLATEAU
BRENDA
BUTTE
CANADA
USA
LITTLE BELT
MENDOCINO
SIERRA NEVADA
UINTA
MURRAY
WASATCH
JEROME
SALT VALLEY
COLORADO PLATEAU
TEXAS
WICHITA
FRONT RANGE
TEXAS
PLATEAU
USA
MEXICO
GULF OF MEXICO
CLARION
BRENDA DEPOSIT
IN RELATION TO SELECTED
MAJOR TECTONIC FEATURES
DATA ADAPTED FROM SOURCES LISTED IN TEXT
SIGNIFICANT MINERAL DEPOSIT
BOUNDARY OF MAJOR OROGENIC BELT
HIGH ANGLE FAULTS, DASHED WHERE INFERRED
BOUNDARY OF SW USA COPPER PROVINCE
SUB-SEA FRACTURE ZONE
PLATEAU CRATON

FIG. 4