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MINERAL DEPOSITS IN THE CALLAGHAN CREEK AREA, SOUTHWESTERN B.C.***

Polymetallic sulphide deposits in the Callaghan Creek area of southwestern British Columbia occur in a roof pendant of pyroclastic rocks surrounded by various masses of the Coast Plutonic Complex (figure 1). These coarse-grained pyroclastic rocks are divisible into five easily mappable units of rhyolitic to andesitic composition. The units dip steeply to the east, strike northerly or slightly west of northerly, and appear to form a homoclinal succession with tops to the east. The sequence has been correlated tentatively with the Gambier Group (Lower Cretaceous) by others on the basis of general lithologic similarities with type sections of the Gambier rocks to the south. A crystal tuff (Unit 3) in the sequence has been cut by what are thought to be genetically related horneblende-rich dykes for which a single K-Ar date on hornblende is 124 $\pm$ 4 m.y. A brief description of principal rock units follows and is keyed to the geological map of figure 1.

Greenstone (unit 1):	'Acidic,' fine-grained volcaniclastic rock, commonly extensively sheared, generally pale green in colour.
Agglomerate(unit 2):	Massive volcanic fragmental rock with fragments up to 50 centimetres in diameter in a tuffaceous matrix that is 5 to 40 per cent of the rock.
Crystal Tuff (unit 3):	Medium-grained pyroclastic rock containing abundant plagioclase fragments and less abundant hornblende fragments. Locally well layered.

TABLE

SUMMARY OF LITHOLOGIES

Era	Period or Epoch	Formation and Thickness	Unit	Lithology
Cenozoic	Pleistocene and Recent	Garibaldi Group 700 m.	7a	Olivine basalt
		Contact relations not known		
	Tertiary to Pleistocene	Possibly in part Garibaldi Group	7b, 7c, and 7d	Equigranular and porphyritic rhyodacite, epiclastic breccia
Mesozoic	Upper Jurassic to Cretaceous	Unconformably overlies and intrudes pendant and plutonic rocks		
			6a, 6b, and 6c	Quartz diorite with minor diorite, hornblende diorite with minor hornblende quartz diorite, granodiorite
		Unconformable (?); fault, intrusive		
		Gambier Group 2000+ m.	5, 5a, 5b, and 5c	Andesitic agglomerate, epiclastic breccia, arkosic wacke and mudstone, andesitic crystal tuff
		Conformably overlies		
		Gambier Group	4, 4a, 4b, and 4c	Dacitic agglomerate, siltstone and arkosic wacke
		Intercalated and conformably overlying		
		Gambier Group	3	Andesitic crystal tuff
		Conformably overlying		
		Gambier Group	2	Andesitic agglomerate
		Contact relations not known		
		Gambier Group	1 and 1a	Greenstone, minor limestone and chert

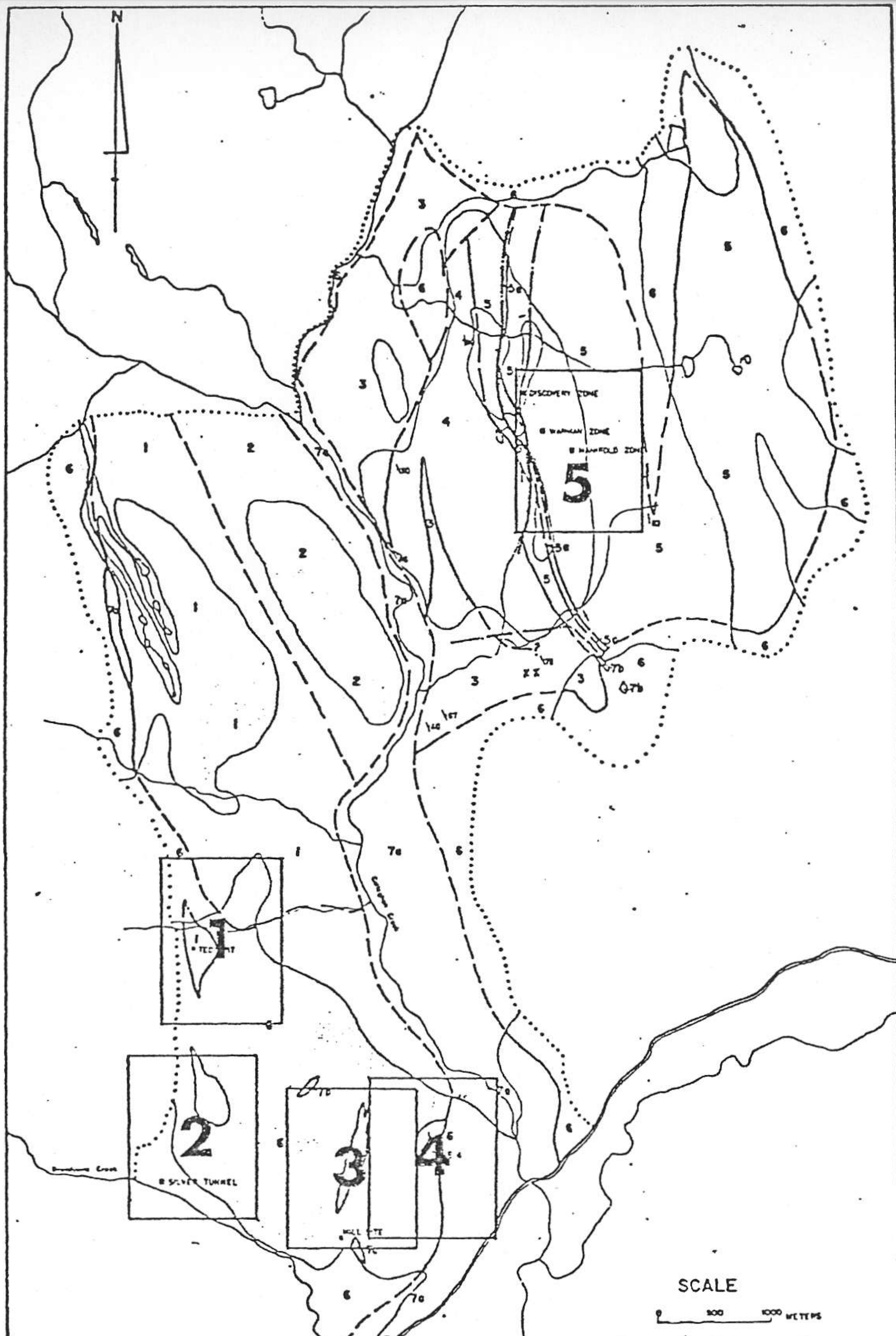

Fig. 1: General geology of part of the Callaghan Creek pendant (after Miller and Sinclair, 1978). Geological units numbered 1 to 7 are described in the text. Numbered rectangles enclose the main mineral occurrences referenced in the text. Dotted lines are limits of mapping, dashed lines are geological contacts.

Acidic volcanic rock (unit 4):	Principally dacitic and rhyolitic tuffaceous rocks with rare large fragments. Locally contains up to 5 per cent pyrite.
Tuffaceous aggomerate (unit 5):	Massive pyroclastic unit, principally tuffaceous material near the base and predominantly rounded volcanic fragments higher in the section. Near the base this unit contains a 60-metre-thick marker bed of volcanic breccia with abundant fragments mostly 3 to 5 centimetres in diameter.
Coast Plutonic Complex (unit 6):	Includes quartz monzonite, quartz diorite, and hornblende diorite.
Tertiary volcanic rocks (unit 7):	Fresh, blocky basalt for the major flow in the map-area, and elsewhere much smaller amounts of more acidic composition. Correlations with Garibaldi calc-alkalic volcanic suites.

Seven mineral occurrences are known in the map-area and are listed below:

1 Silver Tunnel

2 Millsite

3 Tedi Pit

4 Zone 4

5 Discovery zone

6 Warman zone

7 Manifold zone

The first four mineral occurrences are held by Van Silver Explorations Ltd. (now in receivership) and the last three are held by Northair Mines Ltd. Limited production has come from the Silver Tunnel and Tedi Pit areas; whereas the Manifold, Warman and Discovery zones are in production at present.

Silver Tunnel mineral occurrence is within well sheared greenstone (unit 1) and a dyke of equigranular rhyodacite oriented north-south with a vertical dip. Sulphide minerals primarily occur in veinlets cross-cutting

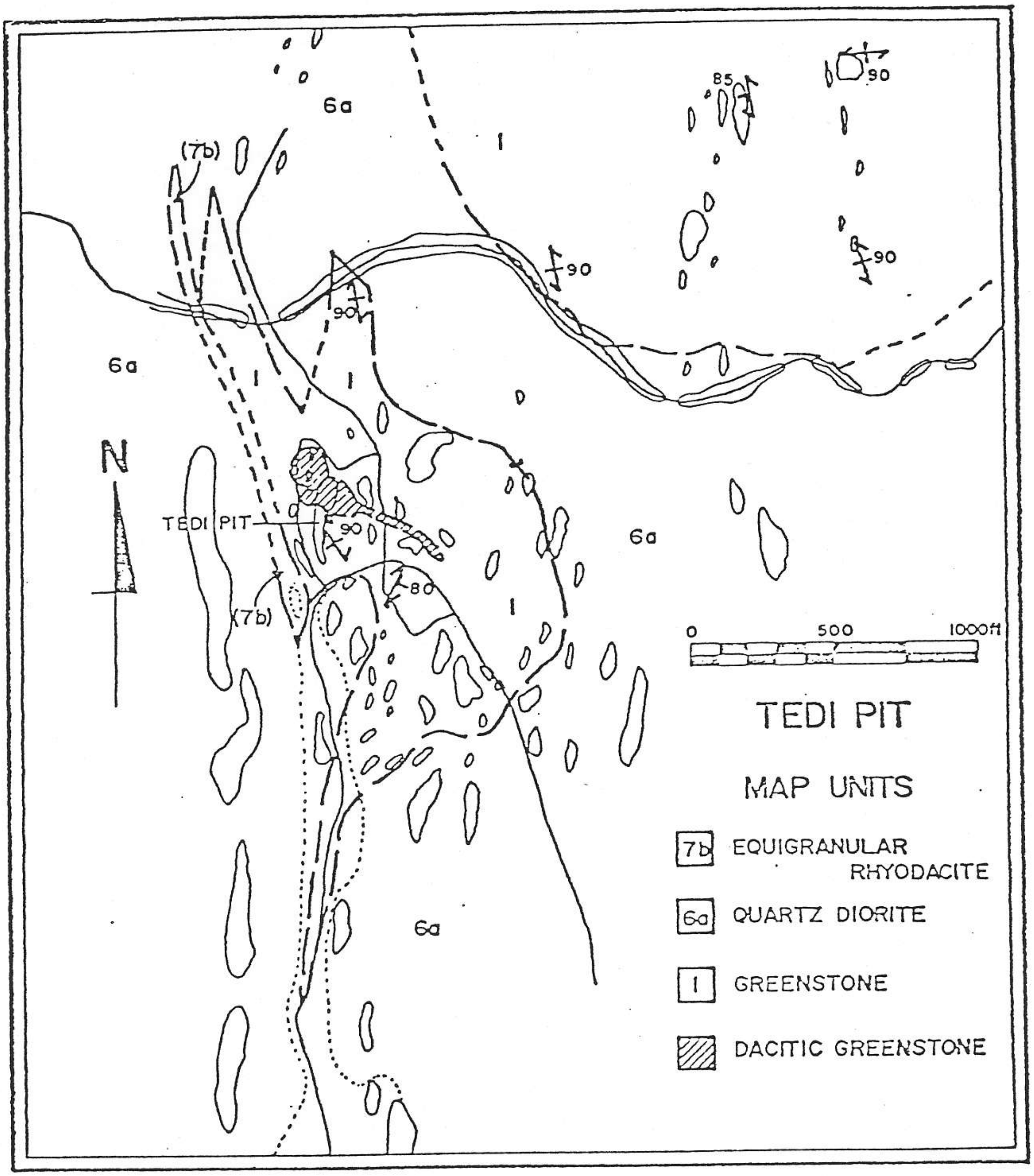

Figure 2 Detailed geological map of the Tedi Pit mineral occurrence.

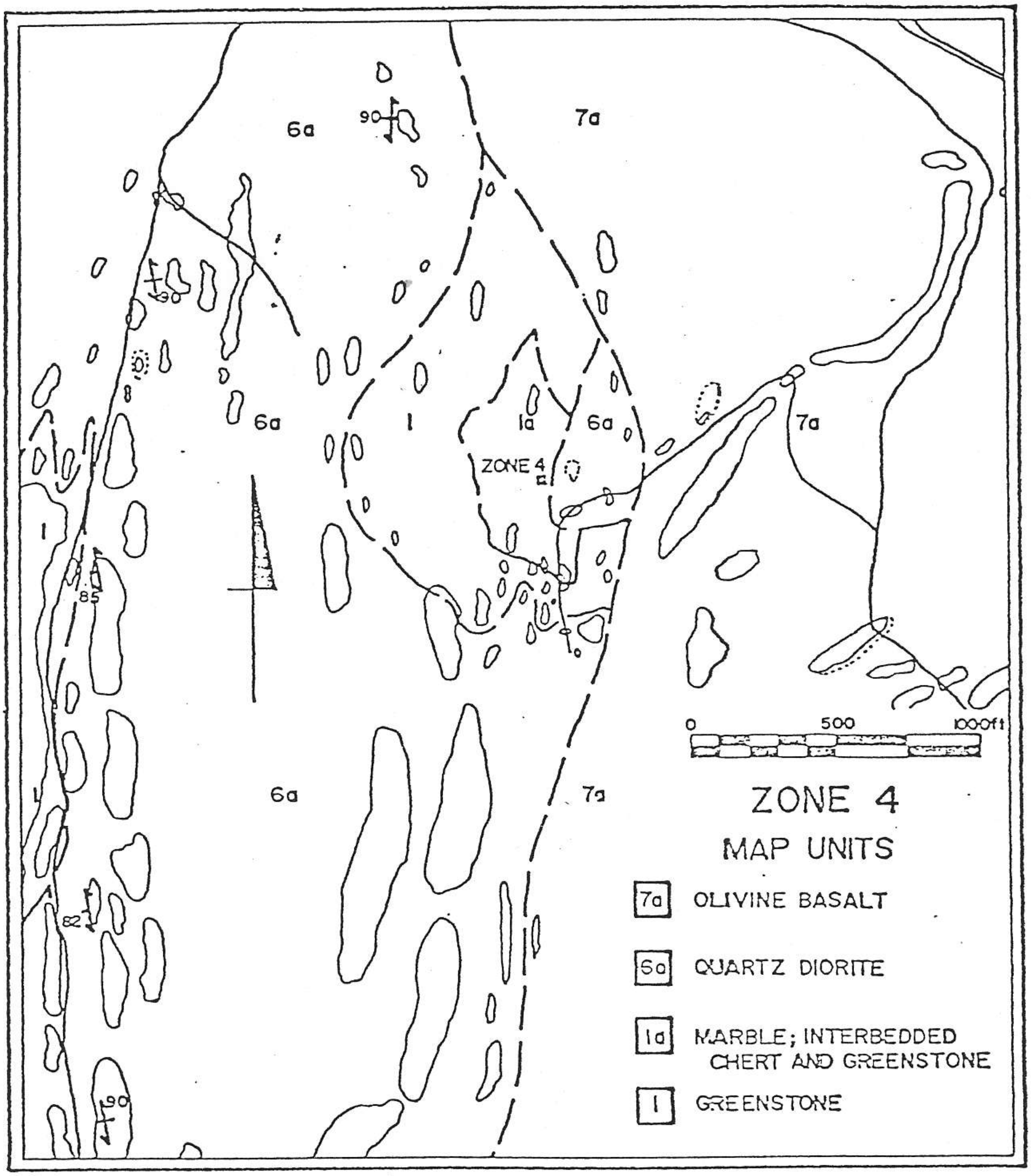

Figure 3. Detailed geological map of the Zone 4 mineral occurrence entirely contained within Unit 1a.

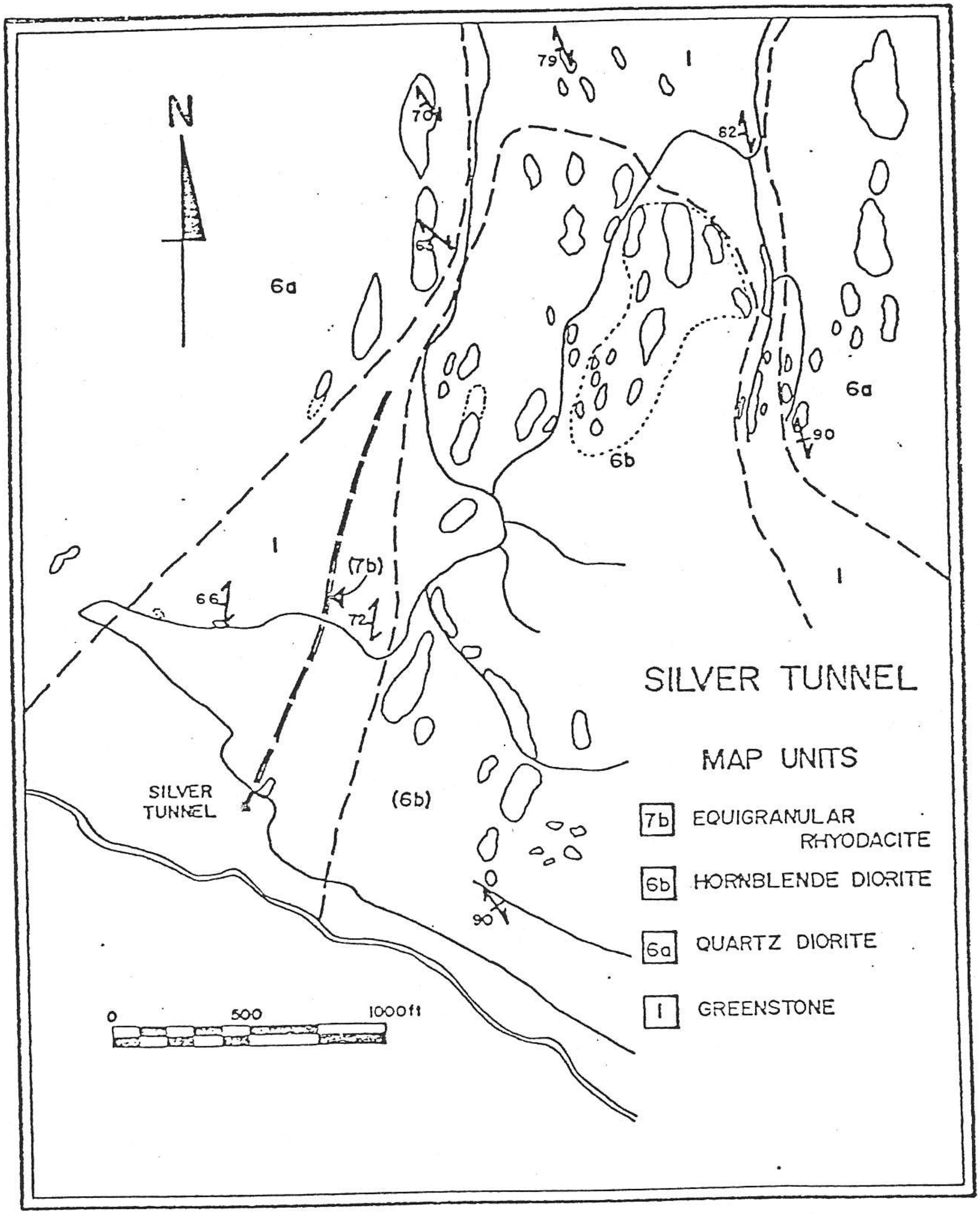

Figure 4 Detailed geological map of the Silver Tunnel mineral occurrence.

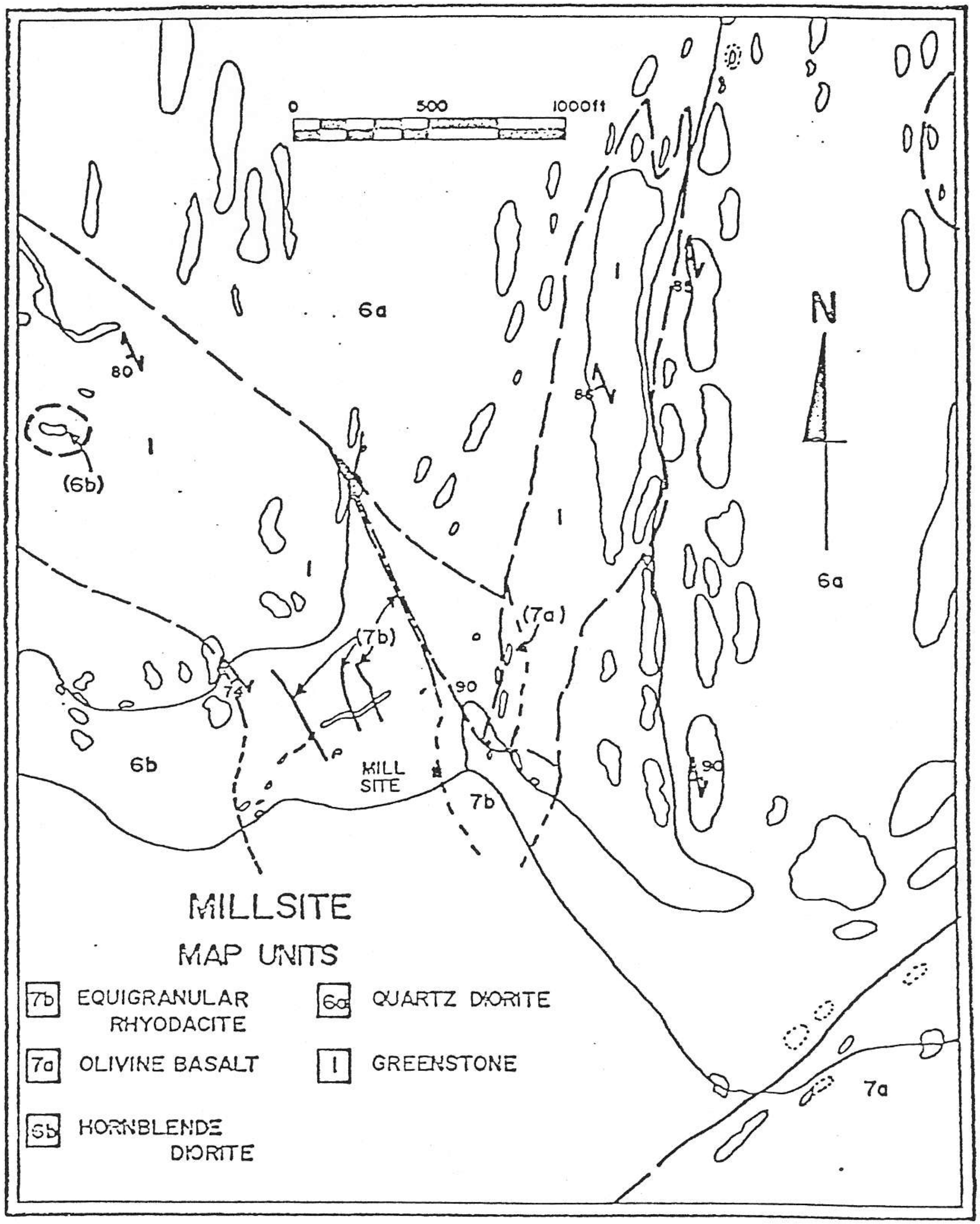

Figure 5 Detailed geological map of the Millsite mineral occurrences.

the dyke or greenstone but also as disseminations and interstitial to massive sulphides, locally layered parallel to the regional foliation within the greenstone. Millsite mineral occurrence is within greenstone (unit 1) near a small body of hornblende diorite (unit 6b). Sphalerite-galena veins and stringers with less abundant chalcopyrite- and hematite-bearing veins occur within the greenstone. Stockwork copper mineralization is present within a pod of hornblende diorite. Tedi pit mineral occurrence is in greenstone (unit 1) with the sulphides primarily occurring as disseminations and massive sulphides locally layered parallel to the regional foliation, and in veins. Zone 4 mineral occurrence is contained entirely within a marble pod (unit 1a). Sulphides are in intimate association with calc-silicate minerals, with both the sulphides and calc-silicate minerals occurring in sporadic patches.

Pyrite, sphalerite, galena, chalcopyrite and tetrahedrite, in decreasing order of abundance, occur in similar relative proportions in the Silver Tunnel, Tedi Pit and sphalerite-galena veins of the Millsite area. Trace amounts of argentite, electrum, bornite and ruby silver also occur in Tedi Pit. In Zone 4 the sulphides occur in approximately this order of decreasing abundance: sphalerite, chalcopyrite, pyrrhotite, pyrite, galena, covellite, argentite and electrum.

Three ore zones are known on the Callaghan Creek property of Northair Mines which are, from north to south, the Discovery, Warman, and Manifold zones (Fig. 34). All zones are tabular in form, strike about north 40 degrees west and have near vertical dips. Average thicknesses are about 1.8, 2.4, and 5.1 metres respectively from south to north. Ore grades differ progressively from zone to zone. In general the southern (Manifold) zone is high in precious metals and low in base metals. The converse is true for the Discovery zone and the Warman zone is intermediate in character. Similarly, the form of mineralization varies from south to north. In the south (Manifold) zone sulphides are disseminated or thickly layered in a siliceous carbonate layer and in the north (Discovery) zone sulphides are layered and locally massive in form. Again the Warman zone is intermediate in character.

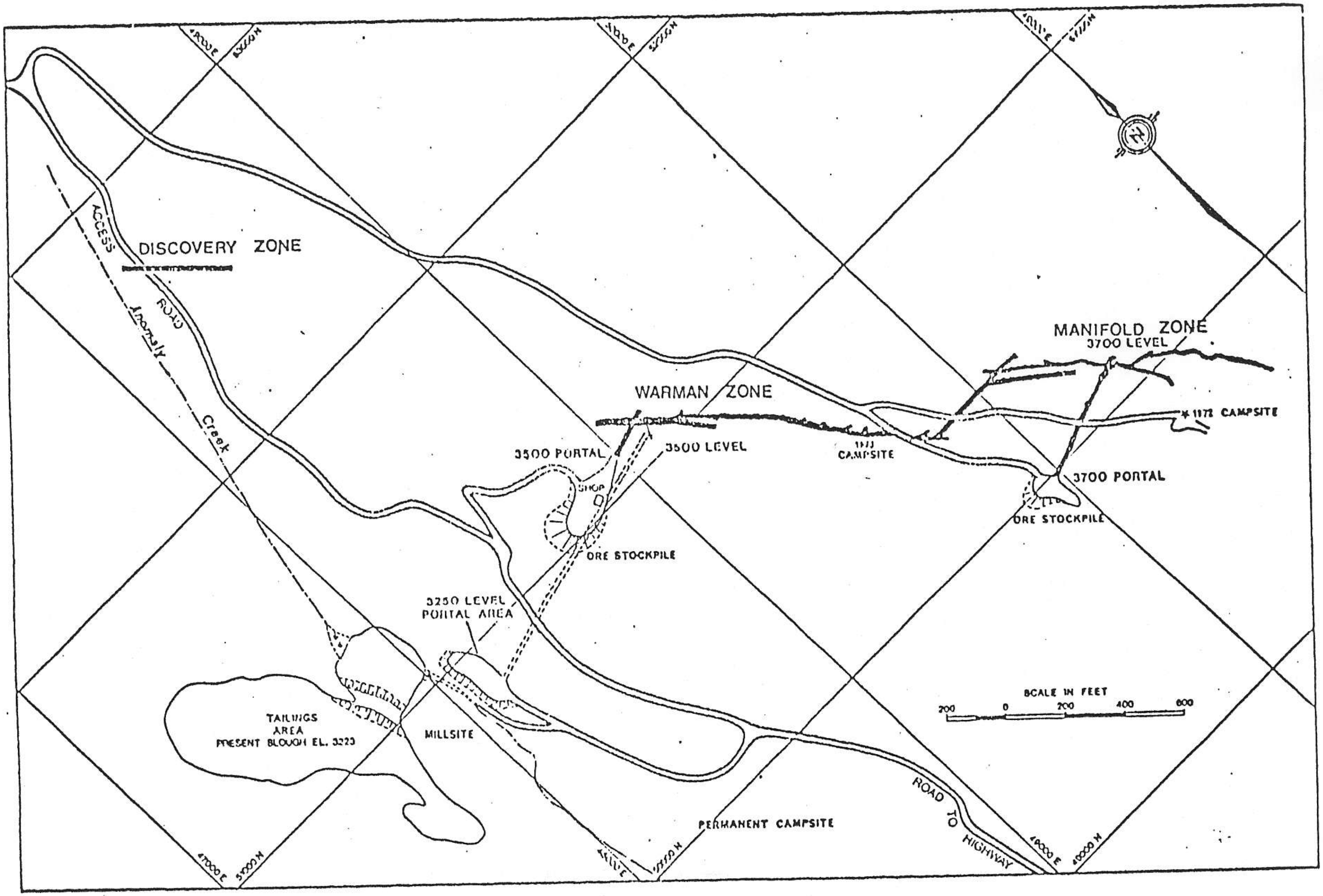

Fig.34: Generalized surface and underground development, Northair Mines, showing relative position of the three main mineralized zones.

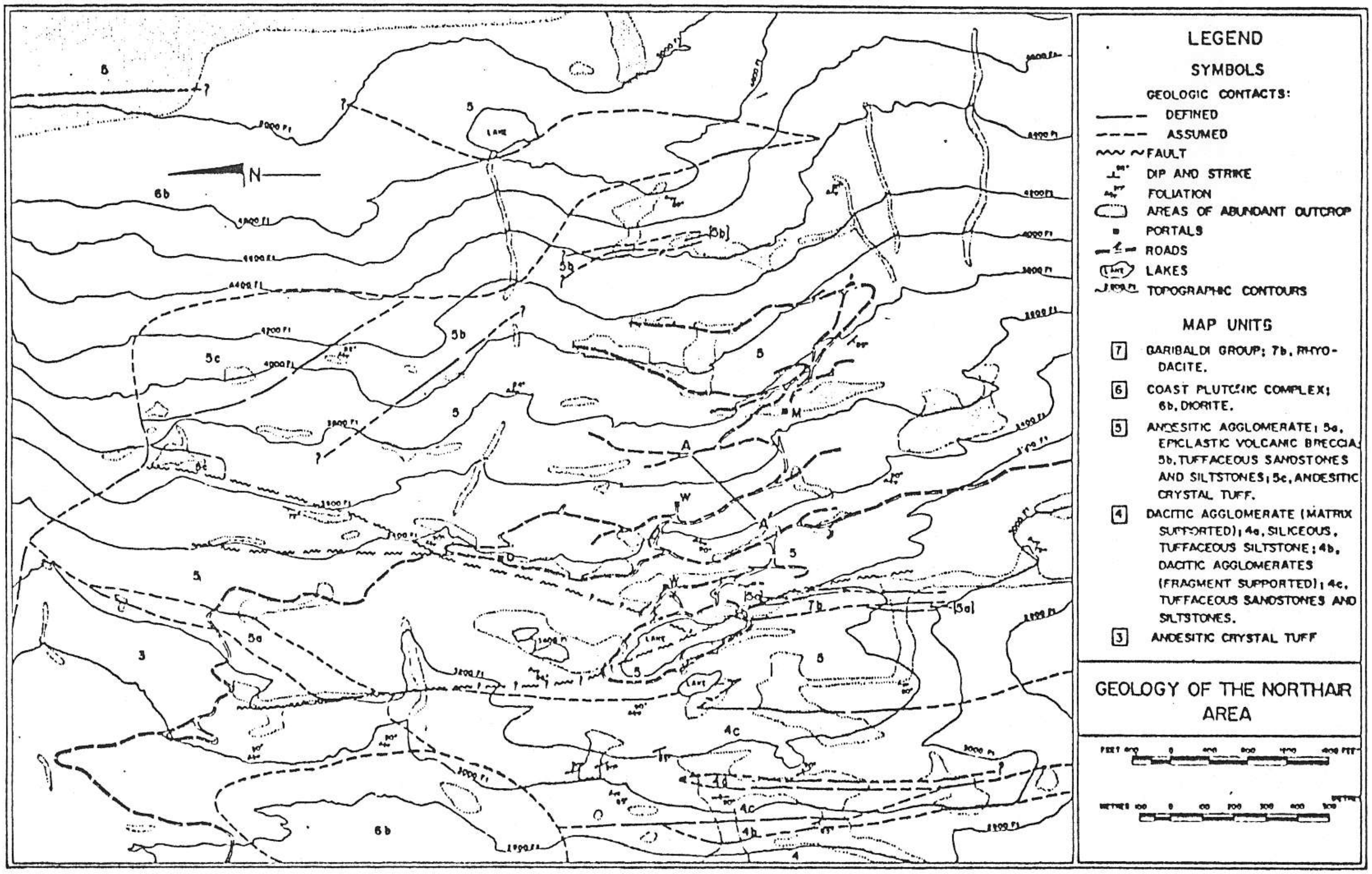

Figure 32. Detailed geological map of a part of Callaghan Creek pendant including mineral deposits of Northair Mines Ltd. Portals to the main deposits are labelled: M — Manifold zone, W — Warman zone, and D — Discovery zone. A—A[1] is the location of a cross-section through the Warman zone, shown in Figure 35.

The three zones appear to represent faulted segments of a single mineral-rich sheet. Such an interpretation is apparent underground *between* the ends of the Warman and Manifold zones where small faulted segments of the ore have been identified. A more complex fault zone exists between the Warman and Discovery zones. This 'single sheet' hypothesis is supported by the gradational characteristics of the ore if all three zones are reconstructed to a single body. Characteristics of both the Discovery and Manifold zones extend to the respective adjacent parts of the Warman zone.

Origin of the Northair mineral deposits recently has been the subject of controversy with the two general extreme points of view being (1) a vein hypothesis and (2) a volcanic exhalative origin followed by partial mobilization accompanying plutonism. We will not consider all the arguments for genesis in this discussion, but some results of the 1978 fieldwork have a direct bearing on the problem. One of the main points used in the past as indicative of an epigenetic nature to the ore zones has been the apparently diverse orientations of bedding and the tabular ore zones. The northwesterly trend of the ore zones has been contrasted with the northerly regional trend of bedding measured hundreds of metres to the west and south of the ore zones. Extrapolation of these bedding orientations into the area of ore deposits has led to the suggestion of transgressive geometry for the ore shoots and therefore an epigenetic origin.

Detailed examination of core from 12 exploratory drill holes to the southwest of the Warman zone has established a local detailed stratigraphy that extends the length of, and parallels, the Warman ore zone. An example is shown in cross-section A-A' (Fig. 35), the location of which is indicated on Figure 32 and 34. The immediate footwall of the Warman zone is a 113-metre-thick layer of andesitic agglomerate which consists of a fine-grained tuffaceous matrix containing 70 per cent large fragments as in the general description of unit 5. About 34 metres below the Warman zone is a 0.3 to 4.6-metre, fine-grained tuffaceous marker layer that locally is disrupted into fragments. Below the andesitic agglomerate layer is a pale grey to green tuffaceous sandstone unit that contains rare subrounded fragments up to 3 centimetres in diameter. The contact between the tuffaceous sandstone and the andesitic agglomerate is gradational over about 1.5 metres. A similar andesitic agglomerate containing a thin tuff marker has been observed in a single diamond-drill hole on the southwest side of the Discovery zone, but the marker cannot be traced because of lack of both outcrop and other appropriately located drill holes. Nevertheless, this occurrence indicates that the stratigraphy immediately southwest of and parallel to the Warman zone extends over a total distance of at least 500 metres. As yet we have not been able to check the presence of a comparable stratigraphy to the southwest of the Manifold zone because of the deteriorated condition of boxes of drill core from exploration holes drilled several years ago. However, we note the parallelism of so-called alteration zones mapped in one cross-section of the Manifold zone by Little (1974) and suggest the possibility that in reality these zones which parallel bedding defined above, represent original compositional differences rather than superimposed alteration zones.

In addition to recognition of a parallelism between ore zones and bedding on a scale of hundreds of metres, it is common in underground workings to see sulphide layers from a few millimetres to a few centimetres thick that parallel alternating layers of carbonate, quartz, and, locally, silicates, over distance of centimetres to metres. These layered sulphides are part of a highly deformed (folded and fractured) interlayered sequence that is cut by veins of coarse-grained calcite with or without quartz and/or sulphides. In places these form a myriad of sulphide-bearing veinlets of post-deformation age, superposed in places on layered sulphides that appear to represent vestiges of a pre-deformational mineralizing event. It was this obvious finely layered aspect, apparent underground locally in all ore zones, that originally led us to suggest an early 'volcanogenic' stage in the development of the ore zones (Miller and Sinclair, 1977; Miller, *et al.*, 1978).

In idealized form the model that we propose is a distal volcanogenic or exhalative model in which a local marine basin formed during a hiatus in explosive rhyodacitic to andesitic volcanism. Ore fluids were fed to the water-sediment interface from a pipe zone, not now known, to contribute base and precious metals to the basin of chemical sedimentation. Further explosive volcanism followed. The deposit was deformed and metamorphosed to greenschist facies during subsequent emplacement of Coast plutonic rocks and it was late in this interval that post-deformational, sulphide-bearing carbonate and/or quartz veinlets formed by mobilization of originally syngenetic material. Similar veinlets removed from known mineral zones are free of sulphides. The deposit was later disrupted by northerly trending faults, many with significant strike-slip components. One of these faults truncates the Discovery zone on the west.

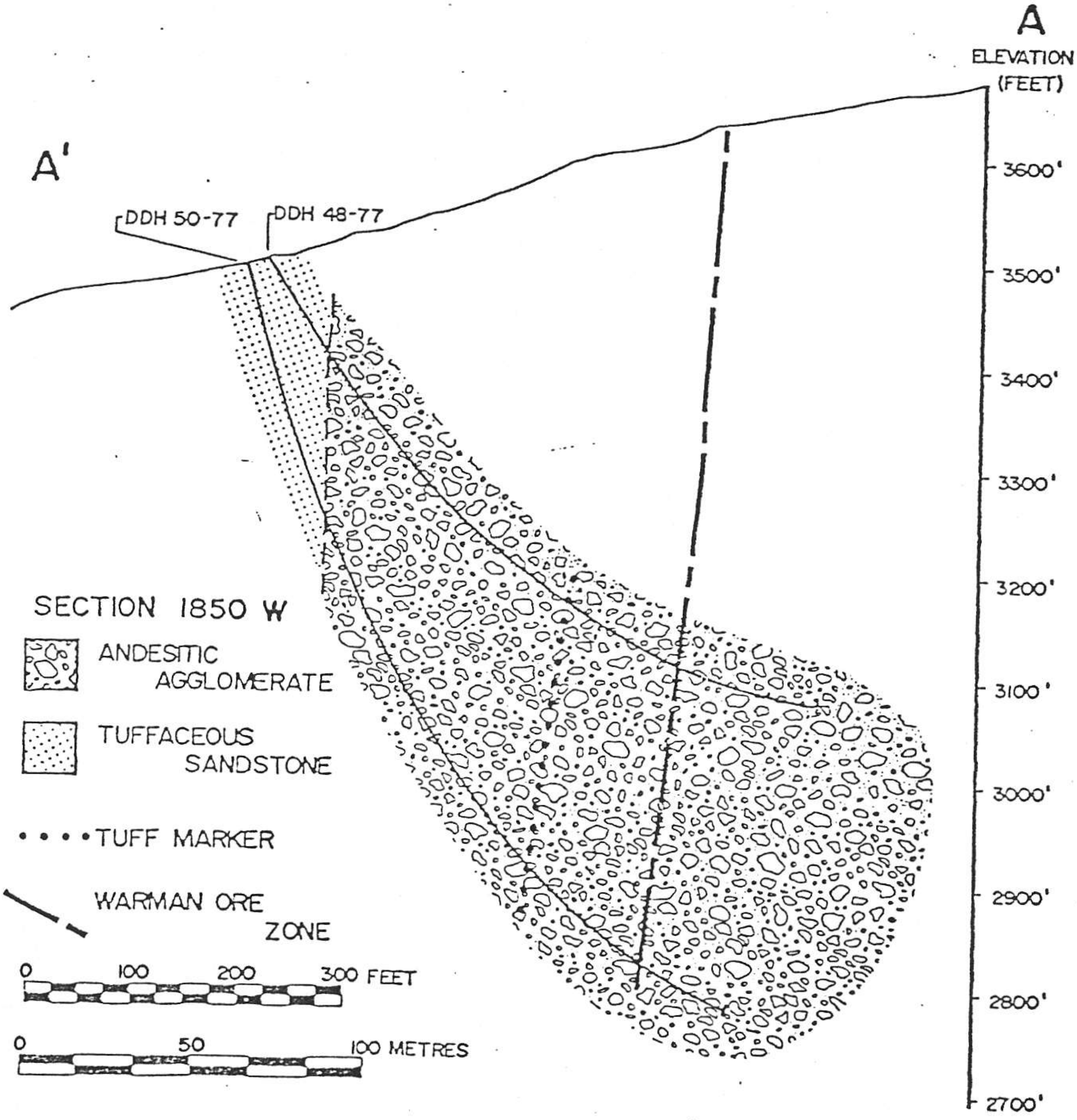

Figure 35. 1850 cross-section perpendicular to Warman zone showing parallelism of lithologic contacts and the Warman zone whose thickness is shown to correct scale.

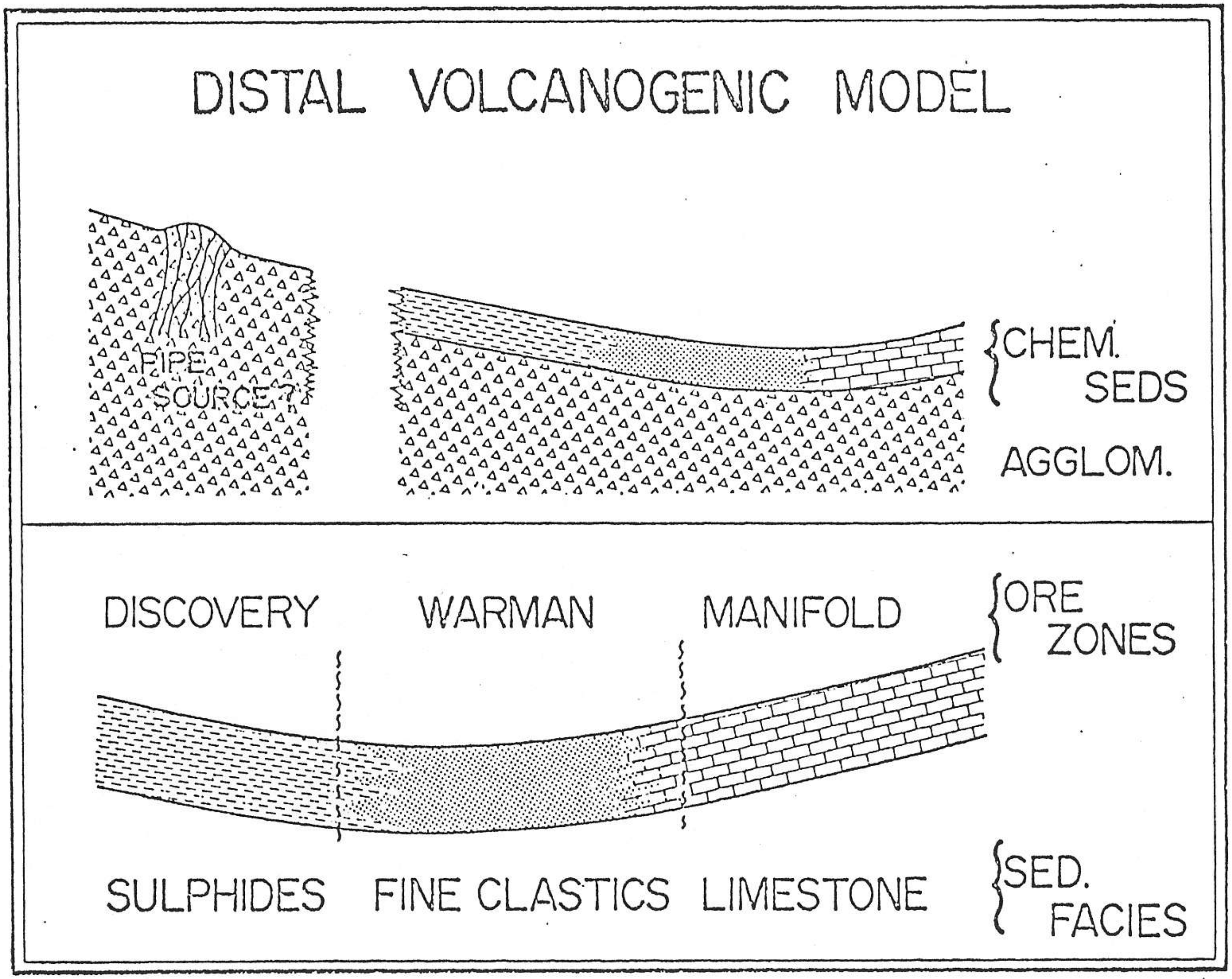

Fig. 3: Conceptual model for genesis of the three main mineralized zones of Northair Mines. A later period of formation of sulphide-bearing veinlets is attributed to mobilization during metamorphism accompanying emplacement of Coast Plutonic rocks.

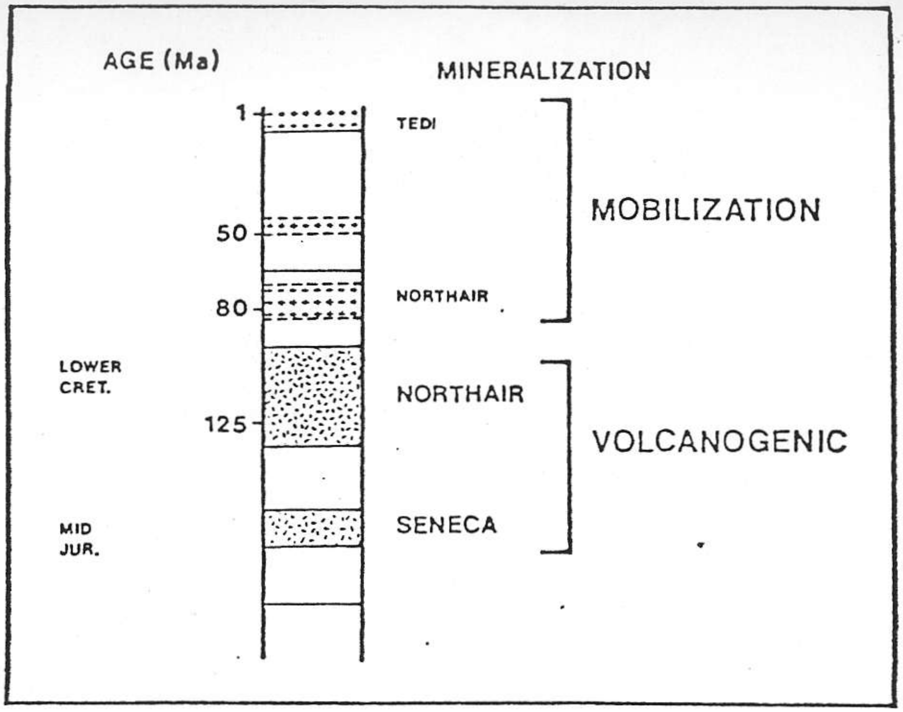

Figure 69. Outline of a general metallogeny for polymetallic sulphide deposits within volcanic rocks of the southern Coast Crystalline Belt. A volcanogenic phase of mineralization is identified in the Middle Jurassic and Lower Cretaceous. Subsequent mobilization of sulphides has occurred in response to local heat centres related to emplacement of intrusions at various times.

Lead isotopic data from the Northair and Van Silver deposits are of particular interest from a genetic point of view. The samples include deformed, 'layered' sulphides in quartz-carbonate rock and anhedral sulphides from post-deformation, sulphide-bearing carbonate veins at Northair; intensely deformed, layered sulphides from the Tedi pit of Van Silver; and thin sulphide veinlets cutting Garibaldi volcanic rocks between the Tedi and Silver Tunnel (Blue Jack) deposits. All these varieties of mineralization have lead isotopic compositions that are identical within experimental error, a fact in accord with a complex origin for deposits in the area. Miller and Sinclair (1979) suggested that an early exhalative phase of mineralization was followed by remobilization about 80 Ma ago when nearby plutons were emplaced.

Lead isotopic data are surprisingly uniform for a variety of mineral occurrences in and about the south end of Coast Crystalline Belt. Where geological controls exist it appears that this uniformity resulted because lead was derived from a thick volcanic sequence. An important implication of this data is that lead in all the deposits studied probably had the same general origin, that is, they were derived from the spatially related volcanic pile.

A metallogenic scheme for the area (Fig. 69) incorporates an initial episode of volcanogenic mineralization which segregated lead from uranium by formation of galena. During subsequent thermal events this lead was locally remobilized to form the various post-deformation sulphide-bearing vein deposits recognized in the area.

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6/10/81.

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