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Structural character of *en echelon* polymetallic veins at the Silver Queen mine, B.C.

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ABSTRACT

Epithermal Zn-Pb-Cu-Ag-Au quartz-carbonate-barite veins at the Silver Queen mine near Owen Lake, west-central B.C., are hosted by Late Cretaceous Tip Top Hill andesitic volcanic rocks. The veins form a rectilinear northwest-northeast pattern that differs slightly from regional structural trends. The main northwest trending veins are oriented very close to the trend of regional northwest faults, but the crossing veins tend to be more east-northeasterly (070^o) compared to a regional northeasterly trend (040^o). The character of the veins suggests they are extensional features formed by dextral slip related to Paleogene oblique subduction, or intrusion of magma at depth, or both.

In detailed exploration at the mine, the veins cannot be modelled as simple tabular sheet-like bodies. Instead, they are complex structures that divide and rejoin, forming multiple veins or stringers, or are found in shear zones as replacement features with quartz-sericite-clay-carbonate-pyrite alteration haloes of variable width that make definition of vein margins and correlation from hole to hole ambiguous. In addition, individual veins within each of the main structures have en echelon character both along strike and down dip.

Geological and assay data must be carefully studied to define the margins of these complex veins before any estimation of ore reserves may be made. Where multiple veins occur in a section, ore/gangue mineralogy, assays, character of wallrock alteration, and thickness of vein and mineralized hangingwall, median and footwall zones must be used to evaluate continuity of mineralized structures. Well-defined sections are projected into areas of increasing complexity. Once the vein boundaries are defined, metal concentrations, important metal ratios (Au/Ag, Pb/Zn, Cu/Zn), and true thicknesses of the vein provide the basic data for reliable ore reserve estimation.

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Introduction

The Silver Queen (Nadina, Bradina) deposit of New Nadina Explorations Ltd. at Owen Lake is located within the Buck Creek Basin near Houston, 100 km southeast of Smithers in the Bulkley Valley region of central British Columbia (Fig. 1). The deposit has had a long history of exploration since its discovery in 1912, and produced 3160 oz Au, 168,000 oz Ag, 893,000 lbs Cu, 1.55 million lbs Pb, 11.1 million lbs Zn and 34,800 lbs Cd from 210,185 tons of ore during a brief period from 1972 to 1973; mine closure was due to overdesign of the mill and complex metallurgy (Cummings, 1987). Recent rises in the price of gold and the discovery of zones of elevated gold content at depth have rekindled interest in the property. Reserves presently stand at approximately 500,000 tons grading 3 g/t Au, 200 g/t Ag, 0.23% Cu, 0.92% Pb and 6.20% Zn, with potential for larger reserves at lower grades. Extensive surface and underground diamond drilling and underground mapping on the Silver Queen veins since 1963, both before and after production (Dawson, 1985), has resulted in a voluminous database. However, modelling of these veins for reserve estimation must take into account their complexity: they form multiple, often en echelon structures that are difficult to define and correlate from section to section, or even from hole to hole. Ore reserves may be significantly overestimated if predicted vein portions are absent due to en echelon character.

The structural study of the Silver Queen veins presented here is part of a more extensive project dealing with geology and origin of polymetallic deposits in the Buck Creek Basin. The currently producing Equity Silver mine (total reserves plus production of approximately 30 million tonnes of 0.4% Cu, 110 g/t Ag, and 1 g/t Au) lies 30 km to the east-northeast.

Geologic setting

West-central British Columbia lies within the Stikine terrane, which includes submarine calc-alkaline to alkaline immature volcanic island-arc rocks of the Late Triassic Takla Group, subaerial to submarine calc-alkaline volcanic, volcaniclastic and sedimentary rocks of the Early to Middle Jurassic Hazelton Group, successor basin sedimentary rocks of the Late Jurassic and Early Cretaceous Bowser Lake, Skeena and Sustut groups, and Late Cretaceous to Tertiary calc-alkaline continental volcanic arc rocks of the Kasalka, Ootsa Lake and Endako groups (MacIntyre and Desjardins, 1988). The younger volcanic rocks occur sporadically throughout the terrane, mainly in downthrown fault blocks and grabens. Plutonic rocks of Jurassic, Cretaceous and Tertiary ages form distinct intrusive belts (Carter, 1981), with which porphyry copper, stockwork molybdenum and mesothermal and epithermal base-precious metal veins are associated.

The Buck Creek basin has been characterized as a resurgent caldera, with the important Equity Silver mine located within a window eroded into the central uplifted area (Church, 1985). The Silver Queen mine lies on the perimeter of the basin, which may be delineated by a series of rhyolite outliers and semi-circular alignment of Upper Cretaceous and Eocene volcanic centers scattered between Francois Lake, Houston, and Burns Lake (Figs. 1 and 2; figure 59 of Church, 1985). A prominent 30 km long lineament, trending east-northeasterly from the Silver Queen mine towards the central uplift hosting the Equity mine, could be a radial fracture coinciding with the eruptive axis of Upper Cretaceous volcanics and a line of syenomonzonite stocks and feeder dykes (Units D, E and F on Fig. 2) to the Tertiary volcanics.

However, block faulting is common in the basin, locally juxtaposing the various ages of volcanic rocks. Both the Silver Queen and Equity deposits are found in the oldest rocks in the basin, implying that they are in uplifted blocks. Thus, an alternative explanation to the caldera theory for the observed distribution of units within the basin would be by extension related to dextral shear, caused by oblique subduction during the Paleocene and Eocene (Gabrielse and Yorath, 1989).

Within the basin, a Mesozoic volcanic assemblage is overlain by a Tertiary volcanic succession. The distribution of these units and a stratigraphic column are given in Figure 2. The oldest rocks exposed within the basin are at the Equity Silver mine and the Silver Queen mine. The Equity deposit is enclosed by rocks variously ascribed to the Telkwa Formation of the Jurassic Hazelton Group overlain with angular unconformity by Lower Cretaceous Skeena Group sedimentary rocks (Church and Barakso, 1991), Skeena Group (Church, 1985; Wojdak and Sinclair, 1984), or Skeena Group sediments overlain by Kasalka Group volcanics (Wetherell et al., 1979; Cyr et al., 1984). The Kasalka Group is an Early Cretaceous (Armstrong, 1988) or Late Cretaceous (MacIntyre, 1985) continental volcanic succession that is predominantly porphyritic andesite and associated volcaniclastic rocks. It is well exposed in the Kasalka Range type section near Tahtsa Lake, 75 km southwest of Houston. Possible correlatives are similar rocks found in the Mt. Cronin area 25 km northeast of Smithers (MacIntyre and Desjardins, 1988). The latter were mapped as Brian Boru Formation by Tipper and Richards (1976), and correlated to Brian Boru rocks as defined by Sutherland-Brown (1960) in the Rocher Deboule Range 75 km northwest of Smithers.

Areas of Upper Cretaceous rocks are exposed westwards from the Equity mine to the Owen Lake area, where they host the Silver Queen deposit (Fig. 2). These stratified rocks are assigned to the Late Cretaceous Tip-Top Hill Formation of the Francois Lake Group (Church and Barakso, 1991). At the deposit, these Upper Cretaceous rocks are dated at 77.1 ± 2.7 to 75.3 ± 2.0 Ma by K-Ar on whole rock (Church, 1973).

The Upper Cretaceous rocks are overlain by the Eocene Goosly Lake and Buck Creek formations of Church and Barakso (1991). The Goosly Lake andesitic to trachyandesitic volcanic rocks are dated at 48.8 ± 1.8 Ma by K-Ar on whole rock, and this is supported by similar dates of 49.6 ± 3.0 to 50.2 ± 1.5 Ma for related syenomonzonite to gabbro stocks with distinctive bladed plagioclase crystals (Church, 1973) at Goosly and Parrot Lakes, between Equity and Silver Queen (Fig. 2). The Buck Creek andesitic to dacitic volcanic rocks, which directly overlie the Goosly Lake Formation, are dated at 48.1 ± 1.6 Ma by K-Ar on whole rock. These ages correlate with ages of 55.6 ± 2.5 Ma by K-Ar on whole rock for dacite immediately north of Ootsa Lake (Woodsworth, 1982) and with ages of 49.1 ± 1.7 Ma by K-Ar on biotite for Ootsa Lake Group rocks in the Whitesail Lake area immediately south of Tahtsa Lake (Diakow and Koyanagi, 1988).

Basalts of the upper part of the Buck Creek Formation (Swans Lake Member: Church and Barakso, 1991) may correlate with the Endako Group of Eocene-Oligocene age. These rocks give ages of 41.7 ± 1.5 to 31.3 ± 1.2 Ma by K-Ar on whole rock samples from the adjacent Whitesail Lake map-area (Diakow and Koyanagi, 1988; cf. the range of 45-40 Ma reported by Woodsworth, 1982).

The youngest rocks in the Buck Creek basin are cappings of columnar olivine basalt of Miocene age, called the Poplar Buttes Formation by Church and Barakso (1991). These have been dated at 21.4 ± 1.1 Ma by K-Ar on whole rock (Church, 1973).

Geology of the Silver Queen Deposit

The preliminary geology of the study area immediately surrounding the Silver Queen mine, as determined by fieldwork and petrologic studies completed in 1989 (see Leitch et al., 1990 for details, including a pictorial stratigraphic column), is shown in Figure 3 (units are defined in Table 1). The area was mapped previously by Church (1970, 1971) as part of his regional study of the Buck Creek basin.

The rocks hosting the deposit are subdivided into five major units plus three dyke types. A 10 m thick basal reddish purple polymictic conglomerate (Unit 1) is overlain by up to 100 m of fragmental rocks ranging from thick crystal tuff (Unit 2) to coarse lapilli tuff and breccia or lahar (Unit 3), and this is succeeded upwards by voluminous (>100 m) feldspar porphyritic andesite flows (Unit 4), intruded by microdiorite sills (Unit 5) and other feldspar porphyry (Unit 5a) and quartz porphyry (Unit 5b) dykes and stocks up to 1000 m in diameter. The stratified rocks form a gently northwest-dipping succcession, with the oldest rocks exposed near Riddeck Creek to the south and the youngest exposed in Emil Creek to the north (Fig. 3). All the units are cut by dykes that can be divided into three groups: amygdaloidal dykes (Unit 6), bladed feldspar porphyry dykes (Unit 7), and diabase dykes (Unit 8). The succession is unconformably overlain by basaltic to possibly trachyandesitic volcanics that crop out in Riddeck Creek and further south. These volcanics may be correlative with the Goosly Lake Formation (Church, 1973).

Mineralized veins cut the amygdaloidal, fine-grained plagioclase-rich dykes (Unit 6), and are in turn cut by the series of dykes with bladed plagioclase crystals (Unit 7). The former are generally strongly altered, whereas the latter are unaltered. The latter dykes, some of which also contain pyroxene phenocrysts, are probably correlative with the Ootsa Lake Group Goosly Lake volcanics of Eocene, approximately 50 Ma age (Goosly Lake volcanics are divided into two groups, one with and one without pyroxene in addition to the ubiquitous bladed plagioclase: Wetherell, 1979). These bladed feldspar porphyry dykes cut the amygdaloidal dykes, and both are cut by the diabase dykes (50.4 1.8

Ma: Leitch et al., in prep.) that may correlate with basalts of the Eocene Buck Creek Formation (?Endako Group).

Veins: Character and Problems in Correlation

Veins at the Silver Queen deposit are polymetallic and epithermal in character. They are mainly 0.1 to 2 metre thick banded, vuggy quartz-carbonate-barite-specular hematite veins that contain disseminated to locally massive pyrite, sphalerite, galena, chalcopyrite, tennantite and argentian tetrahedrite. Quartz is banded and chalcedonic in places. Locally, in chalcopyrite-rich samples, there is a diverse suite of Cu-Pb-Bi-Ag sulfosalts such as aikinite, matildite (in myrmekitic intergrowth with galena), pearcite-arsenpolybasite, and possibly schirmerite. Berryite (Harris and Owens, 1973), guettardite and meneghinite (Weir, 1973), boulangerite (Marsden, 1985) and seligmannite and pyrargyrite (Bernstein, 1987) have also been reported but not yet confirmed. Native gold (as electrum) with a fineness of 510-620 has been sporadically recognized throughout the various veins.

The major veins are concentrated into two main areas on the property centered on the Mine Hill and Cole Lake areas, with an apparently less mineralized area between in which only the George Lake vein has been found to date (Fig. 3). However, this intervening area is heavily covered by overburden and more veins may remain to be discovered here (the relatively minor Jack and Axel veins, not shown on Figure 3, are located west of the George Lake vein). The most important vein on the property, both in terms of length and tonnage potential, is the No. 3 which outcrops for over 1000 m on Mine Hill. It is best termed a vein "zone" (see below) but for simplicity will be referred to as a vein throughout this paper. Its extension to the north appears to taper and die out, but significant potential may exist on faulted extensions to the south where exploration has been hampered by heavy overburden cover. South of Riddeck Creek (Fig. 3) post-mineral volcanic cover may preclude further exploration.

The predominant strike direction for the main veins, and the relatively minor Church, Chisholm and Owl veins (Fig. 3) is northwesterly, with moderate to steep northeasterly dips. However, strikes of the Cole Lake, Camp, No. 5, and Switchback veins are more variable (see structural analysis below), and even the No. 3 vein swings from 145° to 085° over its length. Figure 4 shows the sinuous character of the No. 3 vein and the related footwall and hangingwall veins in plan view at various levels from 2900' down to 2000' elevation. Dykes and faults on the property have orientations similar to those of the veins, although one major difference is the presence of gently west-dipping dykes; no veins of this orientation are seen.

The veins are highly variable in character, ranging from simple massive or banded gangue-rich veins with well-defined walls (Fig. 5a), to irregular massive sulphide veins (Fig. 5b), to ill-defined stockwork zones (Figs. 5c and d). The veins commonly bifurcate (Fig. 5a) or further divide into several sub-parallel thin veins or stringers (Figs. 5e and f), making correlation difficult even between closely spaced drill holes. In places, the vein pinches out, both along strike (Fig. 4) and down dip (Fig. 6 c, d). During preparation of the structure contour analysis (Fig. 4) it was noted that this zone of pinching rakes moderately east in the plane of the vein, and appears to correlate with areas where the vein flattens. Post-mineral shearing is common along the veins, further complicating correlations by attenuating or faulting out the mineralized section.

Wall rock alteration envelopes are generally phyllic or argillic in nature and are extensive, ranging up to 50 m thick; alteration minerals include quartz, sericite/illite, kaolinite, carbonate and pyrite (Cheng et al., 1991). Strong bleaching associated with quartz-sericite-carbonate alteration is found close to the veins, with envelopes 1 m wide (Figs. 5e and f) or rarely up to 10 m surrounding major veins. In places, the width of altered (and weakly mineralized) rock in the hangingwall, footwall or median zones may be distinctive enough to aid correlation between drill holes. True thickness of the mineralized vein or all the vein strands is also a general aid to correlation if the total thickness is compared from hole to hole. However, the strong lateral and vertical variations in thickness make this a less useful tool over longer distances between sections. Determining the true thickness of each vein intersection is not a trivial task, given the highly variable orientation of drill holes with respect to the vein (holes were drilled in "fans" from underground stations), the variable inclusions of mineralized wallrock with vein material during assaying, and the bifurcation and en echelon character of the veins.

Mineralogy of the veins is variable both from vein to vein and along strike and down dip (Hood et al., 1991), leading to veins and portions of veins with distinct ore mineral assemblages requiring different metallurgical treatment. Thus the Camp veins are characterized by high silver values contained within tetrahedrite and pyrargyrite in a carbonate-rich gangue; the Switchback, No. 5, and Copper veins are characterized by abundant chalcopyrite with associated silver-bearing sulfosalts and electrum in a quartz-rich gangue; the Cole Lake veins are typically composed of quartz, barite, galena and sphalerite; and the main No.3 vein is broadly zoned from rhodochrosite-galena-sphalerite at its northern end to quartz-barite-Mn-siderite-pyrite-sphalerite-galena-chalcopyrite in the center to quartz-barite-pyrite-tetrahedrite at its south end. Some sections of all veins are anomalous in being rich in only pyrite and hematite, and others are rich only in sphalerite. The mineralogy of footwall and hangingwall veins that parallel the No.3 vein is also variable, with no coherent pattern discernible. In general, it is found that the tenor of mineralization, as measured by assay composites for the key metals Au, Ag, Zn, Pb and Cu, is the most reliable correlation tool. Although zinc and lead assays are necessarily a reflection of vein mineralogy, the silver and gold values that have proved to be the most important correlations, cannot be seen visually. Metal ratios, such as Au/Ag, Pb/Zn, and to a lesser extent, Cu/Zn, may also useful in making correlations.

The problem of correlation is made more difficult by the presence of one or more hangingwall or footwall veins that are found discontinuously along the length of the major vein structures. The presence of these subsidiary structures has been well established during underground development for exploration of the No. 3 vein. In fact, some of the "hangingwall" and "footwall" veins are probably merely *en echelon* portions of the No. 3 vein; in other places they may be splays off the No. 3 vein (Fig. 4).

In drill core, it is difficult to be sure if a given intersection is of a splay, a hanging/footwall vein, or an *en echelon* shift of the main vein. One of the most difficult problems in making correlations is the *en echelon* character of many of the veins, both along strike and down dip. Resolution of this problem is important because of the implications it has for physical continuity of the vein and, consequently, for tonnage and grade estimations. For example, intersections of veins in the No. 3, George Lake, Camp and Cole Lake areas can be interpreted either as simple tabular bodies or as *en echelon* lenses (see sections in Fig. 6); there may be no vein, or an attenuated vein, in the locations predicted by the simple tabular model. Potential problems are (1) an increased, non-quantifiable error in tonnage estimation, and (2) disregard for possible different grade character of two *en echelon* vein segments; ore shoots of higher grade are common within the veins, both along strike and down dip.

Structural Interpretation of the Owen Lake Veins

The structure of the Silver Queen mine area is dominated by a gently west to northwest-dipping homocline. There is no folding apparent at the scale mapped; the sequence appears to have been tilted 20° to 30° from the horizontal by block faulting. The average bedding plane is 032/25°NW (Fig. 7a). The most prominent joint set dips steeply, roughly perpendicular to the bedding, at 057/77°SE, although there are many other minor nodes (Fig. 7b).

Two prominent sets of faults displace this homoclinal sequence, cutting it into a series of fault panels: a northwest-trending (NW) set and a northeast-trending (NE) set (Fig. 3). The former predates or is contemporaneous with mineralization, whereas the latter is mainly post-mineral (a few veins trend east-northeast). The NW faults dip 60° to 80° to the northeast (average 315/75°NE in Fig. 7c), and the "cross" or NE set appears to be subvertical (070/90°). There are subsidiary trends indicated at 295/85°NE and 085/90°, and a few flat-dipping faults possibly roughly parallel to bedding planes (Fig. 7c). Most of the mineralized veins and the dykes follow the NW faults, and in places veins are cut off and displaced by the NE set.

Movement on the NW faults includes some dip slip, so that each successive panel to the east is upthrown, leading to successively deeper levels of exposure to the east. Thus, in the panel between the George Lake and the Emil Lake faults (Fig. 3), there is considerably more of the lower fragmental rocks (Units 2 and 3) exposed than in the next panel to the west, between the Owen Lake and the George Lake faults. There does not seem to be much displacement across the No. 3 vein fault; slickensides seen underground on this structure suggest a reverse sense of last movement with undeterminable horizontal component.

The sense of motion on some of the NE faults appears to be south side down, with a small component of sinistral shear. Offsets of No. 1 and 2 veins across the fault along Wrinch Creek (Fig. 3) suggest a few metres of left-lateral displacement, but the displacement of an amygdaloidal dyke near the portals of the 2880 level suggests the south side must have dropped as well. The boundaries of this fault zone, and its dip, are not well constrained; in outcrops in Wrinch Creek, it appears as a vaguely defined zone up to 10 metres wide, with segments that have possible shallow southerly to moderate northerly dips. The Cole Creek fault is not well exposed at surface; a splay from it may cause the change in orientation of the No. 3 vein to the Ruby vein (Fig. 3). A considerable left-lateral offset of as much as 200 metres is suggested by drill-hole intersections of the NG3 vein, which may be a faulted extension of the No. 3 vein south of the Cole Creek fault. Underground, this fault is exposed at the southernmost extent of drifting as a NE-trending gouge zone 1 to 2 metres thick. Other examples of minor NE faults are seen underground.

The orientations of the veins comprising the Silver Queen deposit are compared to the trends of regional faults in the rose diagrams of Figure 8; structural block diagrams and a discussion of proposed stress orientations are in Thomson and Sinclair (1991). Although the principal northwesterly Cordilleran trend is developed both regionally (321°) and at the deposit (315°), the less dominant northeasterly trend crossing the structural grain trends 040° regionally but 070° at the property. Neither the regional nor the property fracture patterns are compatible with formation by east-west compression, and therefore do not fit with easterly-directed subduction of the Pacific plate under North America in Cretaceous to Tertiary time. However, the regional pattern could be explained as a typical conjugate shear set with the axis of maximum compression oriented north-south (or extension oriented east-west). If the veins on the property were conjugate shears, the axis of maximum compressive stress would bisect the acute angle between the vein-filled fractures and be oriented roughly east-west (it would plunge 20° to 287° azimuth: Fig. 7d), but the last motion on the NE fault set has the wrong sense for such an east-west compression, and members of the NW set (including the No. 3 vein) seem to be extension veins rather than shear veins. A group of veins approximately parallel to such an axis of maximum compression (Ruby, Switchback, No. 5 and Camp veins), would have the right orientation to be typical extension gashes developed by east-west-compression and then rotated by continuing sinistral shear. However, the best way of rationalizing all the observations is to suggest that they formed in a regional extension regime. This would fit with the regime of uplift and extension proposed for the Paleocene due to dextral shear as a result of oblique subduction (Gabrielse and Yorath, 1989). Alternately, the extensional character of the veins might be explained by inflation of the crust due to the intrusion of a magma at depth (Thomson and Sinclair, 1991).

Most of the dykes show similar orientations to the veins, with the pre-mineral amgdaloidal dykes commonly found parallel and adjacent to the veins (compare the maxima for dykes of 325/90° and 298/90° from Fig. 7e with similar maxima for veins of 325/85°NE and 310/60°NE from Fig. 7d; the 90° dips for dykes are artificial since they are biased by data from surface outcrops where dip cannot be measured). In places this feature (a distinctive dyke parallel to and on a given side of a vein intersection) is useful in making correlations from drill-hole to drill-hole. Along the No. 3 vein, one such major dyke causes significant dilution problems due to the incompetent nature of some of these soft, strongly clay-altered dykes near the veins.

There is one major exception to this northwest trend: a prominent gently west-dipping (323/33°SW: Fig. 7e) set of Unit 6 (pre-mineral amagydaloidal dykes) is well-developed in both the No. 3 vein and Cole Lake areas (Fig. 6a, b, f). In places this dyke set may dip gently east (Fig. 6b, d). This gently-dipping set is roughly orthogonal to the main, steeply northeast dipping dykes and veins, and also roughly parallel to the general gentle westerly dip of the host stratigraphy. A similar orthogonal fracture pattern, with steeply dipping fractures better mineralized and with stronger alteration surrounding them than the gently dipping fractures, is also observed in outcrops in Wrinch Creek.

Discussion

This evaluation of vein character and structure has been carried out in part as a prelude to a companion study on ore reserve/resource estimation of the No. 3 zone (Nowak, 1991). The structural information presented here is far more detailed than existed previously and clearly will provide a sound basis on which to build a picture of reserves/resources.

The geometric form of veins in the No. 3 zone has been evaluated from the perspectives of (1) vein thickness and (2) continuity in the plane of the vein structure (i.e. between drill holes). Vein thickness, a superficially simple measurement, had to be interpreted from old drill logs for much of our data base. The approach developed for correlation was based on recognition of patterns in the tenor of mineralization for 5 key metals (Ag, Au, Zn, Pb and Cu) for which assay information was available for veins and substantial distances into country rock. This procedure provided thicknesses consistent with observed thicknesses where these latter data were avalilable. Precious metal profiles were particularly useful in this regard.

Vein continuity was interpreted on the basis of assay values, width of vein and alteration haloes, mapped and interpreted faults and vein orientation information, from which the structure contour map of veins in the No. 3 zone was prepared (Fig. 4). This interpretation presents clearly the likely en echelon character of the veins in the No. 3 structure, a previously unrecognized characteristic that is important to our understanding of physical continuity of vein material and, consequently, is an essential component of reserve/resource estimation. Moreover, our geological approach to the question of continuity has provided confident estimates of vein continuity in the ambiguous cases where drill holes intersected two or more veins near the expected intersection of the main No. 3 vein.

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Figure Captions

FIGURE 1. General geology of west-central British Columbia, showing the regional setting of the study area. Taken from MacIntyre (1985); note that Upper Cretaceous rocks such as Tip Top Hill Formation are included in unit Kk on this map.

FIGURE 2. Geology of the Buck Creek Basin (from Church, 1985). Stars mark locations of known mineral deposits or occurrences. Tertiary rocks of the Buck Creek basin are white; Mesozoic units are stippled; intrusive units D, E, F are marked by a dark pattern.

FIGURE 3. Detailed property geology of the Silver Queen deposit, Owen Lake area, west-central British Columbia (from Leitch et al., 1990). Units are defined in Table 1.

FIGURE 4. Structure contour map of the main No. 3 vein and the adjacent footwall and hangingwall veins at various levels from 2900' down to 2000' elevation. Solid vein outline represents the vein at the 2500' level where continuity has been observed in detail. Note the sinuous character of the veins and the strong change in orientation towards the south end.

FIGURE 5. Photographs from underground exposures of the No. 3 vein system illustrating the range of vein characteristics:

(a) massive, crustified, gangue-rich vein with well defined walls (note bifurcation of vein at top of photo).

(b) irregular, sulphide-rich vein with poorly defined walls and variable thickness.

(c) ill-defined stockwork zone characterized by a network of thin mineralized veinlets (note the thin faulted sliver of Unit 6 dyke on the right-hand side).

(d) irregular, poorly defined stockwork and stringer zone with included blocks of unmineralized altered wallrock (note the strong alteration on the hangingwall side to the left of photo compared to weak chloritic alteration to the right).

(e) thin, symmetrically banded (crustified) vein with subsidiary stringers in strongly altered wallrock.

(f) four or five thin stringers in strongly altered wallrock.

FIGURE 6. Cross-sections of the Silver Queen deposit (all sections are from southwest at left to noertheast at right):

(a, b) Camp vein sections 100 and 102 to show gently-dipping dykes approximately perpendicular to the steeply-dipping vein systems.

(c, d) No. 3 vein system, cross-sections at 21,000 E (BU-116) and 20,000 E (S-88-031) respectively, to show branching and *en echelon* character of the vein.

(e) Cole Lake area, showing gently-dipping dyke of unit 6 cut by later dykes of units 7 and 8.

(f) George Lake vein system at the 2600 level of the Bulkley crosscut, with the available intersections interpreted as part of an *en echelon* system.

FIGURE 7. **Lower hemisphere projections of poles perpendicular to structural features at the Silver Queen deposit. Maxima (heavy crosses) are discussed in text.**

(a) Bedding (solid dots, n=11) and foliation (open circles, n=4) in Cretaceous Tip Top Hill stratigraphy. Average bedding is 032/25°NW; foliations are not contoured.

(b) Joints (n=33) in Cretaceous Tip Top Hill stratigraphy. Strongest concentrations are at 057/77°SE (roughly perpendicular to bedding, plane indicated) and 330/60°NE, with a weak concentration at 005/15°W.

(c) Faults (non-mineralized; n=42) cutting Cretaceous rocks. Main northwest faulting (plane indicated) is at 315/75°NE, with a subsidiary set at 295/85°SW; northeast or "cross" faulting is at 070/90° and 085/90°, and poorly defined flat faulting at about 020/30°SW.

(d) Veins cutting Cretaceous rocks. Open circles are for No. 3 vein (310/60°NE, n=11). Other veins are not distinguished (solid circles, n=48). There are concentrations at 325/85°NE and 350/80°NE (the combined average for these groups at 312/70°NE, with the No. 3 vein included, is indicated). The weak "cross" vein concentration is at 075/90° (also indicated; bisector would plunge 20° to 287°).

(e) Early Tertiary dykes (n=70), with concentrations at 298/90° (plane indicated), 325/90° and 323/33°SW.

FIGURE 8. Rose diagrams for (a) the Silver Queen veins and faults (taken from Fig. 2) and (b) regional faults (taken from Fig. 1).

TABLE 1. TABLE OF FORMATIONS, OWEN LAKE AREA

PERIOD	EPOCH	Age (Ma)	FORMATION	SYMBOL	UNIT	LITHOLOGY
TERTIARY	Miocene	21	Poplar Buttes	M_{PBv}		Olivine basalt
	Eocene-Oligocene	45-30	Endako Group	EO_{Ev}	8	Basalt, diabase dikes
	Eocene	56-47	Ootsa Lake Group	E_{Ov}	7a	Trachyandesite, basalt
					7	Bladed feldspar porphyry dikes
			------ MINERALIZED VEINS -----			
					6	Amygdular dikes
CRETACEOUS (Late)			"Okusyelda"	uKqp	5b	Quartz-eye rhyolite stock, dykes
				uKp	5a	Intrusive porphyry sills, stocks
				uKud	5	"Mine Hill" microdiorite
					4a	Feldspar-biotite porphyry dikes
		85-75	"Tip Top Hill" Formation	uKfp	4	"Tip-Top Hill" feldspar porphyry (voluminous porphyritic andesite)
				uKb	3	Medium to coarse tuff-breccia
				uKt	2	Crystal tuff, local lapilli tuff
					2a	Fine ash tuff
				uKc	1	Polymictic basal conglomerate, sandstone and shale interbeds

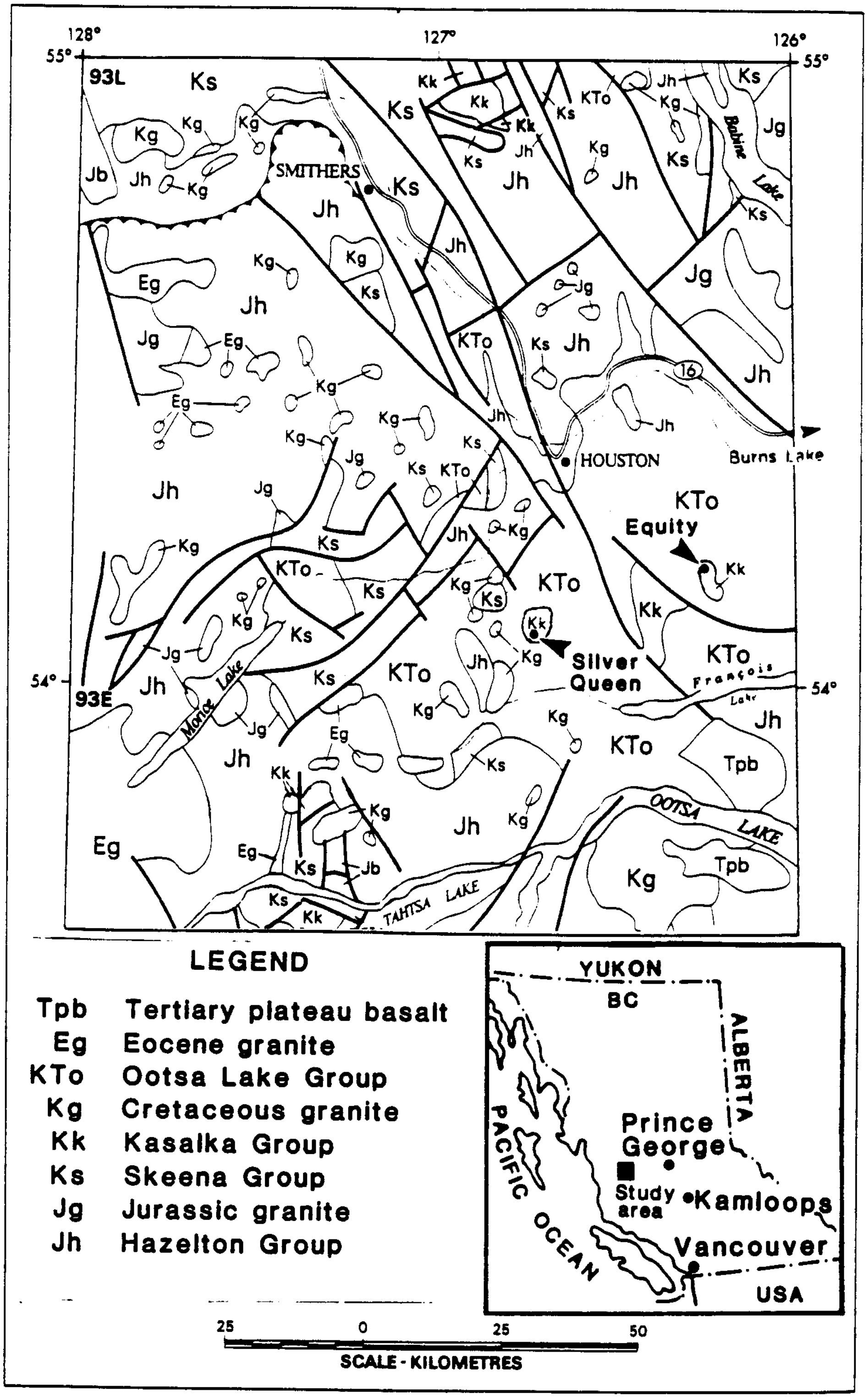
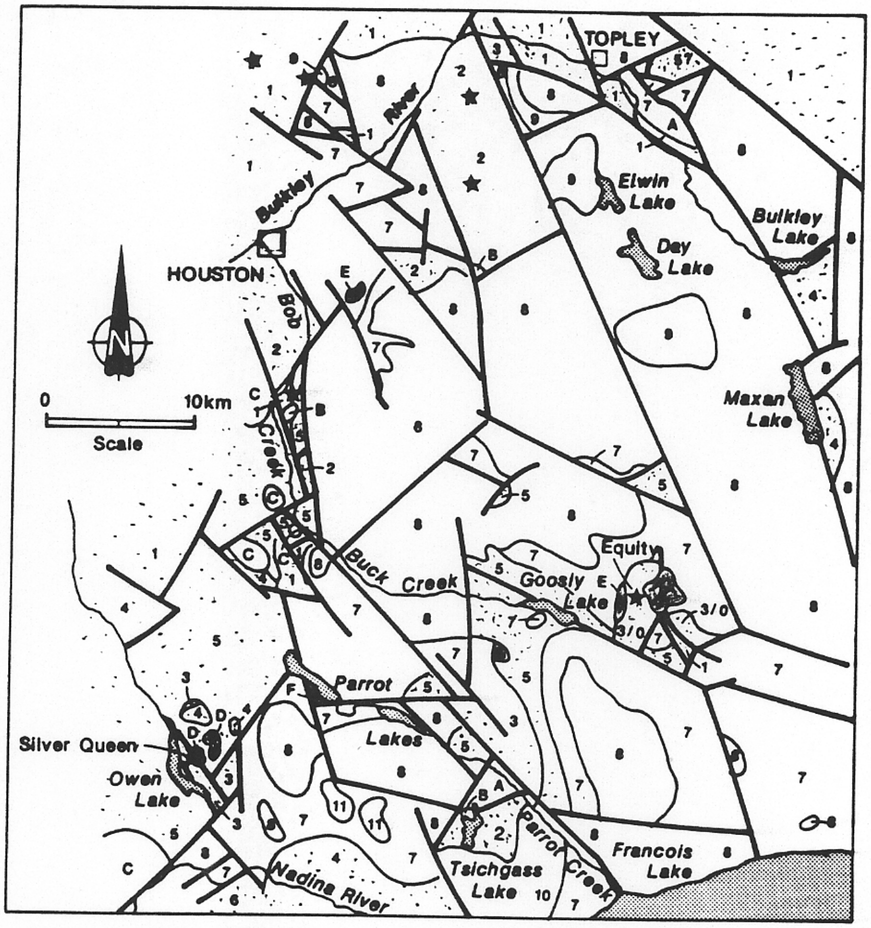

128°
127°
126°
55°
55°
54°
54°
93L
93E
SMITHERS
HOUSTON
Burns Lake
Equity
Silver Queen
Babine Lake
Morice Lake
François Lake
OOTSA LAKE
TAHTSA LAKE
16
Ks
Kg
Kk
Jh
Jb
Jg
Eg
KTo
Tpb
Q
LEGEND
Tpb Tertiary plateau basalt
Eg Eocene granite
KTo Ootsa Lake Group
Kg Cretaceous granite
Kk Kasalka Group
Ks Skeena Group
Jg Jurassic granite
Jh Hazelton Group
YUKON
BC
ALBERTA
PACIFIC OCEAN
Prince George
Study area
Kamloops
Vancouver
USA
25
0
25
50
SCALE - KILOMETRES

Fig. 1



BEDDED ROCKS

MIOCENE

11 - POPLAR BUTTES FORMATION: columnar olivine basalt

EOCENE

BUCK CREEK FORMATION

10 - Parrot Mountain Member: andesite breccia

9 - Swans Lake Member: basaltic lava

8 - Houston Member: andesite and dacite lavas and breccia

7 - GOOSLY LAKE FORMATION: andesite and trachyandesite lavas, breccias, sills and stocks

6 - BURNS LAKE FORMATION: conglomerate, sandstone, shale

UPPER CRETACEOUS

5 - TIP TOP HILL FORMATION: biotite-hornblende andesite lava and pyroclastic rocks

4 - Acid volcanic rocks: rhyolite lava and related quartz porphyry intrusions on Okusyeida Hill

LOWER CRETACEOUS
SKEENA GROUP?

3/0 - mixed assemblage: chert pebble conglomerate, sandstone, and felsic volcanic rocks

JURASSIC
HAZELTON GROUP

2 - Undivided dacitic andesite, rhyolite and basaltic lavas and volcaniclastic rocks

1 - TELKWA FORMATION: maroon tuff and tuff-breccia)

0 - MAXAN LAKE FORMATION: sandstone, may include chert-pebble conglomerate assigned to Unit 3)

IGNEOUS INTRUSIONS

EOCENE

F - Goosly intrusions: syenomonzonite-gabbro stocks

E - Nanika intrusions: Equity quartz monzonite stock

Bulkley intrusions

D - Mine Hill microdiorite sills and dykes

C - Biotite-plagioclase and quartz-feldspar porphyry stocks

B - Basic and intermediate stocks

JURASSIC

A - Topley intrusions: granitic stocks

Fig. 2

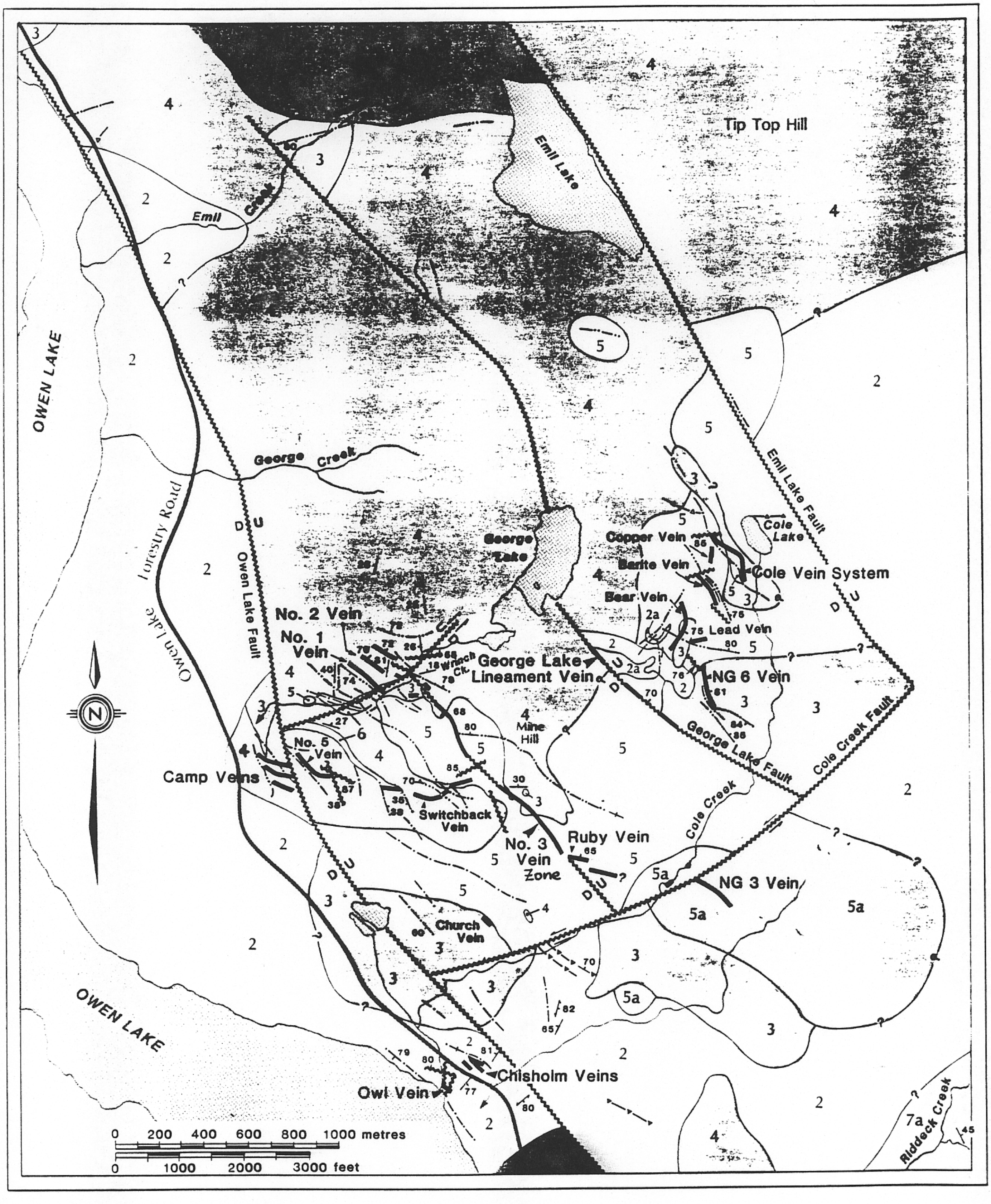
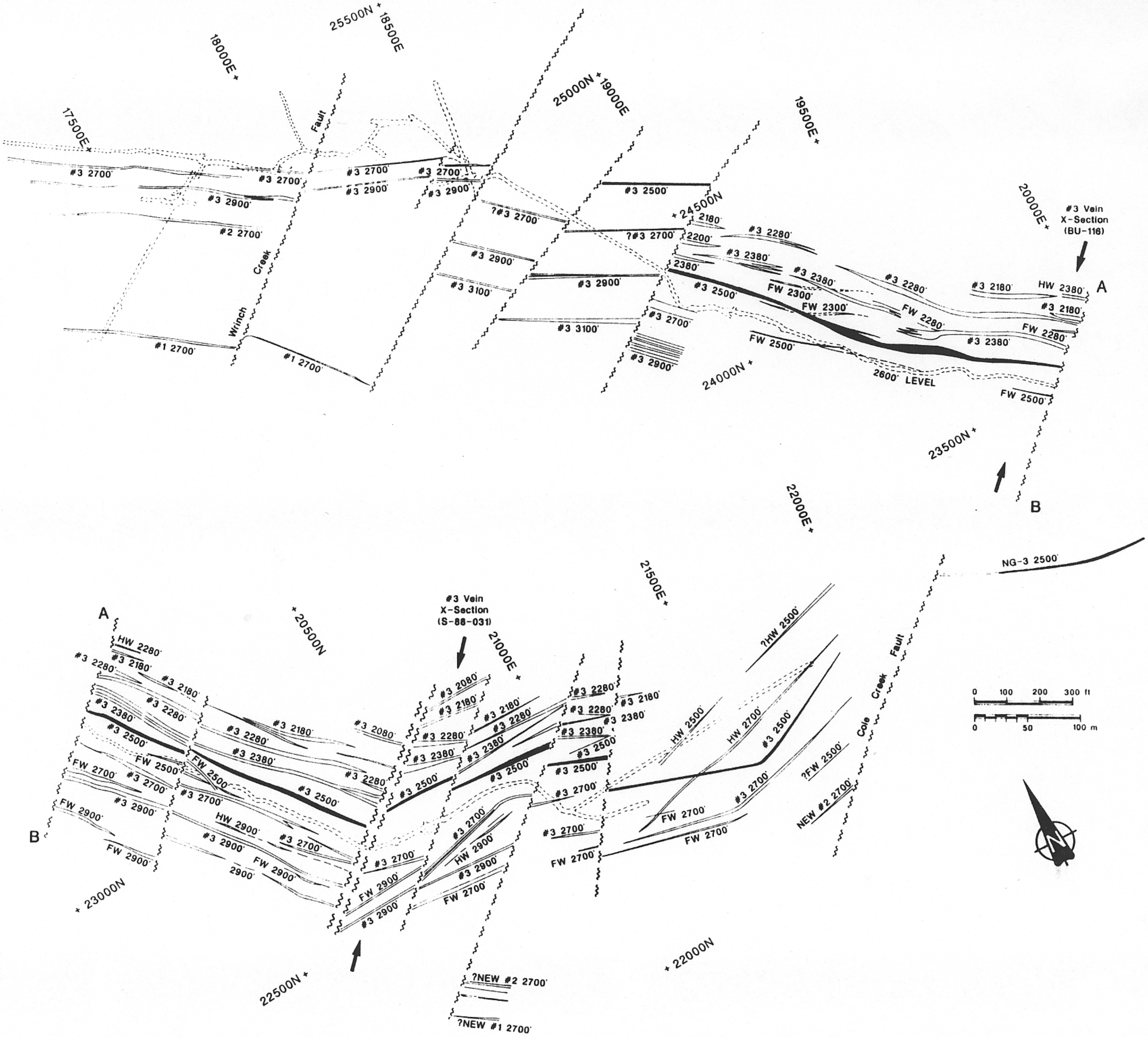

Tip Top Hill
Emil Lake
Emil Creek
OWEN LAKE
George Creek
Owen Lake Forestry Road
Owen Lake Fault
George Lake
Copper Vein
Cole Lake
Barite Vein
Cole Vein System
Bear Vein
Lead Vein
NG 6 Vein
Emil Lake Fault
No. 2 Vein
No. 1 Vein
Wrinch Ck.
George Lake Lineament Vein
Mine Hill
No. 5 Vein
Camp Veins
Switchback Vein
No. 3 Vein Zone
Ruby Vein
George Lake Fault
Cole Creek Fault
Cole Creek
NG 3 Vein
Church Vein
OWEN LAKE
Chisholm Veins
Owl Vein
Riddeck Creek
D U
N
0 200 400 600 800 1000 metres
0 1000 2000 3000 feet

Fig. 3



25500N
18500E
18000E
17500E
25000N
19000E
19500E
20000E
24500N
24000N
23500N
22000E
21500E
21000E
20500N
23000N
22500N
22000N
Wrinch Creek Fault
Cole Creek Fault
#3 2700'
#3 2900'
#2 2700'
#1 2700'
#3 2500'
?#3 2700'
#3 3100'
#3 2180
#3 2200'
#3 2280'
#3 2380'
#3 2380'
FW 2300'
FW 2280'
FW 2500'
HW 2380'
#3 2180'
2600' LEVEL
#3 Vein X-Section (BU-116)
A
B
NG-3 2500'
#3 Vein X-Section (S-88-031)
HW 2280'
#3 2080'
#3 2180'
FW 2700'
FW 2900'
HW 2900'
HW 2500'
?HW 2500'
HW 2700'
?FW 2500'
NEW #2 2700'
?NEW #2 2700'
?NEW #1 2700'
0 100 200 300 ft
0 50 100 m
N

Fig. 4

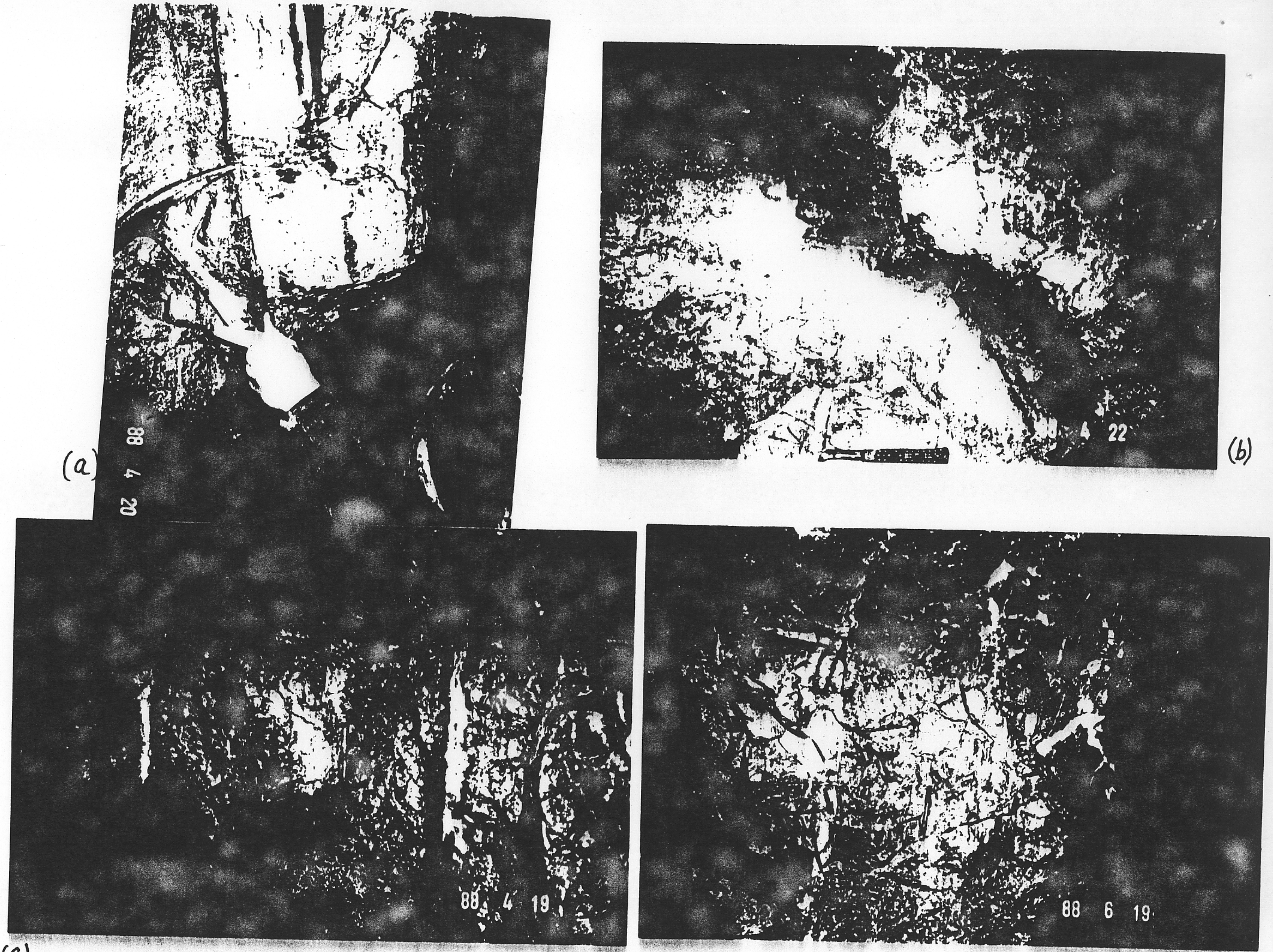
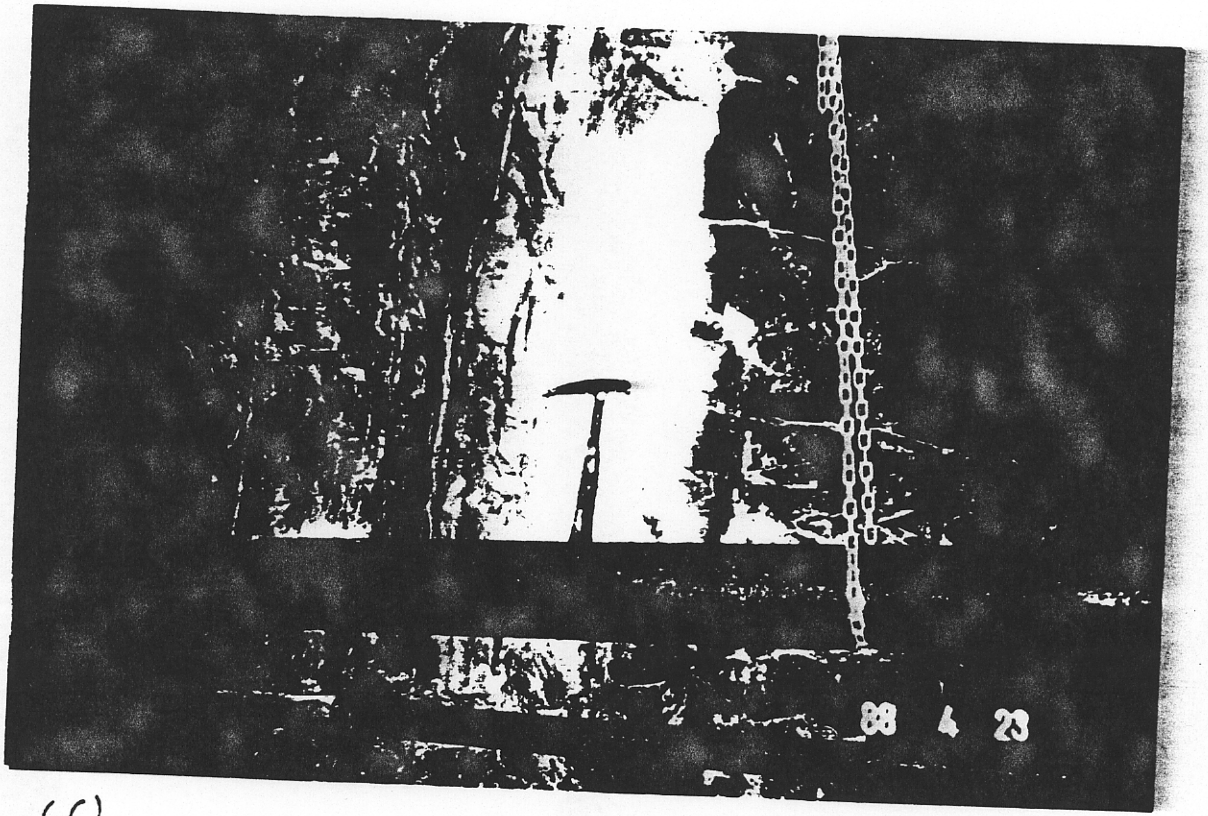


Fig 5

(e)



(f)

Fig.5

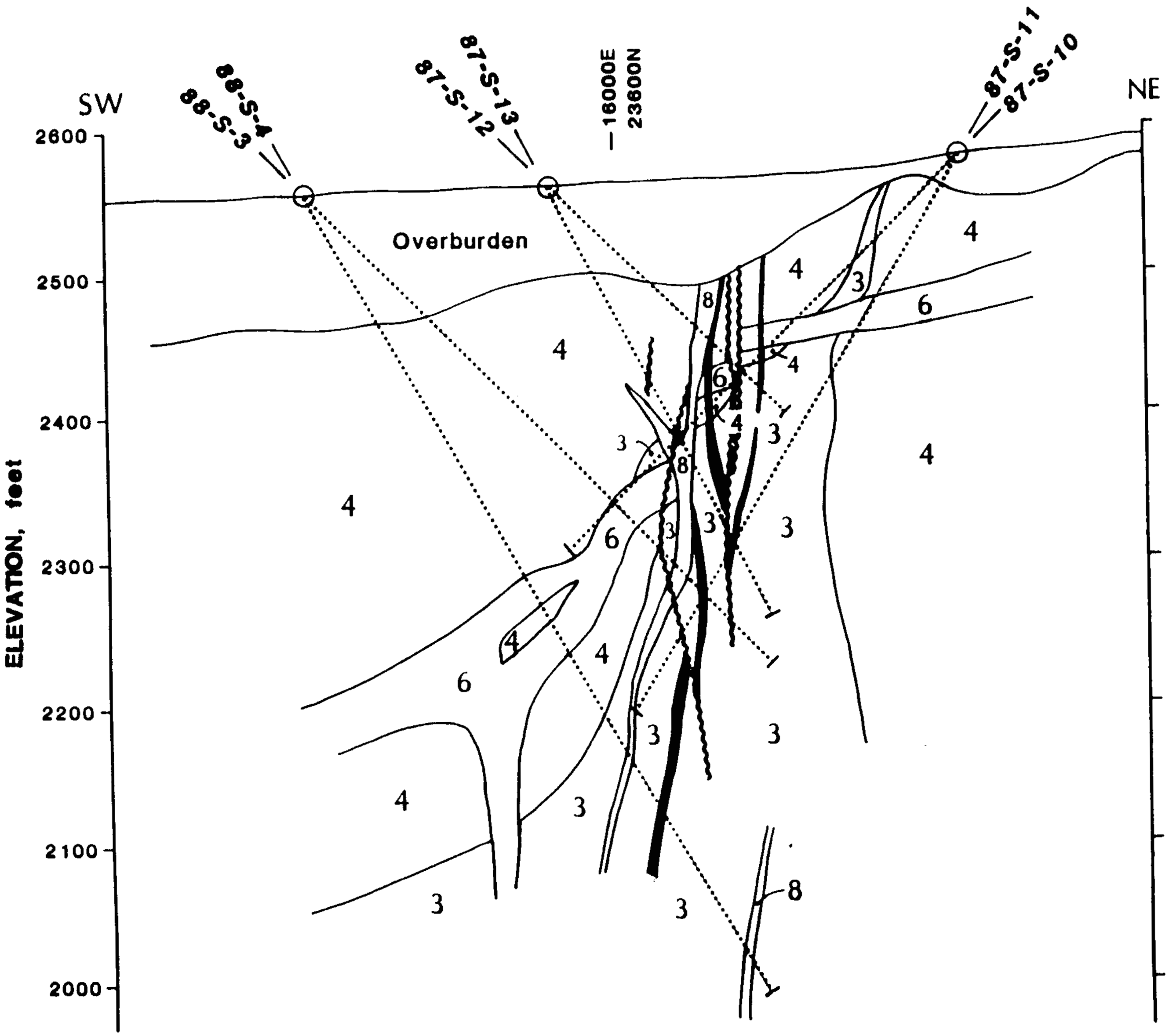


Fig. 6 a) CAMP VEINS SECTION 102

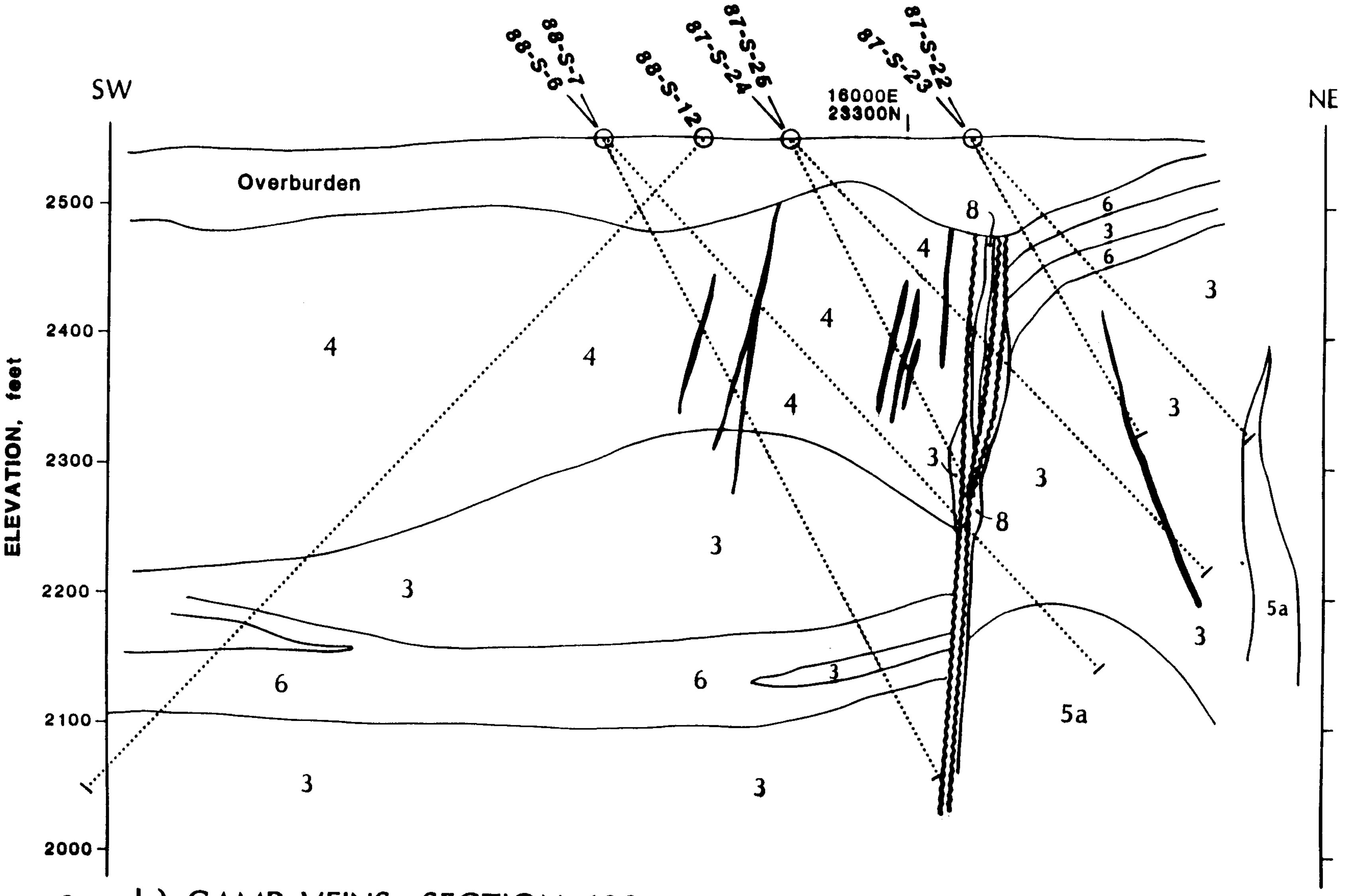


Fig. 6 b) CAMP VEINS SECTION 100

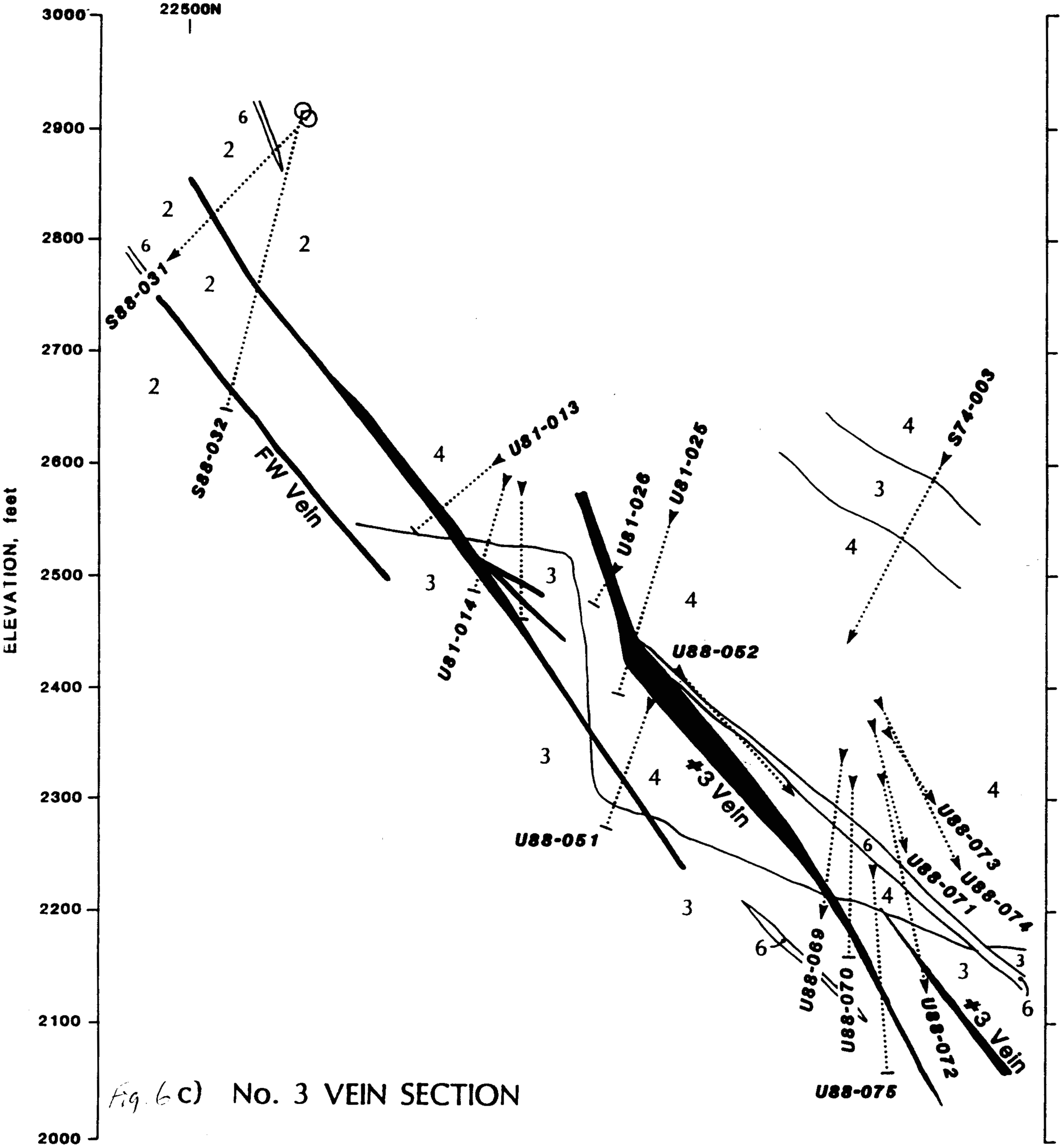


Fig. 6 c) No. 3 VEIN SECTION

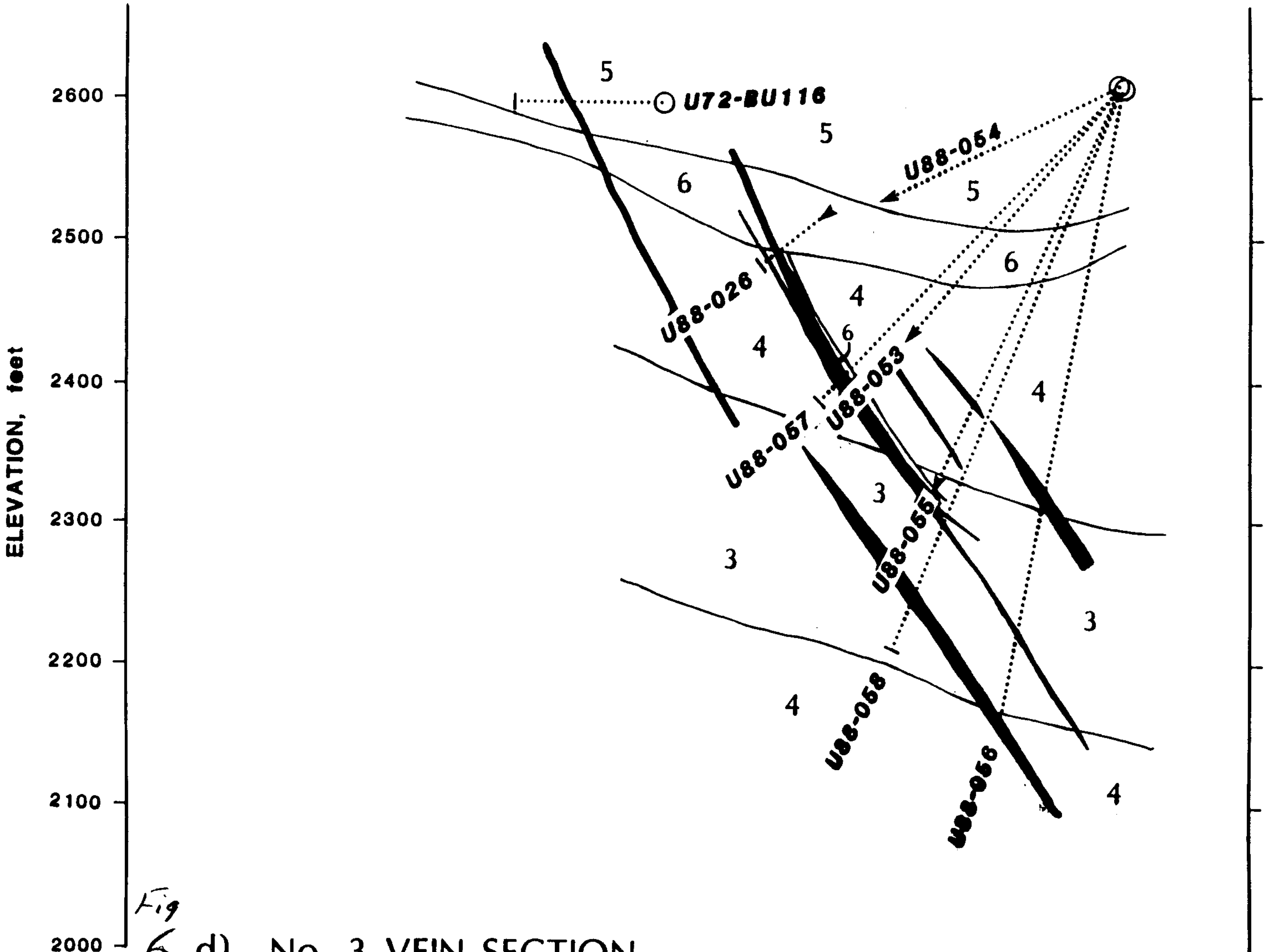


Fig 6 d) No. 3 VEIN SECTION

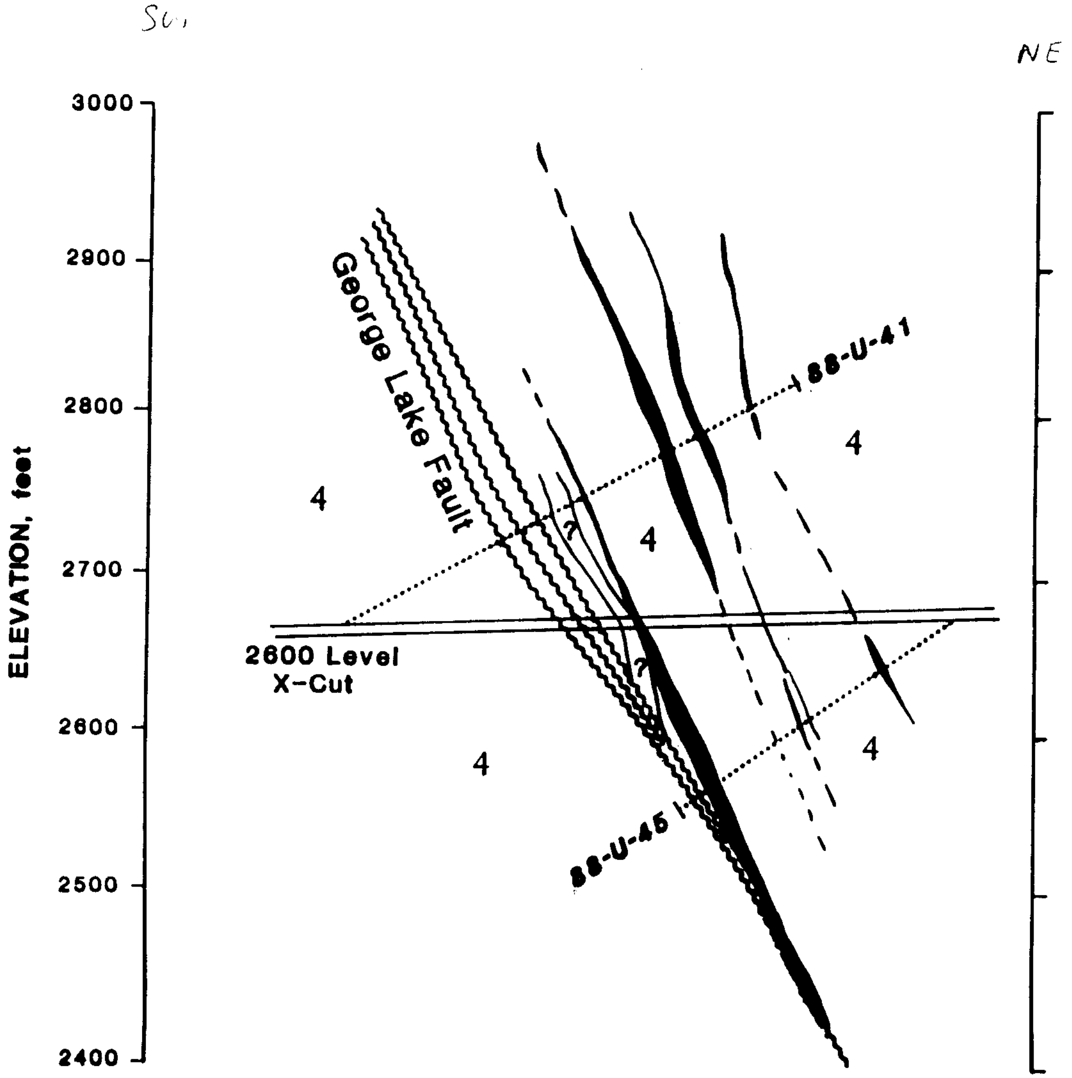


Fig. 6 e) GEORGE LAKE VEINS SECTION

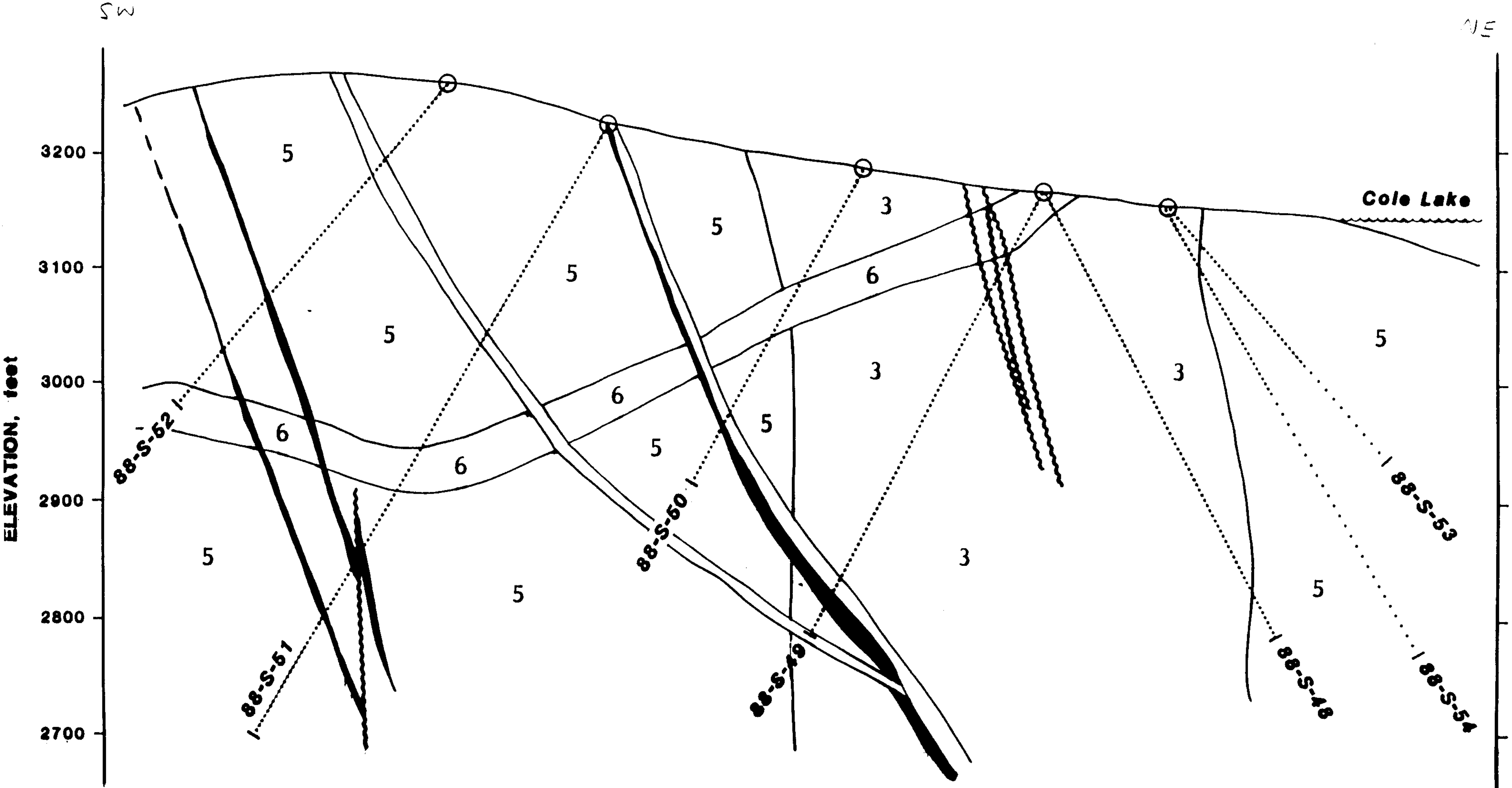
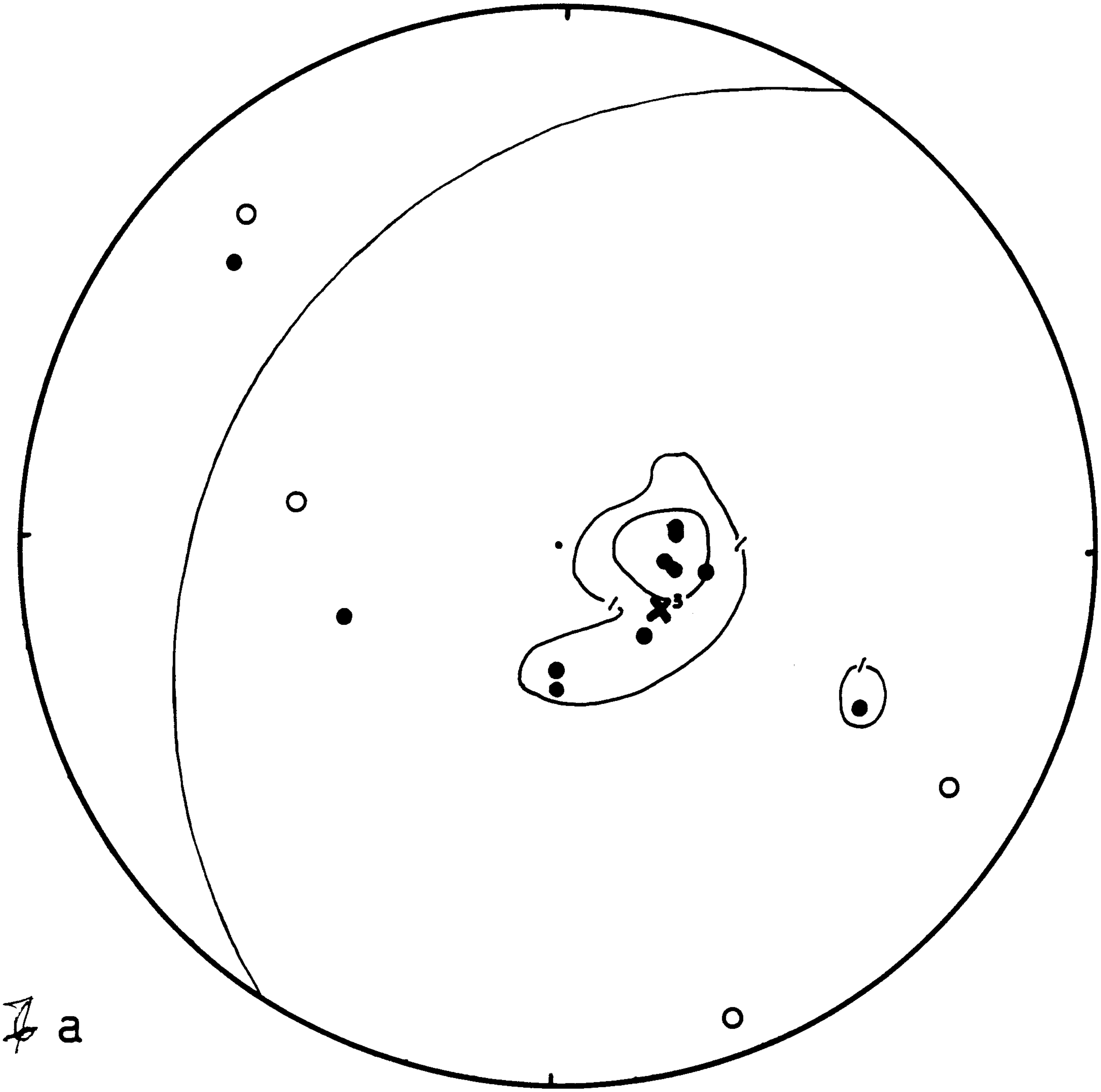
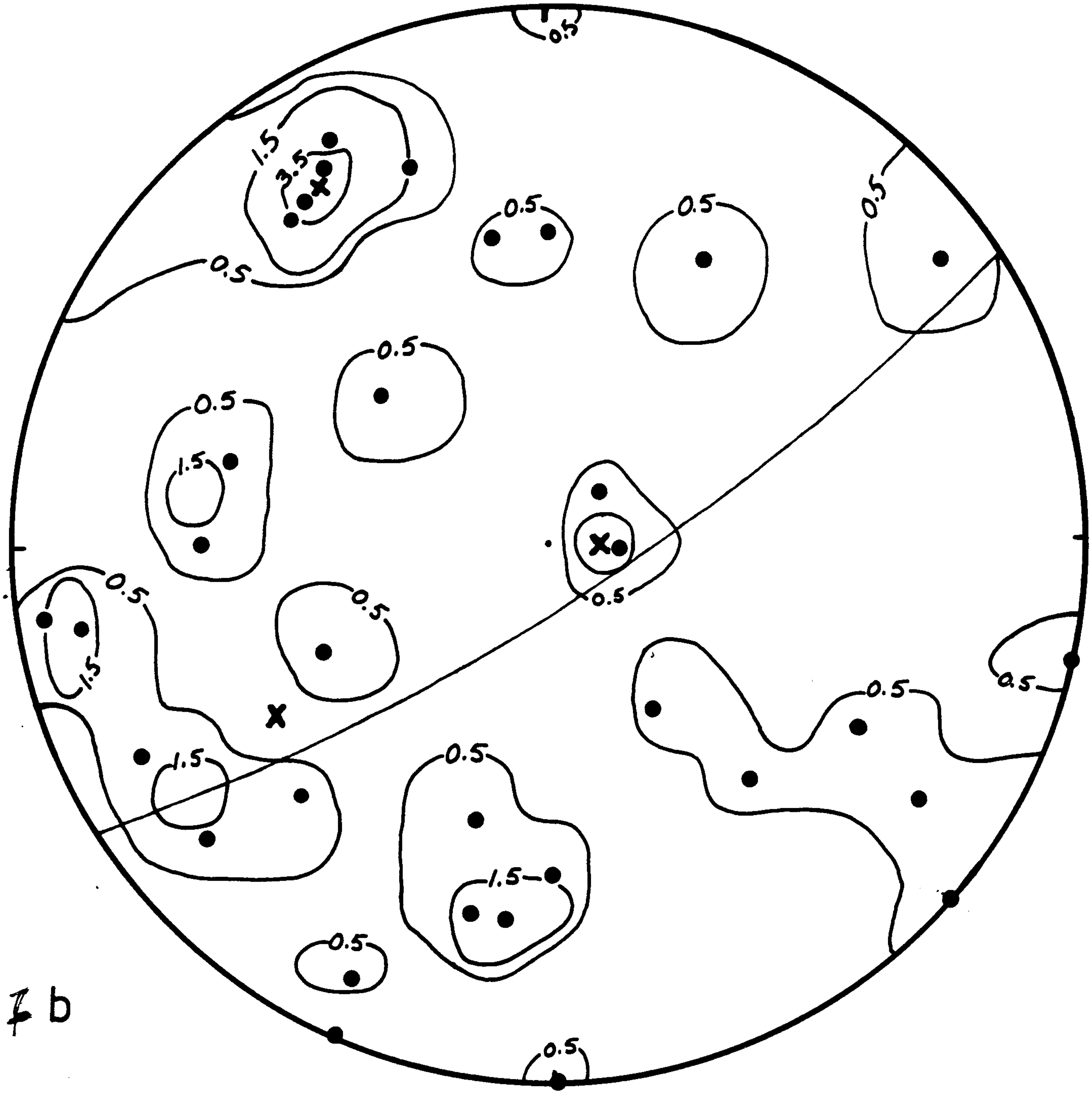


Fig. 6 f) COLE LAKE VEIN



7a



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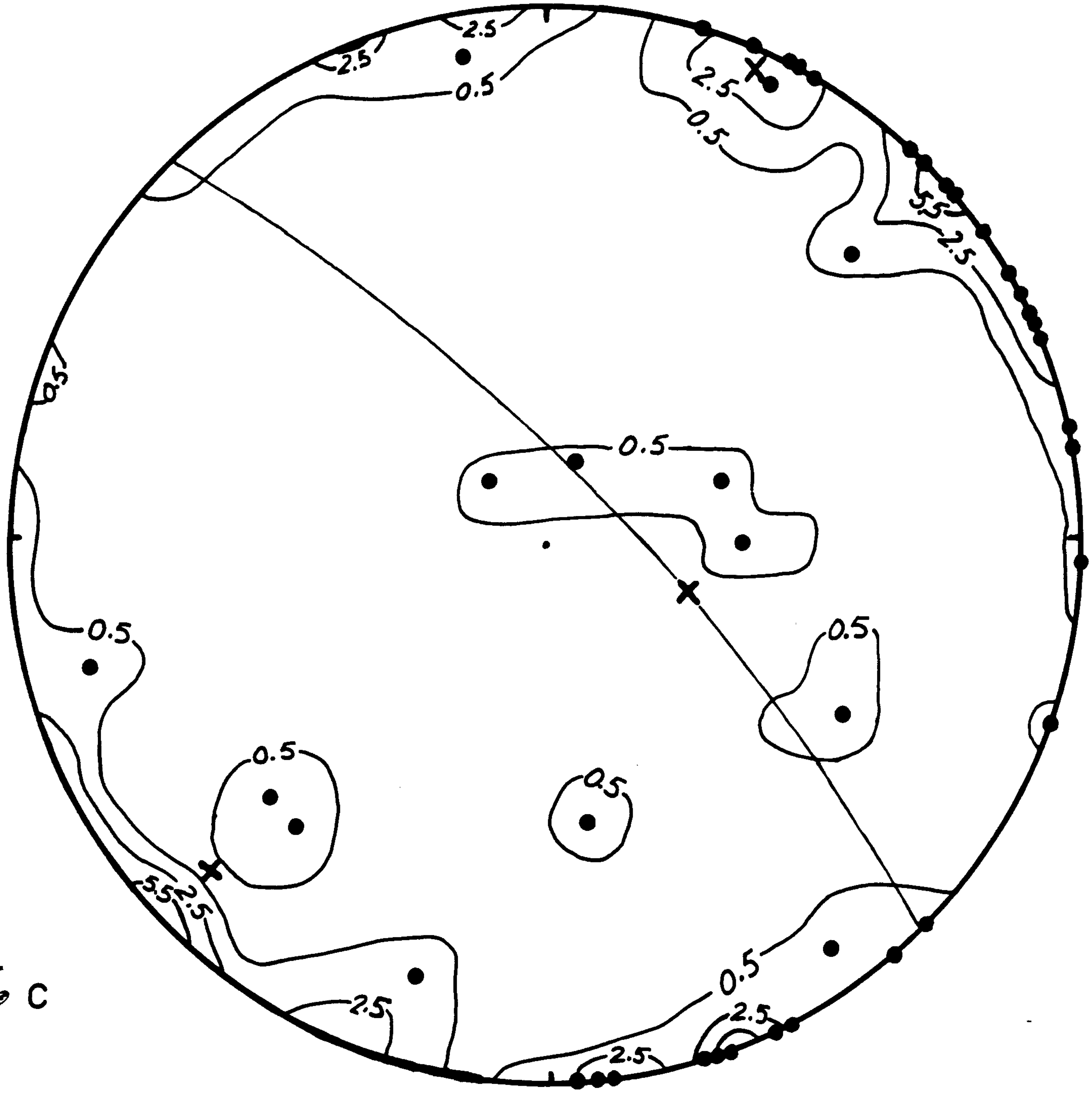
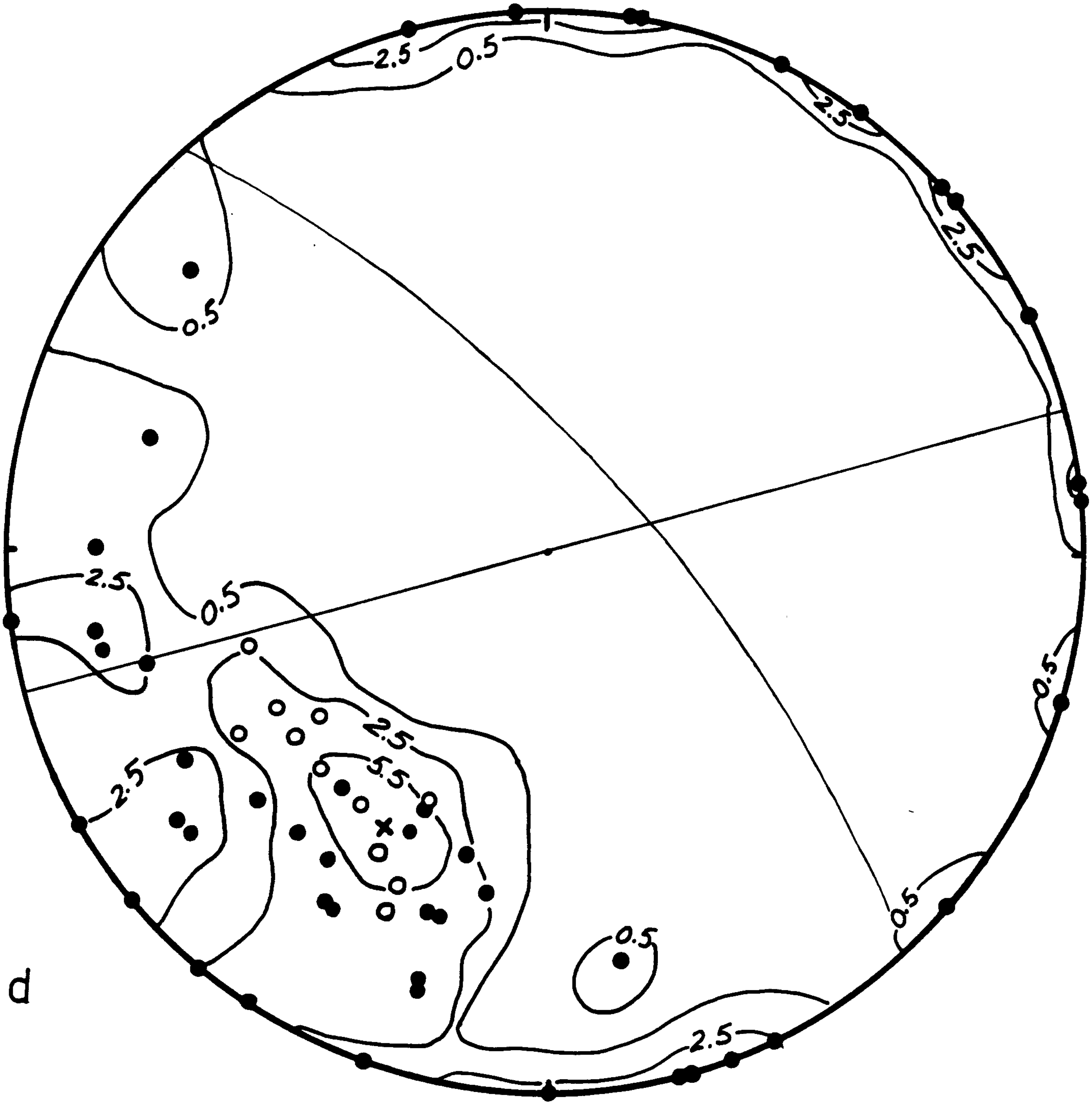
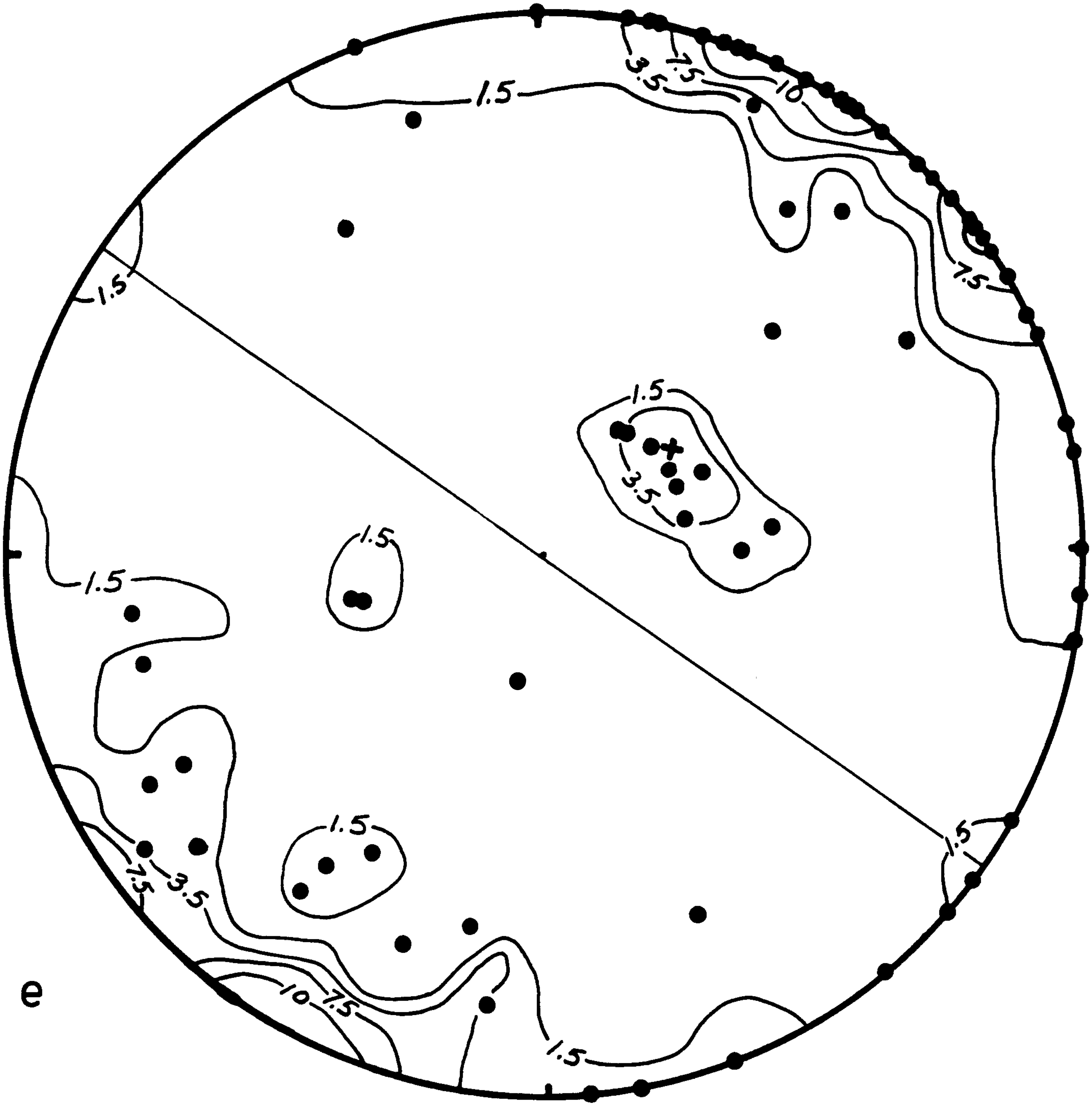


c



d



e

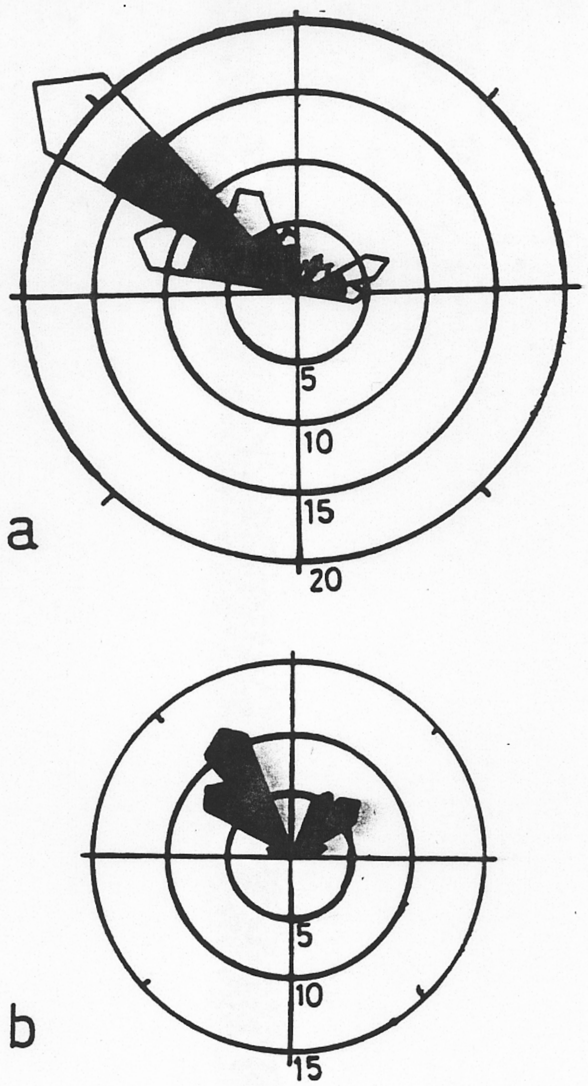


Figure ~~7~~ 8. Rose diagrams for (a) the Silver Queen veins and faults (taken from Fig. 2) and (b) regional faults (taken from Fig. 1).

Fig. 8