DISPERSION OF LEAD AND ZINC WITHIN A SIL.-ORD. BLACK SHALE UNIT, SELWYN BASIN, YUKON

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Abstract

Active exploration within the shales and carbonates of the eastern Yukon has produced a need to accurately describe metal dispersion in various lithologies as an aid in exploration. A problem peculiar to the Selwyn Basin is the unreliability in using Zn threshold values for determining mineralized anomalies.

Studying a mineralized black shale unit in the Selwyn Mtn.'s by means of vertical profiles across a 360 ft. trench, it was found that Pb was positively related to the Si component of the shales whereas Zn was positively related to Fe. The latter relation does not appear to hold at depth and may therefore be a surficial weathering feature. In permanently frozen bedrock, there is little transport of either metal. Pb is transported mechanically along the soil-bedrock interface primarily by soil creep, but with minor and local bedrock movement. Zn is transported both mechanically by soil creep, and hydromorphically. Seasonal permafrost within the upper 2 to 3 ft. allows slight hydromorphic dispersion of Zn resulting in a downslope dispersion pattern almost twice the extent as that of Pb. Across a 40 ft. anomalous zone, the Zn/Pb ratio reached a minimum value, indicating a probable greater increase in Pb than Zn.

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Chapter One

Introduction

Exploration in the eastern Yukon, particularly the areas of the Bonnet Plume, Summit and Godlin Lakes, is currently increasing due to the discoveries of several mineral deposits. Rock types in the area vary from Proterozoic schists and quartzites to Paleozoic limestones, cherts, quartzites, shales, granites, and Tertiary volcanics. The more sizeable deposits tend to lie within the Paleozoic sediments and in particular, within the shales, siltstones, and carbonates. Lead-zinc deposits, including those in the Selwyn Basin, appear to be stratabound on a regional scale, indicating some general relation between mineralization and lithology.

Within the region, metal dispersion, and indirectly, geochemical anomalies, have been related to the weathering conditions of the various lithologies in a study by Fletcher and Doyle (1973), results of which showed several metals, including Zn being leached from the bedrock under strongly acidic conditions generated by the weathering of shales. Regionally, the threshold values for Zn cannot solely be used to define geochem anomalies as a study by Earle (per. comm.) showed that in many instances geochem anomalies of Zn are not representative of local Zn mineralization. Although the study dealt primarily with stream sediment samples, there certainly exists the possibility of the same conditions existing in both soil and bedrock environments.

Studies by Earle (per. comm.) and Scott (1974) have dealt with the Selwyn Mountains with respect to determining background, threshold and anomalous relationships between Pb-Zn mineralization and various lithologies. Earle (per. comm.) and Fletcher (1973) have determined that on a regional basis, dispersion of Pb and Zn must be controlled by some as yet unknown factors other than pH and lithology. Obviously the correlation between weathering and development of anomalies, as derived from various lithologies within the area, is complex, and a better understanding of weathering processes and products of each lithology would be an aid in exploration.

This thesis deals with a Silurian-Ordivician black shale-argillite unit within the Selwyn Mountains, containing a Pb-Zn anomaly. The purpose of this thesis is to determine the relative importance of mechanical vs. hydromorphic transport in producing secondary dispersion patterns for Pb and Zn within a seasonaly frozen medium such as the black shale. Also, major elements are to be studied as an aid in understanding the trace elements and, indirectly, if major elements are in any way related to the dispersion patterns.

Previous Work

There has been little documentation of the weathering of mineralized black shales. As noted previously, Fletcher et al (1973) and Earle (per.comm) have concluded some weathering and dispersion relationships on a regional scale in the eastern Yukon. On a slightly more local scale, Scott (1974) has found that within a section of a mineralized black shale-argillite unit in the Selwyn Basin, there was no apparent dependance of metal concentration on lithology.

Studies of unmineralized shales are more common and will be useful in comparing the weathering and dispersion of major elements in the mineralized study shales to unmineralized conditions. Most studies however, have been in areas of mature soil development, unlike the present area of study in the eastern Yukon. This factor will have to be considered in noting any differences in dispersion patterns and correlations.

In a study of the Pierre Shales of the Great Plains, Tourtelot (1962), looked at changes in composition with weathering using a 150 ft. long road-cut to note lateral changes, and a 70 ft. high dam spillway to note vertical changes. From road-cut analysis, he found that Al and Si increased downslope as a result of residual concentration due to the loss of soluble constituents. He also found that sulfur in the insoluble form (S) was reciprocally related to the ferric iron content and explained this by the occasional presence of pyrite nodules in bedrock. Calcium content showed a decrease while K,P, and Ti remained relatively constant. In the spillway study, it was found that Al was independent of Si, ferric iron was greatest in surficial weathered samples and Ca decreased sharply from the bottom to top of the vertical profile. This decrease in Ca was attributed to and paralled a sharp decrease in carbon dioxide content. Sulfur increased with depth due to oxidation of pyrite. Other major elements, K, P, and Ti, showed a uniform content throughout.

On a more regional study, Vine and Tourtelot (1970), collected 20 sets of samples to represent black shale deposits in the U.S. and concluded that Al, K, and Fe are associated with the detrital fraction of black shales, Ca is associated with the carbonate fraction of most black shale deposits, and Pb and Zn are most commonly associated with the organic fraction.

Description of Area

Location and access (Fig.1)

The Pas Claim Group is within the Watson Lake Mining District, approximately 110 miles east north-east of the village of Ross River, Yukon Territory (N.T.S. map sheets 105-I-6 and 105-I-11; longitude 129° 14′ W, latitude 62° 29′ N)

Access during the 1974 field season was by helicopter from the Howards Pass airstrip, 2 miles south of the claims, and from Summit Lake, 10 miles to the south-west.

Topography (Fig. 2)

The property is completely above timberline at elevations of 5000 to 6000 ft. North slopes of the mountains are dominantly talus with slopes of approximately 30° to 35°. Southern slopes have less talus, are considerably more vegetated, and have an average slope of 10° to 20°. Two major creeks drain the property, one system flowing south south-west, the other north west. Where the creeks flow over shallow gradients at the base of the hills, poor drainage results in the accumulation of semi-consolidated clastic material. pH conditions in the creeks draining the trenched hill range from 6.7 to 7.2.

Previous property work

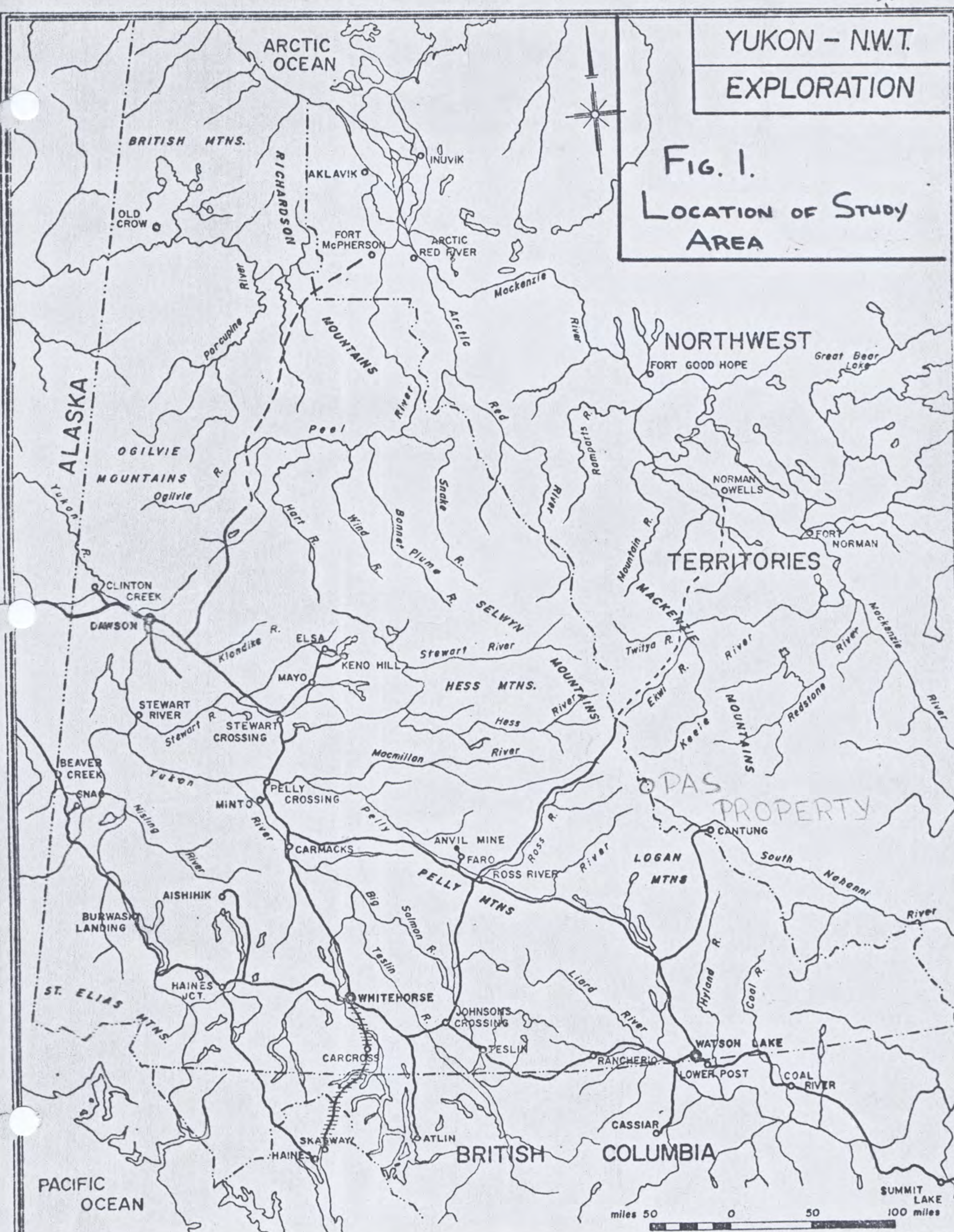
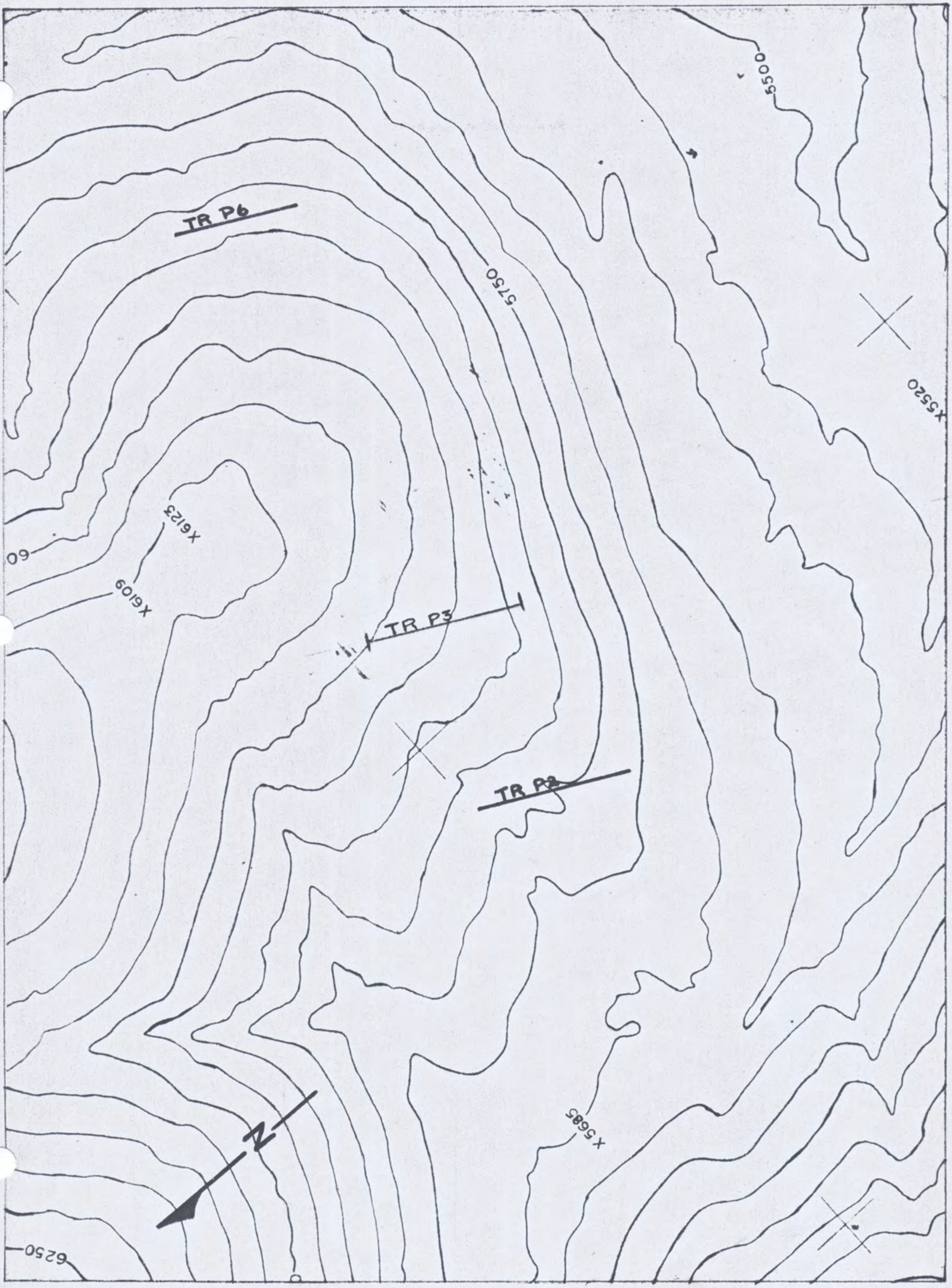


Fig. 1.
Location of Study Area

FIG. 2 TOPOGRAPHY OF STUDY AREA

SCALE: 1" = 400' CONTOUR INTERVAL 50'



F. DALEY 1975

Climate

Climatic conditions in the study area have not been monitored in great detail. However, the region probably has a typical continental alpine climate. Temperature range is from -20° F to 60° F Annual precipitation (rainfall) is approximately 20-25 inches. Total snowfall is in excess of 10 ft. Upon arrival on June 28, 1974, there was still an average of 18 to 24 inches of snow on the ground, considerably more on the north slopes. Snow returned in late August, giving a field season of about 8 weeks.

Soil conditions

Regionally, Regosols, and to a lesser extent, Brunisols are common on the well drained upland regions whereas the flatter, poorly drained areas are characterized by Gleysols and organic soils.

Locally, soil development is poor and seldom exceeds 1 ft. in depth, more commonly 4 to 6 inches. Two soil horizons are present at higher elevations, as well as a thin (½ inch) layer of volcanic ash which separates the organic-rich surface horizon from the underlying mineral soil. Capps (1915) suggested that the ash was derived from a major volcanic eruption in the Saint Elias Range. The upper soil horizon is characteristically a fine to medium grained, dark brownish clayey horizon rarely greater than 2 inches in thickness and in places, absent alltogether. The lower horizon is a coarser grained, light to dark greyish brown sand horizon of some 2 to 6 inches in thickness, containing fragments of the underlying shales and argillites.

Permafrost is distributed discontinuously throughout the area. In trenches, the upper limit of the permafrost ranged from 4 to 6 feet in depth. Related to the permafrost were several concentrations of "frost boils", typically found at higher elevations and consisting mainly of debris from the lower soil horizon and shale fragments.

Vegetation

Vegetation consists mainly of mosses, grasses, and forbs. Four species of mosses, including caribou moss (*Cladonia alpestris*) and a fluorescent green moss are present across the trenched anomaly. Poorly drained areas below the trenched zone supported abundant vegetation, including several species of forbs such as lupins (*Lupinus arcticus*)

Previous property work (Fig. 3)

The Pas Property was staked by Dynasty Explorations Ltd. in the summer of 1973 on the basis of mineralization found within a black argillite-shale unit on the adjoining property owned by Canex Placer Ltd. Regional geochemistry was carried out early in the summer and on the basis of these results, a soil grid (200 x 100) over a length of 5000 ft. was established and sampled. Results of sampling and mapping indicated a linear anomaly of Pb and Zn of some 500 ft. in width over a length of 5000 ft. corresponding to the black shale-argillite horizon.

Geology

Regionally, the geology has been described by L.H. Green & J.A. Roddick (1960) and S.L. Blusson (1962, 1966)

The geology of the Selwyn and Mackenzie Mountains is characterized by thick sequences of Helikian to Cretaceous clastics and carbonates which become younger towards the east. Clastic rocks, predominantly marine grit and shale, were deposited in the Selwyn Basin and grade eastward into marine carbonates deposited in the shallow shelf environment over the Redstone Arch. East of the Redstone Arch, the carbonates give way to shales deposited in the deep marine emvironment of the Root Basin. The shelf sediments consist mainly of limestone and dolomite with local interbedded sandstone, shale, argillite, and chert. Of particular interest are the fronts between the deep water shales and the shelf carbonates where reefal carbonate accumulations commonly formed.

These fronts are the host to the Pb - Zn mineralization.

Cretaceous granite plutons intrude the sedimentary sequences near the Yukon - N.W.T. border. A line along the eastern front of the intrusions marks the geological boundary between the Selwyn and Mackenzie Fold Belts. There are no igneous rocks east of this line in the Mackenzie Mtn.'s.

The property is underlain by Paleozoic sediments and is contained within the Road River Fm. (Ord.-Sil.), a series of clastic marine sediments that have undergone folding and compaction. (Table 1)

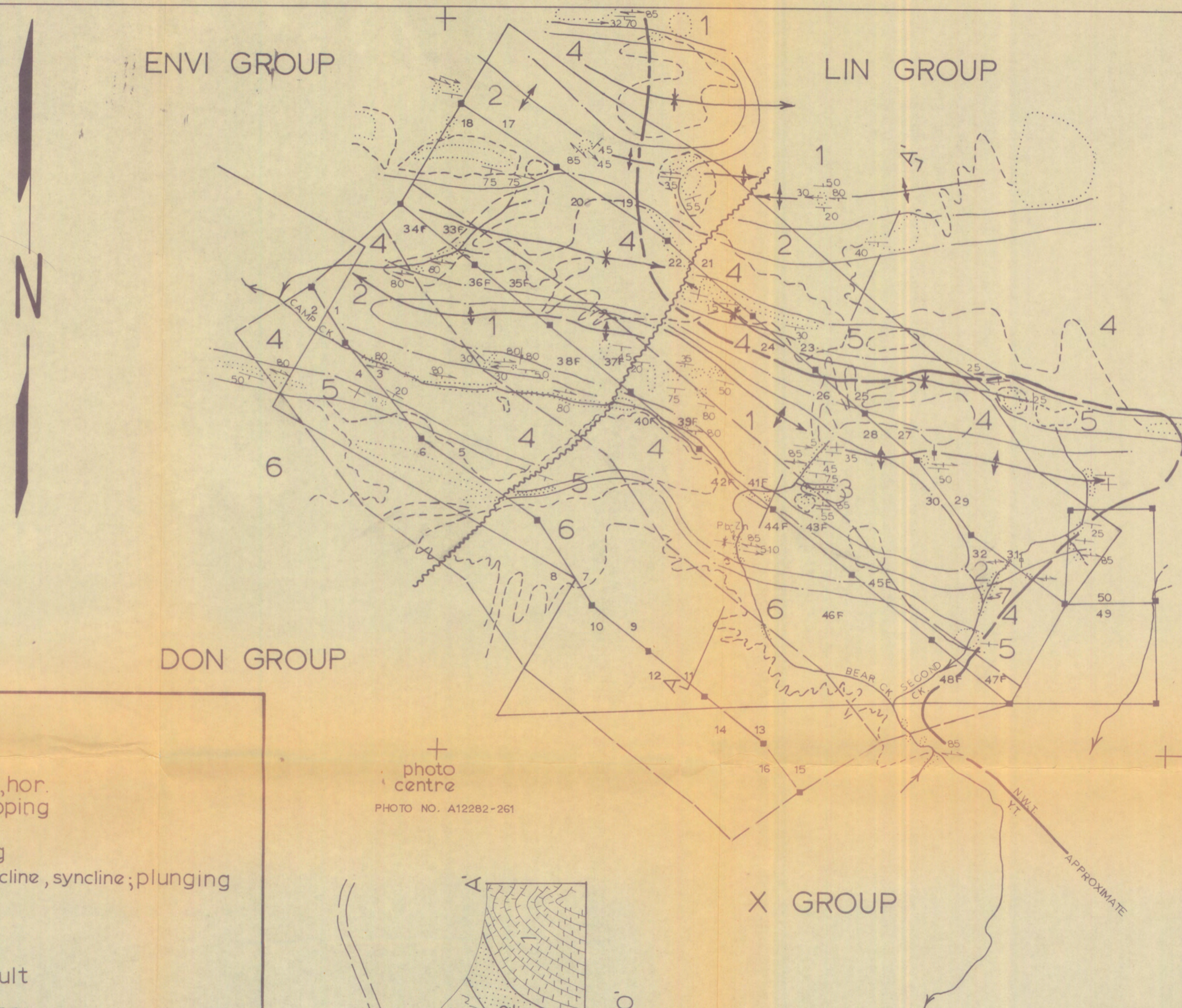
Unit 1, the lowest stratigraphic unit on the property, is a wavy-bedded limestone - finely laminated dolomite rock with lenses and pebbles of coarser grained, medium grey laminated limestone. This grades up into unit 2, a thinly bedded, buff-weathering dolomite. Unit 3 is a black, calcareous, non-graptolitic shale containing numerous thin pyrite beds.

The black shale-argillite, unit 4, which on the property is supposedly host to Pb-Zn mineralization, overlies the carbonates. It has a total thickness of approximately 500 to 600 ft. in outcrop and can be subdivided into 6 sub-units, as in Table 1. Bedding within this unit suggests intense deformation as unit 4 shales are highly foliated and convoluted on a small scale. Axial plane foliation however, is the dominant planar feature in all rocks and is either vertical or dipping 70-80 N.

Table I:

Table of Geologic Units In Study Area

Devonian-Miss.		
	6	Black shales, often calcareous
	5	Black streaked argillic, buff to orange weathering, disseminated pyrite and pyrite nodules, often calcareous or dolomitic
Upper Ordivician		
	4	Road River Fm. Black, graptolitic shales, minor chert, limestone, siliceous mudstones. Galena and sphalerite associated with a siliceous mudstone horizon
	4f	Grey to black, slightly rusty weathering shales and argillites; often breaking in shards.
	4e	Dark grey to brownish to black shales and argillites containing spherical limestone concretions.
	4d	Black chert.
	4c	Medium to dark grey, very finely laminated siliceous mudstone; main host to Pb-Zn mineralization.
	4b	Fine to medium grained dark grey limestone, interbedded with black shales and cherts.
	4a	Black shales and argillites, usually graptolitic, often calcareous
Ordivician (?)		
	3	Black calcareous shales, numerous thin pyrite beds, non-graptolitic.
	2	Thinly bedded buff or black weathering dolomite
	1	Wavy-bedded limestone.

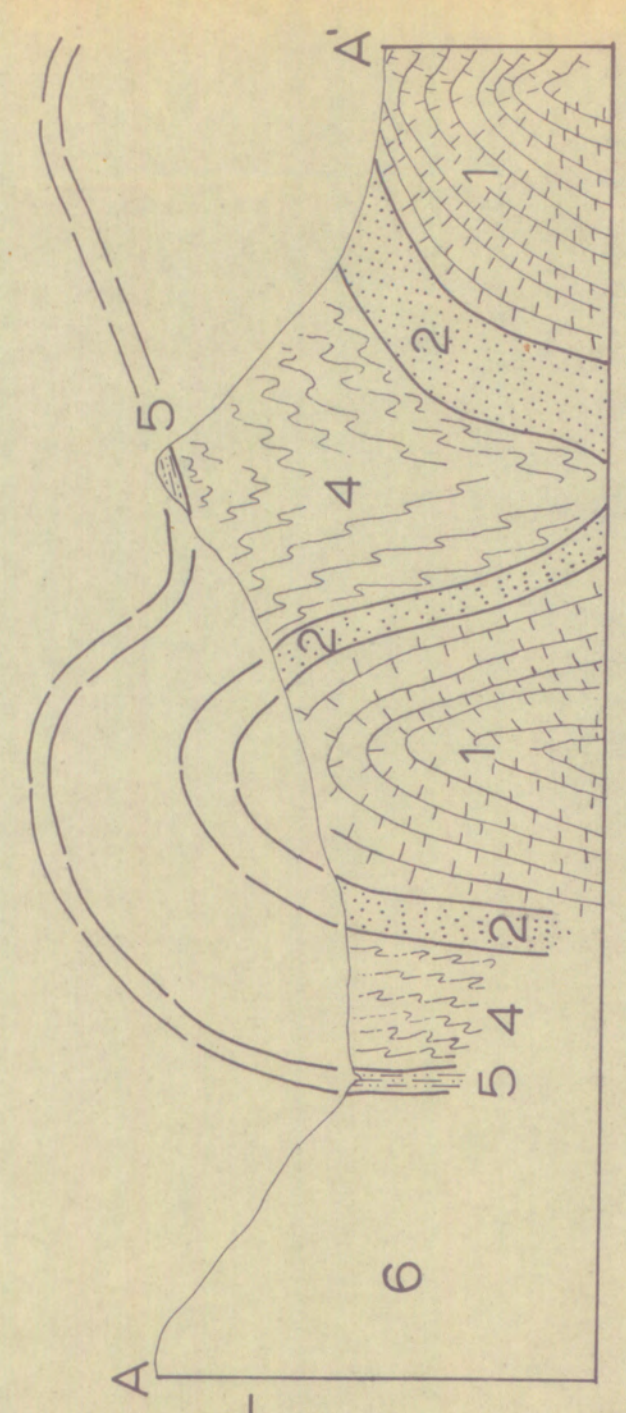


LEGEND

- bedding: vert., dipping, hor.
- axial cleavage: vert., dipping
- lineation
- joint (AC): vert., dipping
- horizontal trace of anticline, syncline; plunging
- outcrop
- talus, float
- claim line, posts, name
- contact
- fault

GEOLOGICAL UNITS

- 7 basic sill (?)
- 6 black calcareous shale
- 5 buff to orange weathering argillite with black streaks, sometimes dolomitic and calcareous; disseminated pyrite, pyrite blebs
- 4 black shale, partly calcareous; cherty shale; some pyrite, galena, sphalerite zones
- 3 black calcareous shale, pyrite bands
- 2 transitional rock: thinly laminated buff and black weathering dolomitic rock
- 1 wavey-bedded limestone: transitional rock plus grey limestone pebbles, bands



SECTION AA'
Approximate scale: 1" to 1300'

DYNASTY EXPLORATIONS LTD.

PAS GROUP GEOLOGY

N.T.S.: 105 I-6,11

Scale: 1 in. = 1/4 mi.

0 1/4 1/2 1 mi.

MAP 2

geology by: John D. Curry

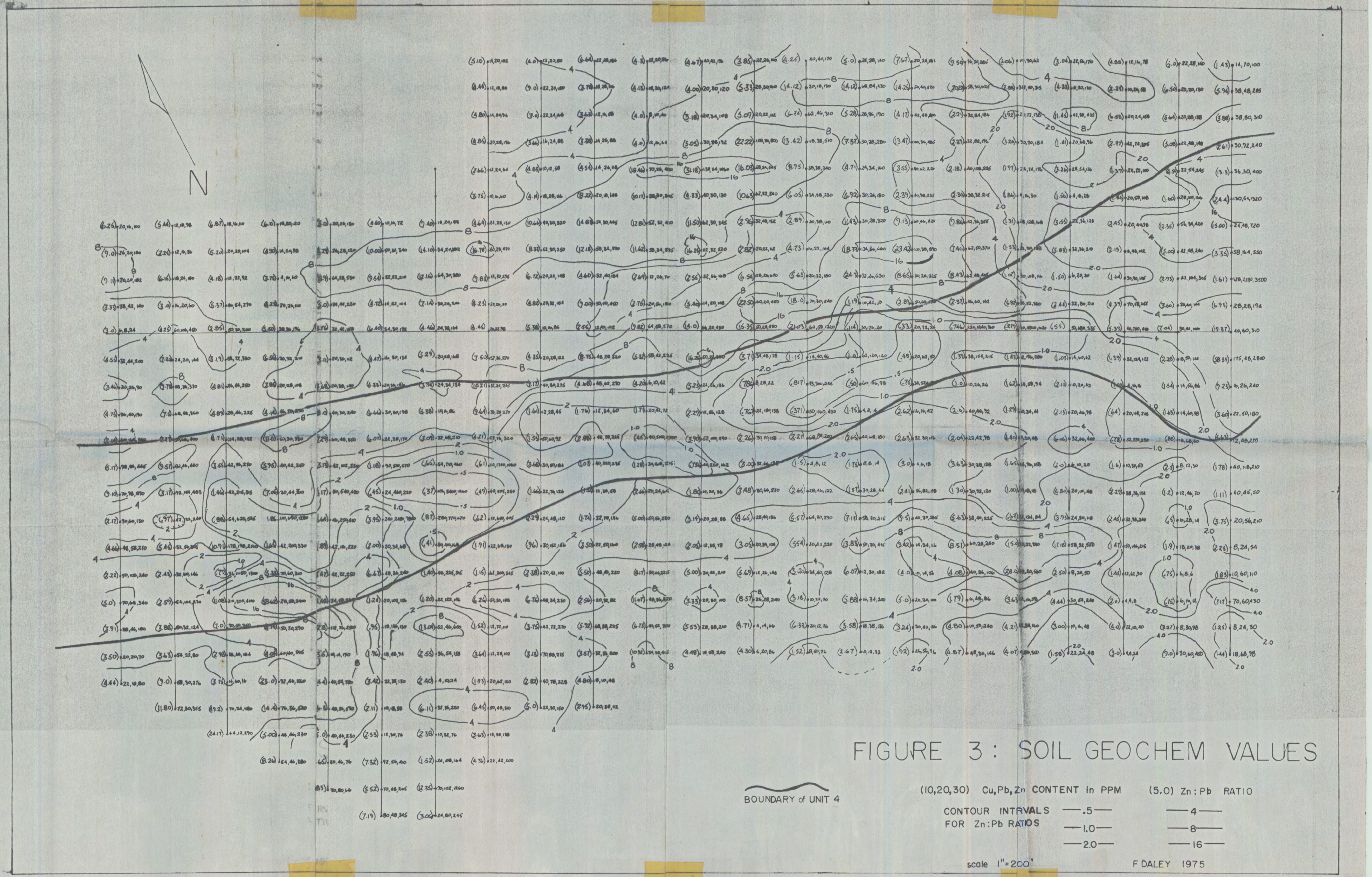


FIGURE 3: SOIL GEOCHEM VALUES

Mineralization

Mineralization is restricted to unit 4, and to a very minor extent, in the underlying interbedded limestones and shales, and immediately overlying black cherts. In most trenches and drill core assay samples that gave greater than 1% combined Pb-Zn results, only galena and pyrite were visible in hand specimen. Sulphide mineralization occurs as thin, very fine grained beds with sharp contacts, as coarser "blebs" in bedding planes, and as remobilized lenses in cleavage planes. Minor, irregular galena-pyrite nodules also occur along thin quartz-calcite veinlets. There is no evidence in hand specimen of sphalerite or hydrazincite, both of which are present in the trenches on the adjoining Canex Placer property.

Field sampling

Sampling in trenches TR-P2 and TR-P3 (Fig. 2), with TR-P3 being sampled in greatest detail, consisted of a series of vertical profiles at 10 foot intervals up to 80 feet on either side of the anomalous zone (3+60S to 4+00S). Beyond 80 feet from the anomaly, profile spacing was increased to 20 feet. Individual samples within profiles were collected to represent an area of approximately 1sq. ft. with a maximum vertical separation of 5 ft. In addition to the upper and lower soil horizons, the immediately underlying bedrock, and bedrock at the bottom of the trench were sampled. Vertical profiles were complemented by 10 ft. channel samples taken along the base of the trench in order to assay the freshest bedrock.

Sample analysis

All samples were analyzed by atomic absorption for Ag, Cd, Pb, and Zn. On the basis of these results, 6 individual profiles were selected for further analysis by XRF. Si, Al, Fe, P, K, Ti, and Ca content, as well as S, were determined by XRF, and with the exception of S, expressed as oxides.

Samples were dried overnight in an open oven prior to crushing with a jaw crusher. A thoroughly mixed and representative subsample was then ground in a tungsten carbide ball mill. As a check on reproduceability, every 15th specimen was prepared in duplicate. Soil samples were crushed in the same manner to ensure comparable preparation of all samples.

0.50g (± .005g) samples were digested in a 4:1 mixture of nitric-perchloric acids (Appendix I); residues taken up in dilute HCL and analyzed for Ag, Cd, Pb, and Zn on the Perkin Elmer 303 A.A. Spectrophotometer. Background correction was used in determining Ag, Cd, and Pb. (Appendix I)

Unfused pellets were prepared from individual samples prior to analysis by XRF (Appendices I &). Si, Al, K, Fe, P, Ti, and Ca were expressed as oxides and the percent of the individual oxides was calculated by ratioing the sample c.p.s. to the standard c.p.s. and using the calibration curves in Appendix II.

The procedure for determining S differs in that it requires a set of S standards to be run simultaneously with the samples. (Appendix I). Sulfur standards used were combinations of a U.B.C.standard and HV-1 standard in propartions of; pure U.B.C. standard, $\frac{1}{99}$, $\frac{2}{98}$, $\frac{5}{95}$, $\frac{10}{90}$, $\frac{25}{75}$, $\frac{50}{50}$, and HV-1. A calibration curve was drawn from the results (Appendix II), and used to calibrate S content.

Precision

Precision for A.A. results are given in Table II.

Some elements determined by XRF, such as Al and Si, are in abnormally high abundance resulting in total element content being over 100%. The error is due to a matrix difference as standards used were from an igneous origin and are therefore almost devoid of organic matter. Pas shales however, probably have a high organic content, and as such would have a different effect on the X-rays. Therefore, although the overall contents may be high in some cases, all samples were analyzed in the same manner, and should produce relatively

Table II:

Duplicate and Replicate Analyses of A.A. Samples*

Element	Duplicate Analyses		Sample Number
Pb	14.679	15.881	157R
	1276.854	1488.542	184 R
	76.876	40.828	204 R
	17.181	17.395	226 R
	38.683	41.823	130 L
	30.774	33.356	165 L
	55.596	44.449	212 L
Zn	207.058	254.689	157 R
	2182.985	2087.841	184R
	177.900	178.618	204 R
	57.537	60.102	226 R
	539.573	511.322	130 L
	236.111	232.005	165 L
	310.846	304.277	212 L

Element	Replicate Analyses		Sample Number
Pb	24.755	23.134	132 R
	21.837	25.008	164 R
	55.990	57.112	197 R
	17.080	17.395	226 R
	35.422	32.548	173 L
Zn	36.514	36.049	132 R
	17.100	16.096	164 R
	337.710	316.171	197 R
	57.537	60.475	226 R
	294.260	283.860	173 L

* all figures in counts per second (c.p.s.) unless otherwise stated.

Table III: XRF Precision; Deviation in Standard Content*

Element	Run No 1	2	3	4	5	6
Fe	39970	39930	39936	39922	39730	39697
Ti	51086	52075	51700	51766	52027	51865
Ca	138692	139324	139716	141066	141065	141534
K	43926	42686	41067	39547	38536	37508
P	674	662	727	680	740	687
Si	15959	16067	15825	16154	16020	15855
Al	3896	3952	3855	3960	3923	3904

Element	Run No. 1	2	3	Sample	Standard
S	1535	1582	1557	144 R	50/50
	6398	6581	6595	162 L	25/75
	5517	5658	5687	163 R	HV-1

* all figures in counts per second (c.p.s.) unless otherwise stated.

correct results. Precision for the individual major elements is given in Table III.

Geology of TR-P3

Bedrock was exposed along the entire length of TR-P3. The northern 300 ft. of the trench cuts unit 4a. At approximately 1+50S, a distinctive 5 ft. thick bed of massive, very pyritic arkose is exposed. The 4a shales and argillites are generally broken and slumped and contain scattered quartz-limonite zones. Assay sampling over the entire 4a interval gave only very low results; a maximum of .01% Pb and .08% Zn.

Unit 4a is overlain by horizons of several minor lithologies, collectively referred to as unit 4c. These include grey-black cherts, light grey siliceous mudstones, brownish cherty argillites, and colour banded, interspersed limonite-jarosite. Unit 4b limestones are not encountered in this trench. Assay results for the 30 ft. section of ynit 4c showed a combined Pb-Zn value of .39%.

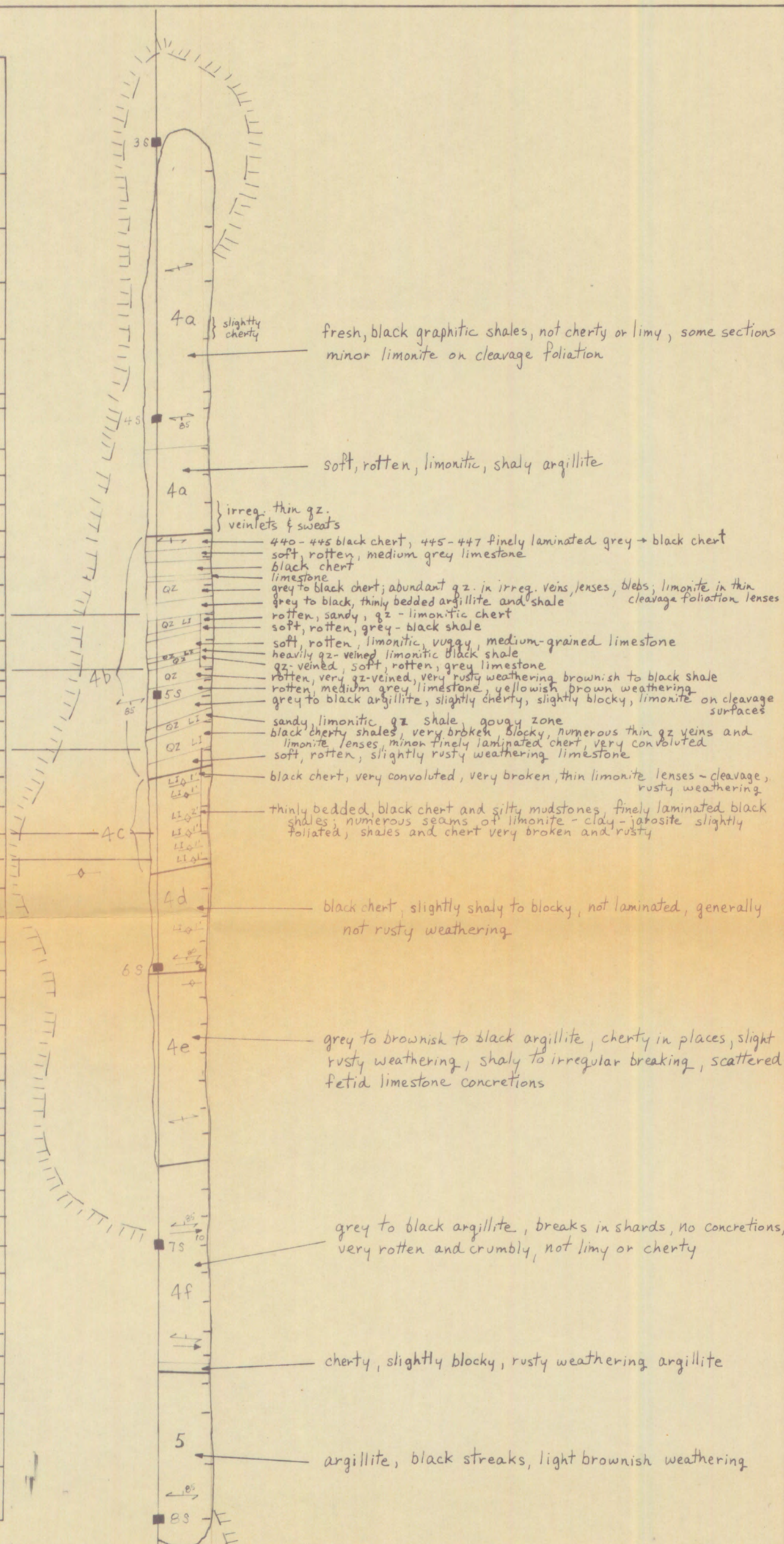
Stratigraphicly above 4c and exposed in the trench are units 4d, a massive, blocky, rusty stained black chert; 4e, a finely laminated to massive argillite-chert with limestone concretions; 4f and 5. Assay results in these units ranged from trace to less than .05% Pb-Zn. Contacts between units are usually easily defined. Bedding in most units is difficult to recognize but dips steeply north in most cases. The dominant feature in all units is the near-vertical axial plane folation. Tight folding, generally plunging SE, is best seen in the argillites of units 4e and f.

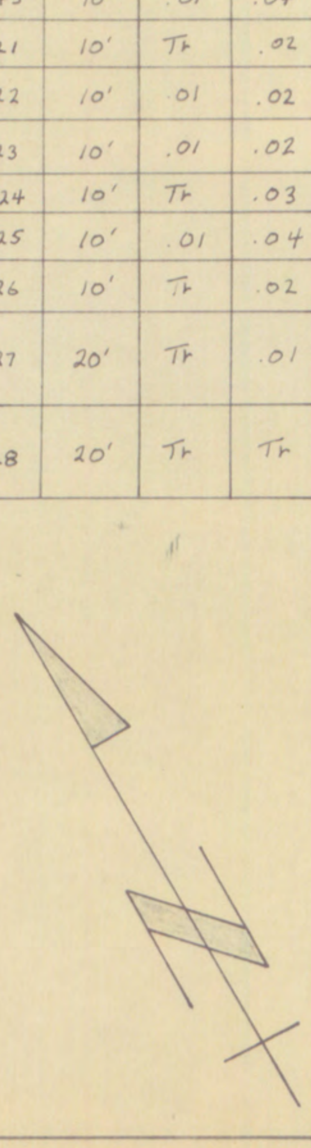
TAG #	INTERVAL	LEAD ASSAY	ZINC ASSAY
6003	20'	.03	.02
6004	20'	Tr	.03
6005	20'	Tr	.02
6006	20'	.01	.01
6007	15'	.10	.15
6008	10'	.01	.01
6009	10'	.01	.05
6010	10'	.27	.02
6011	10'	.13	.09
6012	10'	–	.24
6013	10'	.01	.04
6014	10'	.33	.94
6015	10'	.35	.78
6016	4'	.03	.18
6017	6'	.03	.24
6018	10'	.01	.18
6019	10'	.07	.19
6020	10'	.75	.24
6029	10'	.83	.18
6030	10'	1.03	.25
6031	10'	.15	.08
6032	10'	.10	.01
6033	10'	.03	.01
6034	10'	.01	.03
6035	10'	.04	.02
6036	10'	.05	.01
6037	10'	.01	.02
6038	10'	Tr	.02
6039	10'	.01	.01
6040	10'	.01	.01
6041	10'	.01	.01
6042	10'	Tr	.03
6043	10'	.01	.02
6044	10'	.01	.07
6045	10'	.01	.04
6021	10'	Tr	.02
6022	10'	.01	.02
6023	10'	.01	.02
6024	10'	Tr	.03
6025	10'	.01	.04
6026	10'	Tr	.02
6027	20'	Tr	.01
6028	20'	Tr	Tr

1.2 % comb. over 20' (6014–6015)

.73 % comb. over 90'

1.09 % comb. over 30' (6020–6030)





DYNASTY EXPLORATIONS LTD.

SELWYN PROJECT

PAS MINERAL CLAIM GROUP

BULLDOZER TRENCH P – 2

SCALE : 1" = 40'   DATE : NOVEMBER 1974

NTS 105-I-6   T. ADAMSON   fig. 7

FIGURE 6

LEAD CONTENT (ppm)

scale 1"=10'

contour intervals 25,50,100,250,1000,2000 ppm

F. DALEY 1975

FIGURE 7

ZINC CONTENT (ppm)

scale 1" = 10'

contour intervals 10,50,250,1000,2000

F. DALEY 1975

FIGURE 8

$\frac{ZN}{PB}$ RATIOS

scale 1" = 10'

contour intervals 1,2,5,10

F. DALEY 1975

Pb content

Figure 6 shows a north-south profile of the eastern wall of TR-P3 with Pb values arbitrarily contoured at approximate logarithmic intervals of 25, 50, 100, 250, 1000, and 2000 ppm.

Both up and downslope of the anomaly, Pb content within individual profiles decreases with depth. Upslope, bedrock values within unit 4a are relatively constant, varying between 10 and 40 ppm with an average of 21ppm. Soil content is also fairly constant although at a slightly higher level of 20 to 50 ppm, and averaging 34 ppm. Pb conto rs between 2+00S and 3+60S sub-parallel the surface and roughly correspond to the soil-bedrock interface.

Increased metal values within the anomalous unit 4c, from 3+60S to 4+10S steepen the contours considerably and produce a single major Pb anomaly. Bedrock values in this 50 Ft. section generally vary from less than 200 ppm to 1500 ppm with a maximun value of 24,000 ppm. Moderate variation in content within individual profiles is common, particularly between the two soil horizons, the lower being 2 to 5 times as enriched as the upper. Only in the lower soils is Pb content greater than in the bedrock. Proceeding away from the anomaly in either direction, bedrock content exceeds soil content, with the exception of stations 4+30 to 4+60S in unit 4c, where there is Pb enrichment in the soils and values greater than 2000 ppm are unrelated to levèls of 40-100 ppm in underlying bedrock.

Downslope of station 4+60 and continuing to the end of the trench, Pb values in units 4f through 5 decrease in bedrock to a greater degree than in soils but still produce features similar to those upslope from the anomaly: contours sub-paralleling the surface, and Pb content decreasing with depth. Bedrock, and particularly soil content below the anomaly are at a slightly higher level than above the anomaly. The consistent downslope Pb anomaly covers a distance of approximately 80 ft.

Zn content

Zn values, arbitrarily contoured at intervals of 10, 50, 250, 1000, and 2000 ppm within TR-P3 are shown in Fig. 7. Although there are apparent similarities in the distribution of Pb and Zn, particularly in areas up and downslope of the anomaly, there are also several major differences. With the exception of a few abnormally high values, Zn content within unit 4a profiles between 2+00S and 3+30S tends to decrease with depth. Bedrock values in this section vary form less than 10 to 40 ppm, and average 15 ppm. Soil content is slightly greater, varying from 30 to 50 ppm and averaging approximately 40 ppm. Contour intervals are sub-horizontal, roughly parallel to the surface slope. Passing from unit 4a to 4c between stations 3+30S and 3+70S, there are two minor anomalous zones defined by the 250 ppm contour, where content increases to greater than 250 ppm in bedrock, and greater then 300 ppm in soils.

Within individual profiles, Zn content may fluctuate drastically resulting in a downslope steepening of the contours; soil content in this section is high regardless of the underlying bedrock content.

Unit 4c anomaly, between 3+70 and 4+00S is best defined by the 1000 and 2000 ppm contours. Content varies from about 200 to greater than 2000 ppm with a maximum value of 4500 ppm in bedrock and about 500 ppm in the overlying soils. Contour intervals are steep as a result of fluctuating Zn values within individual profiles and show downhill dispersion, particularly within the top 2 to 3 feet. Downhill from station 4+00S and continuing through units 4e and 5, the relatively enriched soils with greater than 300 ppm Zn appear unrelated to bedrock content of 30 to 50 ppm. Disregarding the three minor high values in this section, bedrock Zn content is relatively stable. Soil content decreases with lateral distance from the anomaly but remains high irrespective of Zn content in the underlying bedrock. Contours in this section are once again sub-parallel to the surface.

Zn/Pb ratios

For purposes of comparing Pb and Zn content, Zn/Pb ratios were calculated and contoured at intervals of 1, 2, 5, and 10 to 1 (Fig. 8) along the profile of TR-P3.

Within the first 110 feet of unit 4a, Zn/Pb ratios decrease with depth. Bedrock ratios of less than 0.3 to 1.5 are consistently less than ratios in the overlying soils of between 1.0 and 6.0. Contour intervals are sub-parallel to the surface. Profiles at 3+20 and 3+30S, still within unit 4a, show an increase with depth and as such cause a minor change in dip of the contours to a more inclined position. Maximum ratio in this section in 21.1. Stations 3+40 to 3+70S are similar to sections 2+00S - 3+10S as ratios once again decrease with depth, only now at a slightly higher value of 3 to 10 in bedrock and 10 to 20 in soils.

Ratios in unit 4c between 3+70 and 4+10S decrease with depth to anomalously low values of 0.2 to about 1.5 in bedrock and less than 1.0 to 2.0 in soils. Contours in this section are inclined to the surface and generally form sub-parallel "fingers". (Fig. 8)

Within units 4d and 4e, Zn/Pb values increase with depth Ratios in bedrock range from less than 1.0 to 4.0 whereas soils have a consistently low ratio of less than 1.0. Contour intervals in this section, and generally continuing to the south end of the trench, are approaching "sinusoidal" form and do not show the close approximation to the surface as in the north end of the trench. Zn/Pb ratios below the anomaly are generally greater than those above with 10 of 12 profiles sampled showing an increase with depth while 9 of 11 profiles above the anomaly decreased with depth.

Table IV: % Content of Major Elements as Determined by XRF

Profile	Sample	CaO	TiO2	Fe2O3	K2O	P2O5	SiO2	Al2O3	S	Total %
1	141 L	.15	.62	2.68	5.47	.16	69.55	15.49	.21	94.12
	142 L	.15	.65	5.36	6.03	.22	66.85	15.64	.29	94.90
	143 R	.10	.58	2.61	5.47	.11	75.40	15.49	.15	99.78
	144 R	.10	.75	1.31	6.56	.09	68.20	18.26	.11	95.27
2	162 L	.35	.51	8.11	4.40	.62	69.10	12.72	.57	95.81
	163 R	.10	.48	3.60	4.43	.18	80.35	11.99	.49	101.83
	164 R	.10	.42	1.77	4.11	.07	88.00	11.26	.37	105.73
3	170 L	.40	.50	7.42	3.19	.66	69.55	14.47	.18	96.16
	171 R	.10	.52	2.22	4.14	.11	88.45	15.05	.16	110.59
	172 R	.10	.47	2.45	4.23	.12	85.75	11.62	.17	104.74
4	182 L	.85	.35	10.10	2.33	1.40	71.80	8.93	.29	111.60
	183 L	.45	.18	24.40	1.09	2.31	57.85	5.13	.28	103.90
	184 R	.40	.14	12.09	.89	.88	85.30	4.26	.07	91.24
	185 R	.10	.14	7.12	.80	.39	98.30	4.26	.08	95.76
5	202 L	1.20	.57	6.43	3.69	1.08	71.35	11.70	.12	96.02
	203 R	4.75	.33	1.61	2.54	2.66	75.40	8.49	.11	95.78
	204 R	5.40	.55	3.68	4.14	3.87	68.65	12.28	.16	98.35
6	219 L	.15	.81	6.51	5.50	.27	67.30	15.34	.22	95.88
	220 R	.10	1.40	9.79	5.47	.40	62.35	13.45	.09	92.96
	221 R	.10	.74	11.32	4.79	.15	66.85	12.14	.07	102.09

Major elements

Major element trends are summarized in Figures 9 and 10 and Table IV. Several relations are apparent between element content with respect to both depth and downslope variation.

Profiles 1 and 2, both within unit 4a and upslope of the anomaly, show certain similarities. In both, Ca, Ti, Fe, P, and S content is greatest in the soil and, with the exception of Ti, increases between profiles. Both Al and K content is greater at depth in profile 1 and decreases downslope to a mimimum in the lower bedrock in profile 2.

Between profiles 2 and 3 there is a change in lithology from unit 4a to the anomalous unit 4c. Corresponding to this, soils show an increase between profiles in Ca, P, Si, and Al content, and a decrease in Ti, Fe, K, and S, with S showing the greatest decrease from .57% to .18%. In bedrock, Ti, Fe, and K increase whereas S, al, and Si decrease. Within profile 3, Ca, Fe, P and S are greater in soils whereas Si, Al, and Ti are concentrated in bedrock just below the soil, and K content is greatest at the bottom of the trench.

Moving downslope to profile 4, element trends strictly within the anomalous zone are more evident. Ca, Fe, P, and S all increased in soils between profiles, with Fe (7% to 24%) and P (0.1% to 2.3%) showing the greatest increases. Ti, Al, and K content decreased in both soils and bedrock, while Si showed an interesting trend by decreasing in soils and increasing

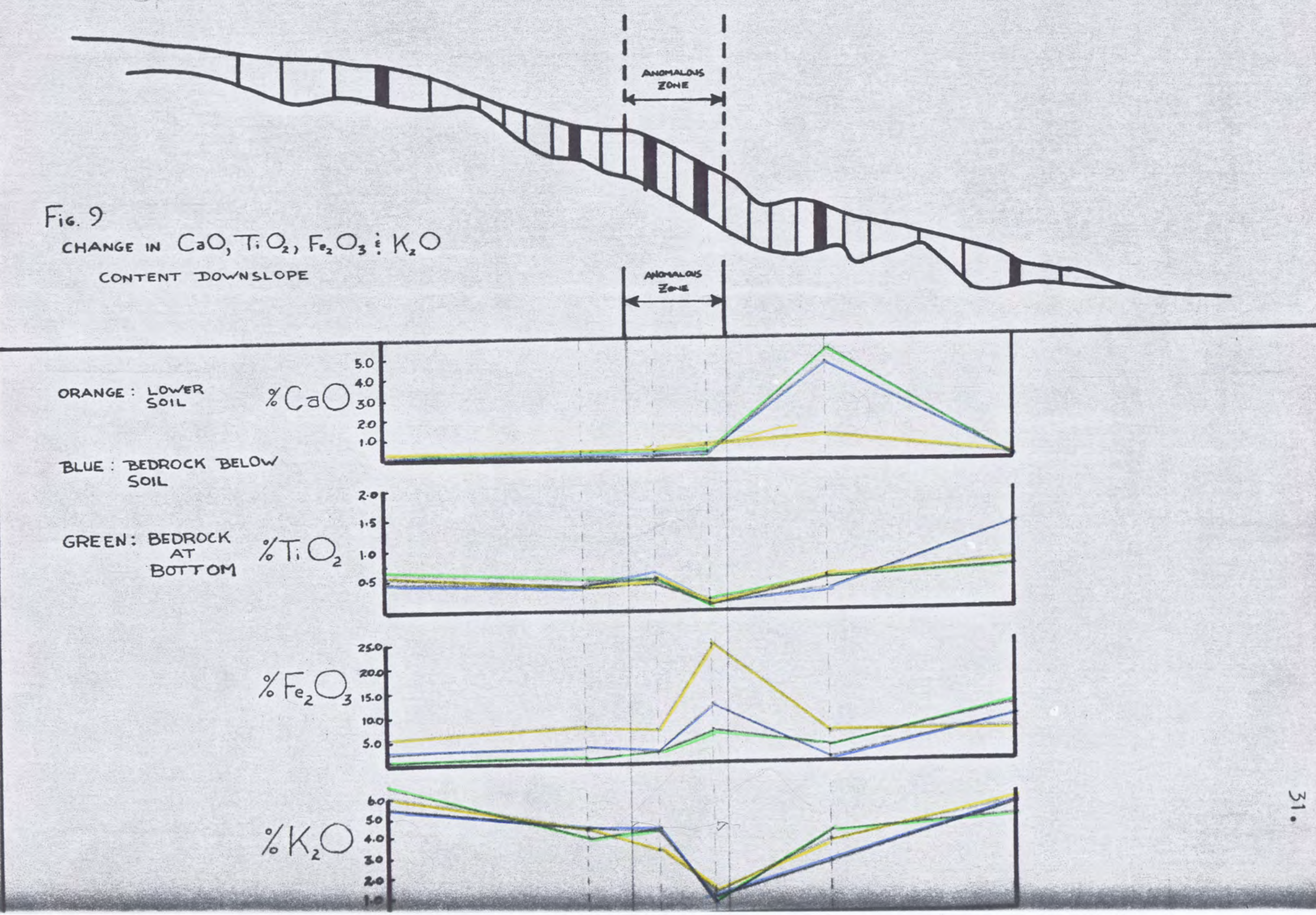


Fig. 9
CHANGE IN CaO, TiO_2, Fe_2O_3 & K_2O
CONTENT DOWNSLOPE

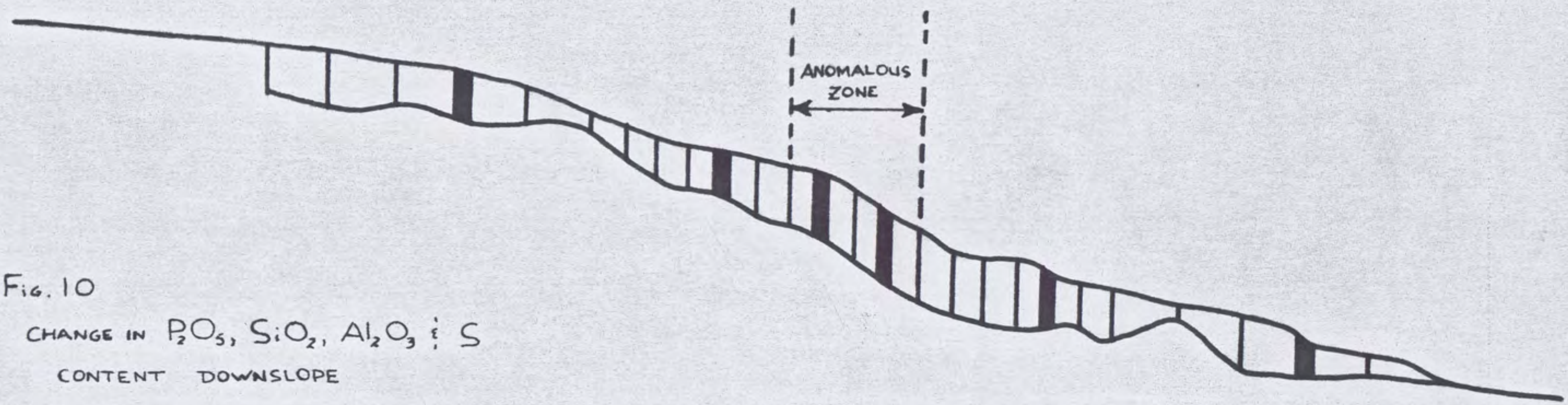


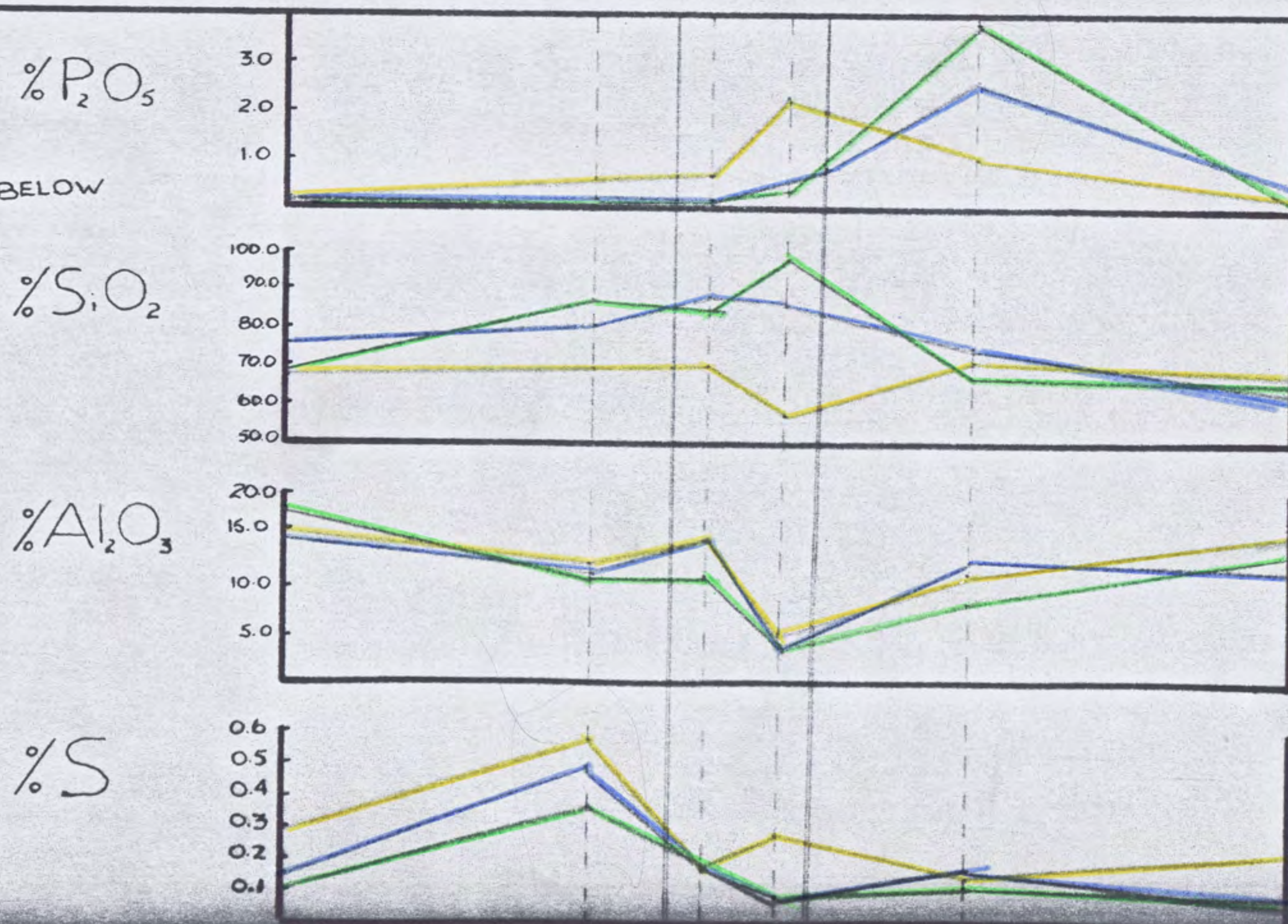
Fig. 10

CHANGE IN P_2O_5, SiO_2, Al_2O_3 & S CONTENT DOWNSLOPE

ORANGE: LOWER SOIL

BLUE: BEDROCK BELOW SOIL

GREEN: BEDROCK AT BOTTOM



in bedrock across the anomlay. Sulfur reacted oppositely to to Si; increasing in soil and decreasing in bedrock. Within profile 4, all elements, with the exception of Si, are in greater abundance in soils than bedrock.

Passing from profile 4 to 5, and moving form unit 4c to 4e, several significant changes take place. Bedrock content of Ca (0.1% - 5.0%), ti, K, P (0.4% - 4.0%), Al (4.0% - 12.0%) and S all increase while Si (98% - 68%) and Fe (7% - 3%) decrease. S, Si and P all showed negative relations between the soil and bedrock content; decreasing S and P in soils while increasing in bedrock and increasing Si in soil while decreasing in bedrock. Within profile 5, Si, Ca, K, P, Al, and S are all greater at depth, while Ti and Fe are greater in soils.

Between profiles 5 and 6, and passing into unit 5, all elements generally return to their original relative proportions as found in the north end of the trench, the only difference being a slightly greater Ti content in the bedrock just below the soil. Otherwise, Ca, P and Si bedrock content decreases between profiles whereas Ti, Fe, K, Al, and S increase. The same holds true for the soils, with the exception of Fe which tends to decrease. S, Al, Si, K, and Ca content is greater in profile 6 soils while Ti, Fe, and P are greater at depth.

Soil/bedrock ratios

Figure 11 shows the soil/bedrock ratio content for both

A.A. and XRF results. Ratios show that the upslope boundary of the Pb-Zn anomaly is better defined than the downslope boundary. This is particularly evident in the Zn content ratio. There is a noticeable change between the relatively constant ratios upslope and the erratic values downslope of the anomaly.

With respect to the major elements, Si reaches its minimum ratio in the anomalous zone, while S, Al, and K are at a minimum immediately upslope. Ca, Ti, Fe, and P reach their lowest values in areas downslope of the anomaly. Al and Si in particular show a relatively constant value across the length of the trench.

STATION	2+00	2+20	2+40	2+60	2+80	3+00	3+10	3+20	3+30	3+40	3+50	3+60	3+70	3+80	3+90	4+00	4+10	4+20	4+30	4+40	4+50	4+60	4+80	5+00	5+20	5+40	5+60
Pb	1.1	1.9	1.8	1.4	1.3	2.4	1.3	1.5	2.3	1.9	1.4	0.6	0.4	.0003	5.0	29.6	1.4	—	97.5	0.7	10.7	24.9	1.0	2.4	1.6	4.7	20.5
Zn	6.0	18.5	2.4	2.4	7.4	3.9	2.3	0.9	7.0	2.9	2.5	3.7	0.1	—	0.3	0.5	2.5	—	10.6	5.1	7.8	6.5	1.4	7.3	0.7	3.6	4.4

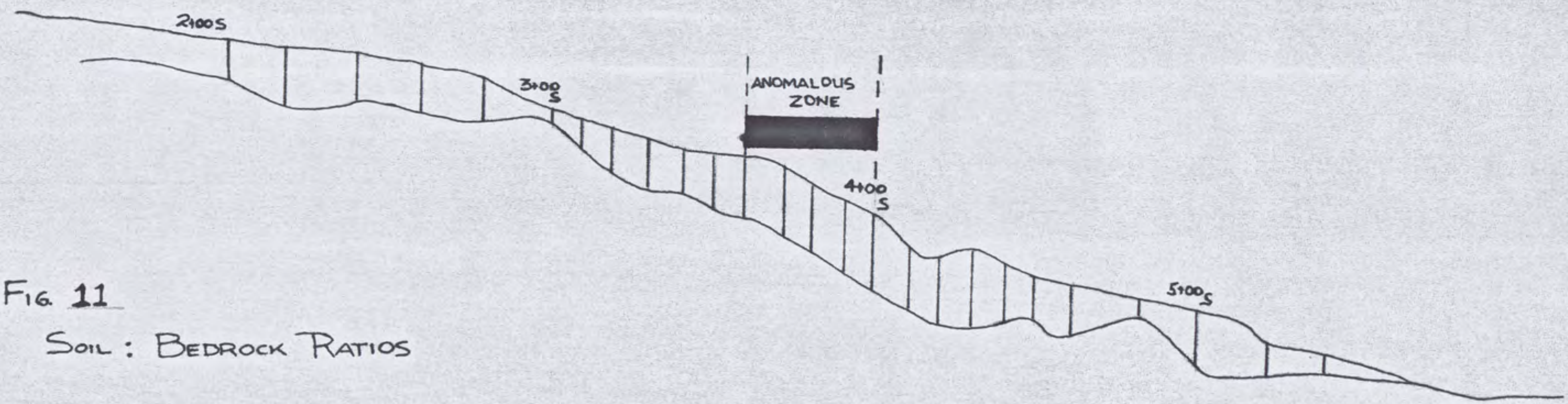


Fig. 11

Soil : Bedrock Ratios

STATION	2+60	3+40	3+60	3+90	4+40	5+20
CaO	1.5	3.5	4.0	1.1	0.3	1.5
TiO_2	1.1	1.1	1.0	1.3	1.7	0.6
Fe_2O_3	2.1	2.2	3.3	2.0	4.0	0.7
K_2O	1.1	1.0	0.8	1.2	1.5	1.0
P_2O_5	2.0	3.4	6.0	2.6	0.4	0.7
SiO_2	0.9	0.9	0.8	0.7	0.9	1.1
Al_2O_3	1.0	1.1	1.0	1.2	1.4	1.1
S	1.9	1.2	1.1	4.0	1.1	2.4

Discussion

Contoured Pb and Zn profiles (Figures 6&7) show that upslope of the anomaly, transport of metals appears to be primarily effected by vertical weathering processes similar to those responsible for soil profile development, and to a minor extent by lateral mechanical dispersion. Both of these factors result in contour intervals sub-paralleling the surface. Within unit 4a, from station 2+00S to 3+10S, both Pb and Zn values decrease with depth. This is associated with decreasing Ca, Ti, Fe, P, and S content.

Within the anomalous zone, unit 4c, characteristically low Zn/Pb ratios seem to indicate a greater increase in bedrock content of P than Zn, as Pb increases from about 30 ppm to greater than 2000 ppm while Zn only increases from about 200 ppm to 2000 ppm. Corresponding to this, Ca, Fe, P, and Si also increased whereas Ti, K, Al, and S decreased. Downslope of the anomaly, Zn develops a larger soil dispersion pattern than Pb, with extents of 110 ft. and 60 ft. respectively. Both metals appear to be dispersed by soil creep or similar mechanical movement, particularly within the lower soil horizon,with Pb moreso than Zn being transported along this soil-bedrock interface. On a smaller scale of about 10 to 20 feet, bedrock dispersion of Pb and Zn is effected by the slight mechanical movement of bedrock downslope.. Where there is only seasonal permafrost in the top 2 to 3 ft., Zn may be transported hydromorphically and result in a larger downslope dispersion of Zn in soils. Above the anomaly, Zn/Pb bedrock ratios decrease with depth, also consistent with the theory of greater Zn mobility.

Soil/bedrock ratios (Fig. 11) as well as contoured profiles and Zn/Pb ratios show that the upslope boundary of the anomaly at station 3+60S is better defined than the downslope boundary.

Metal - element correlations showed that the positive relation between Si and Pb which was evident in field observations in that the more siliceous argillites and shales were host to galena mineralization. There was also a positive correlation between Fe and Zn. However this relation does not appear at depths greater than 90 ft. (Morganti, per. comm.) and may therefore only be a surficial weathering feature. In general, more elements tended to show a positive relation to fluctuating Zn values than to Pb, in particular Fe and S, and to a lesser extent P, K, and Ti.

Major element correlations show a positive relation between Ti and Al in both soil and bedrock and a negative correlation of both to Si. Fe was usually associated with either of both S and P with correlations more obvious with depth than lateral distance. K has a negative correlation to Si although both reach their minimum soil/bedrock ratio content near the upslope boundary of the anomaly. Within the anomalous zone, all elements, with the exception of Fe and Si, decreased in content. In the section 4+10 to 4+40S, directly below the anomaly, all elements, with the same two exceptions, showed an increase in content both with depth and downslope distance. This could be due to two factors; soil creep resulting in an "enriched" layer being transported downslope from the anomaly and subsequently covered by relatively "barren" material from upslope of the anomaly, or secondly, simply due to varying lithologies between unit 4c and 4e.

Anomalous metal values in the trench are not accompanied by either visible mineralization or secondary alteration minerals such as hydrozincite, both of which are reported on the ajoining Canex Placer property. There are three possible explanations for this, the first being that both primary and secondary minerals have simply been weathered away. This would be possible if the rate of weathering exceeds the rate of mineralization. A second possibility is that mineralization is, or has been, structurally controlled by the intense folding and faulting. From drill records, unit 4 appears well faulted at depth and there exists the possibility that metals were transported or removed through this fault system, leaving only minor bedrock and surficial traces. A third possibility is that stratigraphiclly, we are above the mineralization, again resulting in only minor occurrences.

Unlike findings by Scott (1974) there appear to be relations between mineralization and lithology in this black shale unit, as Pb and Zn results were higher in the more siliceous units of the argillite-shale than in the carbonaceous section. Similar to the findings of Earle (per. comm.) and Morganti (per. comm.), there is a decrease in Zn/Pb ratio associated with increased metal content.

This last point could be important in exploration of the Selwyn Basin. On a regional scale, Earle has shown that in many cases high Zn values in stream sediments cannot be directly attributed to Zn mineralization. On a local scale however, it has been shown that a mineralized anomaly could have a characteristically low Zn/Pb ratio. On this basis then, one might be better to examine the metal ratios rather than the metal values themselves in deciding which anomalies to follow up.

Conclusions

The relative importance of mechanical vs. hydromorphic transport of Pb and Zn within a seasonally frozen medium was studied across a 360 ft. trench profile averaging 7 ft. in depth. It was found that in permanently frozen ground, the minor transport was by mechanical means. Where seasonal melting occurs within the top 2 to 3 feet, slight hydromorphic transport of Zn results in a larger dispersion pattern, particularly in the lower soil horizon. Fe appears positively related to Zn concentration while Si is positively related to Pb, the latter being evident in other trenches where more siliceous shales were host to galena mineralization. Anomalously low Zn/Pb ratios are characteristic of unit 4c, a result of greater Pb increase in both soil and bedrock with respect to Zn.

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