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ZEBALLOS MINING CAMP

A PRELIMINARY
RESOURCE ASSESSMENT OF ZEBALLOS MINING CAMP

BY

M.C. HANSEN AND A.J. SINCLAIR

A MINDEP PROJECT

DEPARTMENT OF GEOLOGICAL SCIENCES
UNIVERSITY OF BRITISH COLUMBIA
VANCOUVER, B.C. Canada V6T 2B4

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INTRODUCTION

PREAMBLE

Zeballos Mining camp is located on the west coast of Vancouver Island, about 320km northwest of Victoria, B.C. Access is via an allweather road between the settlements of Zeballos (5km south of the camp) and Nimpkish. The surrounding countryside is heavily vegetated, mountainous and rugged, with elevations ranging from near sea level to about 1300m. The climate is wet and mild, with an average rainfall of around 6,000mm.

The first gold-quartz vein staked in the area was the Tagore in 1924, limited quantities of placer gold had been mined previously. Lode production began in 1934, reaching a peak during the period 1937 to 1943, by 1948 most mines had closed and production rapidly declined. Two mines, Privateer and Spud Valley, produced 473,082 of the 651,797 tonnes of ore mined at the camp.

Recorded metal production to date totals 9,465,244 grams of Au and 4,119,118 grams of Ag, as well as minor amounts of Pb and Cu. Average mined grades for the camp are 14.5g Au/tne and 6.5g Ag/tne (respectively 0.47oz/t and o.21oz/t). The veins were narrow but high grade, running 30 to 150g Au/tne. The principle mining methods were cut-and-fill and shrinkage stopping, the latter method causing considerable dilution of vein material.

AIMS

This evaluation was initially oriented towards a quantitative resource assessment following the approach of Sinclair (1979) and Orr and Sinclair (1971). To this end a data file was constructed (presented as Appendix I) to form a basis for quantitative evaluation.

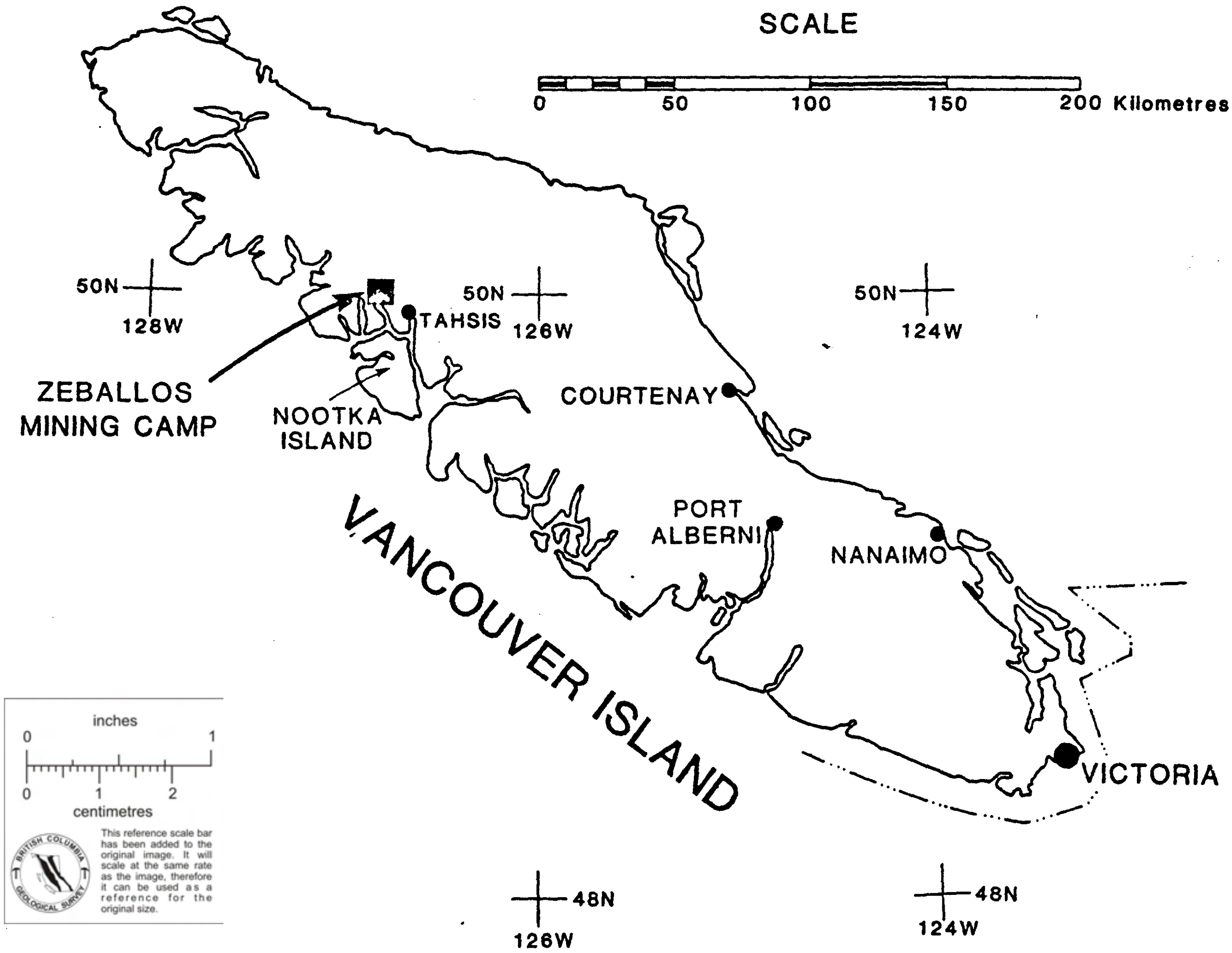

Figure 1: Location of Zeballos mining camp

Because of the scarcity of quantitative data the study was broadened to include a qualitative assessment of geological features, such as structure. This was hampered to a certain extent by a lack of field observations.

DATA BASE

The data have been compiled in Appendices, from two primary sources of information; a report and map by Stevenson (1950), the MINFILE computer file of mineral deposits in British Columbia. These table are self-explanatory, but some comments on the derivation and quality of the data are warranted.

Mined Tonnage refers to ore brought to surface for hand-sorting prior to milling; quoted grade values refer to these figures. The two major vein orientations are shown for each deposit, each orientation may represent several veins, the values are mean directions of undulose surfaces. Where production has been recorded, vein width refers to the most productive segment of the vein/s. The term "sheeted zone" refers to joints which are "... spaced 2 to 8 inches apart and contain either gouge or quartz-sulphide stringers an eighth of an inch to an inch wide/" (Stevenson, 1950). The associated replacement/alteration refers to features observed in a vein or wallrock, such as silicification or oxidation, in general such data are sparse in available literature. Distances from the Zeballos Stock contact were measured from Stevenson's geological map of the camp (Fig. 2, 1950), similarly with distance and bearing from the nose of the stock.

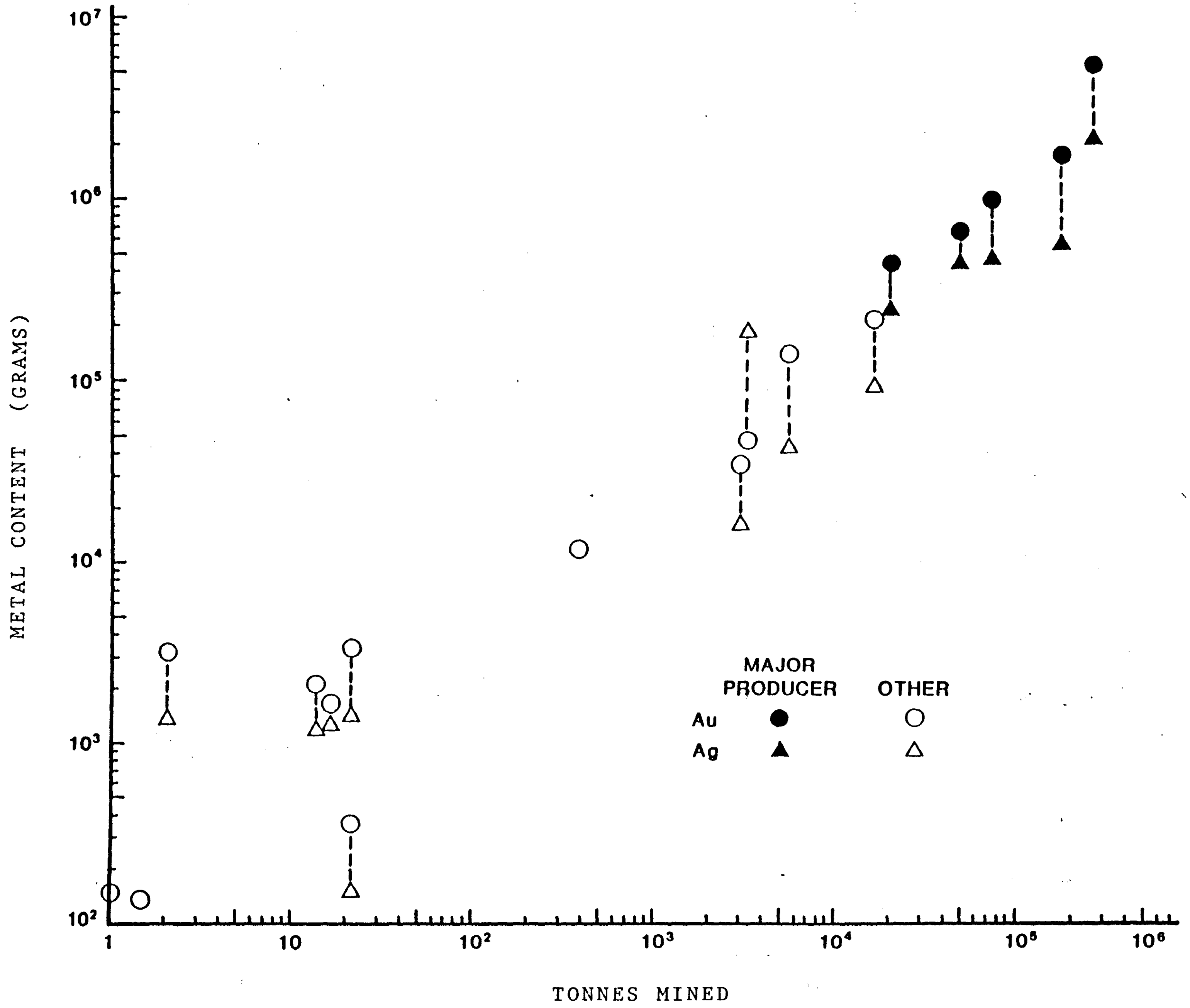

Figure 2: Total precious metal content (grams) versus mined tonnes for vein deposits of Zeballos camp. Circles are gold contents; triangles are silver contents. Data from Appendix I.

STATISTICAL METHODS AND RESULTS

The following techniques all utilize the data as listed in the appendices. The small number of observations for which production data are available is a significant drawback which limits the applicability, although not necessarily the validity, of multivariate techniques. Nonetheless, there are some interesting relationships and trends apparent, as described below. Those variables which do not display an approximately normal distribution (e.g. all production data) are invariably log transformed. No other transformations were considered necessary. The work was undertaken utilizing the computer centre facilities of the University of British Columbia.

LINEAR REGRESSION

Selected plots of the more significant relationships are presented, with the associated statistical values listed in Table 1.

Precious metal contents (Au & Ag) are plotted versus production (mined tonnage) in Fig. 2. The good correlation (refer Table 1) for both Au and Ag indicates that production tonnage is an acceptable single measure of relative value of vein deposits of Zeballos camp (c.f. Sinclair, 1979). The corollary is that average grades among the larger producers are relatively constant. This would be of significant interest to any future producer at the camp.

Average Au grade versus average Ag grade is shown in Fig. 3. Although the correlation is high (r=0.815), the existence of two clusters suggests that this may be at least partly artificial. Nonetheless the cluster representing the larger producers is valid. It can be seen that Au grade is considerably

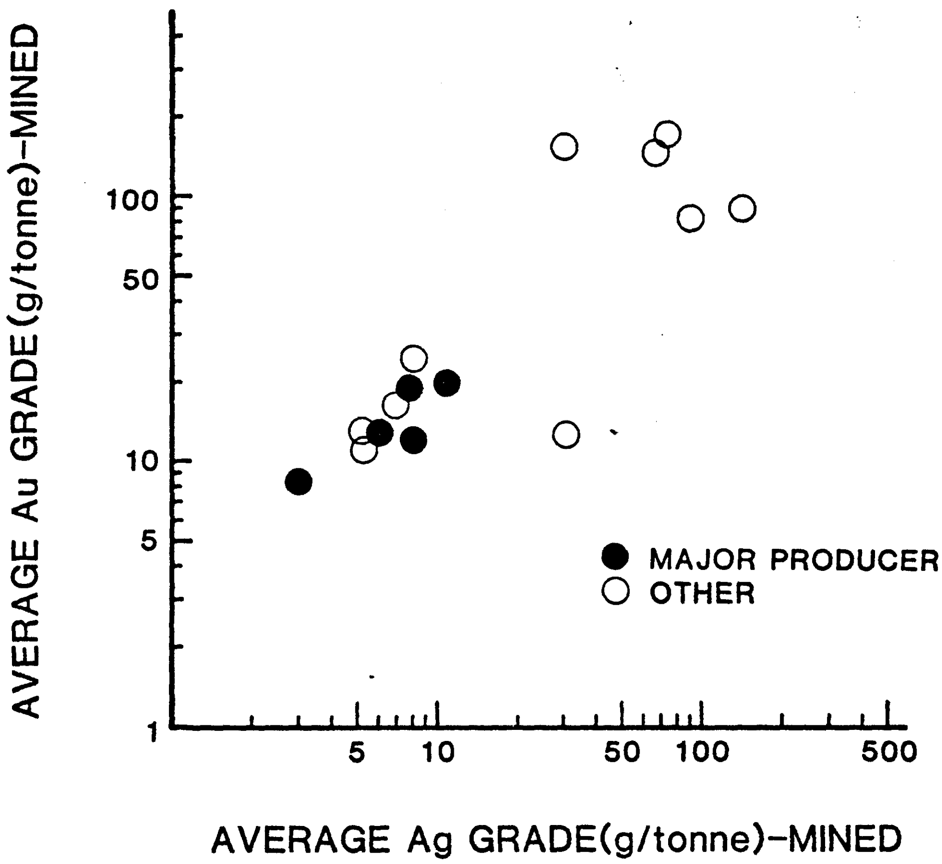

Figure 3: Plot of average gold grades (grams per tonne) versus average silver grades (grams per tonne) for Zeballos vein deposits. Data from Appendix I.

higher than that of Ag, the mean ratio is 2.3, with a standard deviation of 1.3; for the larger producers these values are 2.3 and 0.5 respectively.

In Fig. 4a, total grams of Au per deposit is plotted against average grade of Cu. The good negative correlation over several orders of magnitude suggests Cu grade may be an indicator of deposit relative value. However this correlation may be partly artificial, as a result of selective up-grading of ore in the small deposits. This relationship is discussed further in the following section on multiple regression.

Fig. 4b is a plot of deposit relative value (total grams of Au per deposit) versus distance from the contact of the Zeballos Stock. The graph shows a remarkably consistent pattern both in the stock and in the country rock. The equations describing these trends are given in Table 1. There is potential for this relationship to be used as a value estimate for any deposits remaining to be discovered. However two assumptions, which may not be valid, are implicit in this relationship. The measure of distance from the contact is in the horizontal plane, potential influence of variation in the vertical plane is not considered. Secondly the Zeballos Stock is considered to be the only Tertiary intrusive in the vicinity, this may not be the case.

MULTIPLE REGRESSION

The method used is backward stepwise regression, whereby only the most significant variable/s are retained in the equation at the final step. Although the potential of this method is severly limited by the small number of observations available, it has provided insight into which variables may reflect the mineralizing process.

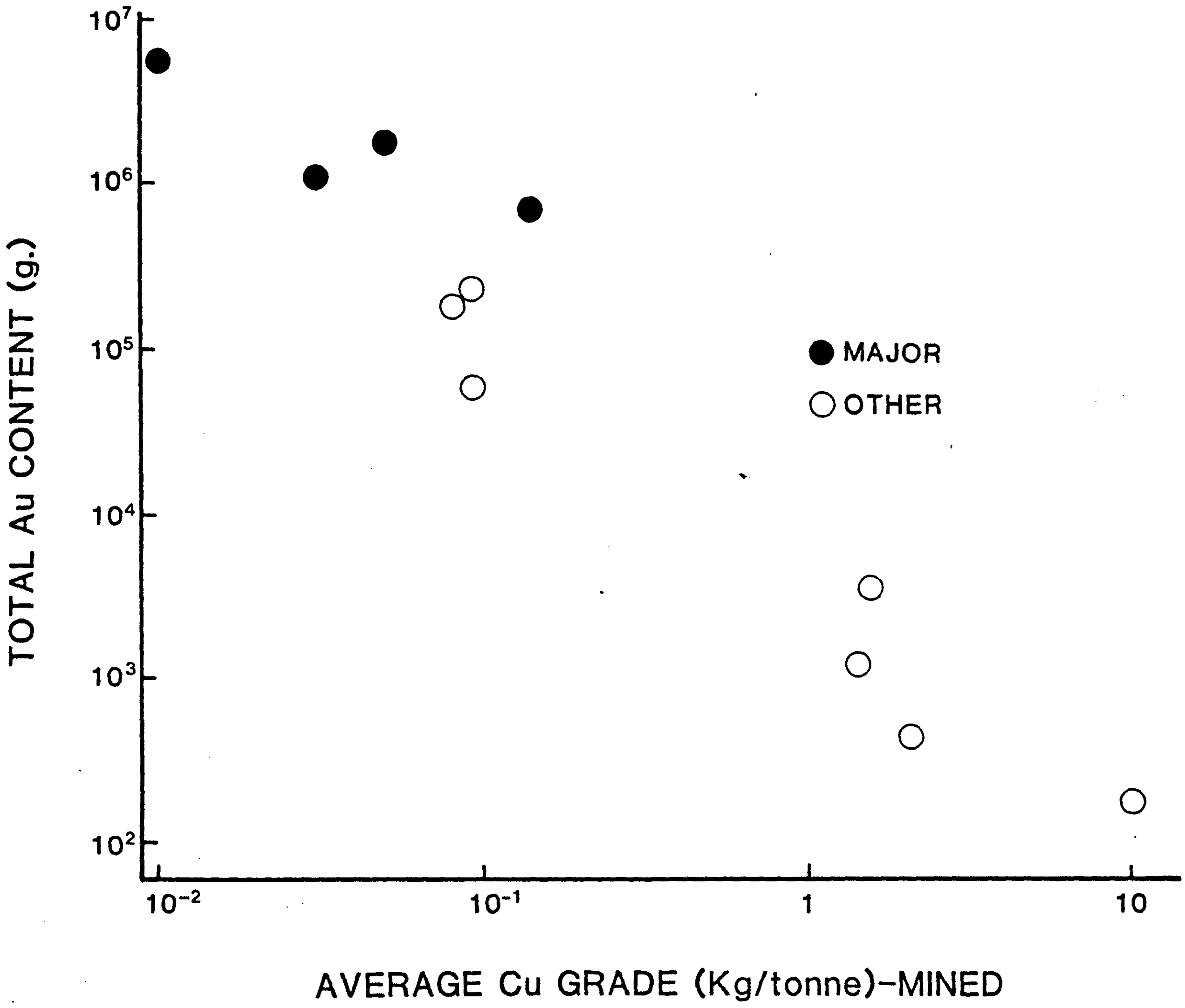

Figure 4a: Total gold content (grams) versus average copper grades (percentage) for Zeballos vein deposits. Data from Appendix I.

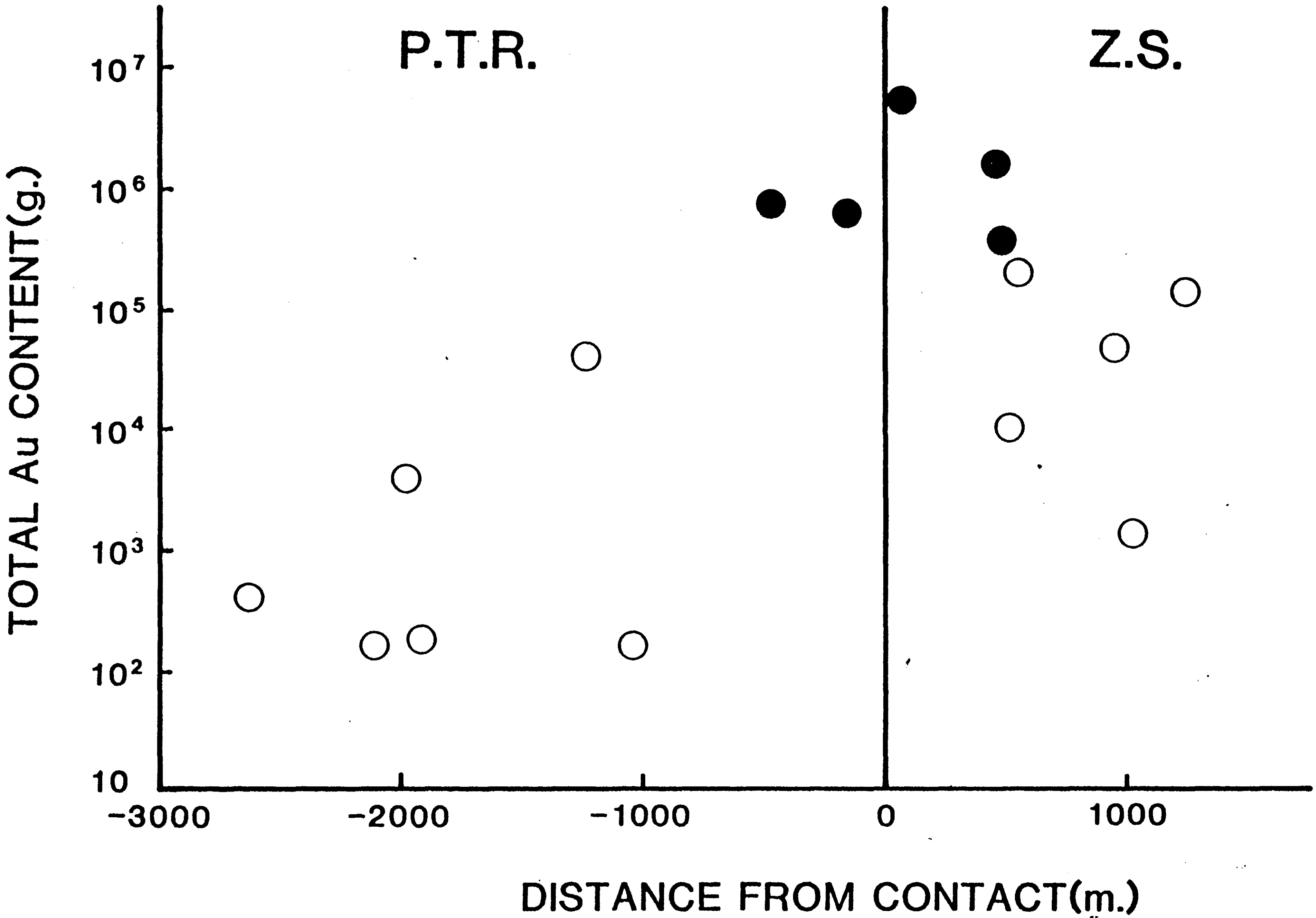

Figure 4b: Total gold content (grams) versus distance (metres) from contact of Zeballos stock. ZS indicates the Zeballos stock side of the contact; PTR refers to pre-Tertiary country rock.

TABLE 1

LINEAR REGRESSION DATA

DEPENDENT VARIABLE	INDEPENDENT VARIABLE	NUMBER OF OBSERVATIONS	DEGRESS OF FREEDOM	CORRELATION COEFFICIENT	RELEVANT FIGURE
LogMINE	LogTOAU	17	16	0.989	
REGRESSION EQUATION LogMINE = 1.23.LogTOAU - 2.46					2.1
LogMINE	LogTOAG	15	14	0.975	
REGRESSION EQUATION LogMINE = 1.18.Log TOAG - 1.94					2.1
LogGRAU	LogGRAG	15	14	0.815	
REGRESSION EQUATION LogGRAU = 0.75.LogGRAG = 0.59					2.2
LogTOAU	LogGRCU	11	10	-0.962	
REGRESSION EQUATION LogTOAU = -1.62.LogGRCU + 3.61					2.3
LogTOAU	DSTC(+ve)	8	7	-0.637	
REGRESSION EQUATION LogTOAU - =0.0019.DSTC + 6.38 (within stock)					2.4
LogTOAU	DSTC(-ve)	9	8	0.713	
REGRESSION EQUATION LogTOAU = 0.0011.DSTC + 5.38 (in wallrock)					2.4

ABBREVIATIONS:

MINE mined tonnage/deposit(tne)

TOAU,TOAG total grams Au/deposit

GRAU,GRAG,GRCU grade of Au in g/tne

DSTC distance from the Zeballos Stock contact

Numerous runs were made using different dependent variables and combinations of all or some independent variables, in addition the observations used were varied.

Naturally the most significant dependent variables as value indicators are mined tonnage and total gold content per deposit. Elevation was used as a dependent variable in an attempt to define any zoning which may be present. Unfortunately the data are too sparse to allow any meaningful correlations in this regard.

The use of mined tonnage or total gold content as dependent variables restricts the number of observations to 18 and 17 respectively. If complete observations are desired the restrictions are even more severe, generally less than 10 or so observations. Where observations are incomplete, mean values are substituted for missing data. The results often do not appear significantly different in such cases.

The most significant independent variables, in approximate order of decreasing significance, are; grade of Cu (GRCU), grade of Au (GRAU), bearing from the northwest nose of the Zeballos Stock to the deposit (BRGN), distance to the contact (DSTC), average minimum vein width (MNVW), grade of Ag (GRAG), grade of Pb (GRPB), distance to the nose of the stock (DSTN), strike of the major vein/s (STR1). This order varies depending on the nature of the other parameters. Of the 9 variables only 6 are considered to be of significance. The variables DSTN and STR1 were dropped primarily because of their low rating. In addition, the values for STR1 are averages and would be difficult to determine for a raw prospect.

The variable MNVW, although useful was dropped for two reasons; it is an empirically determined value, and it is of no quantitative value when considering a prospect with limited vein exposure. The variables GRAG and GRPB were retained because they are quantitative production data and represent information which is relatively easy to obtain from a prospect. The variable BRGN was retained solely because of its significance in the regression analyses. It is difficult to explain geologically except insofar as it is presumably an indirect measure of other variables of significance, as discussed elsewhere, (e.g. position and orientation of shears).

Data resulting from the use of these 6 variables are presented in Table 2. The cases presented are by way of a demonstration of the type of results obtained. Features of interest are; the high values for R^2 (i.e. that fraction of total variance explained by the relationship), the generally low standard error (around a half order of magnitude over 5 to 7 orders of magnitude), the persistence of GRCU as the retained independent variable. It appears that the grade of Cu is of considerable, unexpected, significance in terms of available data. This supports the conclusion in the previous section that grade of Cu may well be useful as an indicator of potential value of a deposit.

CLUSTER ANALYSIS

Much of the data file consists of attributes, that is to say measurements recorded on a nominal scale and having discrete values, e.g. most of the data

TABLE 2

SELECTED RESULTS FROM MULTIPLE REGRESSION ANALYSES

DEPENDENT VARIABLE	MINE	TOAU	MINE	TOAU
INDEPENDENT VARIABLE	GRAU, GRAG, GRCU, GRPB	GRAU,GRAG,GRCU,GRPB	GRAU,GRCU,DSTC,BRGN	GRAU,GRCU,DSTC,BRGN
TOTAL NO. OF OBSERVATIONS	18	17	12	12
TOTAL NO. OF COMPLETE OBS.	9	9	11	11
DEGREES OF FREEDOM	11	11	11	11
FINAL STEP NUMBER	6	7	7	7
LAST VARIABLE REMOVED	GRAU	GRAG	BRGN	BRGN
RETAINED VARIABLE/S	GRAG,GRCU	GRCU	GRAU,GRCU	GRCU
VALUE OF R^2	0.97	0.93	0.97	0.93
STANDARD ERROR	0.41	0.50	0.40	0.48
REGRESSION EQUATION	LogMINE = -0.97.LogGRAG -1.67.LogGRCU +3.09	LogTOAU =-1.62.LogGRCU +3.09	LogMINE=-1.25.LogGRAU -1.53.LogCRCU +3.97	LogTOAU=-1.62.LogGRCU +3.60

NOTE 1 abbreviations explained in text

NOTE 2 all values are logged (as shown), except DSTC and BRGN in appendix V. Although such data may be evaluated empirically, it was considered that more significant results might be derived using a parametric statistical technique. It was desired to group the data from Associated Minerals (App. V) using cluster analysis, after ensuring that such data could be validly used in such a manner. The lower orders of clustering were meaningful, but did not provide information that could not be determined empirically. The higher orders of clustering did not appear to be geologically significant. It was presumed, therefore, that there is practically no practical grouping of observations within these data, other than what can be determined empirically.

DISCRIMINANT ANALYSIS

Productive deposits have been classed arbitrarily in two groups, the 5 major producers and the remaining 13 producers. This classification, as used in Figs. 2 to 4, was arbitrarily based upon the fact that the 5th largest deposit produced almost twice as much Au and two and a half times as much Ag as the 6th largest deposit, and the 5 largest deposits have produced around ½ million grams of Au or more. It was decided that discriminant analysis might show a more significant grouping among the producers than the classification above.

The small number of observations restricted the analysis to two groups, the variables used were; TOAU, GRAU, GRAG, GRCU, GRPB. Where no variables were forced all were rejected except either TOAU or GRAU. In all such cases around 80% of the observations were considered correctly classified, regardless of the composition of the two groups. In other words any grouping using only the one variable would be essentially arbitrary, not an unexpected conclusion. However where all variables were retained as low level forced variables, the best classification (89% of cases correctly classified) placed the 5 largest producers in one group and the remainder in the other group, all other groupings showed noticeably poorer classification. Thus it would appear that the initial empirical classification is indeed the most significant grouping.

GEOLOGY AND MINERALIZATION

GENERAL

The geology of Zeballos Camp, as shown in Fig. 5, consists of a northwest striking, southwest dipping sequence of Mesozoic volcanic and sedimentary rocks cut by Jurassic and Tertiary intrusions. This general structure represents the southwest limb of a northwest-trending anticline (Hoadley, 1953), considerably disrupted by faulting and intrusion. The area to the north of the Zeballos Stock and to the east of the North Fork of the Zeballos River is tightly folded. The Lower Jurassic Bonanza Group is a typical island arc sequence, largely consisting of basaltic to rhyolitic volcanic rocks. This unit is underlain conformably by limestone of the Quatsino Formation. These two units are now thought to be separated by the Parson Bay Formation as elsewhere on Vancouver Island; this is described in detail below. Tholeiitic basalts of the Upper Triassic Karmutsen Formation form the base of the sequence in this area. These bedded rocks are cut by Jurassic plutons of the Island Intrusions, mainly diorite to granodiorite in composition. The Zeballos Stock with its spatially related gold-quartz veins is a quartz diorite phase of the Catface Intrusions of Eocene age.

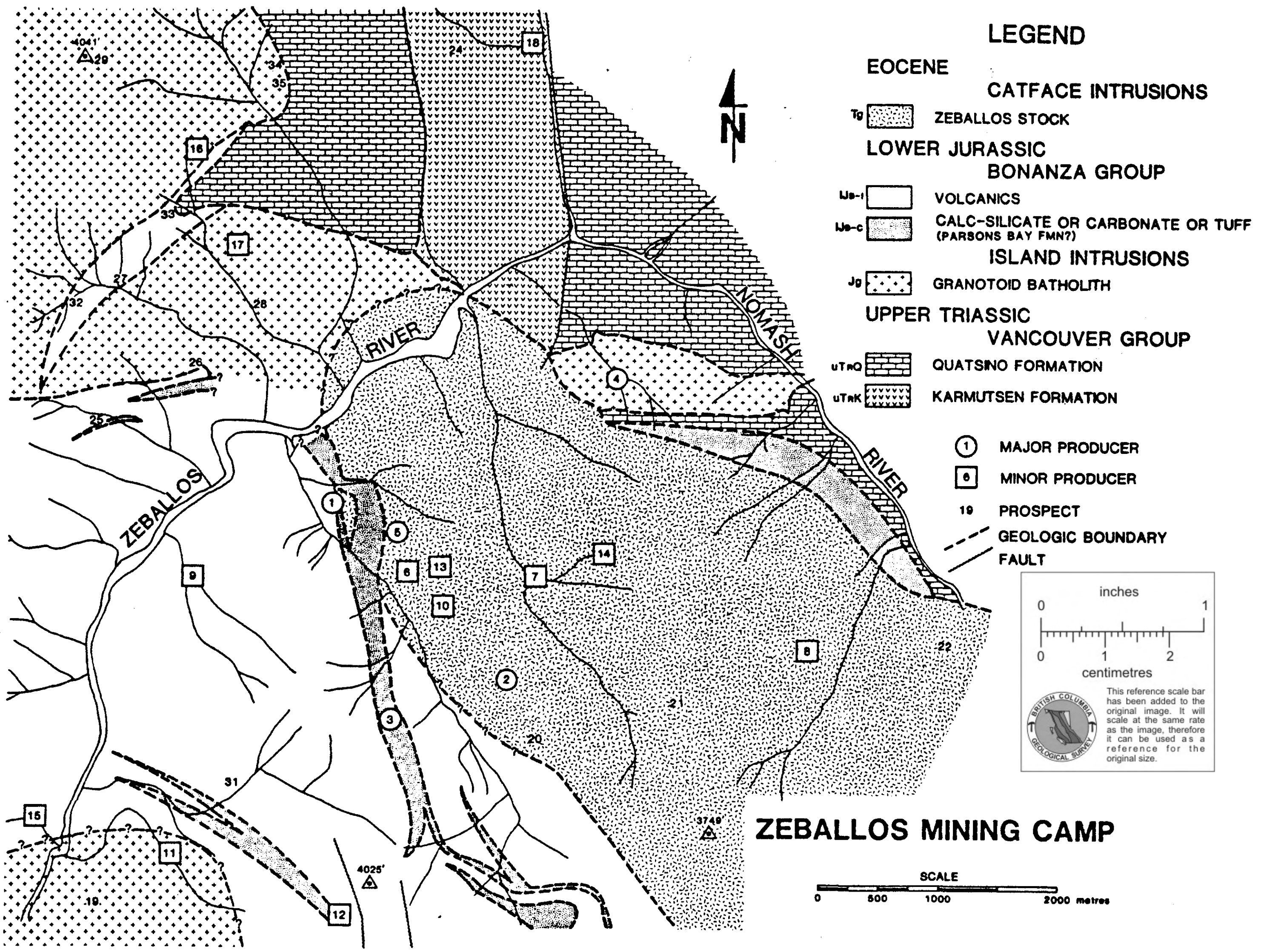

Figure 5: General geology of Zeballos mining camp. Modified from Stevenson (1950)

STRATIGRAPHY

In Fig. 3.1 the Bonanza Group is shown to contain units of carbonate, calc-silicate, and tuff. According to Dr. J.E. Muller (Pers. comm., 1982) these units almost certainly represent the Parson Bay Formation. That is, these units would represent the northwest continuation of the formation as shown on the 1:250,000 map of Nootka Sound (G.S.C. MAP 1537A, 1981). The contact between Parson Bay Formation and Bonanza Group is known to be gradational, as it would appear to be here. The Bonanza Group elsewhere on Vancouver Island is not known to contain any carbonate horizons, although sedimentary units do occur. The calc-silicate adjacent to the Zeballos Stock presumably represents contact metamorphosed carbonate or carbonate-rich sediment. If indeed these units are Parson Bay Formation, the implication is of a more complex structure than was previously thought to exist. The two horizons of Parson Bay Formation to the west of the stock are almost certainly a structural repetition. This would suggest either a tight, doubly-plunging syncline or fault-controlled repetition. The latter explanation is favored because there is no evidence of folding, in terms of the attitude of the bedding or of repetition of the underlying Vancouver Group. Faulting, however, is not only eminently feasible, but a necessity for consistent structural interpretation. This is discussed fully in the section below.

In the extreme southwest of the map area (Fig. 5) Stevenson (1950) has mapped a body of gabbro which contains the Answer and Golden Portal deposits. This gabbro contains fragments and boulders of unreplaced and partially altered volcanics. It is cut by diorite and granodiorite dykes which cut the Zeballos

Stock and perhaps the Island Intrusions. Compositionally it is distinct from the hornblende diorite of the Island Intrusions in that it contains " ... labradorite instead of andesine, and considerable augite with only a minor amount of primary hornblende." (Stevenson, 1950). The presence of pyroxene rather than hornblende suggests the possibility that this may be a feeder dyke (i.e. subsurface equivalent) to the Bonanza Volcanics, or to higher level Tertiary volcanics which have since been eroded. It is of interest to note that there are three gold producers in the immediate vicinity (Tagore, Golden Portal, Beano). It is generally accepted that gold-quartz vein mineralization is intimately related to Tertiary intrusions (e.g. Carson, 1968) on Vancouver Island, yet the Zeballos Stock is 2-3km away. In addition a replacement deposit such as the Beano could be expected to lie quite near the source of mineralization. Thus it is at least possible that this gabbro is of Tertiary age.

There appears to be a close relationship between dykes of a particular age and composition and the gold-quartz veins. Dykes which are the last phase of, or younger than, the Zeballos Stock intrusion are of particular significance. Feldspar porphyries are intimately associated with the veins, a stock of feldspar porphyry occurs within the Mount Zeballos mine area. Orthoclase-rich granodiorite dykes are associated with mineralization at the Privateer and Central Zeballos.

FAULTING

Faulting in this and surrounding areas seems to have been the major structural response to deformation (Muller, Northcote & Carlisle, 1974). With this in

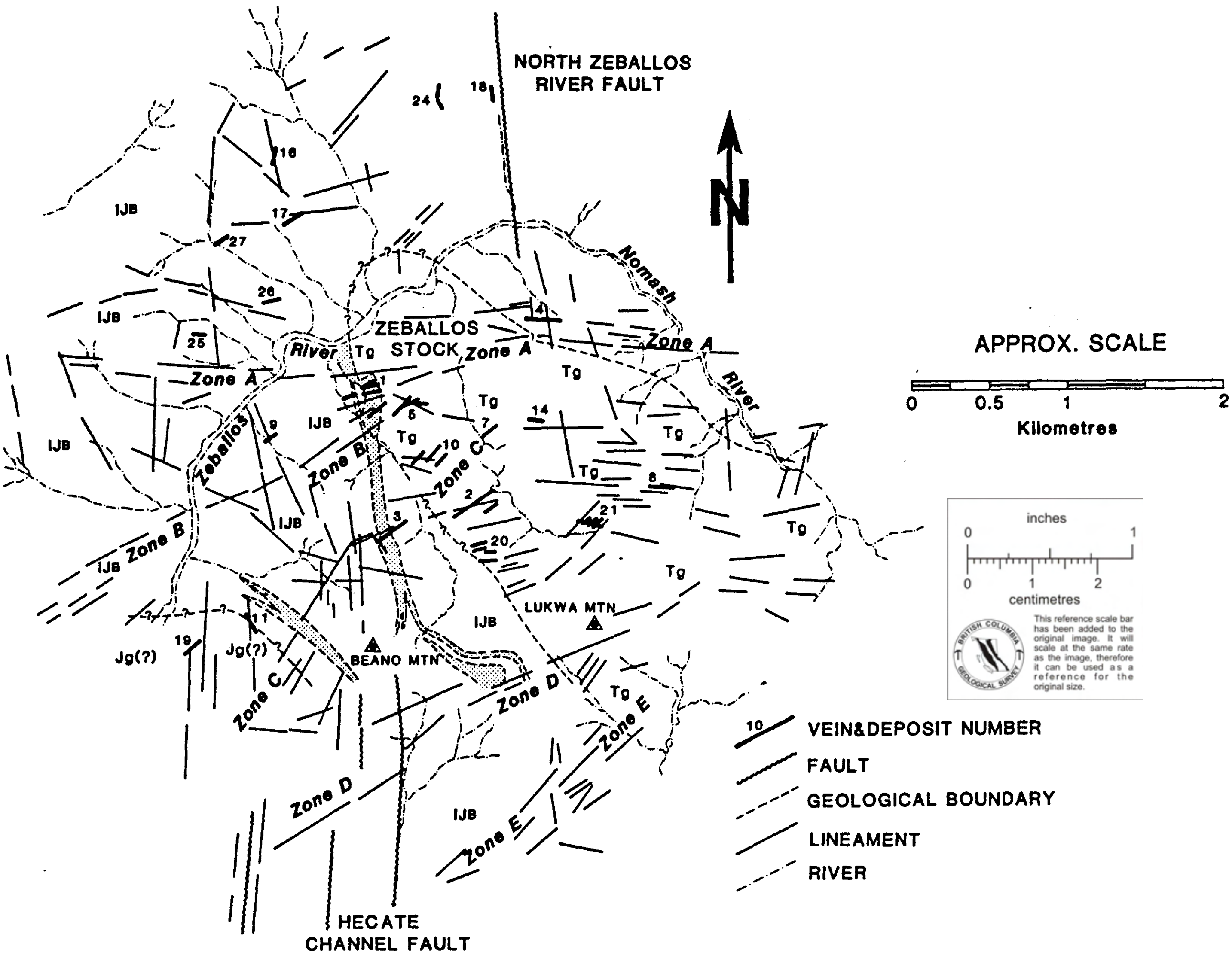

Figure 6: Fracture trace diagram for Zeballos mining camp as interpreted from aerial photographs. Scale is approximate because aerial photographs were used as a base. Several geographical and geological features are included as an aid to correlating this figure with the geological map of figure 5.

mind a fracture trace diagram, reproduced here as Figure 6, was compiled from 1:20,000 scale black & white aerial photographs, taken in August, 1980. Because of the empirical nature of such data and the limited time available, only the major, more obvious lineaments have been shown. In addition the compilation has not been corrected for distortion, nor have the photographs been interpreted by another worker. Not being able to check the features on the ground is naturally a significant drawback. Fig. 7 is a rose diagram of all lineaments, Fig. 8 shows those lineaments greater than approximately 600m in length. This division was chosen on the basis of a percentage histogram of all lineaments. Lengths up to about 600m define a normal population, lengths greater than 600m are a "tail" to this population.

The distinct population in both figures at 150°-190° is thought to represent the continuation of the pre-Tertiary Hecate Channel Fault of Muller, Cameron and Northcote (1981). This fault has been mapped on Bingo and Friend Creeks by Hoadley (1953). The lineaments continue north from these creeks and from the east side of the lower reaches of the Zeballos River. It is thought that this fault continues, offset, on the north side of the Zeballos Stock as the North Zeballos River Fault. These faults and the accompanying lineaments are considered pre-Tertiary as the faults are offset across the Zeballos Stock and north-south lineaments are rare within the stock. This would be in agreement with the conclusions of Muller & Carson (1979) and Muller et.al. (1981), with regard to similarly oriented faults and/or lineaments in surrounding areas.

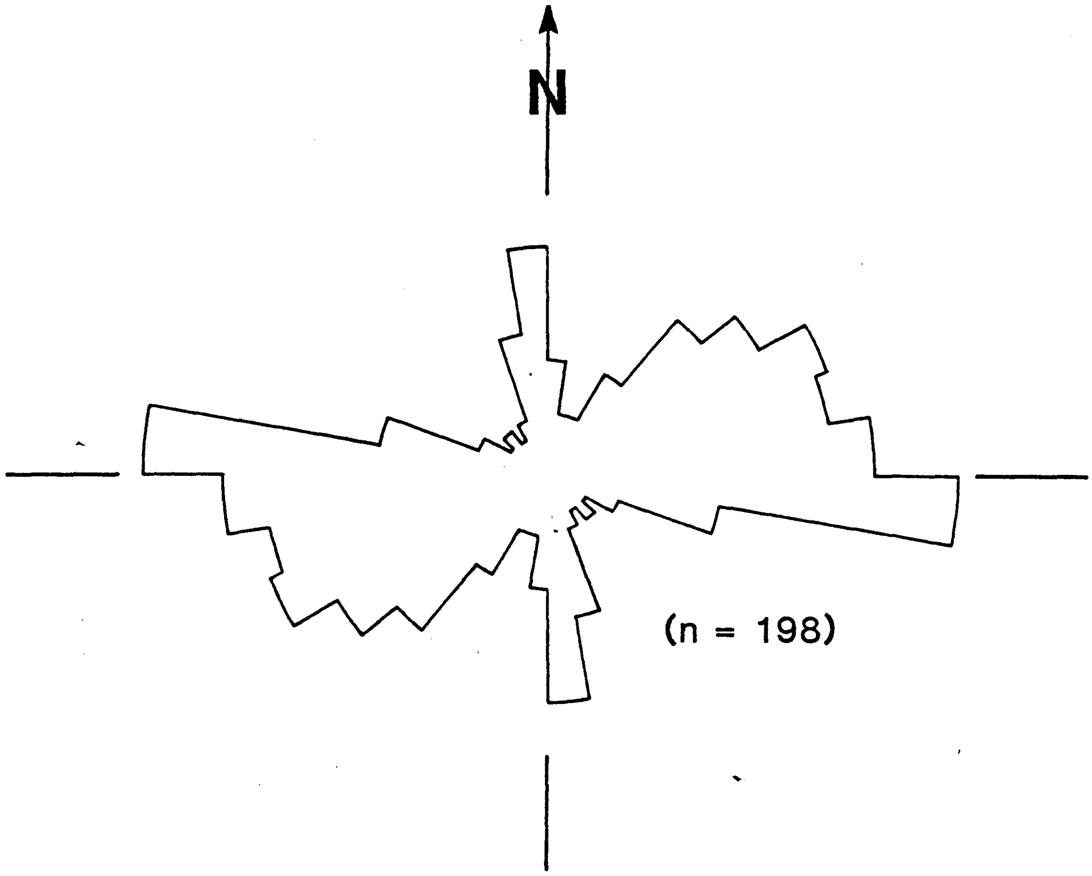

Figure 7: Rose diagram of all fracture traces shown on figure 6.

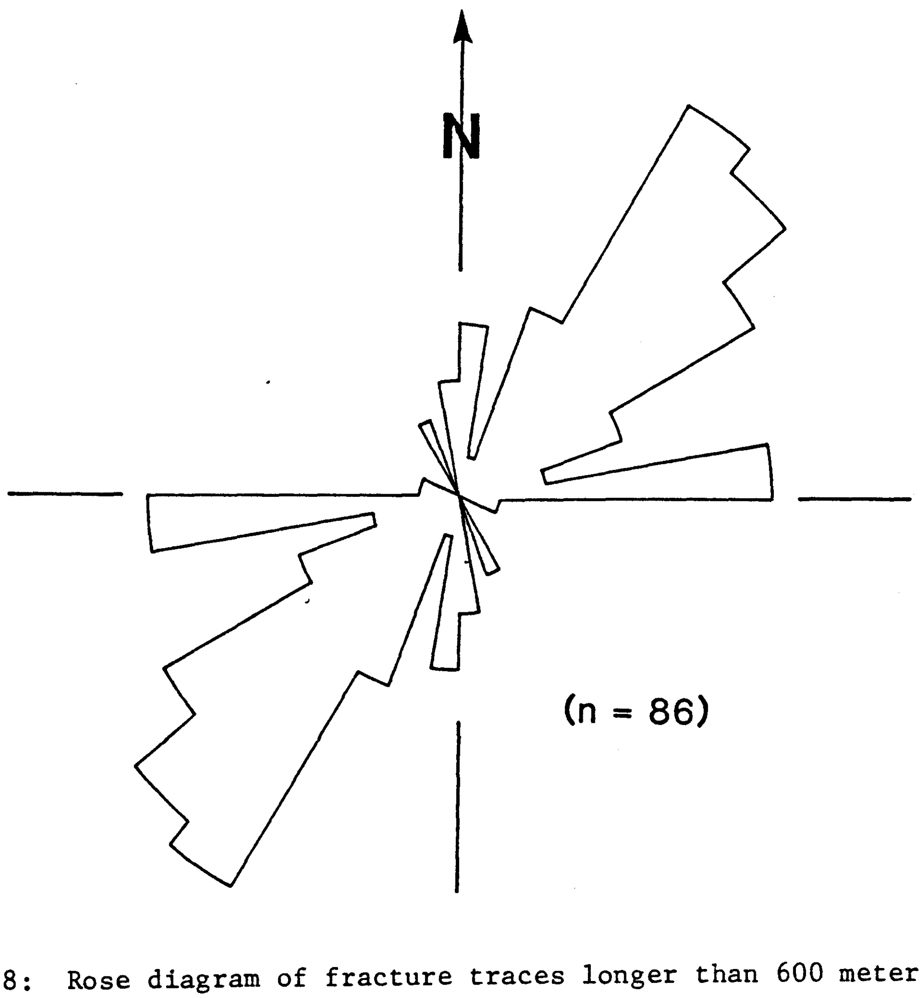

Figure 8: Rose diagram of fracture traces longer than 600 meters as they appear in figure 6.

Some of the lineaments representing this fault pass between the two horizons of Parson Bay Formation. Gunning (1932) considers the North Zeballos River Fault has been downthrown to the east. The same sense of movement on the fault to the southwest of the stock (i.e. continuation of the Hecate Channel Fault) would explain the repetition of the Parson Bay Formation.

Most of the lineaments fall within a large, rather poorly defined population between 30° & 100°, as shown in Fig. 7. Part of this population probably represents second order faults to the previously discussed north trending faults. Numerous east-west trending, generally short, lineaments occur within the Zeballos Stock, these are presumably related to cooling of the stock. A well developed fracture pattern in outcrop is diagnostic of the Catface Intrusions (Muller, pers.comm., 1982). It is possible that such fractures may correlate, at least in part, with the aforementioned set of east-west lineaments for the Zeballos Stock. If there is any such correlation, which would be easy to verify, fracture trace analysis could well prove a fast and accurate method of determing 'age' of particular intrusions.

Of the remainder, many lineaments fall within four relatively well defined zones, shown as zones A-E in Fig. 6. Zone A, passing through the Privateer and Central Zeballos appears to represent a fault which has offset the north part of the Zeballos Stock to the west. It corresponds to a zone of east-west striking granodiorite dykes at Central Zeballos. Lineaments in Zone A are well defined on the photographs, however there is no mention of such a fault by workers in the area. Zones B to E define 4 groups of lineaments striking

40^{o}-60^{o}, to the west of the stock. They may offset the Hecate Channel-North Zeballos River fault. In any event lineaments of Zones A-E appear to all represent the same age of faulting or shearing and may all correlate with Eocene or later faulting i.e. syn- (or post-) intrusive.

In the following section points as discussed above will be related to the gold-quartz veins.

VEIN ORIENTATION

The strain ellipsoid of Fig. 9 is modified after Stevenson (1950). On the basis of two major shears at Zeballos Pacific (035^{o}) and Big Star (090^{o}), along with some supporting data, he has taken the directions of major shearing stress to be 035^{o}/vert and 090^{o}/vert. He derives 062^{o}/vert to be the plane of tension and concludes that this orientation is most important with respect to vein orientation and mineralization, "fractures and consequently veins formed under tension are the most favourable for ore ..."

In a rose diagram for all veins of the camp, Fig. 10, the major vein orientations are 030^{o}- 060^{o} and 080^{o}-090^{o}. These orientations correlate well with the directions of major shearing stress as established by Stevenson. This is to be expected inasmuch as most veins of the camp do occupy shear zones (Bancroft, 1940, Stevenson, 1938, 1950). When total Au is plotted on the basis of vein orientation as in Fig. 11, the 080^{o}-090^{o} orientation can be seen to be of considerable importance with respect to mineralization. Thus planes of shear rather than of tension are important in the localization of

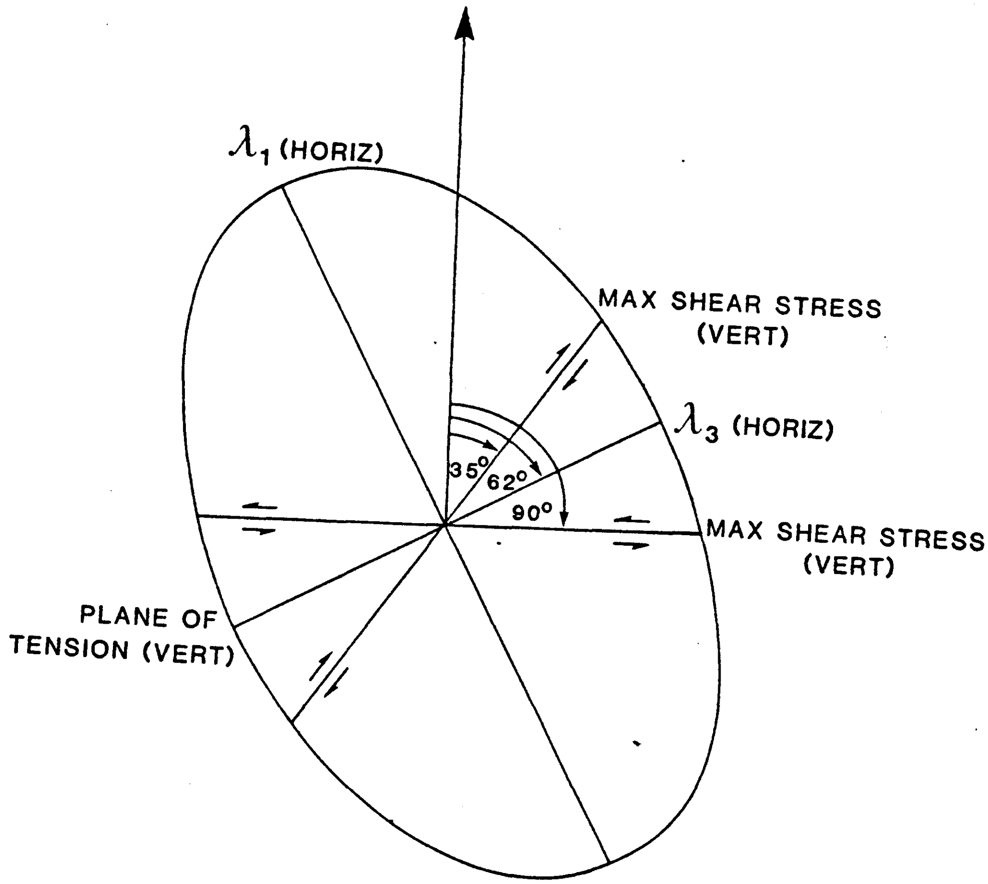

Figure 9: Strain ellipsoid for Zeballos mining camp.

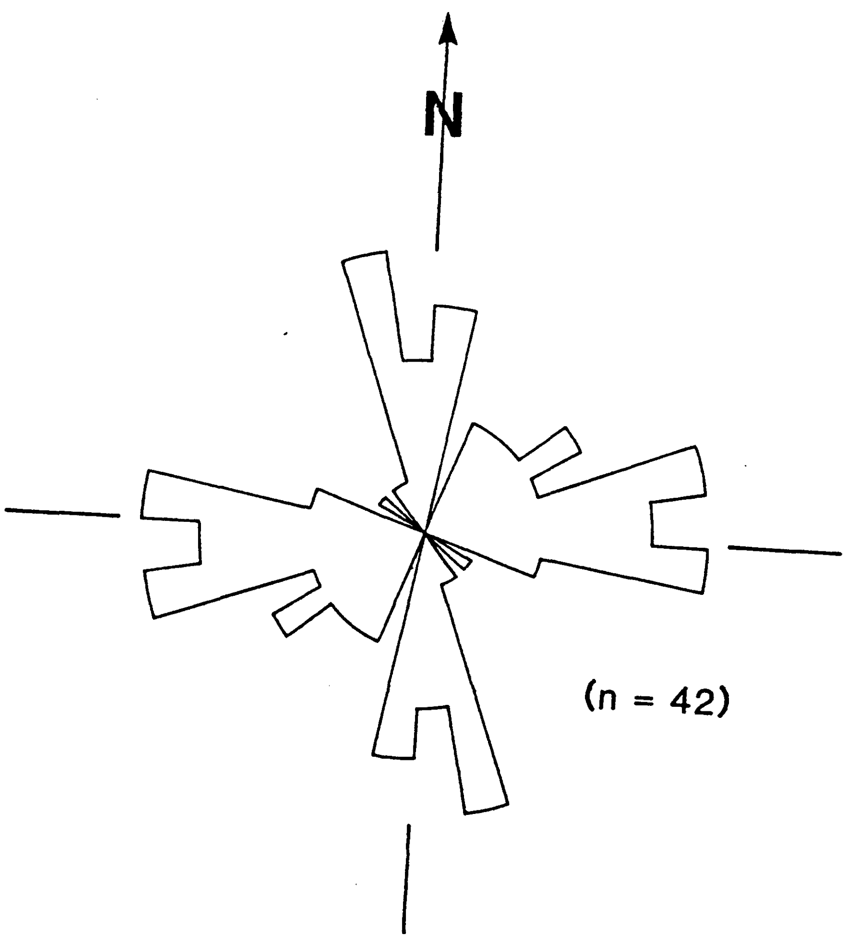

Figure 10: Rose diagram of vein orientations, Zeballos mining camp.

mineralized veins. However tensional features do abound in, or are closely associated with, most veins. Such a situation may be explained by invoking rotational strain.

Rotational strain leads to the development of one prominent shear direction in any particular area, with the conjugate shear being poorly developed or non-existent. The direction of relative movement in such a shear zone will form an acute angle (e.g. 05°-10°) to the individual shear planes within the zone. Such a predominance of one shear direction is commonly observed in the field in numerous geological environments. This appears to be the case at Zeballos, with the directions of major vein orientation (030°-60°, 80°-90°) correlating quite well with Zones A-E of Fig. 3.2 ($040^{\circ}060^{\circ}$, 80°-100°). An example of rotational strain, using a shear direction of 085° is illustrated in Fig. 12.. This example may be directly related to Zone A of Fig. 6 and No. 1 & No. 2 veins of the Privateer. Brecciation and shattering can be expected under low confining pressures, as is indeed the case at the camp. In other areas the conjugate shear is more prominent (viz. Zones B-E of Fig. 6).

To summarize, such an explanation satisfies the basic observations on the veins, viz. most veins occupy shear zones, yet tensional features are of considerable importance. The directions of maximum shearing stress as derived by Stevenson (1950) correlate well with the vein orientations as shown in Fig. 3.6, and with Zones A-E of Fig. 6, , all of which may be

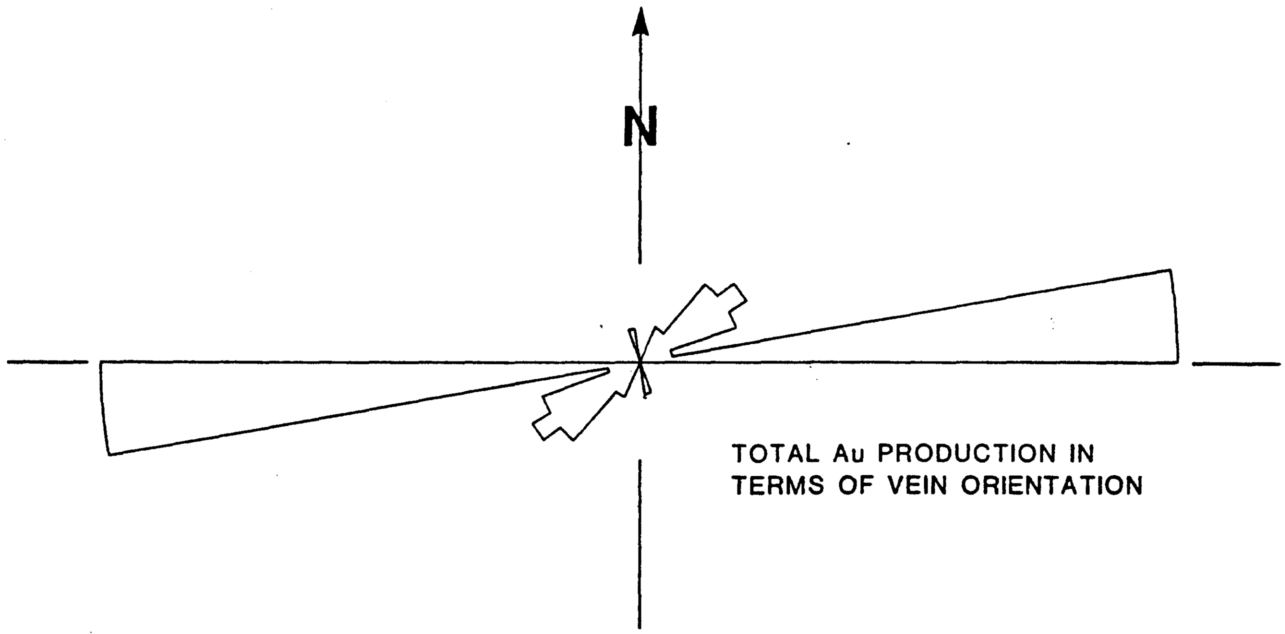

Figure 11: Rose diagram of total gold production as a function of vein orientation, Zeballos Mining Camp.

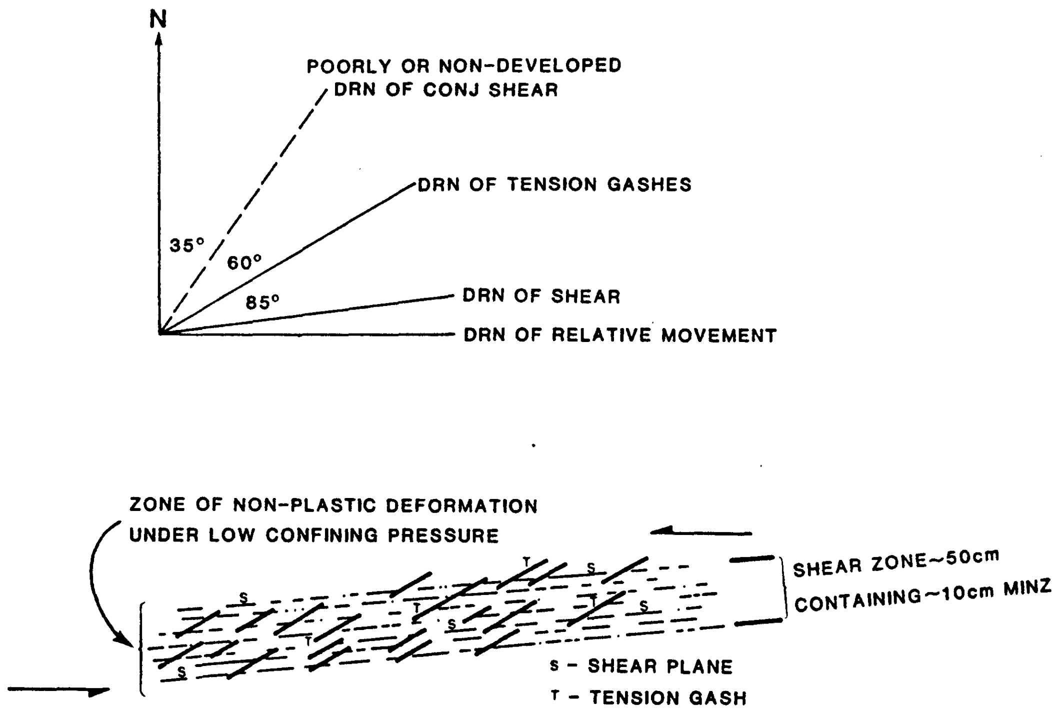

Figure 12: Conceptional model for development of veins and related structural features, Zeballos mining camp.

explained by rotational strain. The 060°/vert plane of tension is primarily of significance when associated with the 080°-090°/vert plane of shearing.

The above conclusions are well supported by the location of the deposits themselves. Zone A, of Fig. 6, contains the Boden, Privateer, Britannia, and Central Zeballos deposits. Zone B the Van Isle and Prident deposits. It is, of course, no coincidence that the Privateer-Prident complex is located at the intersection of two shear zones. Zone C contains the Mount Zeballos, Spud Valley, Zeballos Pacific and C.D. deposits. Zone D contains the Friend deposit, however most of Zones D & E are outside the area of the camp as shown on Fig. 5. Neither zone has hosted any production, however they are both a considerable distance from the nose of the stock, which fact may be of considerable significance with regard to the localization of mineralization.

NOSE OF STOCK

There is a strong correlation between the northwest nose of the Zeballos Stock and mineralization. In a general way the greater the distance from the nose, the fewer the deposits and the less productive they have been. This is presumed to be a result of the extensive faulting and shearing in the vicinity of the nose providing the best pathways for ascending metal-bearing solution. Naturally there are other relationships which obscure the picture to a certain extent, such as that between metal content and distance to the intrusive contact (Fig. 4a). A complicating factor may be the gabbro in the southwest of the map area, if this is Tertiary in age.

VEIN WIDTH

Most productive veins show a wide range in width (e.g. 1-100cm), but the bulk of such veins usually shows considerably less variation (e.g. 10-30cm). The latter variation is described, rather arbitrarily, as typical minimum and typical maximum vein width. Typical minimum vein width is of considerable empirical significance. In general terms productive veins can be expected to have a typical minimum width of around 1-5cm along with a relatively small variation in width. There does not seem to be a correlation between vein width and width of the enclosing shear zone.

HOST ROCK

Host rock to the veins includes all rock types in the area. Particular host rock type appears to have no influence on localization of veins, except insofar as the physical properties of the rock determine how it will react to deformation. Flexures appear to be favourable sites for mineralization, particularly in what is inferred to be Parson Bay Formation (e.g. at Privateer and Mount Zeballos). Elsewhere on Vancouver Island the Parson Bay Formation is seen to be complexly folded, presumably because it reacts in an incompetent manner to deformation. The Bonanza Volcanics could be expected to react in a more brittle manner to deformation, thus more readily providing pathways and sites of deposition for migrating hydrothermal solutions. The presence of sharp bends or curves in the margins of the stock are also likely loci of deposition, as are areas of shattering and brecciation.

ASSOCIATED MINERALS

The sulphide assemblage of the gold-quartz vein occurrences on Vancouver Island (e.g. Bancroft, 1937; Muller & Carson, 1969; Carson, 1968). Pyrite, sphalerite, galena and chalcopyrite are generally present among the producers. Arsenopyrite may be present and pyrrhotite is relatively uncommon. In general terms these sulphides must be present for there to be economic gold available, to what extent is not known due to lack of data. There is a strong negative correlation between chalcopyrite (GRCU) and total gold among the producers as discussed earlier, it is not known whether this relationship applies to the other sulphide minerals. Arsenopyrite, alone, does not seem to be related to gold content, however if present in measurable quantity along with sphalerite, galena and chalcopyrite there is often associated high grade (150-3,000 g/tne) gold in apparently small quantities. Quartz is ubiquitous, calcite occasionally accompanies mineralization, ankerite is rare.

FUTURE WORK

The suggestions listed here are outside the present program of investigation. They merely represent directions in which further work on the topic may prove successful.

1. Zeballos Camp has been the only significant area of production from gold-bearing quartz veins and fissure zones on Vancouver Island. However, there are numerous occurrences of the same age and type of mineralization (e.g. Bedwell River, China Creek, Kennedy River, Forbidden Plateau) that could profitably be included in the data file. Such information would be of considerable value, particularly with regard to the setting of mineralization.
2. The structural setting of the deposits appears to hold the key to understanding the mineralization at the camp. This could be more fully studied, fieldwork would be essential.
3. A more formal and widespread fracture trace analysis would be useful in conjunction with 2. above. Again field check of observations would be essential.
4. The paucity of quantitative data severely restricts the use of geomathematical techniques. However a method is presently being evaluated at U.B.C. by Dr. A.J. Sinclair & Mr. A. Bentzen whereby an arbitrary grid is superimposed on an area. The resulting cells are then assigned a set of measured parameters, e.g. length of particular contacts within a cell, % of particular rock types present, number of particular types of lineaments present, etc. The parameters are then evaluated for a) cells known NOT to contain mineralization, and b) cells known to contain mineralization.

Mineralization potential is then assigned to the remaining cells. Such a method would seem applicable to the Zeballos Camp as it is able to utilize data that are both readily obtainable and empirically related to mineralization.

5. Sulphide mineralogy used as a quantitative or semi-quantitative tool for prediction of deposit value appears to have considerable potential.

6. Other types of gold mineralization, such as the copper-gold skarn of the Beano deposit, are related in time and space to the gold-quartz veins. Such mineralization should be considered in further work on the vein deposits because of this close relationship, and the considerable economic potential such deposits can offer.

EXPLORATION PARAMETERS

The following parameters are intended to be applied to known vein/s under investigation at Zeballos Camp. However it would not be unreasonable to extrapolate the use of some parameters to similar veins elsewhere on Vancouver Island. It should not be assumed that these are the only factors influencing economic mineralization, or that the interpretation of these observations is necessarily unique.

1. Spatial association with the Eocene Catface Intrusions is of primary importance. The best economic potential seems to be within 500-1,000m of the contact.
2. Brecciation of the intrusive and/or host rock, along with pre-existing or contemporaneous faulting aid in establishing pathways for the hydrothermal fluids.
3. Close association with late - or post - Catface Intrusion dykes is a favourable feature. In particular (quartz) feldspar dykes and stocks.
4. Host rock type is important insofar as it's physical properties determine its response to deformation. For example fracturing on fold crests may, in association with other factors, provide a suitable locus of deposition.
5. A folded or convoluted margin to the intrusion, or apophyses, aids in the localization of mineralization.
6. The orientation of the vein and its enclosing shear, if present, along with intersecting shear zones is of considerable importance. At Zeballos it would seem that rotational strain has produced shears orientated at 035°-060° and 080°-090° which, when allied with the tensional features that typically develop, such as cavities and gash veins, may provide

suitable sites for deposition of economic mineralization.

7. The sulphide assemblage should include pyrite, galena, chalcopyrite, sphalerite, ± arsenopyrite; all in measurable quantities.
8. Veins should have a typical minimum width of at least 1cm. A minimum width less than this often seems to preclude the development of economic mineralization, even though sections of the vein in the near vicinity are of greater width. Productive veins generally have a relatively small variation in width.
9. Average Cu grade may be used as an aid in predicting potential total Au present.
10. The Au, Ag ratio is relatively independent of grade among producers. It may be used as an indicator of potential total Au present.

FUTURE VALUE OF ZEBALLOS CAMP

The area of Zeballos Camp is around 5,000ha, it could be expected that any mineralization in such a restricted area would already have been discovered and exploited, if possible. Aside from the possibility of geologically concealed mineralization, the rugged topography of the area, heavy vegetation, superficial cover on bedrock and the small, sometimes insignificant size of the target may easily have prevented discovery of veins carrying economic mineralization. Bancroft (1940) makes a pertinent comment in this regard, in reference to the search for the White Star veins, "Half a dozen prospectors searched the slopes for 4 months before finding the quartz in place ... 500 or 600 feet above the bed of the creek." This was after having found "... rich gold quartz float with granitic rock attached ..." in Spud Creek almost directly below the veins. It would seem that even today there would be considerable opportunity for the discovery of economic mineralization, other parameters being favorable.

Another alternative for the camp is that past producers have not exploited mineralization to its fullest extent, or known prospects may have the potential to become producers. Naturally it is not intended to give specific examples here, however such evaluation in at least a semiquantitative manner should be comparatively straightforward. Finally it is worth mentioning, although not part of this study, the potential for gold occurring in a form other than gold-quartz veins. That is to say as replacement or perhaps disseminated deposits, geologically and possibly spatially related to gold-quartz veins.

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APPENDIX I
LISTING OF MINERAL DEPOSIT DATA FILE FOR
ZEBALLOS MINING CAMP - GENERAL INFORMATION

DEPOSIT NUMBER	DEPOSIT NAME	LOCATION UTMN	LOCATION UTME	MINFILE REF.	YEARS OF PRODUCTION (19__)	ELEVATION (FEET)
1	PRIVATEER	43400	56600	092L/008	34-53,75	750
2	SPUD VALLEY	42400	58000	092L/012	36,39-42,51	2000
3	MOUNT ZEBALLOS	42000	57000	092L/012	39-42,44	2000
4	CENTRAL ZEBALLOS	44800	58700	092L/018	38-42,46,47	1500
5	PRIDENT	43500	56900	092L/009	41-43,47,48	1500
6	WHITE STAR	43200	57100	092L/010	35-42,52,57	1500
7	C.D.	43300	58100	092L/015	38-41	1400
8	HOMEWARD	42700	60400	092L/019	41,42	2000
9	VAN ISLE	43100	55400	092L/038	40	600
10	ZEBALLOS PACIFIC	42900	57500	092L/011	34	1500
11	GOLDEN PORTAL	40900	55200	092L/005	40	750
12	BEANO	40600	56300	092E/002	48,49	2500
13	I.X.L.	43400	57300	092L/081		2000
14	RIMY	43300	58700	092L/016	38	2500
15	TAGORE	41100	54300	092L/006	30,32,39	400
16	BARNACLE	46700	55300	092L/029		2400
17	CORDOVA	45800	55500	092L/027	39	2000
18	KING MIDAS	47700	58000	092L/020	40	500
19	ANSWER	40400	54600	092E/023		350
20	BRITANNIA	41900	58300	092L/013		1900
21	BIG STAR	42300	59300	092L/017		2500
22	MONITOR	42600	57300			1500
23	NORTH FORK EXPL.	48800	57800	092L/021		750
24	GOLD SPRING	47600	57300	092L/039		1750
25	BODEN	44300	54400	092L/022		1200
26	MAQUINNA	44800	55300	092L/023		600
27	OMEGA	45500	54600	092L/024		1400
28	PANDORA	45300	55700	092L/026		850
29	LUCKY STRIKE	47300	54500	092L/030		3750
30	FRIEND	39200	57800	092E/003		2500
31	PROSPERITY	41400	55500	092L/007		1000
32	PEERLESS	45300	54200	092L/025		1900
33	F.L./RIDGE	46200	55000	092L/028		2600
34	CHURCHILL	47400	55800	092L/031		2250
35	CAVALIER	47100	55800	092L/032		2500

NOTE:
1. DEPOSITS 1 TO 5 REFERRED TO AS MAJOR PRODUCERS. DEPOSITS 6 TO 18 REFERRED TO AS MINOR PRODUCERS. DEPOSITS 19 TO 35 REFERRED TO AS PROSPECTS.
2. BLANKS INDICATE NO AVAILABLE DATA, OR NON-APPLICABLE VARIABLE/ATTRIBUTE.
3. DEPOSITS 1 TO 30 & 34 ARE GOLD-QUARTZ VEIN PAST PRODUCERS OR PROSPECTS. THE CHURCHILL PROPERTY ALSO COVERS MAGNETITE REPLACEMENT MINERALIZATION. THE BEANO PROPERTY COVERS SKARN-TYPE MINERALIZATION. THE PROSPERITY PROPERTY SHOWS NO SIGN OF MINERALIZATION AT ALL, BUT IS INCLUDED FOR THE SAKE OF COMPLETENESS. DEPOSITS 33 & 35 ARE MAGNETITE REPLACEMENT DEPOSITS, AGAIN INCLUDED FOR SAKE OF COMPLETENESS.
4. PRODUCTION FROM BIG STAR IS INCLUDED WITH THAT OF SPUD VALLEY. PRODUCTION DATA ARE UNKNOWN, BUT INCLUDE AT LEAST 15,000 TONNES OF MINED ORE.

APPENDIX II
LISTING OF MINERAL DEPOSIT DATA FILE FOR ZEBALLOS MINING CAMP - PRODUCTION DATA

DEP	PRODUCTION (TONNES)		TOTAL METAL CONTENT (GRAMS)		(KILOGRAMS)		GRADE (Gr,Kg/TONNE MINED)			
NO	MINED	MILLED	Au	Ag	Cu	Pb	Au	Ag	Cu	Pb
1	282328	146798	5301289	2160196	4063	10093	18.7	7.7	.01	.04
2	190754	95876	1682859	575219	9195	8093	8.8	3.0	.05	.04
3	74268	51540	946589	444399	2408	12726	12.7	6.0	.03	.17
4	52596	37789	636773	432238	7370	71140	12.1	8.2	.14	1.35
5	21585		433440	239812			20.1	11.1		
6	17500		220987	92531	1563	17144	12.6	5.3	.09	1.00
7	5645	405	143074	44322	470	2982	25.3	7.9	.08	.53
8	3586	1375	46374	108705	318	347	12.9	30.3	.09	.10
9	3044		35929	16470			11.8	5.4		
10	393		11174				28.0			
11	22		373	156	44	39	17.0	7.1	2.00	1.77
12	21		3297	1400	33		157.0	66.7	1.57	
13	20									
14	17		1369	1586			80.5	93.3		
15	14		1245	2022	23	20	89.0	144.4	1.64	1.43
16	2		140				70.0			
17	1		156	31	0	4	156.0	31.0		4.00
18	1		156	31	10		156.0	31.0	10.00	
19										
20										
21										
22										
23										
24										
25										
26										
27										
28										
29										
30										
31										
32										
33										
34										
35										

APPENDIX III
LISTING OF MINERAL DEPOSIT DATA FILE FOR ZEBALLOS MINING CAMP - GEOLOGICAL FEATURES OF HOST ROCK

DEP	HOST ROCK TYPE						HOST ROCK				DIST(M)/BRG FROM NOSE OF Z.STOCK	
			(I)	(C)								
NO	Tg	Jg	lJB	lJB	uTrQ	muTrK	STRIKE	DIP	D/DRN	DYKES	DIST	BRG
1	3	0	3	2	0	0	010	60	270	5	1700	185
2	3	0	1	0	0	0				1	3400	160
3	0	0	3	2	0	0	160	90		2	3400	175
4	3	0	0	0	3	3				3	2270	110
5	3	0	2	0	0	0				2	1890	170

APPENDIX III
LISTING OF MINERAL DEPOSIT DATA FILE FOR ZEBALLOS MINING CAMP - GEOLOGICAL FEATURES OF HOST ROCK

DEP	HOST	ROCK	TYPE				HOST	ROCK			DIST(M)/BRG FROM NOSE OF Z.STOCK	
		(I)	(C)									
NO	Tg	Jg	lJB	lJB	uTrQ	muTrK	STRIKE	DIP	D/DRN	DYKES	DIST	BRG
1	3	0	3	2	0	0	010	60	270	5	1700	185
2	3	0	1	0	0	0				1	3400	160
3	0	0	3	2	0	0	160	90		2	3400	175
4	3	0	0	0	3	3				3	2270	110
5	3	0	2	0	0	0				2	1890	170
6	3	0	0	0	0	0				2	2270	170
7	3	0	0	0	0	0				2	2650	150
8	3	0	0	0	0	0				2	4730	125
9	0	0	3	0	0	0	135	80	045	2	2650	210
10	3	0	0	0	0	0				5	2650	165
11	0	0	3	0	0	0				3	4910	200
12	0	0	3	3	0	0	360	80	090	2	5100	185
13	3	0	0	0	0	0				5	2270	165
14	3	0	0	0	0	0				2	2840	135
15	0	0	3	2	0	0	080	80	000	3	4910	212
16	0	2	3	0	0	0				5	1890	315
17	0	3	0	0	0	0				2	1130	295
18	0	0	0	0	3	5				2	2650	035
19	0	0	3	0	0	0				2	5480	205
20	3	0	1	0	0	0				5	1130	160
21	3	0	0	0	0	0				1	4160	140
22	3	0	0	0	0	0				5	5670	120
23	0	0	0	0	0	3				5		
24	0	0	0	0	0	3	145	60	225	3	2270	020
25	0	0	3	0	0	0				5	2460	245
26	0	3	3	0	0	0	060	75	360	5	1520	250
27	0	2	3	0	0	0	050	80	135		1510	275
28	0	3	0	0	0	0					950	270
29	0	0	0	0	0	0				3	3030	310
30	0	0	3	3	0	0	135	50	225	2		
31	0	0	3	2	0	0	135	90		0	4350	196
32	0	0	3	0	0	0				2	2650	270
33	0	0	3	0	3	0				3		
34	0	3	0	0	3	0	150	45	045	3	2080	340
35	0	3	0	0	3	0				5		

HOST ROCK TYPE;Tg - TERTIARY CATFACE INTRUSIONS (ZEBALLOS STOCK);
Jg - ISLAND INTRUSIONS; lJB - BONANZA GROUP(I-IGNEOUS, C-CALC-SILICATE OR CARBONATE); uTrQ & muTrK - QUATSINO FORMATION & KARMUTSEN FORMATION OF THE VANCOUVER GROUP.
0 - ABSENT; 1 - PRESENT; 2 - MINOR; 3 - MAJOR; 5 - PRESENT TO AN UNKNOWN EXTENT

DYKES,PRESENCE OF DYKES OF VARYING COMPOSITION; 0 - ABSENT; 1 - PRESENT 2 - MINOR; 3 - MAJOR; 5 - PRESENT TO AN UNKNOWN EXTENT

DIST FROM NOSE;BEARING & DISTANCE FROM NOSE OF INTRUSION TO DEPOSIT

APPENDIX IV
LISTING OF MINERAL DEPOSIT DATA FILE FOR
ZEBALLOS MINING CAMP - GEOLOGICAL FEATURES OF VEINS

DEP NO	MAJOR VEIN/S STRIKE	DIP	D/DRN	2NDARY VEIN/S STRIKE	DIP	D/DRN	NO MINZ VEINS	TYP VEIN WIDTH(CM) MIN	MAX	ASSOC ZONES	AV SHEAR WIDTH(CM) MIN	MAX
1	080	65	315	065	80	180	5	15	30	1	30	90
2	055	80	315	070	85	315	3	15	20	1	10	60
3	045	70	135	045	90		2	5	8	1	5	60
4	090	75	180				1	20	25	1	8	45
5	040	80	135	110	80	225	3	2	12	1	30	90
6	040	75	135	040	80	135	2	1	15	1	3	90
7	045	80	135	060	60	315	7	8	12	1	10	45
8	090	85	360	090	90		5	0	30	1	25	75
9	045	75	315	032	80	315	2	3	30	1	3	30
10	035	90		057	80	315	7	1	20	1	5	75
11	160	70	045				1	0	15	1	4	20
12	000	90								4		
13	040	75	135				1	1	10	1	3	90
14	095	80	180	080	90		2	3	8	1	3	25
15	045	90					1	0	35	2		
16	000	90		000	65	135	4	5	10	1	5	60
17	063	80	135				1	0	25	1	5	45
18	176	90		000	90		5	0	8	1	10	20
19	057	75	315	090	90		3	2	5	1	3	5
20	050	90		060	80	315	4	1	3	1	10	60
21	090	90		090	90		10	0	5	1	150	1500
22												
23	010	75	045				1	3	12	1	15	25
24	175	60	135	030	70	135	2	3	20	1	15	20
25	090	72	360				1	5	15	1	15	60
26	090	80	360				1	5	15	1	45	75
27	052	80	135				1	5	10	1	10	30
28	058	90					1	0	10	1	15	180
29	047	90		050	90		2	4	8	1	5	15
30	160	70	135	050	90		3	5	10	1	15	60
31												
32	065	90					1	5	5	3		
33										4		
34	155	60	225				1	0	30	1	50	75
35										4		

ASSOCIATED ZONES; 1 - VEINS INTIMATELY ASSOCIATED WITH SHEAR ZONES; 2 - VEINS ASSOCIATED WITH DILATANT ZONES; 3 - MINERALIZATION ASSOCIATED WITH CONTACT ZONE; 4 - ASSOCIATED REPLACEMENT (SKARN) ZONE

TYP VEIN WIDTH; TYPICAL VEIN WIDTH, MOST PRODUCTIVE VEINS SHOW A WIDE RANGE IN WIDTH (E.G. 1-100CM), BUT THE BULK OF SUCH VEINS USUALLY SHOWS CONSIDERABLY LESS VARIATION (E.G. 10-30CM). THE LATTER VARIATION IS DESCRIBED AS TYPICAL MINIMUM AND TYPICAL MAXIMUM VEIN WIDTH.

APPENDIX V

LISTING OF MINERAL DEPOSIT DATA FILE FOR
ZEBALLOS MINING CAMP - VEIN MINERALOGY AND CHARACTER

DEP	ASSOCIATED VEIN MINERALS									SH'TD	VEIN	TENL		DIST(M) TO
NO	Pyr	Sp	Aspy	Py	Cpy	Gn	Qtz	Cc	Ank	ZONES	FORM	FEAT	REPL	CONTACT
1	1	2	1	3	1	2	3	2	3	3	2	3	2	+ 57
2	0	2	0	2	5	2	3	0	0	2	2	3	0	+ 473
3	0	0	3	3	5	5	3	2	2	0	2	3	3	- 473
4	5	0	0	5	3	3	3	0	0	2	2	2	3	- 151
5	0	3	0	3	5	2	3	0	0	0	1	3	0	+ 473
6	0	2	2	2	2	3	3	0	0	0	1	3	0	+ 529
7	0	2	2	3	2	2	3	0	0	0	2	2	0	+1229
8	0	2	3	3	5	2	3	0	0	0	1	2	0	+ 964
9	2	3	2	3	0	3	3	2	0	2	4	5	0	-1229
10	0	2	2	2	0	2	3	0	0	2	2	2	0	+ 491
11	3	3	0	2	1	2	3	2	0	0	2		0	-2646
12	3	0	0	0	0	0	3	3	0	0		0	3	-1985
13	2	0	2	0	0	0	3	0	0	0	1	5	0	+ 548
14	0	1	2	2	0	1	3	0	0	0	2	2	0	+1040
15	3	3	0	2	1	2	3	2	0	0	2	5	5	-3175
16	2	0	0	0	2	0	0	3	0	0	3		0	-1890
17	0	0	2	2	0	0	3	0	0	0	1	5	0	-1115
18	0	2	2	2	2	1	3	0	0	0	2		3	-2174
19	0	0	0	2	0	0	3	3	0	0	1	2	0	-3400
20	0	0	0	2	0	0	3	2	0	0	1	2	0	+ 113
21	0	1	2	3	0	1	3	2	0	0	2	3	0	+1130
22	0	0	0	3	0	0	3	0	0	0	1	0	0	+ 435
23	2	3	3	0	2	0	3	0	0	0	1		0	
24	0	1	0	3	2	1	3	0	0	0	2	5	0	-1985
25	5	1	1	1	0	0	2	2	0	0	2		0	-1814
26	1	1	2	1	1	1	3	0	0	0	1	5	0	- 983
27	0	1	1	2	1	1	3	2	0	0	1	5	0	-1852
28	0	0	0	1	0	0	3	0	0	0	2		0	- 718
29	1			2			2				1		0	-2948
30	1	1	1	1	1	0	3	2	0	0	1	5	0	
31	0	0	0	0	0	0	0	0	0	0		0	0	-2022
32	0	1	0	0	1	0	3	3	0	0	1		0	-2211
33													3	
34	0	2	3	2	0	2	3	0	0	0	2	3	0	
35													3	

ASSOCIATED VEIN MINERALS ; MINERALS WHICH ARE PRESENT ALONG WITH Au AND Ag; 0 - ABSENT; 1 - MINOR; 2 - MODERATE; 3 - MAJOR; 5 - PRESENT TO UNKNOWN EXTENT.

SH'TD ZONES ; OCCURENCE OF SHEETED ZONES ON THE VEIN: 0 - ABSENT; 2 - MINOR; 3 - MAJOR

VEIN FORM;LOCAL FEATURES OF THE VEINS; 1 - PLANAR & APPROX PARALLEL-SIDED; 2 - VARIABLE IN WIDTH & ATTITUDE; 3 - LENTICULAR; 4 - COMBINATION OF 2 & 3.

TENL FEAT,TENSIONAL FEATURES,E.G.DIAGONAL GASH VEINS; 0 - ABSENT 2 - MINOR; 3 - MAJOR; 5 - PRESENT TO UNKNOWN EXTENT

REPL,ASSOCIATED REPLACEMENT/ALTERATION; 0 - ABSENT; 2 - MINOR ; 3 - MAJOR; 5 - PRESENT TO UNKNOWN EXTENT

DIST TO CONTACT;DISTANCE FROM DEPOSIT TO NEAREST CONTACT BETWEEN THE ZEBALLOS STOCK AND COUNTRY ROCK(+,WITHIN THE STOCK; -,WITHIN THE COUNTRY ROCK).