CONTACT INFORMATION
Mining Records Curator
Arizona Geological Survey
416 W. Congress St., Suite 100
Tucson, Arizona 85701
602-771-1601
http://www.azgs.az.gov
inquiries@azgs.az.gov

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Geology of the Robinson (Ely) Mining District, in Nevada

A Preliminary Report on the Primary Monzonite Porphyry Intrusive Orebodies, and How They Are Formed

[redacted]

duced into a closely spaced network of fine fractures in

The peanut porphyry was not so severely affected because

much of it was situated outside of the most disturbed lines,

appear in the grabens, the following incorrect picture is immediately …

… will be a valuable aid and represent money well spent.

B

GEOLOGIC REPORT
OF THE
ELY, NEVADA, QUADRANGLE

by

Daniel B. Nolan

Mining ---198
Mr. E.Wisser , in charge

University of California
June 4, 1948

INTRODUCTION

The main body of this report treats on the hypothetical study of a hydrothermal ore body genetically related to magmatic intrusion and concomitant tectonic disturbances. The summary and conclusions were fabricated after the study and analysis of available published and personal literature.

Emphasis is directed to the particular delineation of of the pattern of the mineralized zone. The departure from the normal space relationships of disseminated copper ore bodies was dependent upon the strong influence of structural features. The accompanying maps should serve to further bring out this relationship.

Special acknowledgement is given to Mr. E. Wisser and Mr. E.N. Pennebaker for their personal reflections in guiding the pattern and style of attack on the problem.

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3. Trans. of A.I.M.E. 6___"Transverse Faulting at Kennecott,and
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5 Ore Deposits as Related to Structural Features
   E.N.Pennebaker , P128 1942

6. Personal Notes of Mr. E. Wisser .

GEOLOGIC[illegible] REPORT
ON

ELY, NEVADA

Location. The Robinson Mining district, of which this report covers, lies in a pass through the Egan Range, a north-south mountain block, and is bounded by an area 8 miles long and 1½ miles wide.

General Geology of the District

The Paleozoic sediments that are displayed within the exposed belt contain a variety of geologic types. Limestone is by far the most abundant rock, sandstone is present in important amounts, and siliceous shales, commonly resembling argillite, appear in two formations.

	Formation	Description	Thickness
Pennsylvania	Arcturus Ls.	Massive, shaly bbds.	400'
	Rib Hill Ls (Rss)	SS, Sanoyls, Limey SS	3200'
	Ely Ls (Cr)	Massive to thin-bedded, gray, blue, dark blue.	3000'
— —	— — Conformity	— — — — —	—
Mississippi	Chainman shale	Brittle argilite, local Carbonaceous shale, siliceous, shattered well to permit mineralization	250-600'
	Band Ls (C;)	Dense Ls to medium coarse marble; sparse chert, fairly thick bedded	100-475'
	Pilot shale	Siliceous	250-850'
— —	— — Conformity	— — — — —	—
Devonian	Nevada Ls (Dm)	Thin to medium bedded. No chert. Massive beds. Black to white.	4000'
Ordovician	Eureka qtzite	Fine grained dense qtzite; no cement.	150'
	Pogonip Ls.	Thick and thin bedded, gray	1400'

Intrusives

"Ore Porphyry". Always entirely altered, and originally a latite porphyry. Small to medium grained. Orthoclase phenocrysts are relatively small. The ground mass was originally probably glassy. It now is silicified, sencitized, and contains the magnesium mica, phlogopite.

"Peanut Porphyry". The texture varies from dense, aphanitic to coarse grained porphyritic material. It is a Monzonite or quartz Monzonite porphyry. Where not aphanitic, the rock consists of phenocrysts of orthoclase in a groundmass of plagioclase, hornblende, orthoclase, and quartz. Generally, the "peanut porphyry" is later than the "ore porphyry".

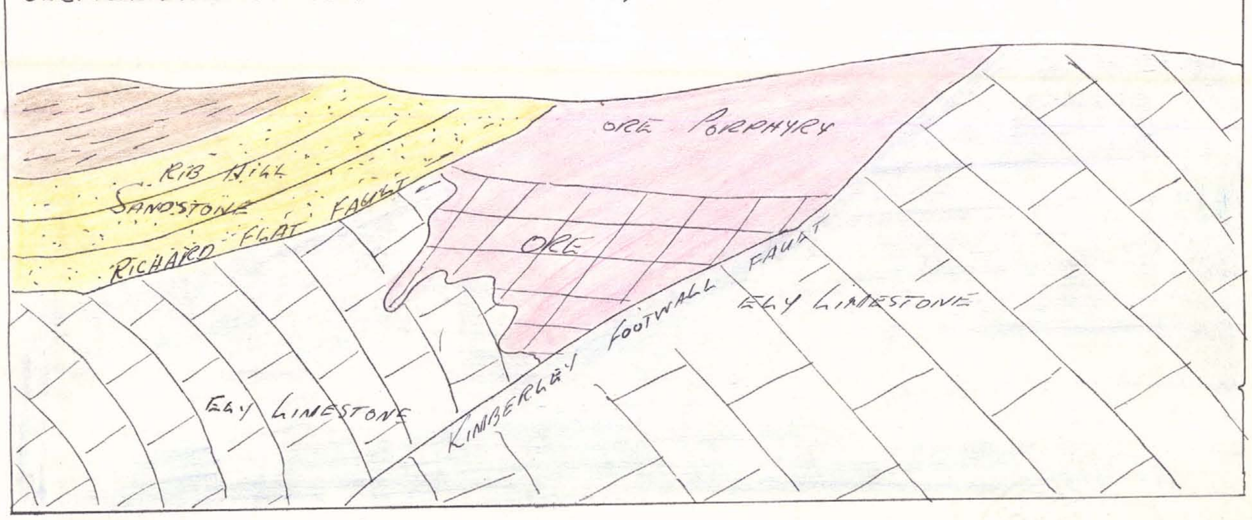
Post-ore Rhyolite Group. The textures are very variable. It contains obsidian, dense white rhyolite, and intrusive breccias. The breccias tend to work into the best fractures. The bulk of the fragments will be of the intruded rock. Where the breccia has picked up enough fragments of ore porphyry, it makes some ore. The main body of the rhyolite is in the west end of the Liberty Pit. The form of the breccia is often extremely irregular. Explosive breccia action exists sometimes without rhyolite being introduced.

The extrusive rhyolite series has a tuff at its base, then a thirty-foot layer of porphyritic pitchstone, then massive rhyolite, mostly with abundant phenocrysts. Some dense gray rhyolite with few phenocrysts is scattered in the area.

General Structure

A general anticlinal structure runs east to west along the center line of the map. This is highly overturned and distroted in the west. The fold is here recumbent to the north; in the east part, the fold is more symmetrical. In the west part the faults are flat, dipping to the south in an imbricated system at angles not greater than 65°, normally. The Kimberley Footwall fault is the footwall of the system.

SECTION THRU MORRIS BROOKS AREA, LOOKING N. 60° W.



North-south normal faulting prevails in the east part giving horsts and grabens. The anticlinal structure is plainly seen in the horsts. In the graben the structure seen on the erosion surface does not fit in well with the anticlinal feature, indicating either a considerable horizontal component to the movement or the north-south faults, or that the anticline was overturned prior to this north-south faulting.

Intrusion

The intrusion zone of ore porphyry bodies follows a pronounced lineal trend from east to west for nearly 6 miles. In the western area, however, the intrusives have worked into the zone of compression faults, and appear low down on the flank of the anticline.

The ore porphyry bodies rest upon an irregular sedimentary floor, so that the definition of a stock does not fit. They have worked in along bedding planes, and arched the roofs, as have laccoliths. In places the intrusive has ruptured and engulfed portions of the roof fault structures, so that it appears ragged and irregular.

Bodies of ore porphyry prefer shale-limestone contacts. Zones of pronounced faulting gave still easier pathways for the intrusive.

In the Emma and Ruth mines, the peanut porphyry appears to be later than the ore porphyry. Both porphyries were intruded, cooled, and fractured premineralization.

Metamorphism

Hydrothermal metamorphism is confined to the main zones of intrusion, and grades in degrees outward from the local areas of the channelways through which the magma rose from its igneous reservoir.

The limestone was silicified by metasomatic replacement forming a Jasperoid rock. Chalcedony in many places fills fractures in the earlier quartz. The quartz grains also have small inclusions of fluorite, apatite, or calcite. Sulfides in seams and bunches are disseminated through the rock as grains and irregular aggregates.

Some of the limestone is altered to calcium silicate. Bodies of pyrite or pyrite and magnetite occur adjacent to areas wherever the porphyry is pericitized, the shales essentially altered, or the limestone "jasperized" or changed to garnet or tremolite.

The Pilot and Chainman shales were converted to pyritiferous hornstones. The gold ores of the Chainman, Aultman, and Revenue mines came from a blanket deposit between the Joana limestone and the Chainman shale. Pyrite is a constant constituent, and they contain, as well, wallastonite, epidote, calcite, pyrite, magnetite, pyroxene, sericite, zoisite, and brown mica.

The porphyry was altered by various changes in the hydrothermal solutions. The initial alteration was followed by quartz bering solutions which deposited the silica in existing fractures. Sulfides later entered, and deposition occurred involving metasomatic processes as well as fracture filling.

Correlation of Literature

In the course of analysis of the written material on the area, a considerable divergence of opinion has been expressed by various geologic authors concerning the major structures.

Consequently, correlation of the features has been one of examining the most recent surface and underground mapping, and superimposing on it the earlier areal maps of different authors in an effort to show consistent significant controls in the genesis of the intrusion and mineralization.

It was hoped in this way that a reasonable explanation could be given for the geologic facts by rejecting anomalous and inconsistent mapping, while at the same time assemble relevant material that would aid in the reconstruction of a logical interpretation of the tectonic, and occurrence of the igneous geology, in particular.

One of the main characteristic features of this region is the lineal extent of the ore porphyry intrusion from east to west. Most recent papers show the intrusions rudely paralleling an east-west anticline, while earlier work indicates the magma as cross-cutting a series of north-south folds. The later papers indicate continuous igneous intrusion along the east-west flat fault planes, while earlier papers report in their vertical sections intermittent feeder channels through which the molten material was fed near the surface from the deep reservoir. However, most literature does show the magma spread out into the adjacent country away from the fault plane forming sill-like bodies, or "chonoliths".

I have compared in detail the fault structures by Pennebaker with the surface geologic map by Spencer. The Footwall fault coincides favorably with the north outcrops of the monzonite porphyry in the Kimberley area. The Flat fault forms a rough south boundary of the linear outcrop of the monzonite.

In the same area to the north, east of Kimberley, the Footwall fault also coincides with the one side of the fingers of the monzonite that extended beyond the main line of intrusion, giving confirmation of local control of the emplacement of the cross-cutting intrusive.

In general, the axis of the anticline shown in Pennebaker's map strikes in the same east-west direction as the monzonite. Severe faulting has dissected the anticline into several offset parts. But extrapolation of the faulted elements to their pre-fault position tends to add momentum to the expression that the entry of the magma bodies was strongly influenced by this fold and the related axial faults.

The portion of the anticline in the western part of the area, according to Pennebaker's map, has suffered overturning and more severe faulting than the eastern segment of the fold. The axis of the overturned fold follows the western extension of the monzonite outcrop. The major east-west faults in the west axis of the fold are parallel to the line of intrusions.

The north-south faults seem to have less direct influence to the control of the magma.

Thenorth-south grabens separated by a horst and bounded by normal faults, in the Ruth area on Pennebaker's map probably formed during the regional Tertiary warping when similar down-thrown blocks were created in the Basin Range.

The following summarization and conclusions emphasize the more recent and more accurate work done by Pennebaker, and papers by him have largely influenced the foundation of the genetics of this area, as outlined below.

Genetic Summary

Relation of Folding to Faulting

The major fault structures near the western limit of the anticline are clearly northeast and northwest structures. Here the sediments are most severely distorted and overturned. The major fault pattern is accompanied by a large number of smaller subsidiary fractures striking in directions closely parallel to these master structures.

The movement in the northwest direction is in most places clearly later than the northeast faults, as the latter commonly terminate abruptly against the plane of the former.

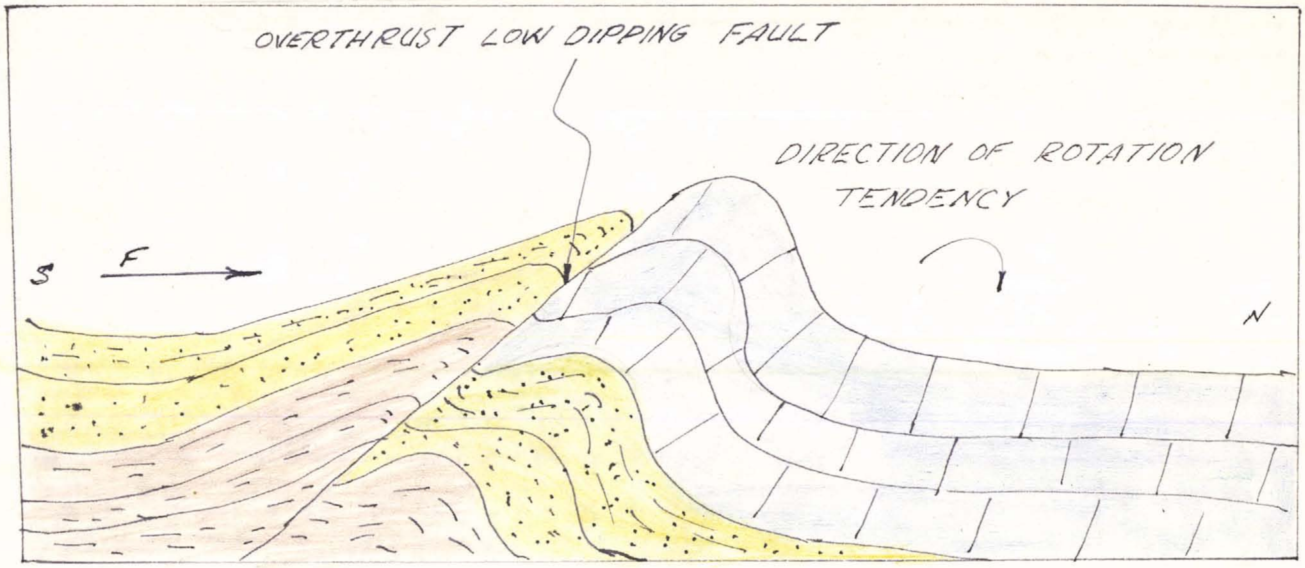
In my opinion, the faulting may be an expression of two stages of unrest. After the deposition of the Paleozoic sediments, the area was subjected to impulses of compression from the south.

Representation of the stressed area may be done by the strained ellipsoid with axis of greatest and least strain. Two fault surfaces should develop, both striking east-west, but one dipping to the north, the other to the south.

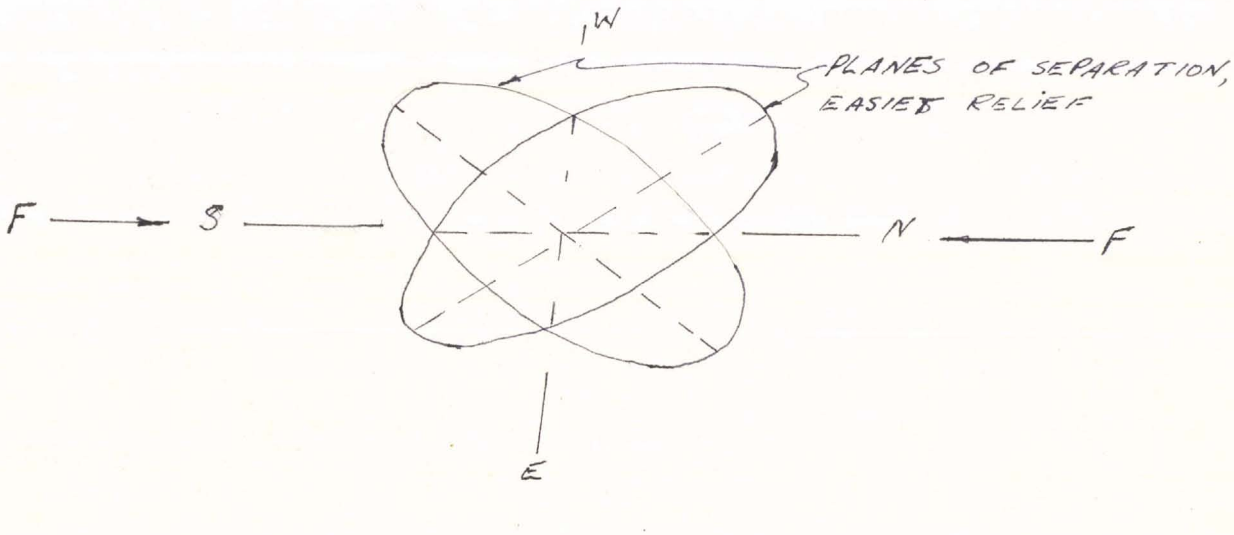
Due to the general brittleness of the beds, they should dip greater than 45 degrees.

During the formation of the anticline, shearing stresses are initiated either by the slipping of the upper beds over lower bed, or by the actual thinning of formations on the limbs of the east-west fold. Usually only one fault will be produced, as relief is generally easier in one tension direction tan the other. This fault will dip toward the easiest relief and strike at right angles to it.

IDEALIZED DIAGRAM



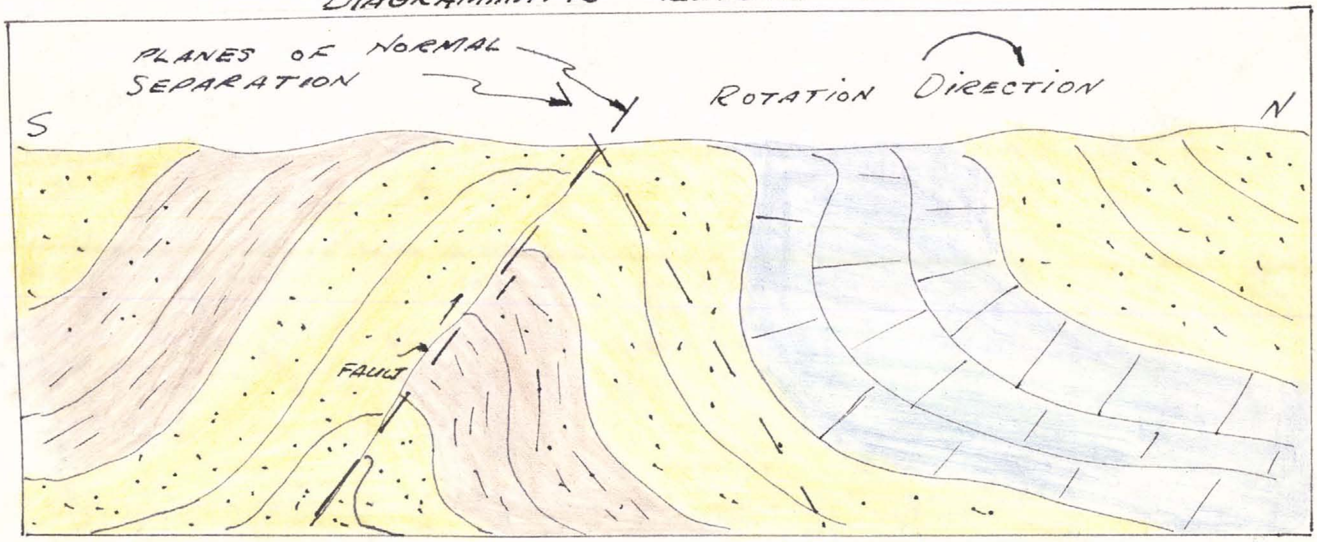
A rotational effect may well have been introduced during the overturning of the anticline. As a consequence, the shear planes along which faulting occurred were a compromise between those tending to form by direct compression and those tending to form by rotational stress. One very compromise is a thrust fault dipping toward the active stress to the south. Since similar east-west low-angle thrust faults dip to the north, the relief in tension in both directions was probably about the same.



If the rotation is carried to a rather high degree, and the folding approaches a recumbent type, these fault surfaces may have a very low dip angle. The Flat fault in the west part of the area dips at approximately

45°, and may well represent such a structure associated with the overturned anticline.

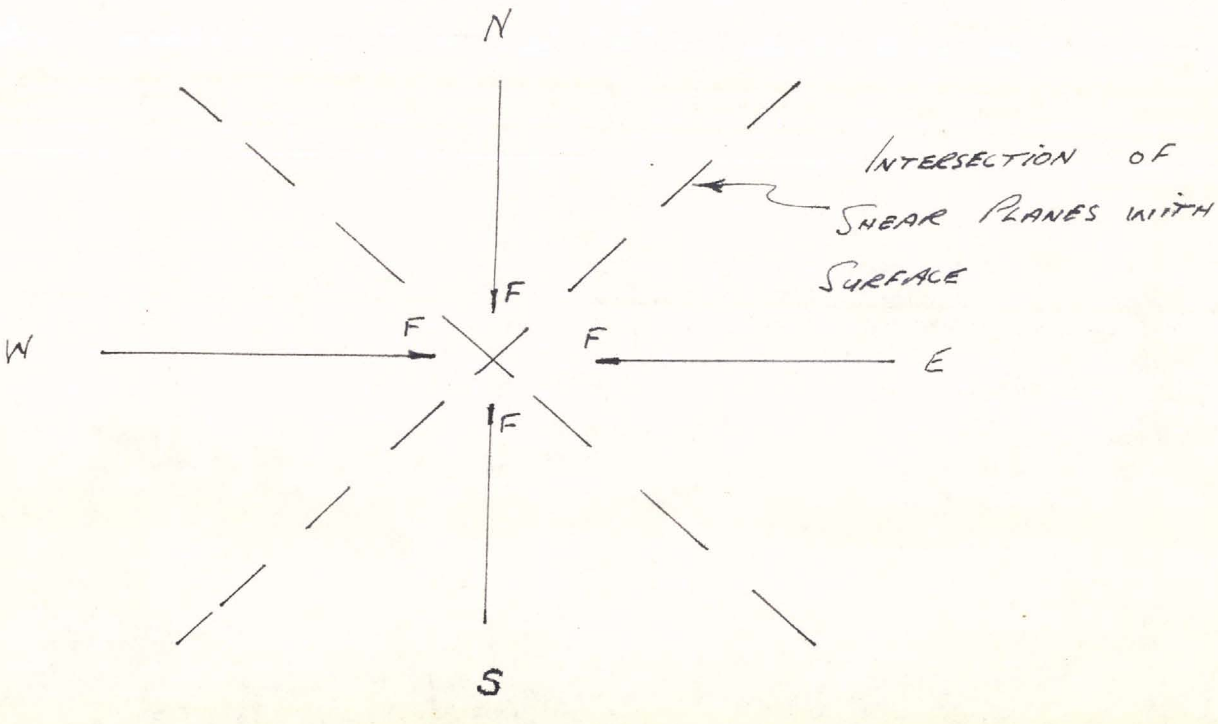
DIAGRAMMATIC ILLUSTRATION



The consequential formation of the overturned fold in the west part of the anticline, to the north, was the result of increased intensity of the force impulses which exceeded the elastic limit of the rocks involved. Concomitant minor warping of the entire area was of strong development.

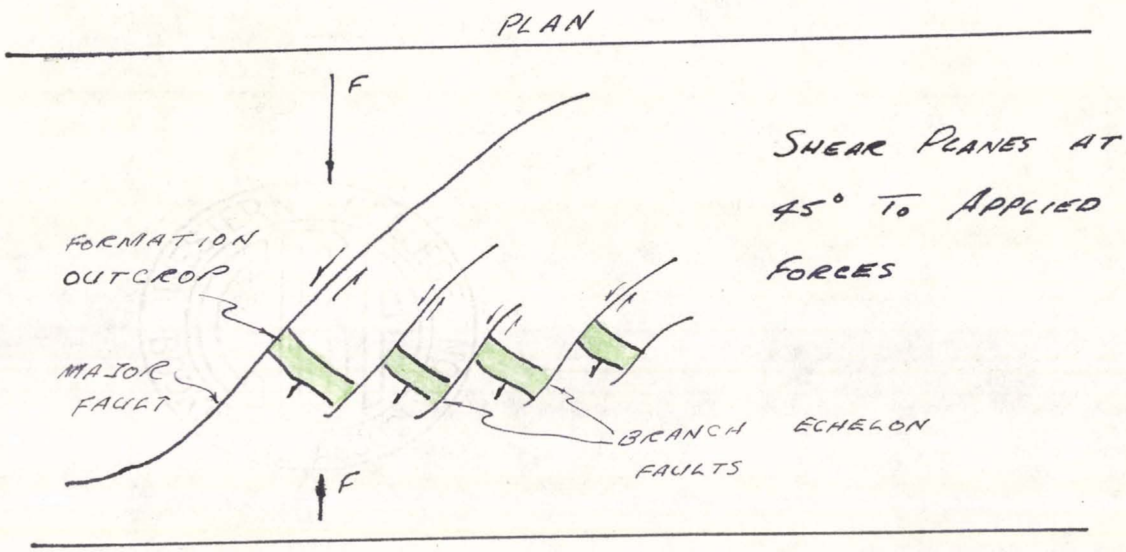
After the creation of the faults along the limbs of the anticline, another force became active in the region. These newly impinging east-west forces coupled with the pre-existing north-south forces to exact shear planes at angles of 45° to the forces.

PLAN VIEW



It is clear, according to Pennebaker's areal geology map, that the north-south forces were dominant during the early part of this secondary stage of faulting. The earlier northeast shear planes are cut off by the later northwest shear zones. Some of the northeast faults turn after traversing a certain distance and strike in the direction of the later faults.

In some areas, a series of parallel faults arrayed somewhat in echelon and paralle to the major local structure, is an expression of failure in that particular area due to inherent weakness of the beds, or to a local concentration of forces.



Instead of being applied at once in full strength, the east-west forces probably began with surges that built up to a maximum value. I do not believe that the earlier tectonic agencies broke off completely before the operation of the east-west forces, but were overlapping devices. However, in some places, the northwest shear planes have been offset by the northeast faults, but the occurrences are few and less significant than the previous relationship.

It seems the mechanics of the shear movement began first to cause separation in the northeast plane. With passing time, the shear forces resolved themselves into stresses that shifted in direction so as to create the major northwest shear surfaces.

A further analysis of the faulted structures in the west part of the region, shows the beds to have many local folds and warped planes with divergent axes. The extreme western part of the area is dominated by formations dipping to the west.

In the region just east of Kimberley, the beds show a concistent local doming with the Nevada (Devonian) limestone along the crest. The correlation of the exposures and dips in this area with those of the area directly north indicates a rude anticline instead of a dome, with the fold axis being nearly north-south.

The upturned beds along the flanks of this rough fold are greatly displaces and have been rendered a complex relationship along the break lines. This fold does not clearly appear to continue into similar repetitive structures to the east. In the eastern part of the area, the warping and minor undulations of the beds are as numerous as in thewest section. Within as short a distance of five hundred feet, the beds may change strike direction by 90 degrees. This indicates the complexity of the area, and the submissiveness of the stratigraphy to warp under pressure.

One of the most consistently dipping parts of the region is north of Lane City, where the beds dip to the east and southeast. Here, a slight down domed warp with an open end to the southeast is the chief variation in the attitude of the beds.

Along the western boundary of Pennebaker's geological map the beds dip generally to the west away from the broad north-south fold, and the rough concentric exposure of the beds bears out the existence of the broad arching in the western area.

Magmatic Intrusion

Sustained movement along the east-west structures was responsible largely for the locallization of the monzonite porphyry. The lineal trend follows quite closely the axis of the anticline and the east-west faults, giving close correlation. The propagated igneous activity was guided near the surface along this plane that projected in depth the restless magma reservoir. The relation of the intrusion in plan, to the sediments is that of a long transverse dike, cross-cutting the paleozoic rocks it encounters.

A study of the occurrence of outlying monzonite bodies indicates some definite control existed near the enlargement areas. In nearly every instance, a major fault is in contact with or is intimately associated with the outcrop of the intrusion away from the central zone. That the hot magma utilized these structures there is little doubt. As the material approached the surface, the weight of the overlying beds became less, and at specific horizons the magma spread out into the layers.

In the overthrusting of a block of folded sediments, the footwall sediments along the torn face of the thrust will tend to be separated and disturbed along the planes of sedimentation by the friction of the overriding block.

SECTION

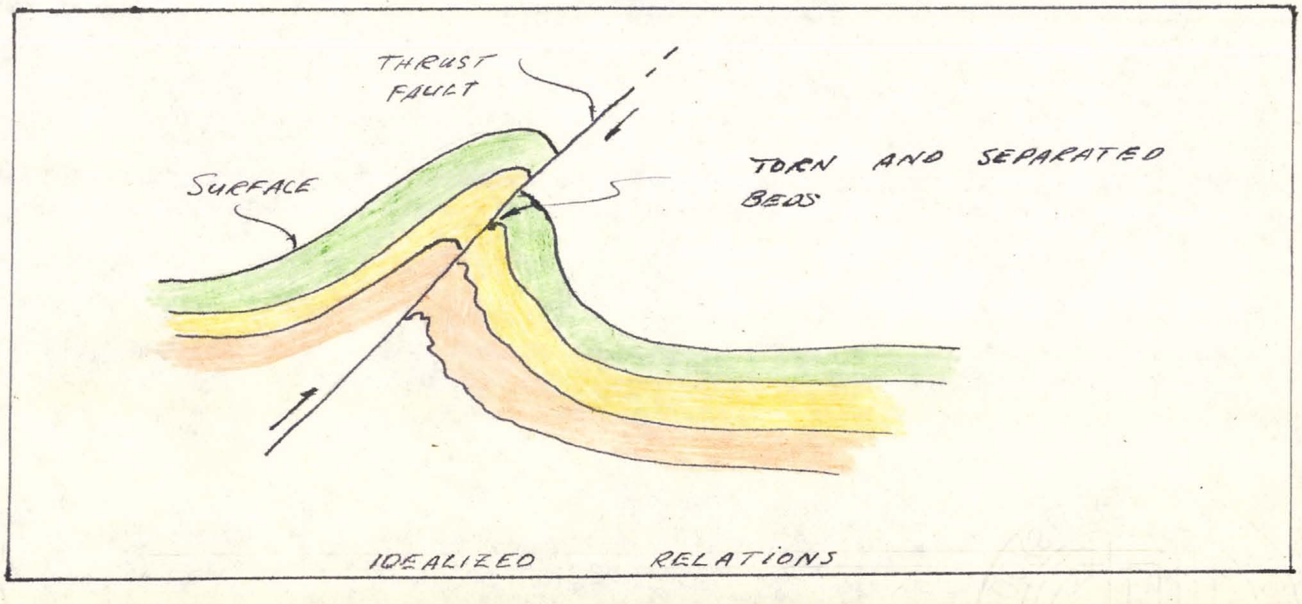
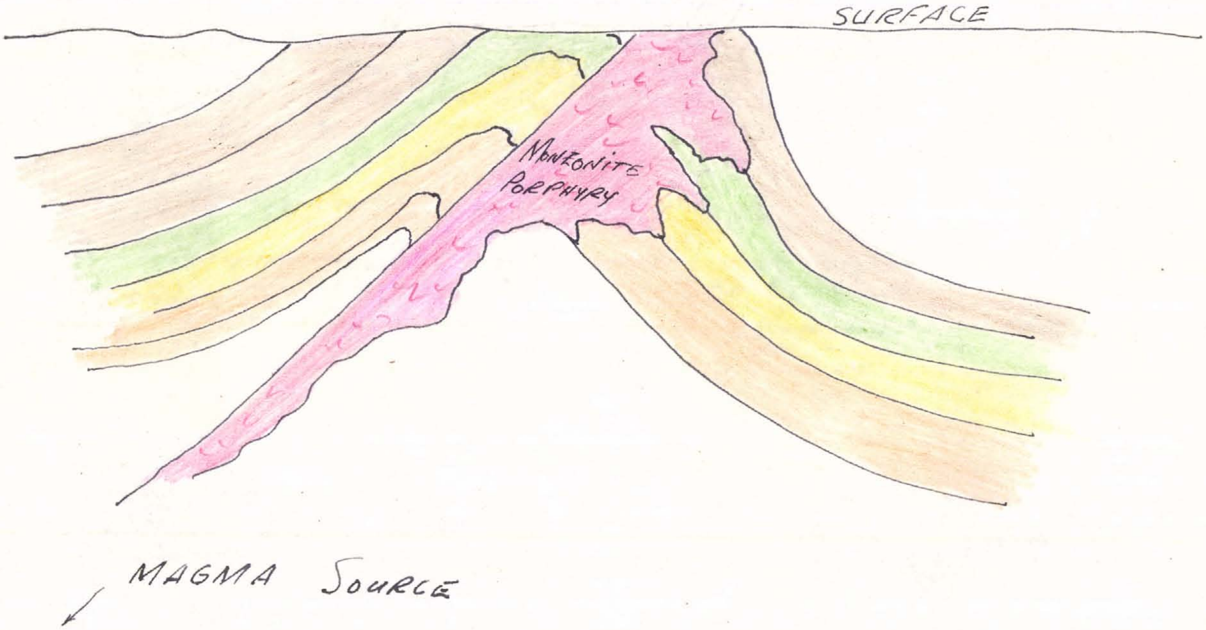


ILLUSTRATION OF ENLARGEMENT OF MAGMA ALONG SERRATED BEDDING PLANES



SECTION

According to the diagram, the invading magma, especially near the surface where the overlying sedimentary load is lighter and where greater relative movement and disturbance of the beds would take place, broke away from its restricted channel and enlarged itself laterally into the serrated and separated sediments to form these sill-like bodies. I also believe "stopping" out action of the shale and limestone beds by metasomatic replacement will help explain the occurrence of the interbedded magma.

The Tertiary volcanism poured out rhyolite and rhyolite tuff on the ore areas amd tje sedo,emts/ This later igneous activity may be related to the wide spread volcanism in the western United States during Tertiary time. The rhyolite moved up along pre-existing fault surfaces that experienced contemporaneous movement, flowing out on the surface, and butting up against the older igneous masses elsewhere.

The cold country rock caused a rapid loss of heat by the early plutonic mass, causing freezing relatively soon after emplacement. This quick solidification prevented the growth of large phenocrysts in the "ore porphyry".

The second monzonite mass, or "peanut porphyry" penetrated along the pre-heated fault planes which theearlier magma ascended along. Since the earliest intrusive is a porphyry of rather small sized crystals, and the latter intrusion is an igneous body of larger phenocrysts, a change in the physical environment during the two phases of intrusion is indicated.

Complete evidence of the more slowly cooling "peanut porphyry" is that of the relatively large and abundant feldspar crystals. In the mechanics of crystal growth, the size of the grain is a direct function of the power of crystallization of the particular mineral, and the ability of the constituents to diffuse to established crystal centers. A material of high viscosity decrease diffusion rates, but a magma, even though relatively viscous, if kept in a liquid state for a considerable length of time, and if the power of crystallization is not too great, will develop crystals of comparatively large size, such as exist in the "peanut porphyry".

I believe automatic brecciation of the peanut porphyry by its loss of heat and differential contraction was largely avoided by maintenance of a stable low temperature gradient. Such a mechanism was impotent to provide for permeable openings. The country was heated to a uniform relatively high temperature by the "ore porphyry", preventing rápid loss of heat by the later "peanut porphyry".

The greatest volume of ore itself is confined to the monzonite in an area limited by the boundary of the fault zone. This, I feel, is conclusive evidence that the brecciation of the plutonic material was the result of pre-mineralization recurrent movements or "lagging" effects along the east-west fault zone. The fresh brittle monzonite lying in the wake of these residual jolts fractured extensively in the zone of the fault. The "peanut porphyry", largely, has farther away from the center of intrusion than the earlier monzonite. But, that "peanut porphyry" occupying space within the zone of renewed tectonic activity was sufficiently crushed and broken with the ore porphyry, thereby ameliorating the condition for entry and deposition of ore minerals.

The ore solutions must be genetically related to the monzonite porphyry bodies if space and time relationships are criteria. The ore occurs disseminated in the igneous along the fault zone and out into certain adjacent sedimentary horizons.

It is evident that the ore solutions came from below via permeable passageways that may have coincided with the present east-west fault structures. If the fault planes guided both igneous intrusion and the later mineralizing solutions, it is logical that the fault served a common magmatic reservoir which genetically relates the intrusion to the mineralization.

A significant observation is that of the affection, preferentially, of the limestone by early siliceous solutions. The local movement brecciated the brittle limestone adequately to permit permeation of the area near the aureole of intense alteration and the center of emanations by the silica bearing vapors. The incompetent shale more easily flowed under stress, preventing the creation of minute fractures amenable to the entry of these solutions.

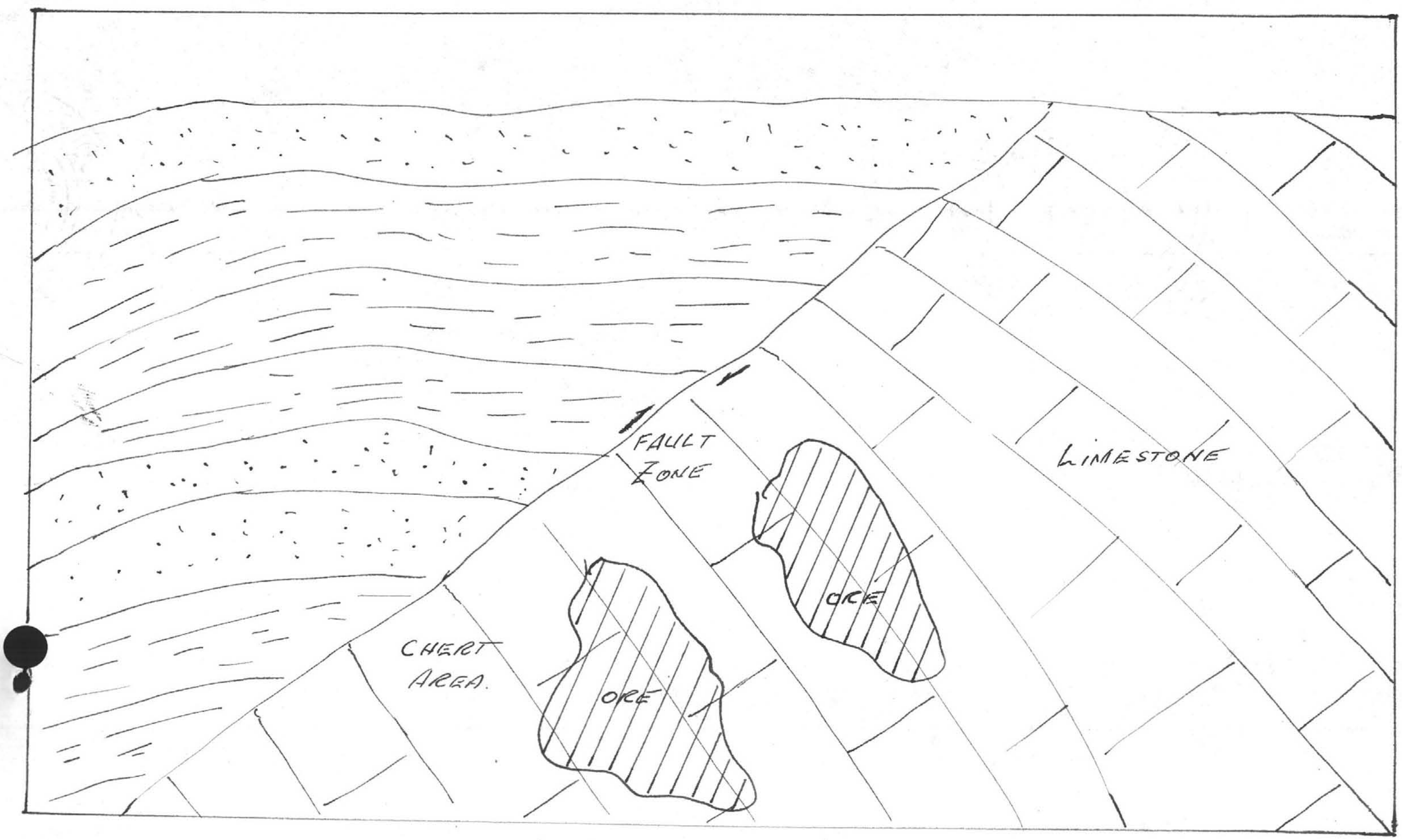
Continued later movement fractured very pronouncedly this chert area, providing for the entrapment of the later hypogone sulfide solutions.

The early hydrothermal solutions altered the feldspars and ferromagnesium minerals to seriate and chlorite wherever they contacted the fresh igneous rock.

The silica which was introduced early in mineralization was merely deposited in the limestone horizons instead of forming contact silicates. This type of replacement occurs in a low temperature environment, and helps to show some of the conditions that existed at this time.

SECTION

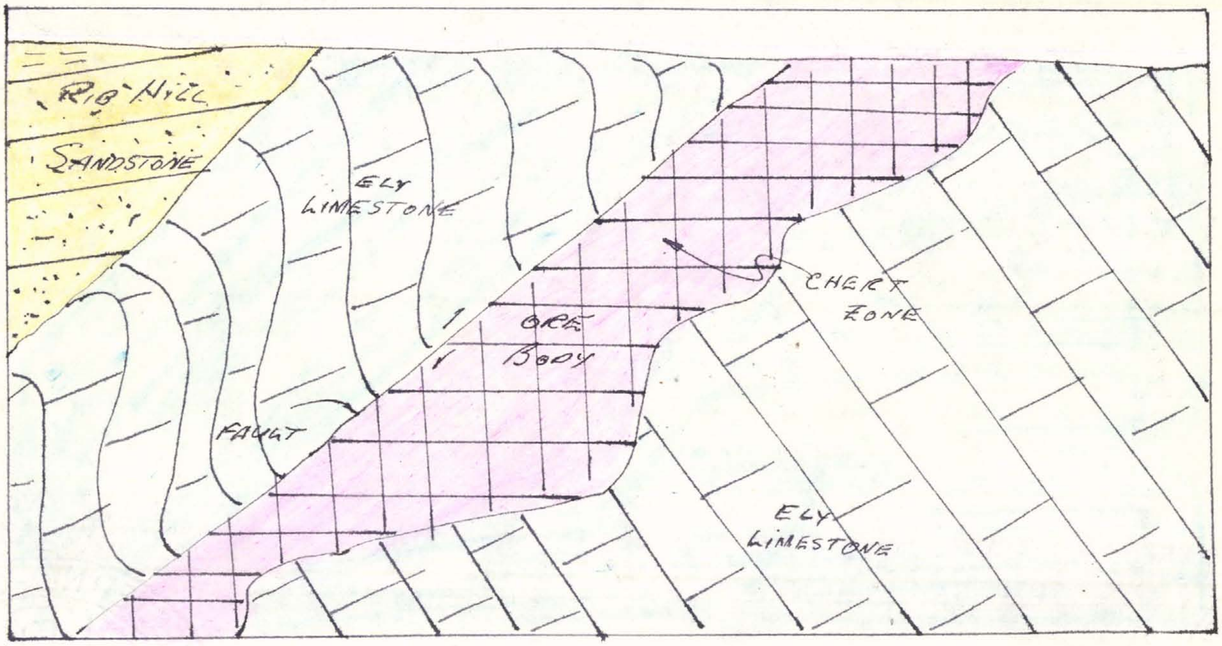
LOCALLIZATION OF ORE BODIES IN CHERT LIME HORIZON



Penetrating mineralizing solutions entered the fractured chert zone and the brecciated monzonite to form primary ore bodies, while adjacent unsilicified sandstone beds are unmineralized.

The diagram below shows how ore bodies localized in the zone of chert and limestone horizons is capped by fault structures.

SECTION OF OREBODY AS REPLACEMENT IN BRECCIATED CHERT ZONE



The basic sulfides of iron and copper, as well as some lead and silver are the ore minerals. The chief ores are pyrite, chalcopyrite. They have been completely oxidized above the water table to malachite, other carbonates, copper oxide, and native copper. The chief new mineral formed is delafossite. The $CuFeO_2$ must contain 4 to 6 percent copper for direct smelting. Thus the primary mineralization transformed the igneous masses into low-grade ores.

Where the porphyry ore is oxidized, the ore is uneconomic. But low-grade ore is economic as a result of three factors:

1. Large volume mining.
2. Simple methods.
3. Susceptibility to low-cost mining methods.

The low grade ore also can be concentrated. The Liberty Pit ore body is near the surface. Here the ore was oxidized giving uneconomic material. But at greater depths, the migrating copper is present as secondary chalcocite in the replacement of other primary sulfides.

Some lead and silver ore bodies occur as replacement bodies in limestone. The local control is by fracturing. These ores lie farther from the intrusive contact at lower temperature regions than where the copper minerals were deposited. The lead and silver sulfides were oxidized to $PbCl_2$ and AgCl (ceragyrite), with little or no downward migration.

— FINIS —

ORE OCCURRENCES
and
SAMPLING AVERAGES

The great payable ore bodies of the district are part of the porphyry mass, mineralized by pyrite and copper glance. The lower limits of oxidation is about 1oo to 150 feet, very irregular, and has no limit to the ground water level.

The pay ore lies under the zone of oxidation, and is about 400 feet thick. The copper values are not evenly distributed, and the richer ground appears controlled by local conditions, permitting the free descent of surface waters. The workable ore bodies are tertiary, not secondary, and result from the leaching of the former secondary ores of the oxidized zone.

Sample averaging yields 10 % pyrite and 3.25 % chalcocite. Many parts of the ore body carry 8 to 10 % copper. At Copper Flat, theporphyry ore differs from that of the Ruth mine in an important particular, that is, in the zone of oxidation the copper has not been leached out, but remains in the form of carbonates.

The ore bodies are of enormous extent. That of the Eureka Mine is 700 by 800 feet. That of the Ruth mine has a width of 50 to 250 feet, and has a known vertical thickness of 250 feet. The rock is leached for 50 to 150 feet down, carrying not over one half % copper. Below this, minute seams of pyrite and copper glance occur in decomposed porphyry. At the Ruth Mine, the ore bodies become low grade at a depth of 400 feet, the approximate limit of secondary enrichment. The ore has an average value of 2.2 % copper at the Eureka Mine.

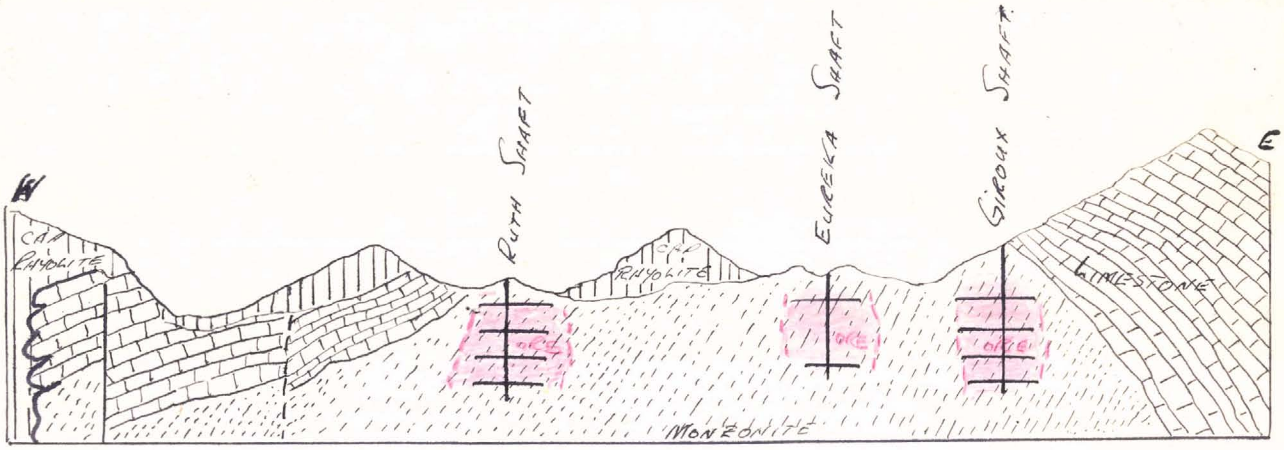
1926

ORE ESTIMATION

EXTRACTED MILLIONS		REMAINING MILLIONS		RATIOS	
TONS ORE	LBS. CU	TONS ORE	LBS. CU	CU/AU	CU/AG
30	700	85	2,500	30,000	10,000

ELY DISTRICT

LONGITUDINAL SECTION SHOWING THREE PRINCIPAL SHAFTS.



SCALE 1 MILE

GEOLOGIC MAPS

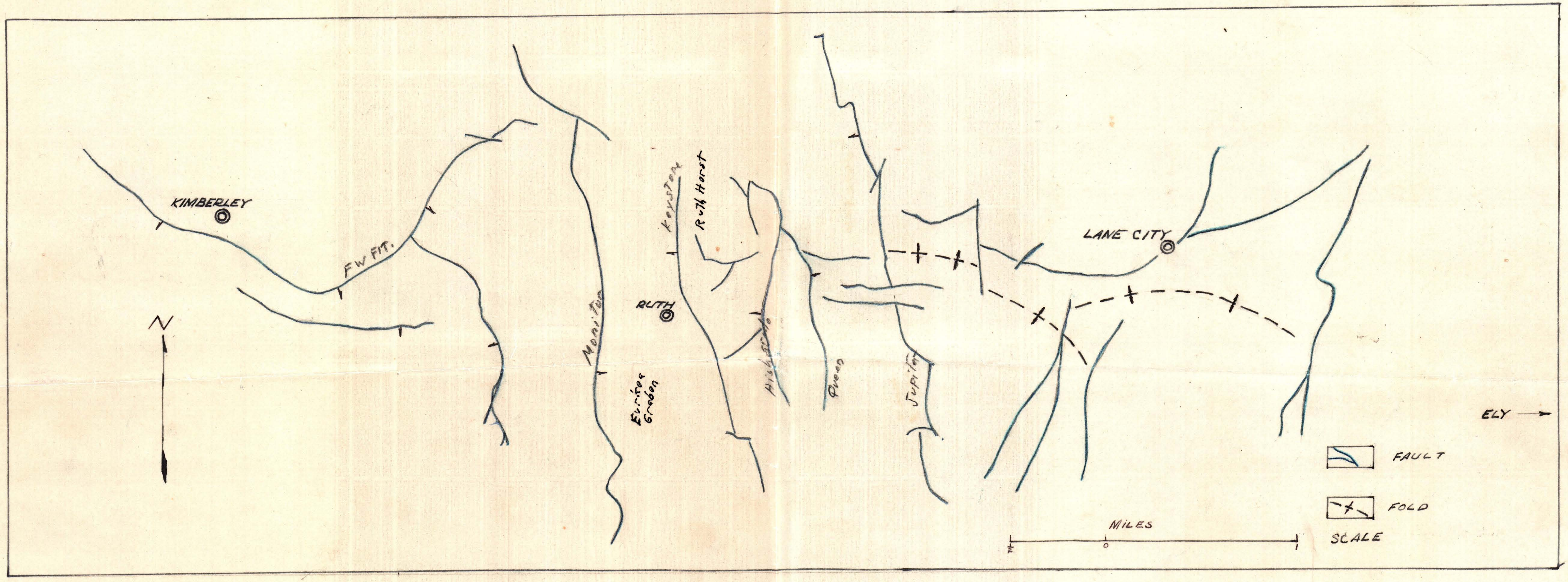
OF THE

ELY NEVADA

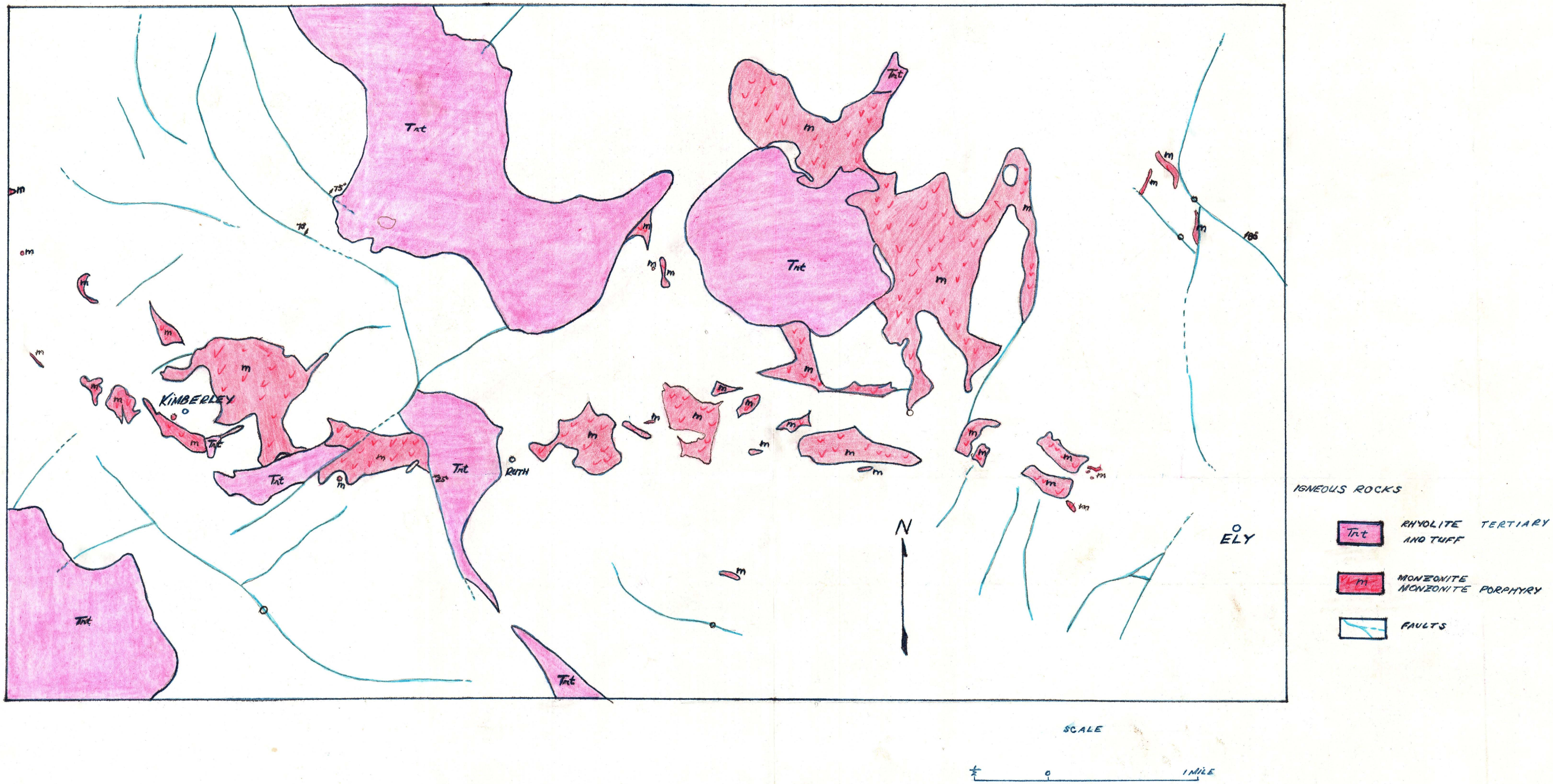
QUADRANGLE

(4 ENCLOSURES)

ROBINSON MINING DISTRICT
ELY NEVADA



PLAN VIEW SHOWING RELATION OF FAULTING TO FOLDING - AFTER PENNEBAKER



ELY NEVADA

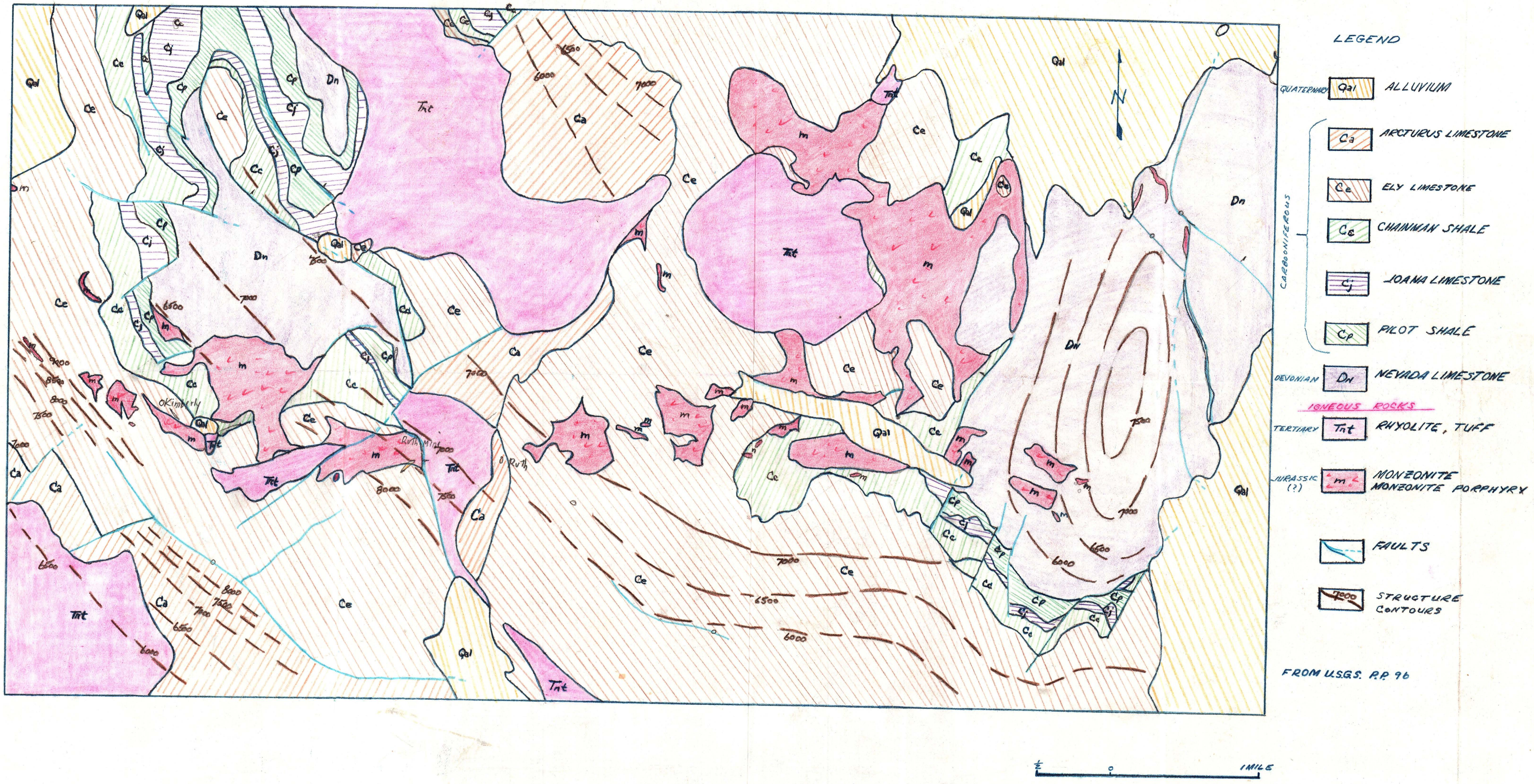
SURFACE MAP

SHOWING THE RELATION OF IGNEOUS ROCKS TO FAULTS

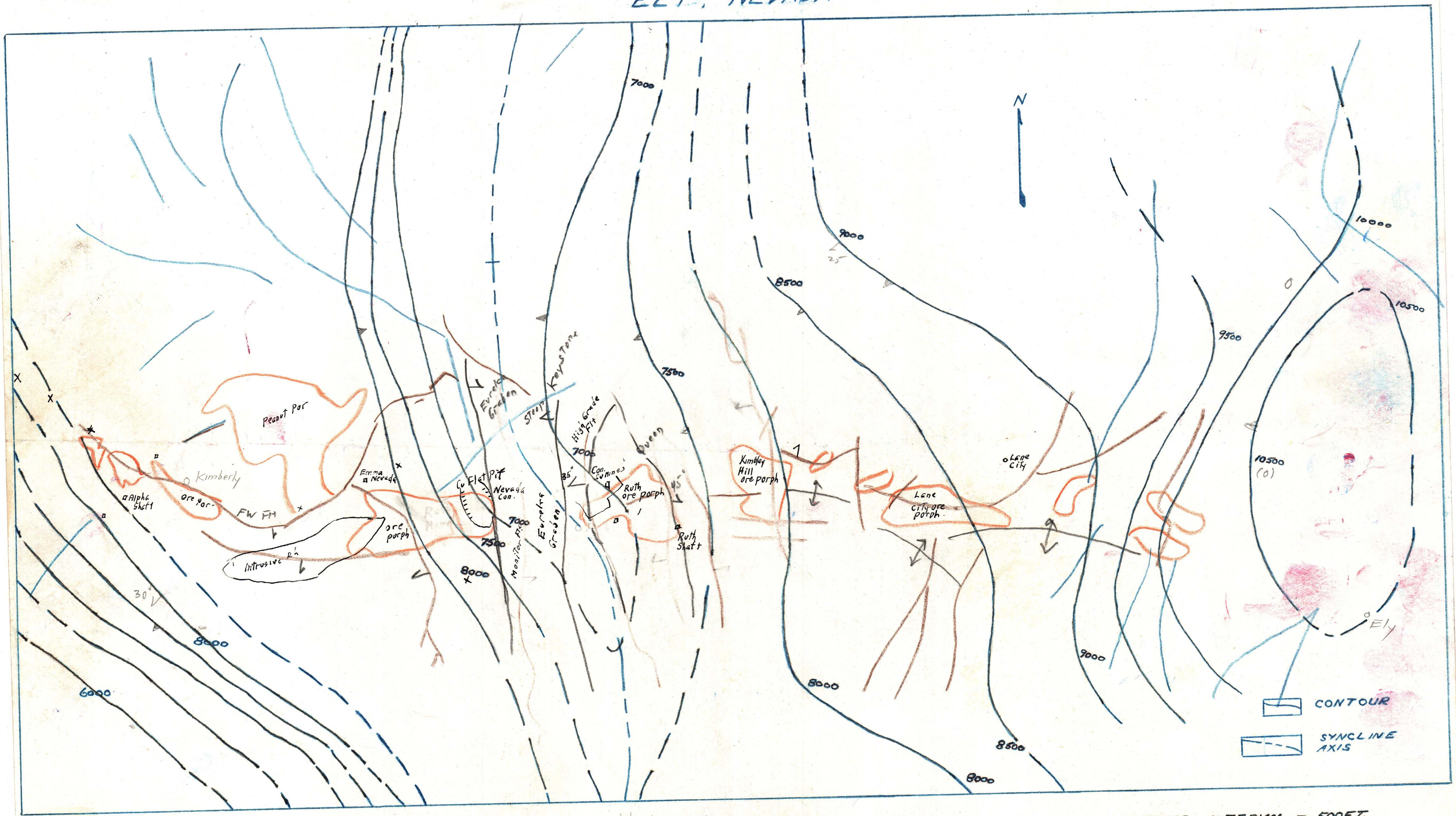
SPENCER, U.S.G.S. P.P. 96, 1917

GEOLOGIC MAP

ELY QUADRANGLE, NEVADA



PRE-FAULTING STRUCTURE CONTOUR MAP
*ELY, NEVADA



*AFTER USGS PP 96

0 — 1 MILE

DATUM - SEALEVEL

CONTOUR INTERVAL - 500FT.

TOP OF ELY LIMESTONE - REFERENCE BED