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GEOLOGY AND ORE DEPOSITS OF THE SHASTA COPPER BELT

Mining 111A Fall, 1948

Victor F. Hollister

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ABSTRACT

The Shasta Copper Belt is the belt of Shasta County, California copper deposits, stretching from Iron Mountain of the south to the Summit and Sutro mines on the north. The deposits are all in one formation, the Balaklala volcanics, and are all of a unique type: bedded replacement deposits.

The formations in the district are all Paleozoic. These were intruded by a heterogenous stock, the rocks of which range in composition from alkali granophyre to hornblende diorite.

INTRODUCTION

The purpose of this paper is to describe the geology and ore deposits of the Shasta Copper Belt in the light of recent work done in the area by the U. S. G. S.

The Shasta Copper Belt, as defined by the U. S. G. S. project mapping the belt, is that area in the Redding, La Moine and Weaverville Quadrangles shown below, (in red).

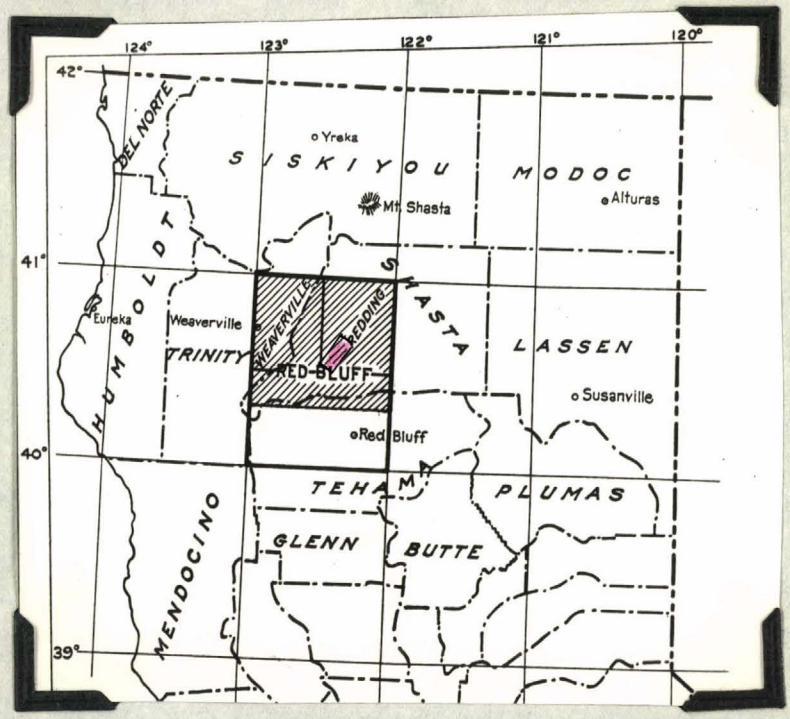


Fig 1.

This is at the southern extreme of the Klamath Mountains. The belt does not include Bully Hill and Afterthought mines; these are considered part of the East Shasta Copper Belt.

The author is deeply indebted to A. R. Kinkel and J. P. Albers of the U. S. G. S. for pertinent information concerning detailed mapping done in the belt. Thanks are also due to Professor Wisser for his kind help.

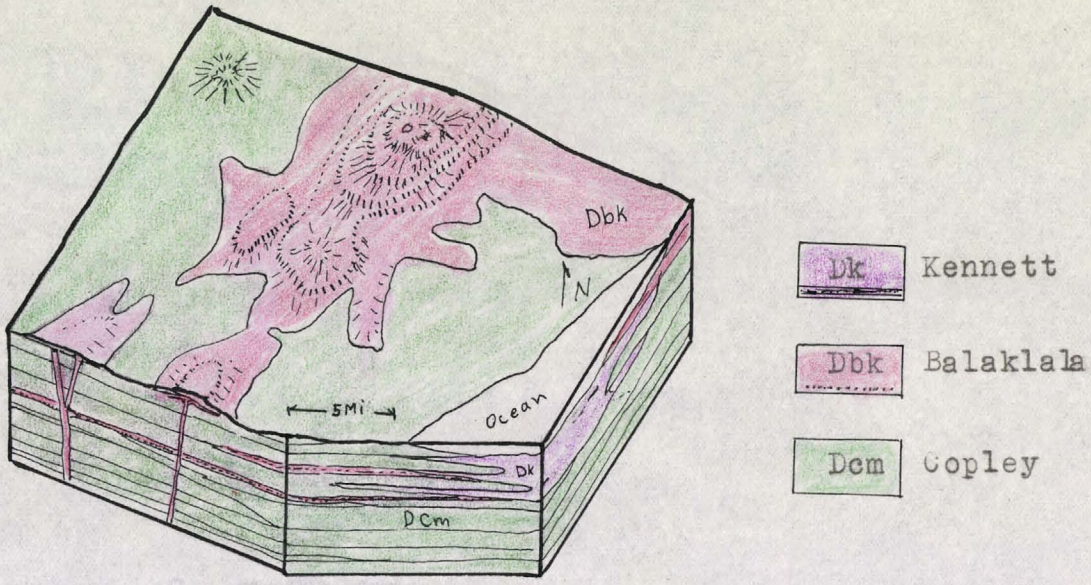
Many workers have made brief reconnsaince trips to the belt but only a few have done detailed work. Among the earliest, and most exact, was that done by J. S. Diller. (3) Diller gave the Balaklala volcanics and the Copley volcanics their respective names. He correctly concluded from his field observations that the Copley is a meta-andesitic rock and that the Balakala is a meta-rhyolite. The Balaklala may be a meta-quartz keratophyre, but rhyolite is certainly a prominent member of the volcanic series. Graton (6) concluded that the Balaklala was not a volcanic series, but was an intrusive laccolithic body of alaskite. Hershey(9) agreed with Graton, and, in order to explain the many types of "Alaskite", he hypothesized six stages of intrusion. Both Graton and Hershey explained the volcanic agglomerate present in the formation as well as the tuffs, sediments and breccias as autobrecciation caused by intrusion. Walker and Walker (16), who now

own the Balaklala and Shasta King Mines, believed the breccia, agglomerats and tuff to be a thrust fault breccia. The sediments they believed to be xenoliths in the "Alaskite." Fergeson (5) found that gold pockets were less numerous in the Balaklala formaiton than in the Bragdon shale. Hinds (11) felt the rock previously called Alaskite should be incorporated with the dioritic stock to the south of the Balkala and regarded the stock as the parent of the Balaklala, proof not withstanding that Balaklala was interbeded with Devonian sediments and the above mentioned stock invaded Jurassic rocks. Hinbs (10) thought the Balaklala to be petrologically identical to the diorite stock. Averill (1) summarized the mining activities and gave shortnotes (2) on techniques employed in mining the copper ore. Kinkle, Albers and the author found that a distinguishable diffenence does exist in the petrology of the Balaklala and Dioritic intrusion, and that the shale and other sedimentary beds in the Balaklala are not zenoliths, as they were seldom seen cut by a dike (the author did not see one single instance of a dike cutting the sediments or tuffs). Professor Turner, in examining a number of sections of Balaklala, thought the original rock was rhyolite, keratophyre and quartz keratophyre. In the field each was found interbedded with the other.

BRIEF GEOLOGIC SKETCH OF THE BELT

Formations

The oldest formation occuring in the area is the Copley meta-andesite. Diller (3) thought the original rock was largely andesite. He also felt the formation was pre-Devonian. Hinds (10) showed that basalt made up a considerable part of the formation. The author, in working south of the copper belt, found that the Copley is interbedded with unfossiliferous shales Diller called Kennett(Devonian). The Copley is also probably interbedded with the Balaklala quartz keratophyre, Petrologic study of the Balaklala shows it to be made up of rhyolite, quartz-keratorphyre, keratophyre and sediments. Individual flows of rhyolite or keratophyre do not exceed 100 feet in thickness, and these may be separated by tuffs, tuff breccias, agglomerates, shales, arkoses, or devitrified obsidian. The balaklala is conformable with fossiliferous Kennet shales and the contact between the two formations is gradational. Kennet shales (Devonian) contain limestone lensesand one flow of Balaklala quartz-keratophyre. An erosional unconformity separates the Kennet from the overlying Bragdon (Miss.) shales. The Bragdon haspractically no economic importance in the district as far as copper mineralization is concerned, though important gold deposits are found in it.



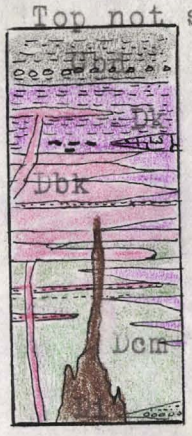
Ideal Block Diagram showing relations between the Copley, Balaklala, and Kennett during Middle Devonian.

GEOLOGIC HISTORY

The earliest decipherable picture of the paleogeography is that of the Devonian. Broad volcanic domes of andesite and basalt covered the region. That the lava flows did not form a broad plateau, such as the Columbia of today, is clearly implied by the great variation in lava composition. Plateau lavas are remarkably uniform in composition but lavas composing the Copley series varied between dacites and basalt in compostion.

While the low broad domes of andesitic and basaltic lava continued to erupt, acidic lava high in soda from a north easterlay line of vents poured out in great amounts. These volcanoes, forming the Balaklala series, rose to heights of about 4,000feet. Middle Devonian fauna can be

STRATIGRAPHIC COLUMN

COLUMN	THICKNESS	NAME	AGE
Top not seen			
	3000'	Bragdon	Mississippian
	750'	Kennett	Middle Devonian
	4000'	Balaklala	Middle Devonian
	7000'	Copley	Middle Devonian
		Mule Mountain Stock--Jurassic	
Base not seen			

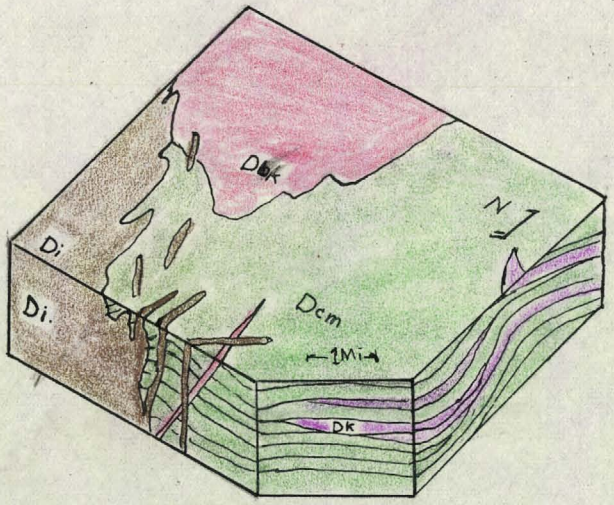
Stratigraphic column as seen in the copper belt.

found in some of the tuff beds between flows. The volcanoes produced much ash with the flows.

As they continued erupting, activity from basaltic and andesitic centers declined and finally ceased. Near the end of the eruption of the Balaklala, subsidence became marked and near shore coral reefs developed on the margins of the volcanoes. As subsidence continued and the ocean covered the volcanoes, igenous activity coninued, but in a continuously diminishing degree. Soft shales and cherts covered the vents and the last activity form the vents consisted of thin dikes into the shales and flows on the then ocean bottom. An unknown thickness of shale, sandstone and limestone was deposited in the Kennet sea and a large part of this was stripped

off in an upwarp of the crust before Bragdon (Missippian) time. Erosion during this interval did not, however, expose much of the Balaklala or Copley. Conglomerate fragments in the Bragdon were almost entirely shale and limestone from the Kennett.

Minor fluctuations in earth movements caused alternate deposition and erosion, with the former predominating, until Jurassic time. Late Jurassic orogenic movements on the crust of the earth metamorphosed the entire region, folding the sediments and volcanics to gently undulating folds. A heterogenous igneous mass, the Mule Mountain stock, intruded the volcanics. This stock is believed to be genetically associated with the copper deposits.



Dk	Kennett
Dbk	Balaklala
Dcm	Copley
Di	Mule Mountain stock

Ideal block diagram showing gentle undulating folding and its relation to intrusion

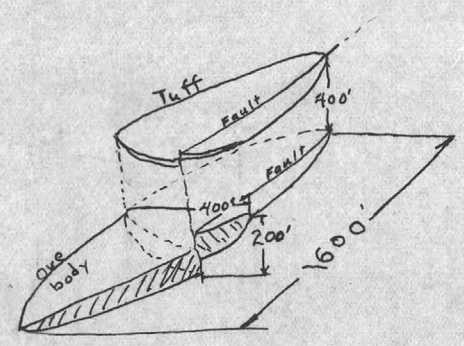
Following the Mule Mountain intrusion the region was tilted to the east by a granodiorite intrusion. This last intrusive, of Late Jurassic age, was much larger than the Mule Mountain stock and is thought to be the "John the Baptist" of the gold deposits. The axis of the granodiorite intrusion strikes about N45°W while the axis of the Mule Mountain stock strikes N-S. The Mule Mountain body intruded the folded rocks before the folding was completed and before regional metamorphism had reached its present isograde. This is clearly implied by the planar schistosity map compiled by Kinkel and Albers. This map shows that only locally has the schistosity of the surrounding rock been crumpled by the intrusion. For the most part the intrusion came in parallel to the schistosity as it exists today, cutting the schistosity in detail, but appearently not crumpling it. The intrusive, coming in parallel to the schistosity during regional metamorphism, would find the effects of crumpling in the schistosity planes obliterated or materially altered by the continuing metamorphism.

The history of the Copper Belt from the Cretaceous on is that of most of the Sierra Nevada: long period of erosion followed by regional upwarping. Erosion stripped the cover from the intrusives and metamorphics and exposed the ore deposits of the district. The topography

is rugged and the stream canyons have the sharp "V" typical of youthful streams. Some of the stream canyons are, in fact, nearly impassible beacuse of their high waterfalls and steep bounding cliffs.

Structure of the Ore Deposits

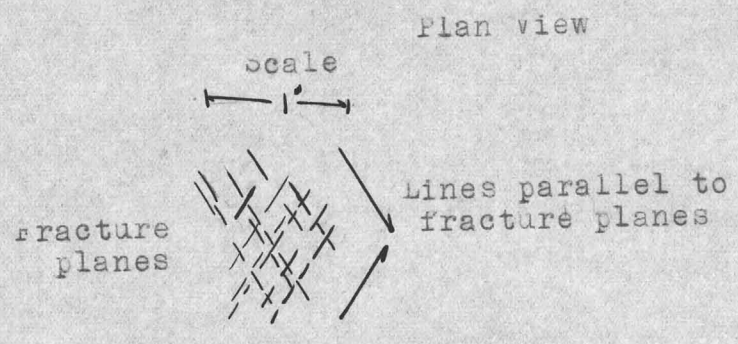
The ore deposits are all blanket replacement deposits; the ore bodies parallel the rock structure in every detail. Usually the ore bodies have the shape of a syncline, but the larger bodies may have the shape of a syncline and an adjoining anticline.



Ideal block diagram of a faulted ore body at Iron Mountain. The ore body exactly parallels and lies just 400' below a tuff bed (marker horizon) in the Balaklala.

Photo graph of the Shasta King gossan showing structure in the Balaklala. Note caved adit for scale,

Frequently the synclinal shape of the ore body is faulted parallel to the length of the syncline. These faults may either act as fissures through which the mineralizing solutions rose, or thay may be parallel to a set of fissures which did. It is interesting to note that the feeding fissures usually have a higher Zn and Cu content than does the ore body above; clearly implying that Zn and Cu were introduced late in the mineralization, after the bulk of the massive sulfide deposite had formed. Above some ore bodies and near others, distinct fractures in the country rock can be seen. These are close spaced, being from an inch to three inches apart, and are cross cutting in their relations. They all appear to be simultaneous and are filled with thin crusts of pyrite. Identifiable faults can not be seen near by and there is practically no displacement along the fractures. They



Ideal plan view showing fractures in the Balaklala near ore deposits.

are not believed to be due to fault action. Under the microscope two directions of shearing can be detected, but since the sections were not oriented in the field, it is not possible to correlate the shear to field obser-bations. In the field a third direction of shearing was observed by Kinkel to be parallel to the bedding.

The ores are of massive pyrite with copper and zinc occuring as chalcopyrite and an iron rich sphalerite respectively. The two metals were introduced into the massive pyrite bodies and intergrowths of chalpyrite-pyrite and sphalerite-pyrite have made concentration of the ores a difficult problem. Some residual boulders of silicified lava occur in the ore, but for the most part the ores run up to 90% or better pyrite.

The ore bearing solutions have replaced a particularly favorable flow or tuff or volcanic formation, and the ores are restricted to the bed and the feeding fissure.

The contacts of the ore to the overlying and underlying horizon are sharp and well defined.

ORE DEPOSITS

Description of the Ore Deposits

The ores deposits occur in well defined structures, usually synclines. The mineralizing solutions forming the ore deposits were limited in their action to but one or two beds in a particular sequence or beds. The bed replaced is usually identical to those beds lying above it and below it, chemically, but is of greatly compentence than the adjoining beds. The replaced bed at Iron Mountain mine is a quartz porphyry breccia and it is overlain by a thick quartz porphyry flow. At the Balaklala mine ore replaced another breccia of quartz porphyry and it is overlain by a quartz porphyry flow which has large quartz phenocrysts. Values at the Balaklala are as follows: 2.7% Cu, 0.9oz Ag, 0.03 oz Au, 21.4% SiO_2, 31.5% Fe, 3.4% Al_2O_3, 4.3% CaO, 212% Zn and 35.2% sulfur.

The Golinsky mine, a fissure and not a bedded deposite, is a gold mine. It is one of the few gold mines in the belt. The fissure strikes N 70° E and dips steeply to the south east.

The Mammouth mine, lying between the Golinsky and the Uncle Sam, is a bedded deposit. The ore bodies have typical spoon or synclinal shape. The ore replaces a breccia and is overlain by a massive flow of quartz porphyry. Walker and Walker, owners of the Balklala, believe this breccia ia a thrust fault breccia. Excellent exposures to the north of the mine in Little Backbone Creek, however, show conclusively the breccia is a volcanic agglomerate with interbedded and cross-bedded tuffs. The ore averages 3% copper and $2 a ton gold.

The Friday-Lowden mine is connected with the Mammouth underground and the ore body replaced the same horizon the ore replaced at the Mammouth.

Keystone Mine is another mine whose ore body is tabular. The ore horizon is a breccia that has been replaced by ore. The keystone body may be a faulted segment of the Balaklala ore body. Average grade of ore is 3% Copper.

Spread Eagle Mine is just east of the Balaklala Mine and like all the other copper mines, is restricted to the Balaklala formation. The Spread Eagle ore body, however, is not far from the base of the Balaklala. The ore occurs replacing a quartz porphyry breccia and is overlain by a rhyolite flow eith strong columnar

jointing. The flow is thin, only about 20 feet thick, but forms a distinctive horizon. Above the flow is a thick massive coarse grained quartz porphyry and below it, partly replaced by massive sulfides, is a breccia. The breccia here is probaly a volcanic agglomerate but hydrothermal alteration has destroyed most of the field evidence pointing to origin near the Spread Eagle.

Stowell Mine is located half a mile west of the Spread Eagle. Exact data concerning the stowell are lacking and it is only known that the ore carries 3% copper and $1.50 in gold and silver per ton. The Stowell is well up into the Balaklala and may be a blanket depoit near the top of the formation or it may be an upfaulted segment of the Keystone ore body.

The Sutro Mine, north of the Mammoth, has a tabular ore body striking about N 70° E and dipping about 25° SE. Appearently only one limb of the syncline in this particular deposit was replaced, though another possibility remains that after formation of the deposit the southeast half of the ore body was faulted away from the northwest half. The tabular body of ore is 25 to 50 feet thick and 200 feet in length. Ore averages 3% copper and $2 a ton gold and silver. The ore replaced a tuff-breccia which was overlain by a massive medium grained quartz porphyry.

Iron Mountain ore bodies lie at the extreme southern end of the belt. They are the largest of the deposits and are nearest the Mule Mountain stock. Copper in the Iron Mountain ores varies within the limits 2.5% to 5% copper with avout $2 a ton in gold and silver. Several ore bodies are know; one has the dimension 1400 feet by 400 feet by 100 feet while another is 800 feet long, 400 feet wide and 200 feet deep. All deposits are tabular and have a spoon shape. The ore replaces a quartz porphyry breccia which is overain by a massive medium grained quartz porphyry flow.

Shasta King ore deposit, north of the Balaklala, is exposed in the canyon of Squaw Creek. The ore body is a "somewhat irregularly basin shaped" deposit, "several hundred feet in width with the longer axis running north south" (1). The ore averages 2% copper and loz silver. The ore replaces rhyolite and is overlain by shale and tuff.

The Uncle Sam Mine, a gold mine with high copper values, is a fissure deposit (see adjoining section). The control of the ore is a contact betwee n a diorite porphyry dike and the Balaklala formation.

The Summit Mine, the most northerly and smallest of the belt, is the farthest from the Mule Mountain stock. It has been explored with only 400 feet of drifts and little is known concerning the grade of the ore.

The mine is high up in the

The mine is high up in the Balaklala formation and is near the Kennet contact.

All the copper mineralization is restricted to the tabular replacement bodies that occure in the Balaklala fo formation. Major bodies of copper ore outside of the Balaklala formation are unknow in the Shasta Copper Belt.

Theories Regarding Mode of Ore Deposition

Any theory postulated regarding depostion in these deposits must take into account and explain these facts:

(a) The massive sulfide deposits were almost completely formed at the time copper and zinc solutions were introduced.

(b) The copper deposits are restricted to the Balaklala formation.

(c) The mineralization appearently affects but one bed in a particular sequence and the bed is overlain by another bed of markedly differing competence.

(d) The copper deposits tend to decrease in size from south to north, the largest being associated with Balaklala volcanics nearest to the Mule Mountain Stock.

(e) Intrusion of the Mule Mountain stock during folding.

The evidence clearly implies, and most writers

agree, that the Mule Mountain stock is genetically associated with the ore deposits. However, from this point on agreement ends. Graton thought the ore replaced breccia resulting from autobrecciation of the Balaklala, which he felt was intrusive. The finding of Middle Devonian fossils in some of the interbedded tuffs proves conclusively the Balaklala is not intrusive and the breccia did not result from fracture of the solididying magma. Hinds, Walker and others felt the breccia is a thrust fault breccia. The presence of crossbedded, tuffs, arkoses and sandstones in the agglomerate constituting the breccia disproves the origin of the breccias as being cataclastic. The breccias are actually volcanic agglomerates, though some of them may be due to shearing. The fragments in the breccias are commonly subrounded and consist of fragments of rhyolite and/or quartz porphyry and, occasionally, copley fragments.

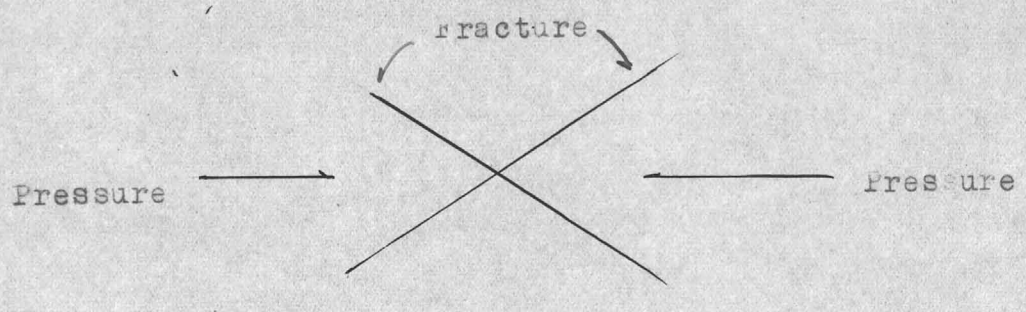
The Mule Mountain stock intruded the Copley and Balaklala while thay were being folded. The Copley series of basic volcanics was relatively incompetent and ore deposits formed in the Copley are small. IN stress the Copley tended to give by plastic flow, while the Balaklala, a series of siliceous compent lavas,

lavastended to give by fracture. Fracture of the siliceous, competent, Balaklala provided the openings needed for the ascending ore solutions. The process in the Balaklala is analogous to the fracture of competent Bingham quartzite near the Utah Copper stock, where the fractures served as permeable waterways for rising mineralizing solutions.

The ore deposits all have one feature in common in their replacement of favorable beds: the bed or volcanic strata replaced always differs greatly in competence, but not in composition, with the overlying volcanics. Usually the favorable bed is an indurated agglomerate, or breccia and it is never of the same competence as the overlying rock when it serves as the replaced bed. Because the volcanic agglomerate usually serves as the locus of ore deposition and it is overlain, in most cases where ore bodies occur, by a thick, massive, quartz porphyry flow of great competence, Kinkel believes the favorable breccia to be one horizon. Field evidence does not support this view. A thick series of tuffs, tuff breccias and agglomerates lies 400 feet above the Iron Mountain ore bodies but directly over lies the Mamouth bodies. Ashale bed directly covers the ore in the Shasta King but lies a considerable

distance above the ore bodies at the Balaklala, across the canyon. Marker beds in the Balaklala can not be traced over great distances, and no marker bed can be found that extends from the Summit to the Iron Mountain Mine.

As a speculative hypothesis it seems reasonable to assume the mineralizing solutions rose through fractures during folding and intrusion until they intersected a sequence of beds which had markedly differing competence. During the folding the more competent overlying bed would tend to drag and brecciate the less competent bed lying beneath it and create openings in the lower bed through which ore solutions permeated, much as has been done in the mineralized thrust in the Cottonwood, Utah district. The fact that intrusion and mineralization were simultaneous and with the folding accords well with this hypothesis. Affirmitive evidence can be found in the shearing parallel to the bedding and two directions of shear normal to the bedding. Shear of this kind, filled with sulfide minerals, could result if pressure were exerted as shown below. The shear parallel to the bedding would result from drag of one bed over another. Pressure folding the beds would be sufficient to create the cross fractures and drag the beds.



Data on orientation of fractures taken fromdrawings acquired in Mining 198,,original from" Zur Experimentellen Tektonik" H. Cloos,

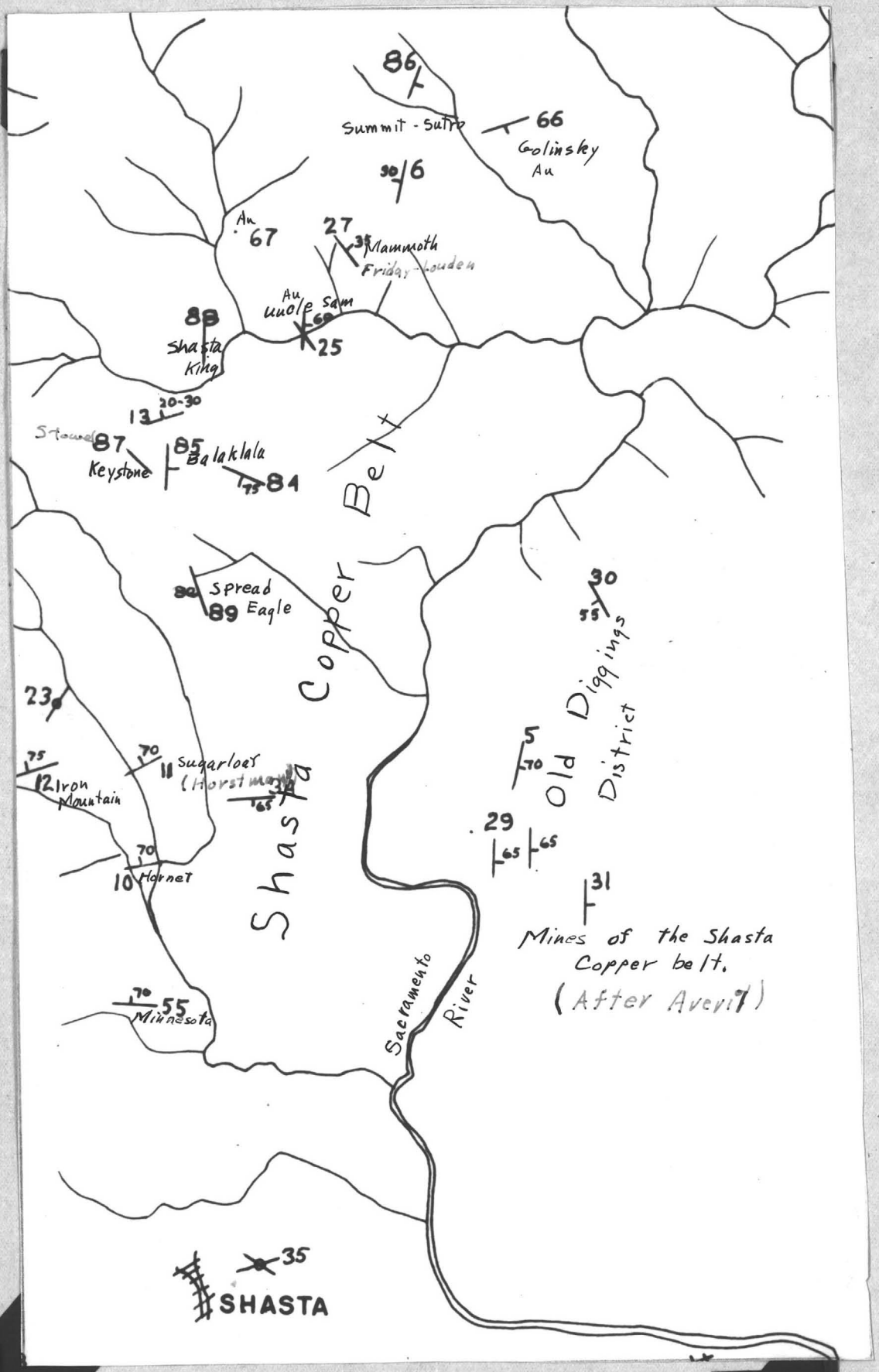
Summary

Mines in the Shasta Copper Belt have three features which they share in common:

1. Their synclinal, or basin, structure.

2. Beds of differing competence in the mineralized sequence serving as favorabel beds.

3. Fissures feeding the massive deposits can be seen below all ore bodies.


86
Summit - Sutro
66
Golinsky
Au
30
6
Au
67
27
35
Mammoth
Friday - Louden
Au
Uncle Sam
60
25
88
Shasta
King
20-30
13
Stowell
87
Keystone
85
Balaklala
75
84
Copper Belt
80
Spread
89
Eagle
30
55
Old Diggings
District
23
75
12
Iron
Mountain
70
11
Sugarloaf
(Horstmann)
65
5
70
29
65
65
70
10
Hornet
31
Shasta
Mines of the Shasta
Copper belt.
(After Averill)
70
55
Minnesota
Sacramento
River
35
SHASTA

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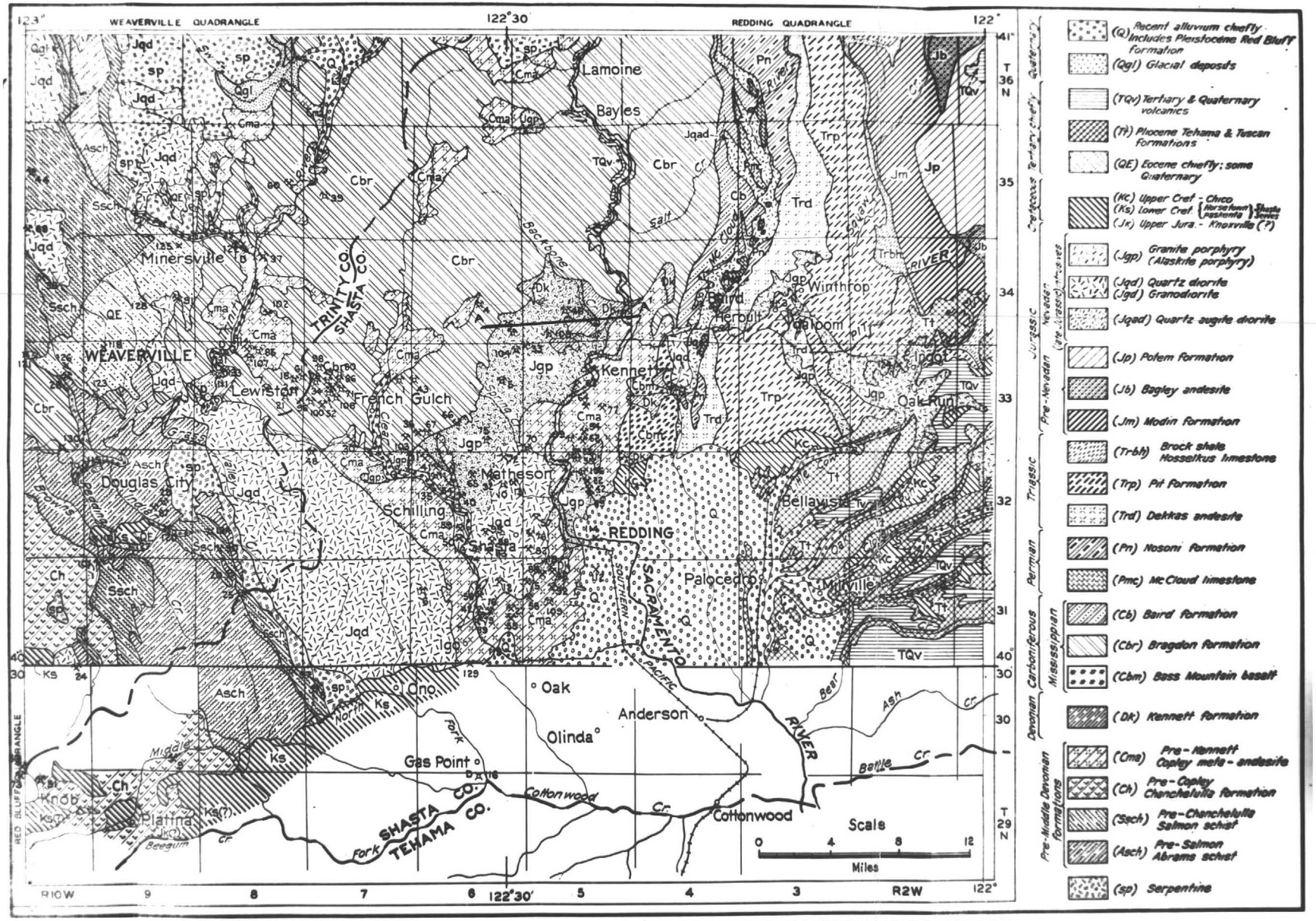
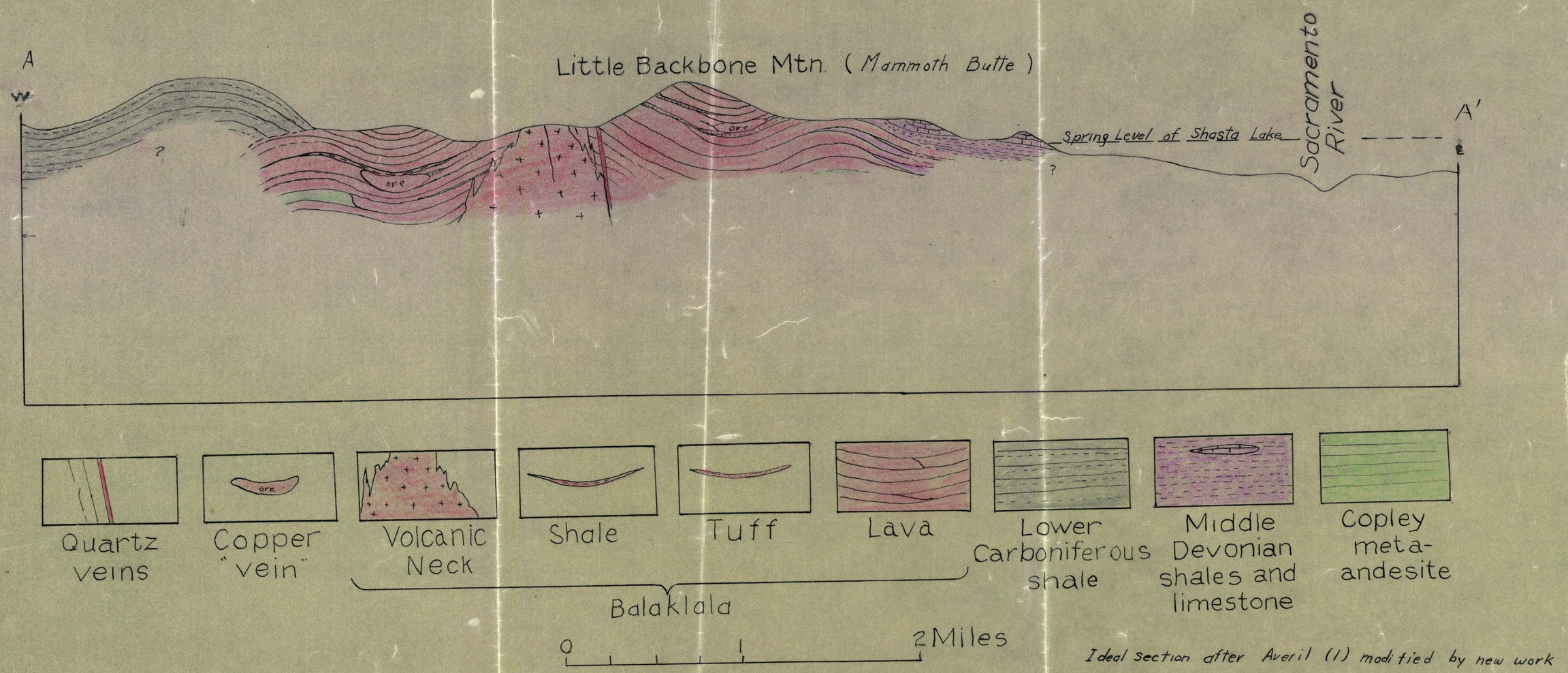
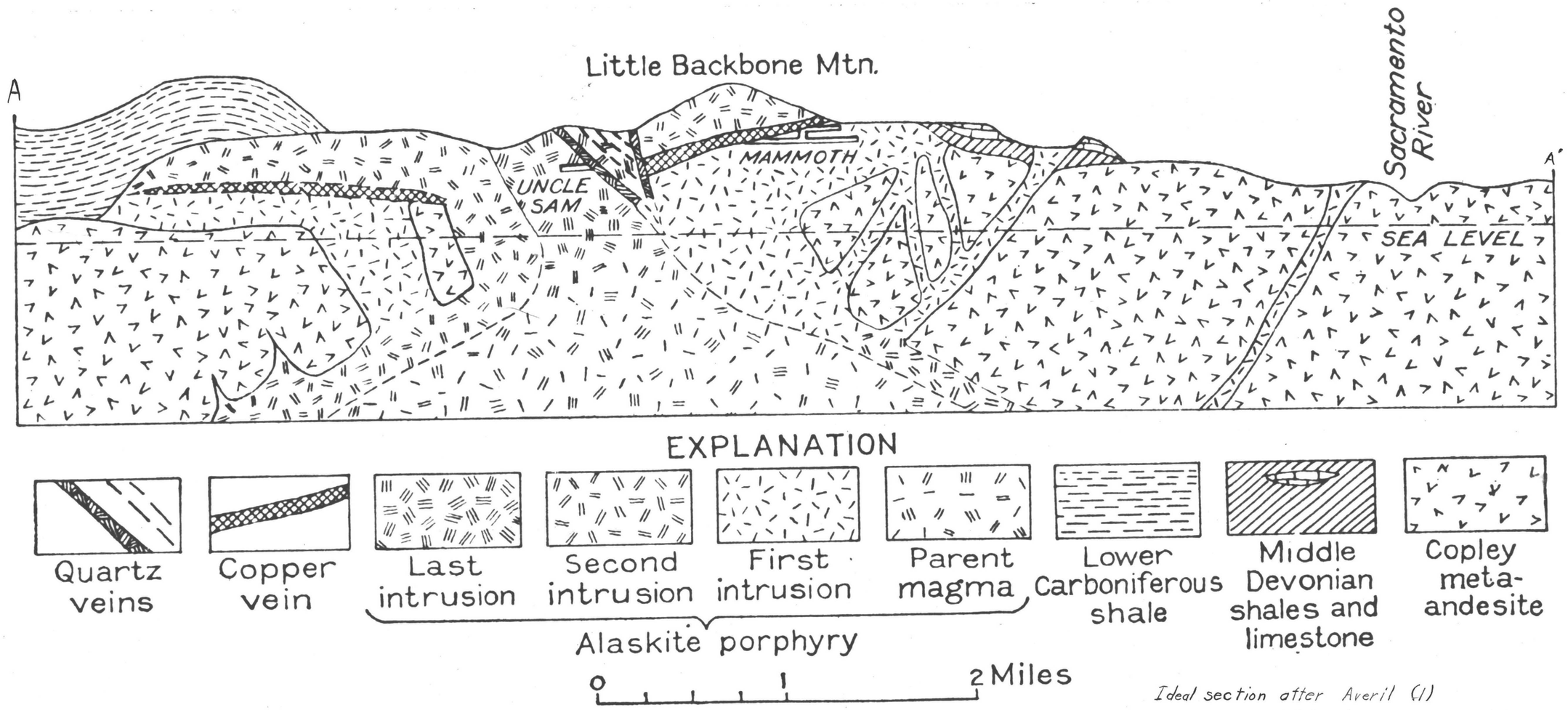


Geologic map of the Redding-Weaverville area after Minds(100)



Ideal section after Averil (1) modified by new work

Faults are not shown



Ideal section after Averil (1)