GEOLOGY OF THE PEACH-ELGIN COPPER DEPOSIT, HELVETIA DISTRICT, ARIZONA

by

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A Thesis Submitted to the Faculty of the

DEPARTMENT OF GEOLOGY

In Partial Fulfillment of the Requirements
For the Degree of

MASTER OF SCIENCE

In the Graduate College

UNIVERSITY OF ARIZONA

1958

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ABSTRACT

The Peach-Elgin prospect, located in the Helvetia mining district, Pima County, Arizona, is a low-grade deposit of disseminated copper mineralization in silicated limestone. Rocks consist of coarse-grained granite, Tertiary(?) quartz monzonite porphyry, andesite porphyry, Horquilla formation, Concha limestone, and Scherrer quartzite. The Horquilla limestones and siltstones are selectively metamorphosed to garnet-diopside rock, garnet rock, tremolite siltstone, and marble, the mineral suites reflecting the original composition of the beds.

The deposit lies in an outlier of the upper plate of the north-south trending Helvetia thrust fault. The outlier lies one and one-half miles west of its pre-thrust position and is underlain by granite. Several similar trending thrusts and the Helvetia tear fault make up the major structures of the district. In the prospect area two faults, imbricate to the Helvetia thrust, move Concha above Horquilla and Horquilla above Scherrer. Several cross faults occur, including the Tip Top fault, which have pre-thrust, post-thrust, and post-mineralization ages. The Horquilla of the Peach hill appears to be folded into a broad syncline.

Copper mineralization of the prospect is largely

confined to the silicated rocks and is controlled in part by bed composition. The aluminum-deficient diopside beds are more favorable than the aluminum-rich garnet beds. Predominant ore minerals are chalcopyrite, chalcocite, chrysocolla, "copper pitch," and bornite with associated pyrite, magnetite and iron oxides. They occur as disseminated grains, replacement veinlets, and in quartz-calcite veins. Ore is localized by the thrust faults, the Tip Top fault, and fault intersections. Depth of oxidation is controlled by topography, averaging 100 feet on steep hills and 50 feet in flatter areas. Bed composition also controls oxidation, mineralization in the garnet beds being strongly oxidized at all depths explored. Enrichment is spotty and is probably restricted to zones of complete silication. Oxidized capping occurs over parts of the Peach-Elgin area.

Mineralization in the district is related to the quartz monzonite porphyry. Intrusion, silication, movement of the Helvetia thrust and of the tear fault, and mineralization occurred nearly contemporaneously.

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INTRODUCTION

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Detailed work on the Peach-Elgin deposit and district-scale work in Helvetia afforded an opportunity to study many of the features of pyrometasomatic copper deposits in calcareous rocks. The object of this study was to gain some insight into the relationship of metamorphism and alteration, oxidized capping, and structure to copper mineralization in these deposits.

Location

The Peach-Elgin area is located about 32 miles southeast of Tucson on the west flank of the Santa Rita mountains in Pima County, Arizona (Figure 1). It lies in the western end of the Helvetia mining district in parts of Sections 14, 15, 22, and 23, T18S, R15W, Gila and Salt River Meridian. The prospect can be reached from Tucson by driving 17 miles south on U. S. Route 89 to Sahuarita, a station on the Southern Pacific Railroad, then 12 miles east on a graded dirt road to the Helvetia townsite which is within the prospect area. The ground is completely covered by patented and unpatented lode mining claims all either owned or controlled by the Lewisohn Copper Corporation.

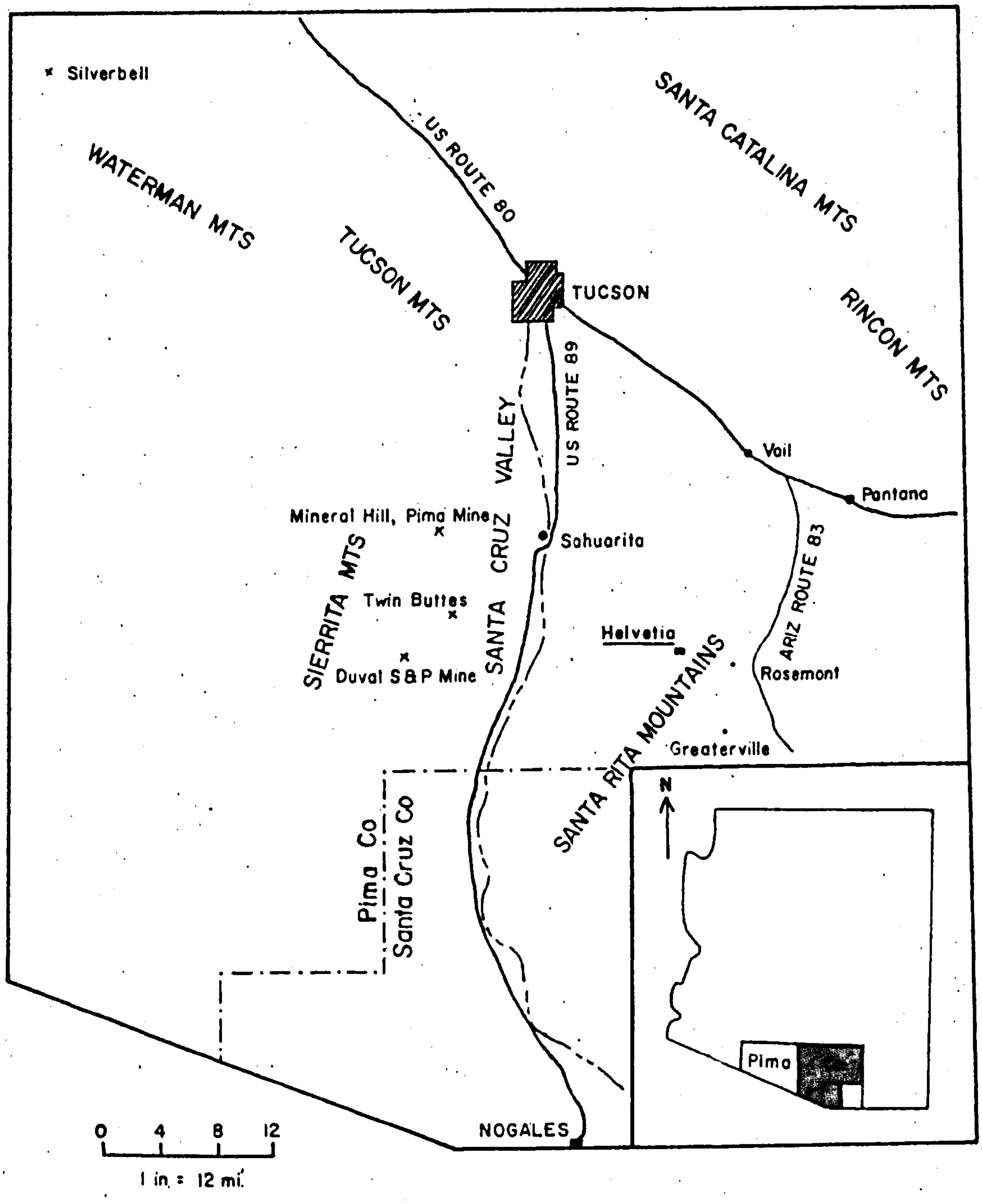

FIG. I LOCATION MAP

Previous Work

The prospect was described in the excellent regional study, Mineral Deposits of the Santa Rita and Patagonia Mountains, Arizona, Schrader, U.S.G.S. Bull. 582, 1915. The area was also mapped as part of a University of Arizona Ph.D. dissertation by Vard Johnson, Geology of the Mineral Deposits of the Helvetia District, Arizona, 1941. Other publications concerning closely adjacent areas in the Helvetia district include the following: Spurr, The Ore Magmas, 1923; Popoff, University of Arizona M.S. thesis, 1940; Jones, University of Arizona M.S. thesis, 1941; and Creasey and Quick, U.S.G.S. Bull. 1027-F, 1955. In addition, reports written by Dr. Harrison Schmitt as consultant to the Lewisohn Copper Corporation were available to me.

Method of Study

The Peach-Elgin area, about three-quarters square mile, was mapped by transit and stadia using a 6,000 foot closed traverse for control. The datum was carried in by levelling from a bench mark about one-half mile southwest of the area. Topography, claims, drill holes, roads and other cultural features were plotted at 1:1,200 (one inch equals 100 feet) for engineering purposes. Several claim corners, marked by white lime, were used as ground control for an aerial photograph which was developed with an accurate scale of 1:2,400 (one inch equals 200 feet). Geology was plotted on the photograph, and the map was completed by reducing the engineering map to the scale of the photograph and superimposing the two.

Geologic maps were made of several other promising-looking localities in the district. The remainder of the district was examined, and a sketch geologic map was drawn using the Johnson map (1941) as a base.

Holes were drilled on equilateral triangle (60° angle) grid patterns on 150 foot centers in the Peach area and on 200 foot centers in the Elgin. Both diamond and churn drilling were used. Standard drilling, sampling, and logging practices were followed, and surface mapping was partly complete before logging began. Rock units were delineated, correlated with surface units, and type samples examined in thin section. All lithologic logs were correlated with assays. About 17,000 feet of drill hole were logged.

Cross and longitudinal sections showing geology and "ore" intervals were drawn at 1:1,200. The intervals were determined on the basis of total copper assay. They were designed for use in interpreting relationships of copper mineralization to rock type and structure and do not necessarily represent ore according to the accepted definition. Oxide versus sulfide zones were delineated megascopically and verified by assaying.

Finally, small scale transparent overlay maps were made to show the relationship between topography, rock type, metamorphism, structure, and capping to drilled and geologically indicated ore-grade mineralization.

Geographic Setting

Topography. The Peach-Elgin area lies at the break in slope between the gently dipping pediment to the west and the steeply rolling hills on the west flank of the Santa Rita mountains. A north-south trending valley, the topographic expression of the Peach-Elgin fault, divides the Peach and Elgin areas. It is steep-sided to the north and grades into a broad vale to the south. The crescent-shaped Peach hill is about 3,600 feet long by 2,000 feet wide with a relief of 600 feet. The Elgin area is comprised of two rolling hills with a relief of about 300 feet. Average elevation is 4,200 feet. Outcrops occur over about 75% of the prospect area, but strong structural features are usually obscured by alluvium.

Drainage. The Santa Ritas in the vicinity of Helvetia are drained by intermittent, generally northwest-trending streams. Helvetia gulch forms the southern boundary of the prospect and loses itself in the prairie to the northwest. The Peach-Elgin gulch drains north to join another northwest-trending arroya.

Climate. The semi-arid climate of the area is typical of the higher parts of the Sonoran desert region. Mean annual precipitation is about 12 inches, falling largely in short summer and winter rainy periods. Towards the crest of the range precipitation is slightly greater and includes minor snow. Summers are hot, but not too uncomfortable for field work; winters are cool and afford pleasant working conditions.

Water. Water is found in numerous workings near the prospect, and permanent water was hit in several holes drilled close to the base of the Peach hill. The nearest source of water in quantity is the Santa Cruz valley six to seven miles west of the prospect.

Acknowledgements

I wish to express my appreciation to the Lewisohn Copper Corporation for allowing me to use for thesis material the geologic work done for the Company.

One of the most rewarding aspects of this work has been the associations it afforded. Mr. Richard E. Chilson offered complete cooperation as an employer and a wealth of experience as miner and prospector. Dr. Harrison A. Schmitt was a constant guide in directing my work for the Company. Drs. Robert L. DuBois and Anil K. Bannerjee offered assistance in petrographic interpretation. I would also like to express my thanks to the other staff members of the University of Arizona Department of Geology for their cooperation and constructive discussion and to Robert C. Fordham, Fred A. Michel, and Theodore Hopfenbeck who helped with topographic mapping, drafting, and calculating.

Particular gratitude is due to Dr. Willard C. Lacy who made arrangements for my working on this thesis and offered helpful suggestions and encouragement. More important, Dr. Lacy taught me that the great reward of the economic geologist is helping to produce products for people.

GEOLOGIC SETTING

The strongly mineralized parts of the Helvetia and Rosemont districts form a broad curving band about one mile wide and five miles long across the northern part of the Santa Rita mountains. The band follows the contact of post-Paleozoic "basement" granite with Paleozoic sedimentaries. On the east flank of the range Cretaceous clastic rocks unconformably overlie the Paleozoics. Along the high part of the range the Paleozoics strike northerly, dip steeply east, and are generally older toward the west. The major east-west high-angle Helvetia fault crosses the crest of the range cutting off the Tertiary(?) quartz monzonite porphyry plug that forms Broad Top butte and dragging massive fragments of Bolsa quartzite one-half mile west along the south side of the fault. The fault divides the mineralized area into two parts having significantly different structure and stratigraphy. The general geology of the area north of the fault is shown on the Sketch Geologic Map of the Helvetia District.

The Broad Top porphyry intrudes Concha limestone with conformable relations to the bedding and is in fault contact with Horquilla limestone. The top of the plug with adjacent sedimentaries was sliced off by the Helvetia thrust and moved one and one-half miles west. The area of Paleozoic and Cretaceous sedimentaries and quartz monzonite porphyry which includes the Peach-Elgin prospect and the Old Dick and Heavy Weight mines is an outlier bounded on all sides by the thrust and lying on the granite. The thrust dips toward the middle of the outlier at all exposures and the sedimentary beds also have a general inward dip.

Structure of the Paleozoics and granite between the outlier and Broad Top butte in the vicinity of the Copper World, Leader, Isle Royal, and Omega mines is complicated and has not yet been adequately worked out.

Peach-Elgin area. The prospect area lies in the western part of the outlier. The Helvetia thrust plane dips steeply east under the Peach hill and gently west under the Elgin area. Granite is exposed below the thrust on the north, west, and south sides of the area, thus forming the bottom and bounding on three sides the area of possible economic mineralization. A similar trending fault exposed on the west side of the Peach hill thrusts a narrow wedge of Scherrer quartzite between the granite and the overlying Horquilla limestone. The Horquilla, comprised from west to east of silicated limestone, marble, and limy siltstone, strikes similarly to the trend of the thrusts and appears to be folded into a broad syncline. The Elgin area is comprised largely of silicated and marbleized Concha limestone and intrusive quartz monzonite porphyry. A third north-northwest trending fault, probably also a thrust, divides the Peach and Elgin areas and brings Permian Concha in contact with Pennsylvanian Horquilla. The ore occurs in the silicated and marbleized limestones and appears to be continuous across the Peach-Elgin fault.

DESCRIPTION OF ROCK TYPES AND METAMORPHISM

General Statement

The sedimentary rocks of the Helvetia district consist of limestones, quartzites, marls, and shales of Paleozoic age overlain by a Cretaceous clastic-volcanic complex. Above Cambrian quartzite lie 2,500 feet of limestone the top 800 feet of which is Horquilla limestone, 700 feet of Earp siltstone, and 1,200 feet of Lower Permian Colina-Epitaph shales, marls, gypsite, and limestone. The youngest Paleozoic rocks are the Permian Scherrer quartzite and Concha limestone, each about 600 feet thick. Of this column only Horquilla, Scherrer, Concha, and possibly Earp occur in the Peach-Elgin area.

The rock units have been described by Schrader (1915), Popoff (1940), Johnson (1941), Jones (1941), Creasey and Quick (1955), and Bryant (1955). Correlation of previous work is more in order than another descriptive column. Below is a tabulation of five stratigraphic columns showing formation names, thickness of formations, and generalized lithology. Bryant's nomenclature is used throughout this paper.

Because virtually no unaltered limestone occurs in the Peach-Elgin area, most of the description of the Horquilla and Concha formations is concerned with the products of metamorphism and hydrothermal alteration.

Three igneous rocks were mapped: post-Paleozoic granite, Tertiary(?) quartz monzonite porphyry, and Tertiary(?) andesite porphyry. The "granite" unit is coarse grained and includes variations to quartz monzonite and monzonite. The fine-grained quartz monzonite porphyry occurs as intrusive plugs and dikes, and is related to the copper mineralization of the district. The andesite porphyry, found only in limited exposures in the northern part of the mapped area, is intrusive into the granite.

Sedimentary Rocks

Horquilla Limestone

The Horquilla formation comprises almost all of the Peach hill from the quartzite contact on the west to the Peach-Elgin fault on the east. Johnson describes the formation as follows:

> Near the base of the formation the limestone beds are light colored, moderately coarse to fine-grained, and may be as much as 10 feet thick. They are interbedded with light gray calcareous shales which metamorphose into siliceous beds which greatly resemble fine-grained white quartzite. The proportion of limestone decreases progressively upward through the section and the bedding tends to grow thinner. The lower 700 feet of the formation is dominantly light colored except for erratic patches of garnetized shales. The upper portion, generally light colored when fresh, tends to weather to a rusty brown color. At the top of the formation is a series of gray-green to brown-green thin-bedded (one to three inches) shales about 800 feet thick [Earp]. The estimated total thickness present in the Helvetia district is 1800 feet. Difficulty in finding an unfaulted series of beds from

bottom to top of the formation precludes any accurate measurement of the section.

The description is valid except that the aluminum content of the siliceous beds is low making them calcareous siltstones rather than shales. Jones estimates the combined thickness of Horquilla and Earp as 1,250 to 1,500 feet. The total thickness of the two formations in the Helvetia district is probably close to 1,500 feet.

The rock types of the Peach hill are all metamorphic units. The westernmost member is almost completely silicated limestone consisting of alternating beds of garnet-diopside and dominantly garnet rock with thin interbeds of metamorphosed gray-green siltstone in both units. Overlying the silicate beds on a sharp contact is a thick marble unit. The marble contains beds of limy siltstone which are thin and widely spaced to the west and increase in thickness and frequency eastward. A line indicating the gradational nature of the contact was drawn between nearly pure marble and marble containing 30%+ siltstone.

The three units represent compositional differences of the original sediments. Broadly, the silicate and marble units, having low siltstone content, are probably metamorphosed lower Horquilla, while the dominantly siltstone unit represents the upper part of the Horquilla and possibly part of the Earp formation. The Earp designation is tenuous, however, because on the surface no thick sequences of siltstone occur without interbedded lime. It is more likely that the eastern part of the hill is largely upper Horquilla. The exposed thickness of the formation in the mapped area is about 1,000 feet, considerably greater than the total Horquilla thickness; hence, thickening must be accounted for by structural means.

GARNET-DIOPSIDE ROCKS. Rocks containing a considerable proportion of minerals in the diopside-hedenbergite series have a characteristic dark green color in hand specimen. They are fine grained, usually rubbly but sometimes massive. Often blebs of brown garnet in the rocks give them a spotty appearance. One light colored variety is made up largely of diopside crystals so small the rock appears to have a clayey texture. A darker sometimes black variety is more dense and siliceous-looking than the typical diopside rock.

The rock occurs in a bed which can be identified in every Peach drill hole except D-14. In the southwest part of the hill there are two discrete diopside beds separated by a garnet bed. Eastward the two appear to blend into one less sharply defined bed. To the north the configuration of beds seems similar but is not as clearly defined.

The garnet-diopside beds are the most important ore-bearing unit in the Peach hill, containing disseminated pyrite, chalcopyrite, and magnetite in almost all specimens examined. Weathering of the mineralized rock forms a distinctive dark green, rubbly cap rock rich in oxide copper minerals and brown "limonite," and interlaced by quartz veins.

Microscopic analysis. In thin section the rock has a crystalloblastic and granoblastic texture. Predominant constituents are grossularite and minerals of the diopside series, either diopside alone or both diopside and salite. The salite has a composition of $Di_{73}He_{27}$. Three specimens of the diopside-grossularite suite have the following mineral assemblages:

grossularite	55%
salite	20%
chlorite	5%
calcite and quartz	15%
diopside, pyrite, chalcopyrite, and "limonite"	5%

garnet (mostly grossularite)	65%
diopside	10%
clinozoisite and epidote	5%
chlorite	10%
calcite and quartz	10%
pyrite, chalcopyrite, and magnetite	1%

grossularite	25%
salite and diopside	50%
quartz	15%
malachite and chrysocolla	5%
clay (from alteration of garnet)	5%
pyrite and chalcopyrite	1%

Garnet is replaced by fine-grained masses of clinozoisite, calcite, and quartz. Epidote also replaces the garnet occurring as small crystals and veinlets cutting the garnet. Chlorite replaces both garnet and the diopside series minerals. Minor calcite occurs between silicate grains and probably represents unreplaced limestone. Most of the calcite is in later veinlets with quartz cutting all the other minerals except the ores. The garnet displays little alteration to clay minerals. Mortar structure was developed at the borders of many of the crystals, but the rock was recrystallized subsequent to the microbrecciation. At least two periods of structural activity are suggested by the facts that some of the recrystallized border material is garnet and some of the lower temperature silicates suffered deformation.

GARNET ROCKS. The garnet rocks are dark red to light tan in hand specimen, moderately coarse grained, brittle, and commonly feature a hackly texture on a broken surface. Locally the garnet is weathered to a soft yellow clayey material. A similar looking material was microscopically determined to be a late introduction of a very fine-grained mixture of quartz and calcite with minor "limonite." Epidote generally occurs as a few scattered crystals or is absent, but it comprises about 20% of one variety of garnet rock. The rock is pale greenish-brown, lacking the color of the diopside-rich rocks.

Both mineralized and non-mineralized garnet rocks outcrop on the Peach hill. Generally, barren specimens are dense and hard, unweathered, and contain little "limonite." Garnet rocks which have significant copper content are usually weathered to a porous red or brown capping containing "limonite" and oxide copper minerals.

Microscopic analysis. The garnet rocks display the same crystalloblastic, granoblastic structure as do the diopside-bearing rocks. Two colors of garnet are observed: grossularite is gray and grossularite containing a considerable amount of the almandine molecule is brown. In some sections veins of almandine are seen cutting the grossularite. No correlation can be made between the colors of garnet in thin section with colors observed megascopically. The following are three examples of the mineral assemblages of garnet rocks:

garnet (grossularite and almandine)	75%
diopside	5%
clinozoisite and hematite	5%
calcite	10%
quartz	5%
pyrite, chalcopyrite, and ilmenite	1%

garnet (mostly almandine)	85%
quartz and calcite	15%
hematite and "limonite," malachite and chrysocolla	1%

grossularite	70%
calcite	10%
quartz	15%
chlorite, hematite, and diopside	5%

Sequence of structural activity and replacement of the garnet by clinozoisite are much the same as in the diopside-rich rocks. Chloritization is less pronounced.

LIMY SILTSTONE. The siltstone occurs as two rock types, very different megascopically, but closely related in composition and history. One is a fine-grained, friable, white siliceous rock resembling diatomaceous earth in appearance. The other is a dense, massive, hard, pale gray-green to black rock. They are composed largely of quartz, calcite, tremolite, and diopside.

Most of the siltstone occurs as distinct beds. In several outcrops, however, small masses of gray-green siltstone definitely cross-cut the bedding. It is probable that the cross-cutting rock is actually silicified limestone, although this could not be proved microscopically. The cross-cutting and bedded siltstones have essentially the same mineral composition, and no differentiation was made between them in mapping.

The siltstone unit outcrops on most of the east side of the Peach hill, as a patch in the northwestern part of the hill, and in the southern part of the valley between the Peach and Elgin areas. On the east side of the hill the siltstone is interbedded with lime. Thus, the contact between the nearly pure marble and dominantly siltstone units as drawn does not represent an Horquilla-Earp contact but merely gradational change in lithology. The siltstone patch in the northwestern part of the Peach hill appears gradational into the diopside rock. It is interpreted as representing a facies change in the original chemical composition of the bed. Both here and in the Peach-Elgin valley, the siltstone unit contains considerable garnet.

Microscopic analysis. Three varieties of the siltstone have the following mineral composition:

Massive, hard, dark green siltstone	
quartz	50%
tremolite	40%
chlorite	5%
calcite	5%
pyrite and chalcopyrite	1%

Intermediate variety	
quartz:	
fine matrix material	35%
coarse vein material	10%
tremolite	25%
diopside	20%
calcite	10%
magnetite	1%

White friable siltstone	
quartz	55%
diopside	20%
garnet	5%
calcite	15%
magnetite and incipient tremolite	5%

Diopside, garnet, and tremolite in a very fine-grained felt-like matte with quartz and calcite replaced the limy siltstone at high temperature. At a lower temperature, tremolite replaced some of the diopside and some of the matte was recrystallized into coarse acicular tremolite. Chloritization accompanied the introduction of hydrothermal solutions.

MARBLE. The marble capping the Peach hill is a coarsely crystalline, dense, white to light gray rock. It has suffered strong brecciation as have the other rocks, but it is now thoroughly healed. Fracture surfaces have a thin, black, rough-textured silicate coating or a hematite coating. Strong fractures are marked by topographic troughs and lack of outcrop. Numerous copper-bearing veins are emplaced in fractures, and locally, in the vicinity of strong fractures, the marble is garnetized.

The marble contains considerable tremolite, largely restricted to specific beds. In some instances pods of marble up to two feet in diameter and unsilicated except for small amounts of tremolite growing out from fractures in the pod are completely encircled by tremolite-rich rock.

PETROGRAPHIC INTERPRETATION. The silicate suites were produced by selective replacement of limestone strata as evidenced by the remarkable continuity of the silicate beds and their conformity with the attitude of bedding observed at the surface. It is probable that with the exception of silica, not much addition of material accompanied the silication. The silicate rocks, therefore, indicate the original composition of the limestones. Garnet rocks formed in shaly dolomitic limestones. The garnet-diopside mixture replaced aluminum-deficient purer dolomitic limestones. The low, variable iron content of both suites may have been present in the original sedimentary rocks or may indicate iron introduction. The tremolite-quartz-calcite suite indicates replacement of a rather unusual rock: an aluminum-low calcareous siltstone.

The three suites represent the same conditions of moderately high temperature metamorphism. The marble capping of the Peach suffered only recrystallization probably because it was impenetrable to the silicating solutions.

The high temperature silicates were brecciated and subsequently recrystallized in an environment in which garnet was stable. Later at moderate temperature garnet and diopside were replaced by clinozoisite and epidote, and tremolite was recrystallized. A second period of brecciation followed. Finally, hydrothermal solutions introduced the ore minerals with calcite and quartz, and partly altered the earlier silicates to chlorite.

The sequence suggests a constantly regressive metamorphism with the hydrothermal solutions a late phase associated with the original silicating solutions. If this is the case, the brecciation may have occurred continuously and contemporaneously with silication and ore mineral introduction. It is impossible to estimate the time lapse between the three phases.

Scherrer Formation

The normal stratigraphy of the Permian Scherrer formation from top to bottom is as follows: 350 feet of quartzite; 200 feet of white, dolomitic limestone; and 100 feet of quartzite. Thicknesses are a compromise between measurements made by Johnson and Jones. In the

Peach-Elgin area the quartzite occurs as a wedge between the granite and the silicated limestone along the west side of the Peach hill pinching out under the hill to the east, a large mass north of the Peach hill, and a small exposure in the northeastern part of the area. A small area of bleached and marbleized limestone containing weak oxidized copper mineralization in fractures outcrops below the quartzite in the northeastern part of the Peach-Elgin area and was tentatively called Scherrer limestone.

The quartzite of the western wedge strikes north-south, dips steeply east, and is broken into five blocks by transverse faults. For mapping purposes the rock was subdivided into two units, a light and a dark quartzite. The light quartzite, comprising the two southern blocks and the western part of the three northern ones, is white to light pink in hand specimen and dark rust colored in large exposures. It is generally fine grained, composed of quartz and minor pink feldspar, completely cemented by silica, has a vitreous lustre and breaks in sharp angular fragments. Locally it is cross-bedded, and a few thin beds of friable, poorly cemented sandstone are found. These characteristics conclusively correlate the rock with the well-established Scherrer below Sycamore ridge two miles to the east.

The dark Scherrer outcrops in a narrow, discontinuous zone between the light quartzite and the thrust fault. It contains manganiferous and calcareous material, some magnetite, and is locally shaly in texture. The contact between the quartzite units is a broken line parallel to the bedding in the four southern blocks, and the thickness of the dark rock is different in each quartzite block. For these reasons it is believed that the two are beds which had different original composition rather than the dark Scherrer being an alteration facies adjacent to the fault.

The light quartzite contains virtually no ore-grade mineralization while the dark quartzite in a thin zone immediately underlying the thrust is usually ore grade. The mineralized quartzite weathers to a prominent irony capping.

Concha Limestone

Dr. D. L. Bryant delineated the Concha stratigraphy in the Helvetia district as follows:

Additional beds of Concha limestone on long dip extending into valley east of Sycamore ridge.	
Limestone: medium gray, weathers same. Chert content 5%. Fossil zone 25 feet above base.	50 feet
Limestone (tan chert zone): light to medium gray, weathers medium to reddish gray. Chert content 30%; light gray nodules that weather pinkish brown.	30 feet
Limestone: medium gray, weathers medium to dark gray. Chert content less than 2%. Fossiliferous.	150 feet

Limestone: medium to dark gray, weathers same. Chert content 20%. Fossiliferous with bryozoa and large productids. 125 feet

Total (without allowance for eastern dip beds) 355 feet

Johnson and Jones estimate the total thickness of Concha as 500 feet and 500 to 750 feet thick, respectively.

Some chert occurs in the marbleized beds outcropping in the Elgin area, but the limestone is too metamorphosed to permit accurate placement in the Concha section.

METAMORPHISM. Only a small portion of the Concha limestone in the eastern part of the mapped area is unmetamorphosed. Generally, the Concha is metamorphosed in zones which decrease in intensity away from the quartz monzonite porphyry. In the southern part of the area the Concha is completely silicated to the Horquilla contact. Toward the north, silication is complete immediately adjacent to the porphyry and rapidly grades into a zone of partially silicated marble which varies from 0 to about 100 feet in width. North of this zone the Concha is a bleached white marble cut by numerous copper-bearing fractures.

In the area of the Elgin pit a mass of white marble overlies the silicates. The marble has low silicate content, but considerable serpentine associated with chalcopyrite and bornite.

The silicates of the Elgin area consist of garnet rocks overlying diopside-rich rocks similar to those of the Horquilla formation. The Elgin area differs from the Peach, however, in that no correlation could be made between bedding and silicate composition.

Igneous Rocks

Granite

The granite is a dark red-brown to dark gray coarse-grained rock composed of quartz, potash feldspars, oligoclase, and biotite, and containing phenocrysts of pink orthoclase up to two inches in length. It generally has a rubbly appearance in outcrop, and even specimens of drill core cut at depths 100 feet below the overlying Paleozoics and 600 feet below the surface tend to crumble readily.

Microscopic analysis. A thin section of granite from a diamond drill hole disclosed the following composition:

Quartz	30%
Microcline	30%
Orthoclase	25%
Biotite and chlorite	10%
Oligoclase	5%
Magnetite, pyrite, apatite, and "limonite"	1%

The large orthoclase phenocrysts comprise about 10% of the rock. Biotite is partially altered to chlorite or is bleached. There appears to be some alteration of biotite to magnetite, and alteration of biotite, chlorite, and magnetite to "limonite." Very little of the biotite remains fresh. The oligoclase and the smaller orthoclase crystals are partly altered to kaolin. There is no significant sericite alteration.

<u>Compositional variations of the granite</u>. The "granite" unit is very variable in appearance and composition. Schrader, Johnson, and Jones analyzed specimens of granite composition. Dunham and Johnson noted quartz monzonite varieties. Creasey states the composition varies from granite to monzonite. In the Peach area, as was stated above, the granite is dark red due to weathering of mafics and ore minerals and is rubbly. In some localities, due to complete chloritization of the biotite, the rock has a dark gray or dark green color. A distinctive facies occurs to the south and west of the Old Dick Hill and outcrops in the Elgin area. Here the rock is pink to dark salmon on weathered surfaces and chalk white in fresh specimens. It is more dense than the variety west of the Peach hill, is not as coarsely porphyritic, and fractures along plane surfaces. In composition the rock is not greatly different from the quartz monzonite porphyry, but can be distinguished from the porphyry by its complete lack of fine-grained groundmass. Walking out the granite contact from the Elgin area to the Heavy Weight mine, numerous local variations in the granite can be observed.

<u>Age</u>. In the Peach-Elgin area the granite is in fault contact with all other rocks; hence, no age relations can be

determined. The degree of local variation, however, suggests that at least part of it is pre-Cambrian. At the crest of the ridge near Hart Butte the granite is unquestionably intrusive into Bolsa quartzite. Dikes of granite appear to intrude some of the large masses of dragged Bolsa south of the Helvetia tear fault, and inconclusive intrusive relations of the granite with Horquilla limestone occur in small outcrops near one of the Bolsa blocks. Cretaceous rocks lie unconformably on the granite. The unit as mapped can thus be considered to consist partly of granite intruded in post-Cambrian (possibly post-Paleozoic) and pre-Cretaceous time, and partly of pre-Cambrian rock.

Relation to mineralization. The granite contains cupriferous pyrite and, close to the thrust contact, veins of quartz-pyrite-chalcopyrite. In every drill hole that penetrated it, the granite was found to have weak copper mineralization running from a few hundredths to a few tenths of one percent. Nowhere in the district is the granite known to contain sufficient copper to constitute low grade ore, but several quartz-gold-silver-lead veins have been worked in the granite. Although much of the ore in the district is located at thrust contacts with the granite or in limestone not far removed from the granite contact, no genetic relation can be established between the granite and ore mineralization. This subject is discussed in greater detail in another section.

Quartz Monzonite Porphyry

The quartz monzonite porphyry is a white to light pink dense rock composed of medium-sized phenocrysts of oligoclase, quartz, and orthoclase in a fine-grained groundmass. It occurs in the Helvetia district in stock-like masses and as dikes and sills intruding Paleozoic and Cretaceous sedimentaries.

Microscopic analysis. Specimens of the porphyry mass in the Elgin area were determined microscopically to have the following average composition:

Oligoclase	45%
Quartz	30%
Orthoclase	20%
Biotite	5%
Apatite, sphene, magnetite, and pyrite	1%

The phenocrysts comprise about 60% of the rock, and mineral distribution is about the same for phenocrysts and groundmass. The oligoclase phenocrysts are subhedral to euhedral and display prominent zoning. Albite twinning occurs in some of the plagioclase, but is absent or extremely subtle in much of it. A few Carlsbad-albite twins were noted. Some of the large oligoclase phenocrysts contain perthitic intergrowths of orthoclase(?). Subhedral quartz phenocrysts are prominent as are numerous euhedral apatite crystals and a few scattered sphene crystals. Much of the porphyry mass is partially kaolinized, and locally the rock is silicified. Seritization was observed in several scattered outcrops, but no well-defined zoning of the alteration was determined.

According to the Johannsen classification, the rock is a quartz monzonite porphyry, or more accurately, a leuco-quartz monzonite porphyry.

Occurrence. Both intrusive and fault relations of the quartz monzonite porphyry with the Paleozoic limestones occur in the Elgin area. One small body of porphyry in the Elgin pit lies on a thrust above Concha limestone. In a prospect pit near the Lewisohn office a vertical dike of porphyry can be seen cutting the lime. The thick porphyry sections in drill holes D-15, 17, and 19 suggest sill-like intrusion, and the thin porphyry stringers in the upper part of D-17 (too small to be shown in Section A-A') are certainly intrusive.

Relationship of porphyry bodies in the Helvetia district. A microscopic examination was made of seven specimens of the Broad Top intrusive, and the rock was found to be almost identical to the Elgin body. The composition and amount of groundmass are comparable. The phenocrysts are similar and the striking perthitic and zoned oligoclase occur in both. Accessories are the same except that the Broad Top porphyry contains minor lazulite altered from pyrite and some zircon. Mafic content of both bodies is about 5% and is composed almost entirely of biotite. Both bodies intrude Concha limestone and Cretaceous rocks.

Several other porphyry bodies in the Helvetia district, particularly in the Rosemont area, are megascopically similar to these two bodies.

Relation to mineralization. The limestone adjacent to all known intrusive contacts of the porphyry is silicated, and copper mineralization occurs in the scarn zones. Several pyrometasomatic ore bodies in the Helvetia district occur in these zones, including the Newman deposit in the Elgin area, the King and Heavy Weight mines, and the Saratoga in the Rosemont camp. It is thus firmly established that the porphyry is genetically related to copper mineralization. It is further assumed that all the porphyry bodies have a common parent source which is responsible for the copper deposits of the district.

Unlike many of the quartz monzonite porphyry bodies related to mineralization in Arizona, the rock at Helvetia virtually never constitutes ore itself. It contains some disseminated pyrite and veinlets and blebs of chalcopyrite. Rarely a small pocket of high-grade ore has been mined out of it, but generally copper content is low to negligible.

Andesite Porphyry

The andesite porphyry is a fine-grained, dark gray, soft rock which has suffered intense alteration to clay minerals. It occurs only as a small mass below a flat thrust in the granite near the Tip Top mine and in two narrow dikes in the granite 800 feet to the east. Near the Tip Top mine the porphyry contains a strong dissemination of azurite and malachite occurring as rounded blebs one-eighth inch to one inch in diameter. Some of the rock has been mined as shipping ore.

STRUCTURAL GEOLOGY

Structure of the Helvetia District

The major structural features of the part of the Helvetia district shown on the sketch geologic map are the Helvetia thrust fault which bounds the outlier of Paleozoic and Mesozoic sedimentaries and porphyry; a set of east-west trending, east dipping thrusts; and the Helvetia tear fault.

Helvetia thrust. In innumerable outcrops and prospect pits on all sides of the Peach-Old Dick-Heavy Weight block, granite can be seen in fault contact with all other rocks. A zone of shearing is present in several exposures of the contact of granite with limestone which is completely free of silication. Shearing is also observed at the granite-quartzite contact on the west side of the Peach hill. On the east side of the outlier a well-exposed west-dipping fault between Concha and granite aligns with the granite-porphyry contact. No intrusive relations of the porphyry into the older granite can be seen along the relatively straight contact between them, and an aplite dike in the granite stops abruptly at the contact. The contact between granite and porphyry in drill hole D-17 (Elgin area) is thoroughly sheared and is definitely a fault surface lying on the plane of the granite thrust established in other drill holes (Section A-A'). The regular, topographically controlled outcrop pattern of the granite contact around the entire outlier also suggests a fault surface. Locally, stream exposures of the contact give typical outcrop patterns of a uniformly gently dipping surface. The conclusion that the entire block is the upper plate of a thrust fault can hardly be avoided. Substantiating evidence is seen in the insert from Schrader on the sketch geologic map of Helvetia: the much greater width of Paleozoics near Helvetia than anywhere north or south along the Santa Ritas suggests thrusting.

The outlier was thrust from the present position of the crest of the range. This conclusion is reached on the basis of the following evidence: (1) The mineral composition and texture of the Broad Top porphyry and the porphyry of the outlier are essentially the same. (2) The porphyry in both areas is intrusive into the Concha limestone and Cretaceous arkose. (3) At no other place in the district is any known Cretaceous found so far removed from the large mass on the east side of the range. (4) The formations occurring in both areas are exclusively Horquilla, Concha, and Scherrer, with minor Andrada in the eastern area. North of the outlier and south of Broad Top butte, the entire Paleozoic section has been mapped. (5) The configuration of beds generally striking around the porphyry is pronounced in the outlier and suggested in the butte. The evidence is not conclusive, but strongly indicative that the outlier was thrust from the area of the Broad Top butte.

Other thrust faults. As can be seen on the sketch geologic map, the Helvetia thrust dips at all exposures toward the middle of the outlier. The north-northwest strike and easterly dip of the westernmost part of the Helvetia thrust is reflected in several other major faults in the district. These include the quartzite thrust on the Peach hill and the faults localizing the Leader and Copper World mines. The granite-Horquilla contact near the Omega mine and the Peach-Elgin fault may be similar structures.

Helvetia tear fault. The Helvetia tear fault is a strongly developed, nearly vertical structure running west-northwest from the Broad Top butte. The Mohawk-Old Dick structure is probably part of the same fault making the strike length nearly two miles, and the fault may also extend a mile or more southeast of the butte. The fault forms the southern boundary of the Broad Top porphyry and includes the Broad Top breccia. West of the porphyry the fault is expressed by a zone of shearing and jointing nearly 1,000 feet wide. Massive blocks of Bolsa quartzite lying in the shear zone, some completely surrounded by granite, are dragged distances up to one-half mile by the fault.

It should be noted that several of the aplite dikes in the granite have a similar trend to the fault suggesting the present expression of the fault may be due to late movement along an old zone of weakness. The fault probably has great vertical extent and could have served as an important conduit for mineralizing solutions.

Structure of the Peach-Elgin Area

Thrust Faults

Helvetia thrust. The major Helvetia thrust underlies the entire Peach-Elgin area. A structure contour map on the top of the granite indicates the surface dips steeply to the east under the Peach hill and gently westerly under the Elgin area (see overlay maps). There is also evidence from surface exposures and drill holes D-14 and C-46 that dips along the north and south borders of the area give the fault plane a basin-like rather than a trough-like configuration.

The shear zone averages 10 feet wide, but extremes from 3 inches to 30 feet were observed. Width and intensity of alteration also varies widely. Limestone adjacent to the contact is sometimes bleached and marbleized, sometimes silicated in a narrow band, sometimes completely unmetamorphosed. The granite is chloritized in a zone which varies in width with the intensity of shearing. Where shearing is intense, the granite is completely altered to chlorite. Next to the 3 inch wide shearing the granite is essentially unaltered and shows no change of texture or composition at the contact. In several diamond drill holes recovery in the shear zone consisted only of chlorite rubble and orthoclase fragments for thickness up to 25 feet.

The thrust serves as a definite control of ore deposition, but almost no copper mineralization occurs within the fault zone itself. An exception is the 10 foot vein in the shear zone cut by hole D-14 (Section E-E').

Quartzite thrust. A second thrust with similar attitude to the main thrust forms the contact between the quartzite and the lime silicates in the western part of the Peach area. Good outcrops show an easterly dip of 70° at the surface and a strike running north to slightly west of north. The dip rapidly becomes more shallow to the east, but the fault plane is undulatory and the position of the quartzite in an individual drill hole cannot be predicted with accuracy. Dip-slip movement was large; strike slip, unknown. Slight undulations caused pinches and swells in the thickness of the dark quartzite bed.

Peach-Elgin Fault

A strong north-trending fault divides the Peach and Elgin areas. At the southern end the fault forms the contact between brown garnet of the Concha formation and green, siliceous, metamorphosed Horquilla. Further north the fault is not exposed, but its position is marked by a steep valley.

In spite of the fact that a vertical movement of over 2,000 feet is necessary to bring Concha in contact with Horquilla, no good evidence of faulting can be found except the topographic expression and the stratigraphy. Nothing is known of the dip of the fault. Because it strikes parallel to the main thrust direction, it is considered a low-angle fault of similar age to the other thrusts.

High-angle Faults

The Tip Top fault in the northern part of the area strikes northeast and is exposed for over 1,800 feet. Its dip is nowhere exposed on the surface, but the shear dipping 70° S in the Peach shaft, 30 feet from the main fault, is probably part of the same structure. In the southern fault block 350 feet of the quartzite is exposed. Bedding is completely obscured in the northern block, but the area of quartzite is so large, bedding is assumed to be nearly flat. This suggests relative movement of the north block was clockwise rotation around an axis perpendicular to the strike of the fault. The fault is displaced by two smaller, probably high-angle faults.

Strong iron and copper staining as much as 100 feet wide mark the Tip Top fault at intervals along its outcrop. The fault zone, exposed in the Peach shaft, is extremely broken by fractures of various attitudes and contains strong sulfides and magnetite.

Several steeply dipping faults with strikes ranging from northeast to southeast cut the quartzite thrust. They are indicated by deep gullies in the quartzite, but are effectively masked in the lime rocks. The entire mass of limestone is broken and microbrecciated so that while minor fractures can be found everywhere, it is difficult to trace major structures through it.

One fault was mapped in the southern part of the area having a right angle curve, one leg parallel to the strike of the thrusts, the other to that of the cross fault direction. Displacement of 150 feet is indicated with the south block dropping down.

In the Elgin area a high-angle fault set striking east-southeast cuts Concha beds and forms the contact between Concha and the porphyry in several places. One of these, exposed in the Elgin pit, is vertical with well-developed slickensides and strong hematite staining, and is related to Elgin mineralization.

Age of Faulting

Time relations of the structural activity is somewhat complicated. There is twofold evidence that the quartzite thrust is older than the granite thrust: (1) the high-angle faults displace the quartzite-lime contact, but appear to be cut off by the granite thrust; (2) in the locality of the Southern Cross mine the granite thrust appears to cut the quartzite thrust.

The Peach-Elgin fault is also probably older than the main thrust. In the northeastern part of the area the granite-limestone contact is covered with alluvium where it crosses the Peach-Elgin fault, but it is almost certainly continuous under the alluvium. In the southern part of the area no displacement of the granite contact is indicated in cross section A-A'. Furthermore, ore appears to be at comparable elevations on opposite sides of the fault.

The Tip Top fault displaces the major thrust as is evidenced by the remarkable drag observed where it cuts the western granite-quartzite thrust contact. Other high-angle faults of the Peach hill probably experienced more than one period of movement. It is believed they were originally pre-ore as is indicated by the fact that they are cut off by the pre-ore granite thrust. But minor post-ore movement along the same trends can be seen in the trench near the Southern Cross mine.

Folding and Distribution of Rock Types

The Horquilla limestone has a consistent north-northwest strike uninfluenced by the crescent shape of the Peach hill. The dip averages about 70° E on the west side of the hill and 80° W to vertical on the east. The dips suggest the Peach hill is a syncline with the crest of the hill roughly corresponding to the trough of the syncline. This interpretation is corroborated by drill hole data which establishes the configuration of the western limb, but which is incomplete and inconclusive on the east. Folding would also account for the greater than normal thickness of Horquilla exposed on the hill.

The attitude of the limestone beds is close to that of the quartzite and granite thrusts at the surface. Numerous drill holes on the west side of the hill showed that the steep dip of the beds at the surface flattens out rapidly under the hill to average about 45° E. The dip of the granite thrust flattens more rapidly than that of the beds. The result is that under much of the northeastern part of the hill the important ore-bearing diopside bed is either cut off or materially thinned by the thrusting.

ECONOMIC GEOLOGY

Mining History and Production

The earliest mining in the Santa Rita mountains was done by the predecessors of the Papago Indians in the 16th century. During the late 1600's, Spanish Jesuit missionaries mined considerable quantities of silver ore, some probably coming from the Helvetia area. Locations were recorded in the Helvetia district in 1879, and by 1883 the Old Frijole, Old Dick, Heavy Weight, Omega, and Columbia mines were producing. All significant mines in the district had been discovered by 1907 when the depression sharply curtailed activity. Since that time, mining in the district was sporadic and of small scale except for two brief periods during the World Wars when production averaged about 1,000,000 pounds of copper a year. From 1951 to 1956 there was a burst of production from the King mine, but now, except for limited shipping from the Narragansett, the district is quiescent. Schrader gives an excellent history of early mining activities in the Helvetia district.

Peach-Elgin area. The first known production in the Peach-Elgin area came from the Columbia mine (Peach shaft) for which Arizona Metals Production reports 50,000 pounds of copper in 1882. The Tip Top mine shipped about 22,000 tons of copper ore from 1904 to 1906 and has been active in recent years. Total estimated copper production from the Tip Top is about 2,750,000 pounds. It is reported that 5,000 to 6,000 tons of ore assaying 3% copper, for use as lime flux, were shipped from the Peach property. Approximately 50,000 tons of 2% copper were shipped from the Elgin shaft and open pit. Small production from the Newman and Southern Cross mines are reported in Arizona Metals Production.

Dr. Harrison Schmitt recognized the possibility of a large, disseminated copper deposit in the Peach-Elgin area in 1949. In 1955 Lewisohn Copper Corporation began exploration of the deposit.

Ore Mineralization

Mineralization of the Peach-Elgin prospect was a four phase process. During the first phase, high temperature silicates, magnetite, and ilmenite selectively replaced Horquilla limestone beds and replaced Concha limestone in a zone apparently concentric to the quartz monzonite porphyry. There is no evidence of structural control of the early metamorphism. Formation of magnetite probably continued through the second and lower grade phase of silication. Next, hydrothermal solutions were introduced which partially chloritized the silicates and brought in the mesothermal ore minerals with calcite, quartz, and small amounts of siderite. Slightly later minor molybdenite was deposited in quartz veins. Finally, the deposit was oxidized and enriched forming chalcocite, covellite, chrysocolla, "copper pitch," malachite; minor azurite, cuprite, and native copper; and abundant iron and manganese oxides.

The copper minerals in order of their abundance are as follows: chalcopyrite, chalcocite and covellite, chrysocolla and "copper pitch," bornite, malachite, azurite, cuprite, and native copper. Non-sulfide minerals constitute 35% to 40% of the total copper.

Ore in the Silicate Rocks

Most of the copper mineralization occurs as disseminated grains and tiny veinlets replacing silicate rocks. Replacement veins of solid chalcopyrite, bornite, pyrite, and magnetite up to three feet thick are found occasionally, but these constitute only a small part of the ore values. Chacopyrite and bornite also occur in calcite-quartz veins, sometimes filling open spaces in fractured and vuggy vein material.

Generally, the total of chalcopyrite, chalcocite, and bornite varies directly with the pyrite and magnetite content. Zones of disseminated pyrite or magnetite which have no significant copper content occur rarely, and in two drill holes the heavy pyrite-magnetite zone extends about 20 feet below the ore cut-off. In the eastern part of the Elgin area bornite and magnetite content is higher than normal, and pyrite content is lower.

The early silicates are partly altered to chlorite, total chlorite never comprising more than 15% of the rock. No intimate association of sulfides to chlorite is seen, but chloritization is probably related to the same solutions as deposited the ore. There is no consistent difference, however, between the chlorite content of ore-bearing and barren rocks, and some silicate ore is chlorite-free.

Bedding control of ore deposition. Chemical composition of the silicate beds served as a strong influence in controlling copper emplacement as shown in Figure 2. The aluminum-low diopside-bearing beds are favorable hosts; the aluminum-rich garnet beds, less favorable. This control is most clearly expressed in the southwestern part of the Peach area where the series of alternating diopside and garnet beds is relatively uniform between drill holes (Sections C-C' and D-D'). The diopside beds almost invariably contain ore grade mineralization, often throughout the total thickness of the bed. Copper values in the garnet beds are sporadic, sometimes reaching ore grade.

Garnet ore zones cut in drill holes were drawn on the cross sections as beds parallel to the diopside beds to represent diagrammatically the ratio of ore to waste

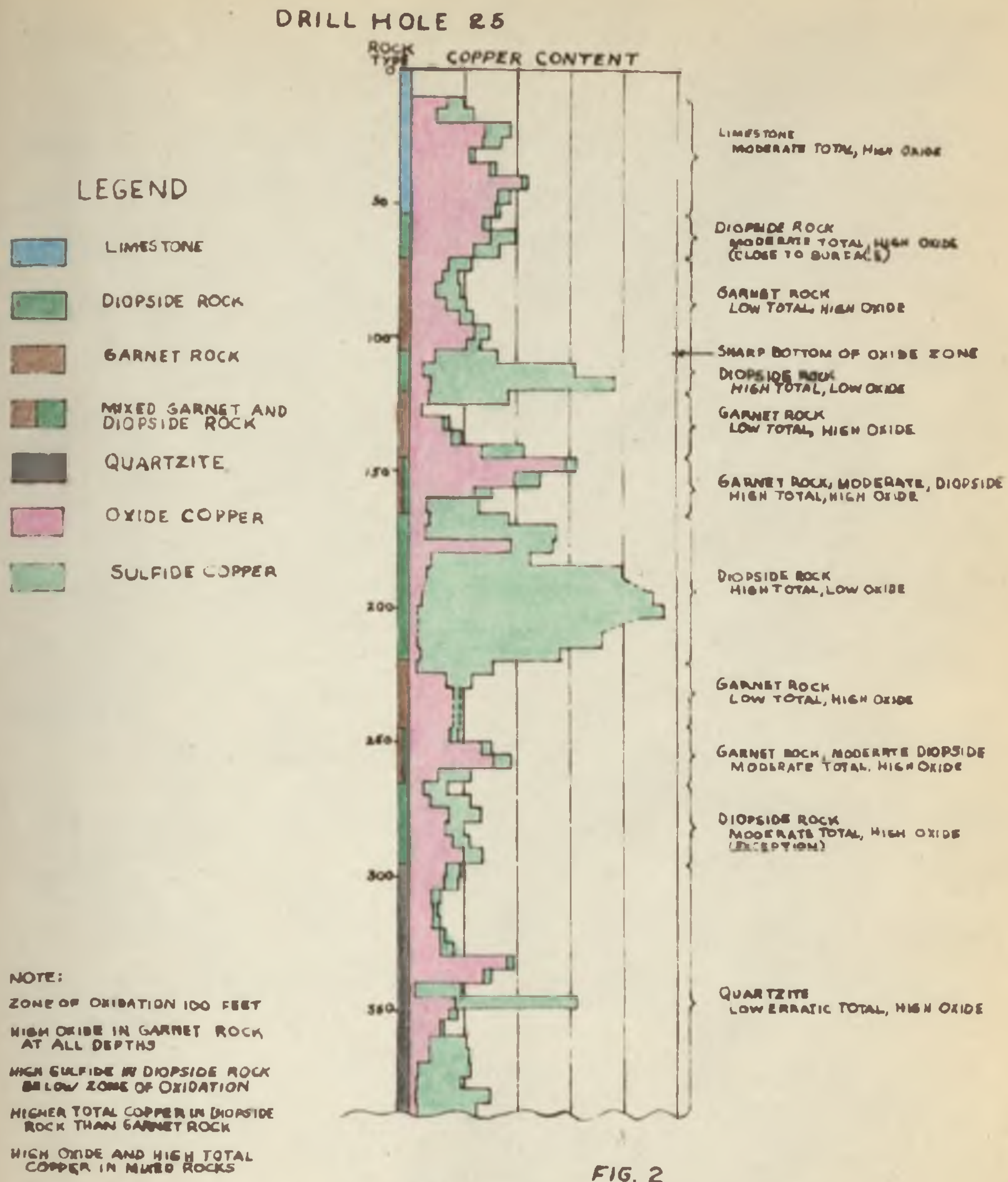

FIG. 2

RELATIONSHIP OF ROCK TYPE TO COPPER MINERALIZATION in the garnet.

The normal habit of an ore zone in the diopside rocks is a sharp, simultaneous cut-off of pyrite and chalcopyrite at the top and bottom of the zone with magnetite grading out about 10 feet beyond the ore limits. In garnet rocks the ore zones are less sharply defined. The grade of the ore is 0.3% to 0.4% higher in the diopside rocks than in the garnet.

Where the ground is extremely brecciated, such as near the intersection of the Tip Top fault and the quartzite thrust and above the roll in the granite thrust near drill hole C-28, ore-grade mineralization pervaded all the rocks and oxidation was more extensive. Still, the favorable diopside host rocks are manifested by higher grade copper.

East of the crest of the hill thick diopside beds cut by three drill holes have similar mineralogy and ground preparation to the best ore beds, but contain only marginal or below-ore-grade copper. More work is needed to determine the explanation of the apparently weaker mineralization.

Referring again to Figure 2, it can be seen that the beds also control oxidation below the level of surface oxidation. The table below summarizes the figure.

	Percent Copper	Oxidation
Diopside beds	High	Weak
Garnet beds	Low	Strong
Mixed beds	High	Strong

With few exceptions the correlation is true. Note that the characteristics of the mixed rocks are a combination of the features of the two prototypes.

The siltstones rarely contain ore. The large mass of siltstone on the east side of the Peach hill is barren, and even where a thin bed of siltstone occurs in a strongly mineralized diopside bed the grade drops perceptibly. It is interesting that the siltstones are not greatly different in composition from the diopside beds: both are aluminum- and iron-poor and calcium- and magnesium-rich. The prime difference is the higher silica content of the siltstones. Apparently it was the dense, impenetrable nature of the siltstones rather than their chemical composition which made them a poor host.

Their low copper content makes the outcrop pattern of the siltstones noteworthy. The strongly mineralized garnet and diopside rocks near the Peach adit are capped by siltstone which shows little evidence of mineralization. It can be inferred that other areas capped by barren siltstone such as the south end of the valley between the Peach and Elgin areas might have ore at depth.

Ore in Other Rocks

In the area of marble capping around the Elgin pit the copper mineralization occurs in veins, with and without quartz, bordered by serpentine alteration averaging one-half inch wide. The bleached marble between the veins is virtually barren, but the rock en masse averages ore grade. Some of the marble beds are massively altered to serpentine, and in these chalcopyrite occurs as extremely finely disseminated, easily overlooked grains. Oxidation even at the surface is extremely limited with only a small amount of the chalcopyrite replaced by "copper pitch."

The marble capping the Peach hill contains copper mineralization as disseminated chalcopyrite and bornite completely free of chloritization or oxidation, usually in irregular masses of dense, hard silicated rock within the marble. Chrysocolla and other oxidized minerals with minor pyrite and chalcopyrite and abundant iron oxides are also common. The non-sulfide copper minerals constitute a little more than half of the values in the marble unit.

The white quartzite is barren in all holes except C-28. The dark quartzite in the northern part of the Peach area contains ore-grade values for an average of about 40 feet below the thrust fault. Mineralization occurs as disseminated oxide and sulfide copper minerals, pyrite, and magnetite. Drill holes usually penetrate a considerable thickness of dark quartzite after the ore peters out and before reaching light quartzite. It is believed that more ore occurs in the dark than the light quartzite both because it is a more favorable host and because it is more prevalent in the northern Peach where ground preparation is more complete than in the south.

Structural Control of Ore Deposition

Both the quartzite thrust and the Tip Top fault are strong ore controls, and their intersection is the most important structural feature of the deposit.

The Southern Cross mine produced high-grade ore from the quartzite thrust zone, and several prospects and outcrops show the ground adjacent to the fault to be more highly mineralized than the average of the deposit. Economic mineralization cuts off at or close to the fault. In the northern part of the area strong copper values extend to about 40 feet below the fault into the quartzite. In the southern Peach area copper content is highest close to the fault at the surface, but drops below ore grade a short distance above the fault at depth.

The high-grade ore in the Peach shaft occurs in the strongly brecciated ground adjacent to the Tip Top fault. Both quartzite and lime rocks are strongly copper and iron stained along the entire outcrop length of the fault.

The highest grade and thickest portion of disseminated copper mineralization lies in the re-entrant formed by the intersection of the quartzite thrust and the Tip Top fault. Here the ore intervals in nine drill holes average 0.1% higher grade and 25 feet longer than the average for the deposit.

The extensive ground preparation associated with the granite thrust and local flexures in the fault surface also serve to localize ore deposition. The anomalously greater depth and higher grade in the ore zone encountered in hole C-28 seems to be closely related to a local downwarping of the thrust surface. It is also possible that the weak mineralization in C-42 is associated with the underlying positive node of the thrust (see structure overlay map).

It is assumed that the high-angle east-west faults also contributed to ground preparation, but no material difference is noted in the grade of ore in drill holes at varying distances from the faults.

Detailed structural control is less apparent in the Elgin area. A strong northwest fault in the Elgin at least partly controls ore deposition. Randomly oriented veinlets of chalcopyrite up to one-half inch thick are most numerous close to the fault, and the deepest mining in the pit was from a trough which was adjacent to the fault. No structure other than the underlying granite thrust appears to control emplacement near C-46, although the grade was comparable to that in the three eastern holes.

Several other deposits in the district occur at fault contacts of granite and limestone. In each case the fault strikes north-south, dips east, and is probably a thrust. Thus, the Leader vein is in such a fault; the Copper World mineralization flanks an aplite dike intruded at the contact between granite and limestone; and the Omega deposit in the Helvetia tear fault lies in Horquilla limestone separated from the granite by a small mass of dragged Bolsa quartzite. Interestingly, several identical granite-Bolsa-Horquilla contacts occur near by, but strong copper mineralization is emplaced only at the Omega, close to a sharp change in strike of the granite-limestone contact from east-west to north-south (see sketch geologic map). Presumably, the north-south strike is due to a thrust between granite and limestone. On the other hand, thousands of feet of east-west striking thrust contacts of granite and limestone are completely unmineralized. It must be concluded, then, that ore deposition is related to the east-dipping thrusts and that granite bears no relation to mineralization except that for structural reasons it often serves as a sole of the thrusts.

Oxidation and Enrichment

Most of the near-surface ore and a large proportion of ore at depth is extensively oxidized. The typical suite of oxide minerals is discussed in the section on capping.

Depth of the surface oxide zone appears to be partly controlled by topography. On the Peach hill the base of the zone averages about 100 feet below the surface, while in the flat between the Peach and Elgin the depth of oxides was less than 50 feet. As was mentioned above, the degree of oxidation is largely determined by the rock type. Sulfides in the dense marble near the Elgin pit and in the marble cap rock of the Peach hill are completely unaltered at the surface. Garnet ore at all depths, even where it occurs below a sulfide zone in diopside rock, is more than 50% oxidized.

In the alternating diopside and garnet beds of the Peach hill the contact of the oxide and sulfide zones is extremely sharp. Often non-sulfide copper content drops from more than 50% to less than 10% in a single five foot churn drill run.

Chalcocite and covellite occur in the sulfide zone and are particularly rich in the strongly broken north Peach area. However, no well-defined zone of enrichment is developed; chalcocite content varies without regard to position in the sulfide zone. It is probable that enrichment took place locally in areas of more complete silication. Low carbonate content of the gangue would allow migration of copper in solution.

Capping

Locke defined capping as "the oxidized equivalent of disseminated sulfide material." The capping of a uniformly disseminated sulfide body in igneous or other unreactive rock may give a close representation of the mineralized area. It should be emphasized, however, that the capping formed on limestone beds differentially favorable to ore deposition represents only the sulfide content of the outcropping bed on which the capping occurs. Further, since the reactive nature of the gangue prevents extensive leaching, the ore content of the capping is close to that of the unoxidized part of the bed. Finally, due to textural differences, outcrops of beds having comparable ore content may be completely oxidized or completely unoxidized as is the case on the Peach hill. The following conclusions can therefore be drawn: (1) The best measure of the ore content of the bed represented by its capping is simply the copper content of the surface rock regardless of oxidation. (2) Favorable capping will not occur unless the ore bed outcrops, and ore can and does underlie barren surface rock. (3) Favorable capping indicates ore in the bed exposed; hence, in shallow-dipping beds extension of the ore is lateral rather than vertical.

Capping in deposits not closely controlled by bed composition must be interpreted with regard to other geologic features. Thus, in the Elgin area, where dominant controls appear to be the underlying thrust and proximity to the porphyry, the well-developed oxidized capping probably closely represents the areal extent of strong copper mineralization. The tabular, fault controlled body of the Copper World outcrops as heavily oxidized material which has approximately the same horizontal width as the sulfides. Finally, massive replacement bodies in white marbleized limestone such as the Omega deposit display virtually no oxidized capping unless the body is actually exposed. The deposits are structurally controlled and have sharp cutoffs; little or no dissemination occurs in the wall rocks. Where these bodies are within 15 feet of the surface, they are indicated by thin veins of "copper pitch," "limonite," hematite, or malachite. There is little surface indication of deeper bodies.

Oxidized capping in the Peach-Elgin area. The prospect provides excellent examples of capping in the traditional sense. The most distinguishing feature is, of course, the copper content. Copper occurs as disseminated chrysocolla, malachite, "copper pitch," and brown and black pulverulent copper-bearing iron oxides. Green stain often pervades the rock and veinlets of iron oxide and copper pitch are prevalent. Oxidation is incomplete in thicker veins, and chalcopyrite can be seen altering to "copper pitch" in a lace-like pattern. The predominant "limonite" color is the typical brown derived from oxidation of copper-iron sulfides. Yellow and red "limonite" also occur and occasionally a small amount of bright carmine derived from chalcopyrite is observed. Pyrite and chalcopyrite boxworks are found in rocks with relatively high copper content, especially in the Elgin area. The diopside rocks are thoroughly broken. Brecciation is less obvious in the garnet rocks, but they are more porous and softer looking than their barren equivalents. Quartz veins locally cut the capping; however, in drill holes heavy quartz content is more usually associated with weak mineralization than with ore.

Ore Values

Only the copper mineralization of the deposit has significant economic value. The considerable iron present as pyrite and magnetite may have some use in the recovery of copper depending on the process used. Spectrographic analysis showed cobalt and nickel content, probably too small for profitable recovery. Molybdenum content has not yet been accurately determined, but it too is low. Silver values are low but recoverable. Gold, lead, and zinc are negligible.

Paragenesis

Magnetite and ilmenite were formed with the early silicates, and magnetite continued to deposit in the mesothermal phase. Chalcopyrite, bornite, and possibly some of the chalcocite were essentially contemporaneous. Most of the chalcocite occurs as a replacement of chalcopyrite. Pyrite formed with the chalcopyrite probably starting a little earlier. Some of the pyrite is embayed by late phase tremolite. No time relations of the cobaltite were observed, but it is assumed it was about contemporaneous with the pyrite. Molybdenite occurs in late quartz veins that cut all the other minerals.

Form of the Ore Body

The area of possible economic mineralization is well defined. Basement granite underlies the upper plate of ore-bearing Paleozoic sedimentaries below a curving fault plane and outcrops to the north, west, and south of the deposit. To the southeast the lime silicates are in contact with the quartz monzonite porphyry. Tentatively, until the western periphery of the intrusive is drilled, the surface expression of the contact may be assumed to represent the ore limit. Intensity of silicate alteration and ground preparation decreases to the northeast and the grade of the mineralization may drop accordingly. Therefore, the area that must be explored by drilling is an eliptical body, saucer-shaped in cross section, with a 4,400 foot north-south axis and a 2,000 foot east-west axis as shown on the Geologic Map of the Peach-Elgin area.

Two ore bodies have so far been indicated by drilling. The Peach body is an elipse 2,500 feet long and 500 feet wide. It is wedge shaped in cross section, dipping and tapering to the east. As shown in Sections C-C' and D-D', in part of the body ore zones are divided by layers of waste. The waste zones are garnet beds between beds of ore-bearing beds of diopside rock. To the north and south of the central part of the Peach body the ore zone is uninterrupted, but the garnet intervals are lower grade than those of diopside. The Elgin ore body, indicated by four drill holes and oxidized capping, covers almost 1,000,000 square feet on the surface. Ore grade mineralization in the Elgin holes starts at or close to the surface and is continuous to the bottom of the ore zone. Good capping in the intervening area indicates that further drilling should prove continuity between the two bodies.

Origin of the Deposit

In its gross aspects, the Peach-Elgin prospect displays most of the characteristics typical of the pyrometasomatic deposits in lime silicate rock common in Arizona and New Mexico. An intrusive capable of causing the 600 foot thickness of silication present in parts of the Peach hill is not found close to the deposit, but numerous similar deposits are found to be associated with faulting rather than with a closely adjacent igneous body. In detail, however, the origin of the deposit is complicated. A study of the Helvetia district indicated the following somewhat unusual sequence of events was involved in the formation of the deposit: (1) intrusion of the quartz monzonite porphyry; (2) extensive thrusting; and (3) copper mineralization by solutions associated with the porphyry. To substantiate this conclusion it will be necessary to review some of the petrology and geologic history of the district.

As was stated above, the granite is partly pre-Cambrian and partly post-Paleozoic (or post-Cambrian). Cretaceous clastics lie unconformably on the granite, and the quartz monzonite porphyry is intrusive into the Cretaceous. A considerable time lapse is thus well indicated between the intrusions. It was also pointed out that, although many of the ore deposits lie at or near contacts with the granite, most of these deposits are adjacent to east-dipping faults. It was concluded that the mineralization is related to the faulting, but probably not to the granite.

The porphyry, on the other hand, is closely related to mineralization as is indicated by the several pyrometasomatic deposits at its intrusive contacts. Since the granite and porphyry are of widely different ages, the granite is not associated with mineralization, and no other igneous rocks occur in significant quantities in the district, it may be assumed that all the copper deposits are genetically related to the porphyry.

It has already been demonstrated that the major Helvetia thrust and the quartzite thrust in the Peach area localize ore deposition. To recapitulate the sequence of events: thrusting followed intrusion of the porphyry, but also served as an ore control, and hence must have preceded mineralization. In fact, a rather impressive number of events seems to have occurred between the time of intrusion and mineralization. The quartzite and Peach-Elgin thrusting preceded the granite thrust, and the granite thrust was cut by the Tip Top fault and the Helvetia tear, both of which later served as ore controls. Some account must be given for the time lapse.

Although the relative age of the events can be established, no estimate can be made of the time interval between them. It is entirely possible that intrusion, thrusting, and tear faulting were nearly contemporaneous in which case there need have been no great time lapse between intrusion and mineralization. Furthermore, the events involved in the formation of other pyrometasomatic deposits are known to have taken place over a considerable period of time. Schmitt (p. 193) states that at Hanover pre-silicate dikes intrude the quartz monzonite stock which was responsible for the silication, and that "pyrometasomatism occurred after solidification of the part of the main intrusive now exposed." He cites numerous other authors who have described similar relations of the "main intrusive" to silication. The lapse between silication and ore mineralization is also well established, since post-silicate pre-ore faulting is a common feature of most pyrometasomatic deposits. It can be concluded that the time between intrusion and mineralization may not have been great, and that even it it was considerable, it would not be an unusual feature of this type of deposit.

<u>Summary</u>. A mass of quartz monzonite porphyry, no doubt much larger than present exposures on Broad Top butte and in the outlier, intruded Concha limestone. Much of the Concha and possibly the Horquilla now in the Peach-Elgin area may have lain above the intrusion. Concha was thrust over Horquilla and Horquilla over Scherrer nearly contemporaneously with silication of the limestones and movement of the entire upper plate of the Helvetia thrust. Also close to the same time, the Helvetia tear fault, the Tip Top fault, and several smaller high-angle faults cut the thrusts and helped to prepare the ground for mineralization. Finally, copper-bearing hydrothermal solutions, associated with the porphyry and using the faults and intrusive contacts as conduits, deposited the ore minerals.

SEQUENCE OF GEOLOGIC EVENTS
IN THE HELVETIA DISTRICT

The following sequence of geologic events was involved in the formation of the Peach-Elgin copper deposit:

1. Paleozoic sedimentaries were deposited on pre-Cambrian "granite."
2. A granite batholith intruded the Paleozoics.
3. Cretaceous clastics and volcanics were deposited.
4. The quartzite thrust moved Horquilla above Scherrer, and the Peach-Elgin fault moved Concha above Horquilla.

   And the Broad Top quartz monzonite porphyry plug was intruded into Concha limestone and Cretaceous rocks.
5. The sedimentaries were cut by cross faults which also displaced the quartzite thrust.
6. The Concha and Horquilla limestones were metamorphosed by solutions related to the quartz monzonite porphyry to high temperature silicates. Silication may also have occurred during and after the movement of the Helvetia thrust.
7. The major Helvetia thrust moved the top of the porphyry body and associated sedimentaries from Broad

Top butte to their present position.

8. The Tip Top fault displaced the Helvetia thrust and greatly brecciated the ground, especially near their intersection.

9. The original high temperature silicates were replaced by lower temperature silicates, and brecciation continued.

And the Helvetia tear fault cut off the porphyry and caused major drag and brecciation over a strike length of nearly two miles.

10. Hydrothermal solutions were introduced, the silicates partly chloritized, and ore minerals deposited.

Events 4 to 10 may have been nearly contemporaneous.

11. Minor post-ore faulting occurred.

12. The deposit was oxidized and enriched.

CONCLUSIONS

1. Copper ore in the Helvetia district is largely restricted to deposits in metamorphosed limestone, primarily the Horquilla and Concha formations. The two important metamorphic types, silicated limestone and bleached, marbleized limestone, each contain characteristic deposits. Both disseminated and massive replacement deposits occur in lime silicate rocks. Only massive replacement deposits occur in bleached, marbleized limestone.

2. Copper deposits in the lime silicates occur adjacent either to intrusive masses or to major faults, usually easterly dipping thrust faults. Both types of deposits are probably related to the quartz monzonite porphyry. Deposits adjacent to major faults are controlled either entirely by structure or by a combination of structure and bed composition.

A. The Peach and Elgin bodies are characterized by disseminated mineralization with minor massive replacement in strongly broken zones and at the porphyry contact. Dominant controls of deposition in the Elgin area are the Helvetia thrust fault and proximity to the porphyry; in the Peach area dominant controls are faults and favorable beds. Capping represents the areal extent of strong copper mineralization in the Elgin area; it does not in the Peach. Chloritization cannot be used as a guide to ore within the silicate body.

B. Other silicate ore bodies are the Copper World and Leader, at thrust contacts with the granite; the Mohawk-Old Dick, in a fault in limestone; and the King and Heavy Weight deposits, at intrusive contacts of the porphyry.

3. Copper deposits in bleached and marbleized rocks are structurally controlled massive replacement bodies with little disseminated mineralization in the wall rock. Outcrop indications of such bodies are subtle, particularly when the deposits are more than 15 feet below the surface.

4. All large masses of lime silicate in the part of the Helvetia district shown on the sketch geologic map contain disseminated copper mineralization, and disseminated mineralization occurs only in the silicate rocks with the exception of the Broad Top breccia deposit in quartzite, porphyry, and lime silicates. No large mass of lime silicate other than those mentioned above outcrops in the area. Hence, the possibility of finding a new, large, disseminated deposit is poor.

5. The possibility of finding structurally controlled, blind, massive replacement ore bodies is still good. Potential areas include the marble east of the Old Dick mine and part of the southeast edge of the Broad Top porphyry where faulting has buried the intrusive contact.

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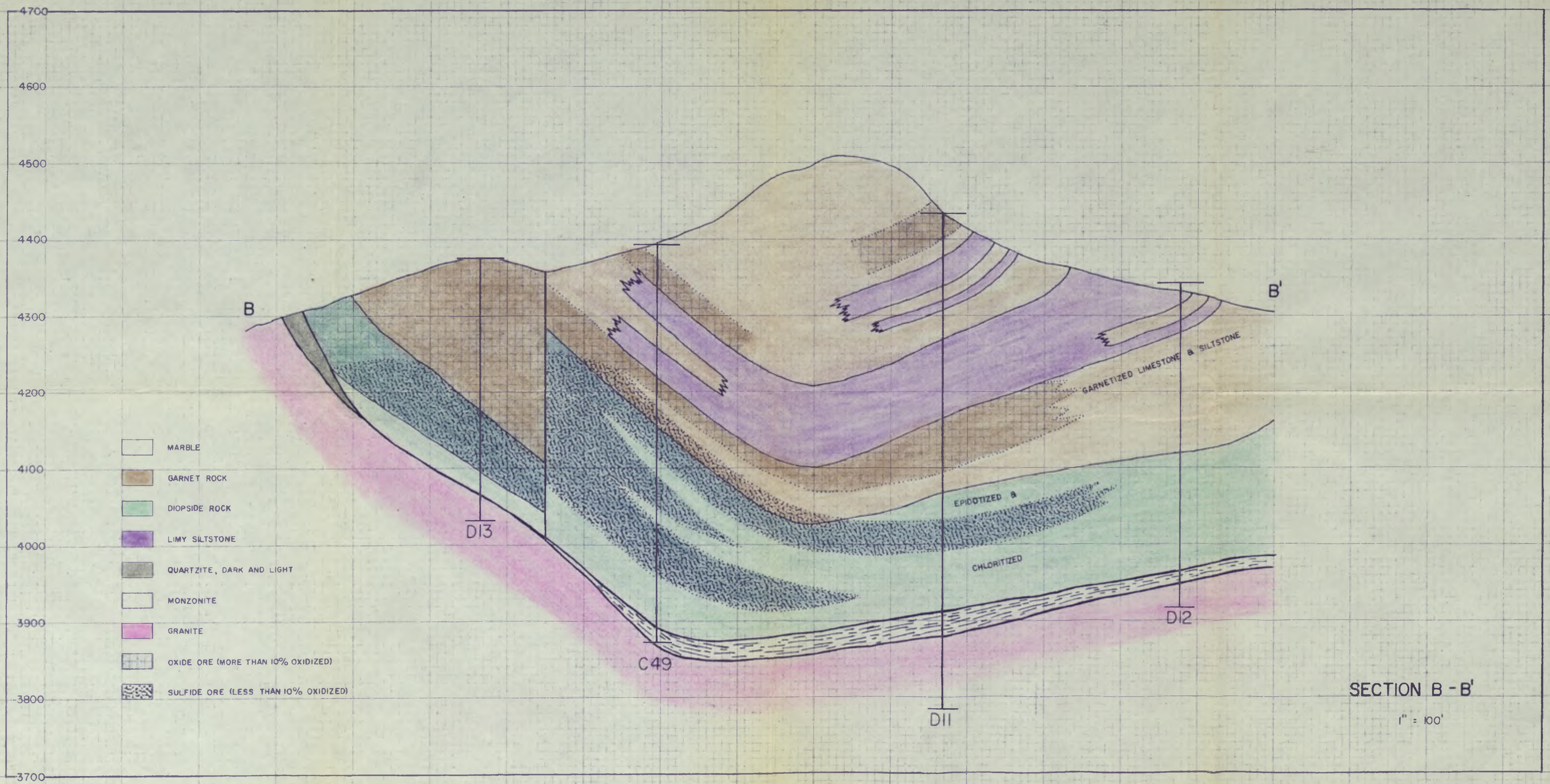
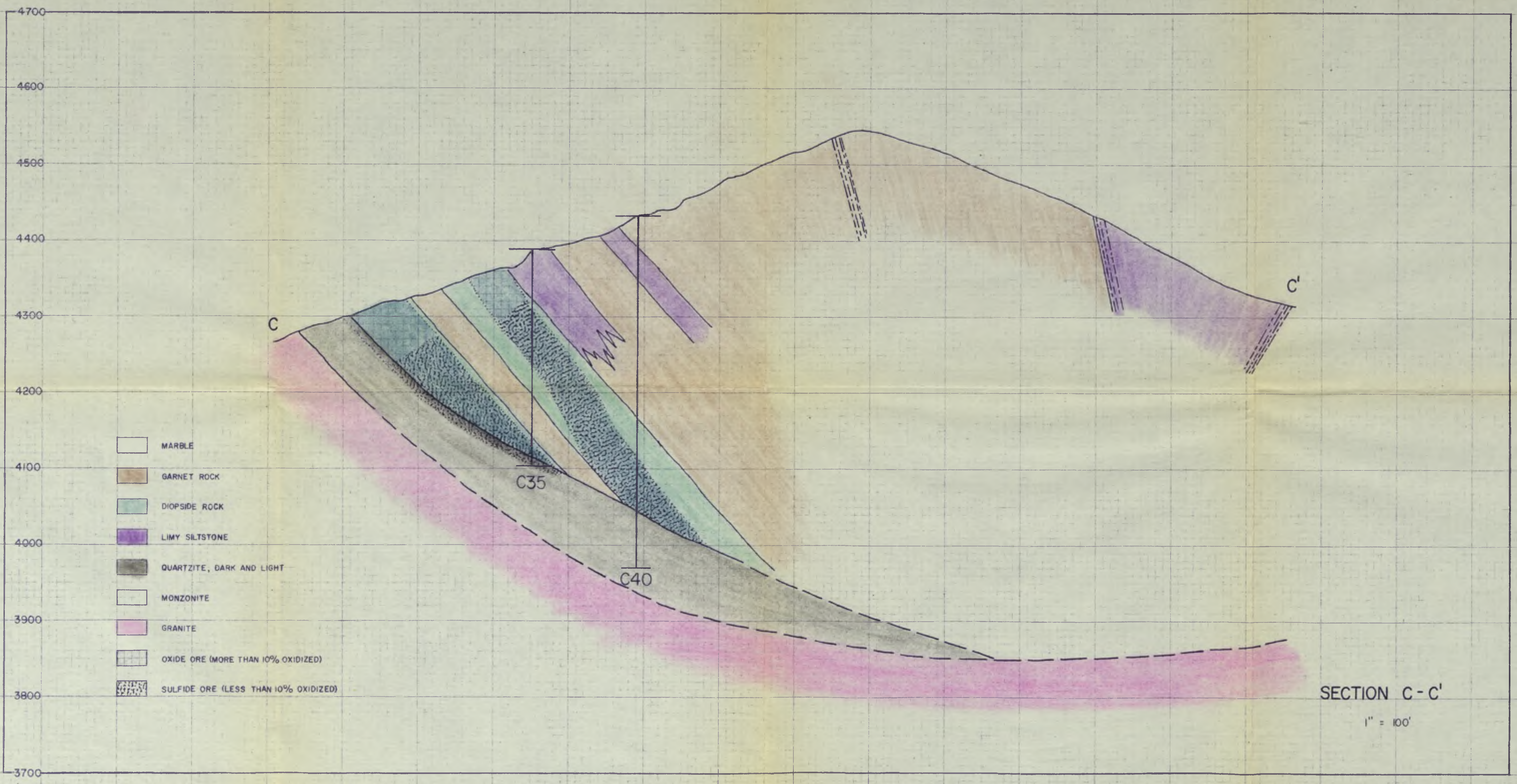
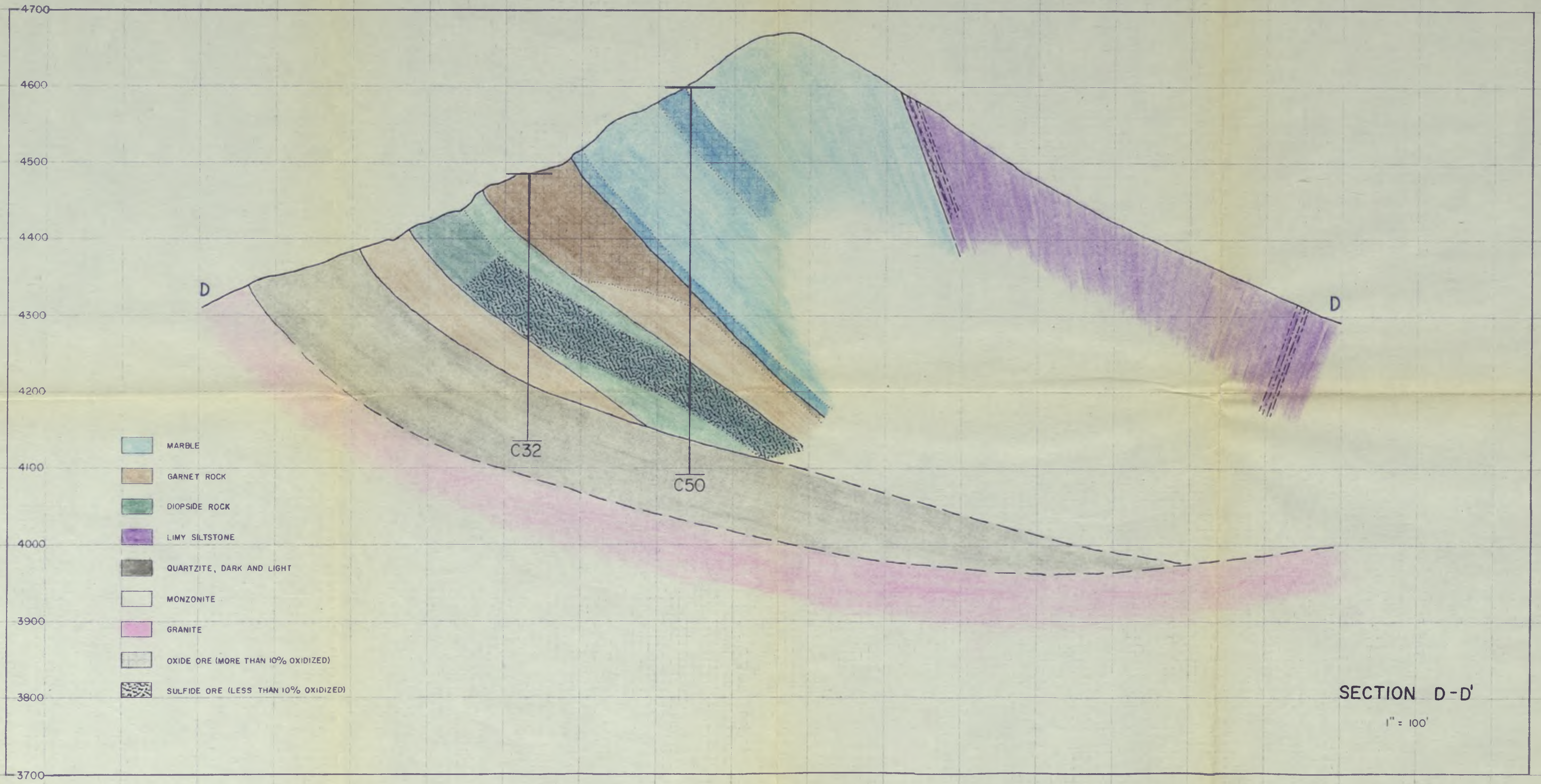
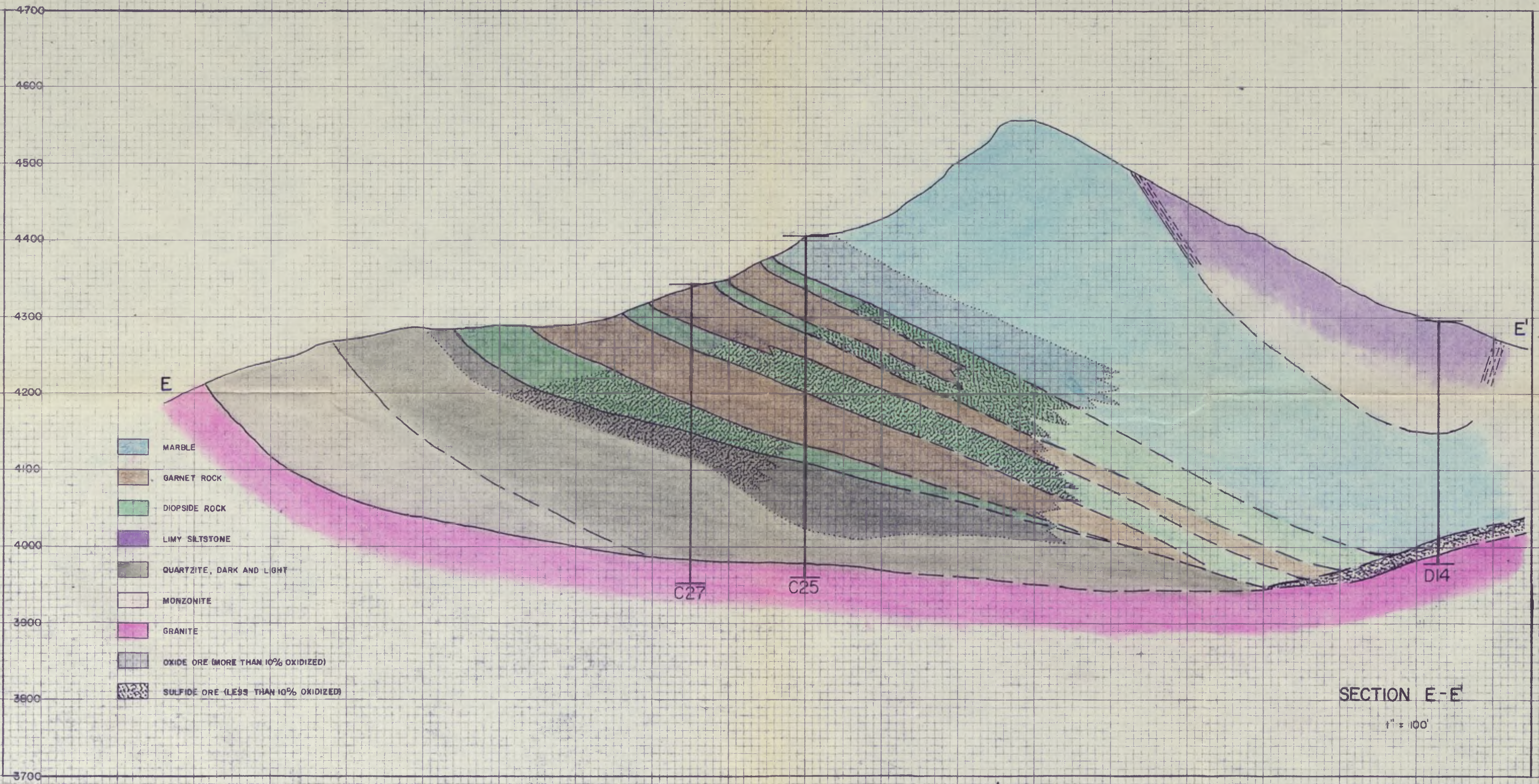
CROSS SECTIONS THROUGH THE PEACH - ELGIN AREA


4700
4600
4500
4400
4300
4200
4100
4000
3900
3800
3700
B
B'
D13
C49
D11
D12
GARNETIZED LIMESTONE & SILTSTONE
EPIDOTIZED &
CHLORITIZED
MARBLE
GARNET ROCK
DIOPSIDE ROCK
LIMY SILTSTONE
QUARTZITE, DARK AND LIGHT
MONZONITE
GRANITE
OXIDE ORE (MORE THAN 10% OXIDIZED)
SULFIDE ORE (LESS THAN 10% OXIDIZED)
SECTION B - B'
1" = 100'

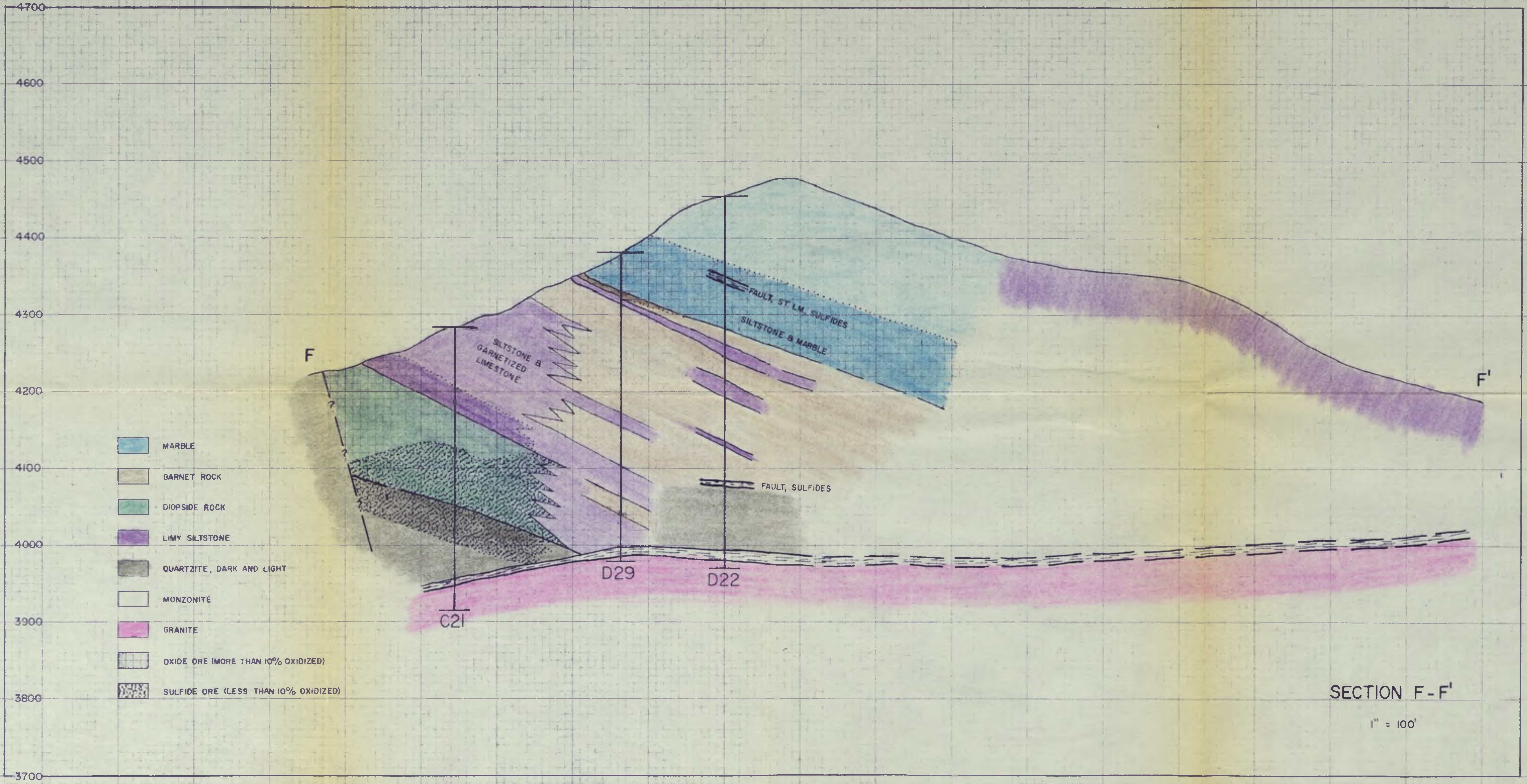

4700
4600
4500
4400
4300
4200
4100
4000
3900
3800
3700
C
C'
C35
C40
MARBLE
GARNET ROCK
DIOPSIDE ROCK
LIMY SILTSTONE
QUARTZITE, DARK AND LIGHT
MONZONITE
GRANITE
OXIDE ORE (MORE THAN 10% OXIDIZED)
SULFIDE ORE (LESS THAN 10% OXIDIZED)
SECTION C - C'
1" = 100'


4700
4600
4500
4400
4300
4200
4100
4000
3900
3800
3700
D
D
C32
C50
MARBLE
GARNET ROCK
DIOPSIDE ROCK
LIMY SILTSTONE
QUARTZITE, DARK AND LIGHT
MONZONITE
GRANITE
OXIDE ORE (MORE THAN 10% OXIDIZED)
SULFIDE ORE (LESS THAN 10% OXIDIZED)
SECTION D-D'
1" = 100'



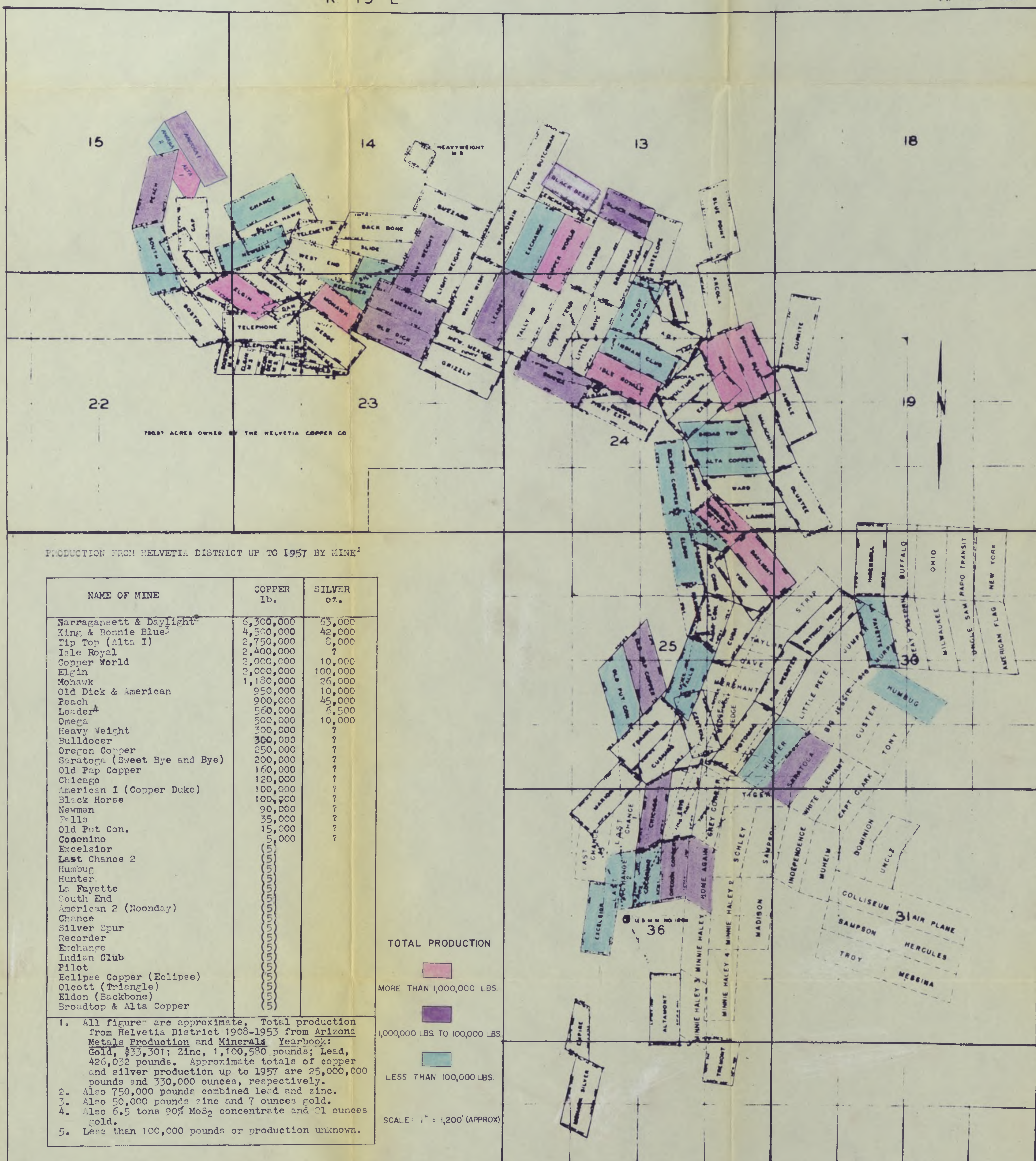
SECTION E-E'

1" = 100'


4700
4600
4500
4400
4300
4200
4100
4000
3900
3800
3700
F
F'
SILTSTONE & GARNETIZED LIMESTONE
FAULT, ST LM, SULFIDES
SILTSTONE & MARBLE
FAULT, SULFIDES
C21
D29
D22
MARBLE
GARNET ROCK
DIOPSIDE ROCK
LIMY SILTSTONE
QUARTZITE, DARK AND LIGHT
MONZONITE
GRANITE
OXIDE ORE (MORE THAN 10% OXIDIZED)
SULFIDE ORE (LESS THAN 10% OXIDIZED)
SECTION F-F'
1" = 100'


LONGITUDINAL SECTIONS THROUGH PEACH AREA
4700
4600
4500
4400
4300
4200
4100
4000
3900
3800
3700
G
G'
G''
G'''
C41
C33
C18
C43
C36
D23
C26
C32
D16
C28
C35
C34
D13
C38
MARBLE
GARNET ROCK
DIOPSIDE ROCK
LIMY SILTSTONE
QUARTZITE, DARK AND LIGHT
MONZONITE
GRANITE
OXIDE ORE (MORE THAN 10% OXIDIZED)
SULFIDE ORE (LESS THAN 10% OXIDIZED)
SECTIONS G - G', G''- G'''
1" = 100'

THE HELVETIA MINING DISTRICT



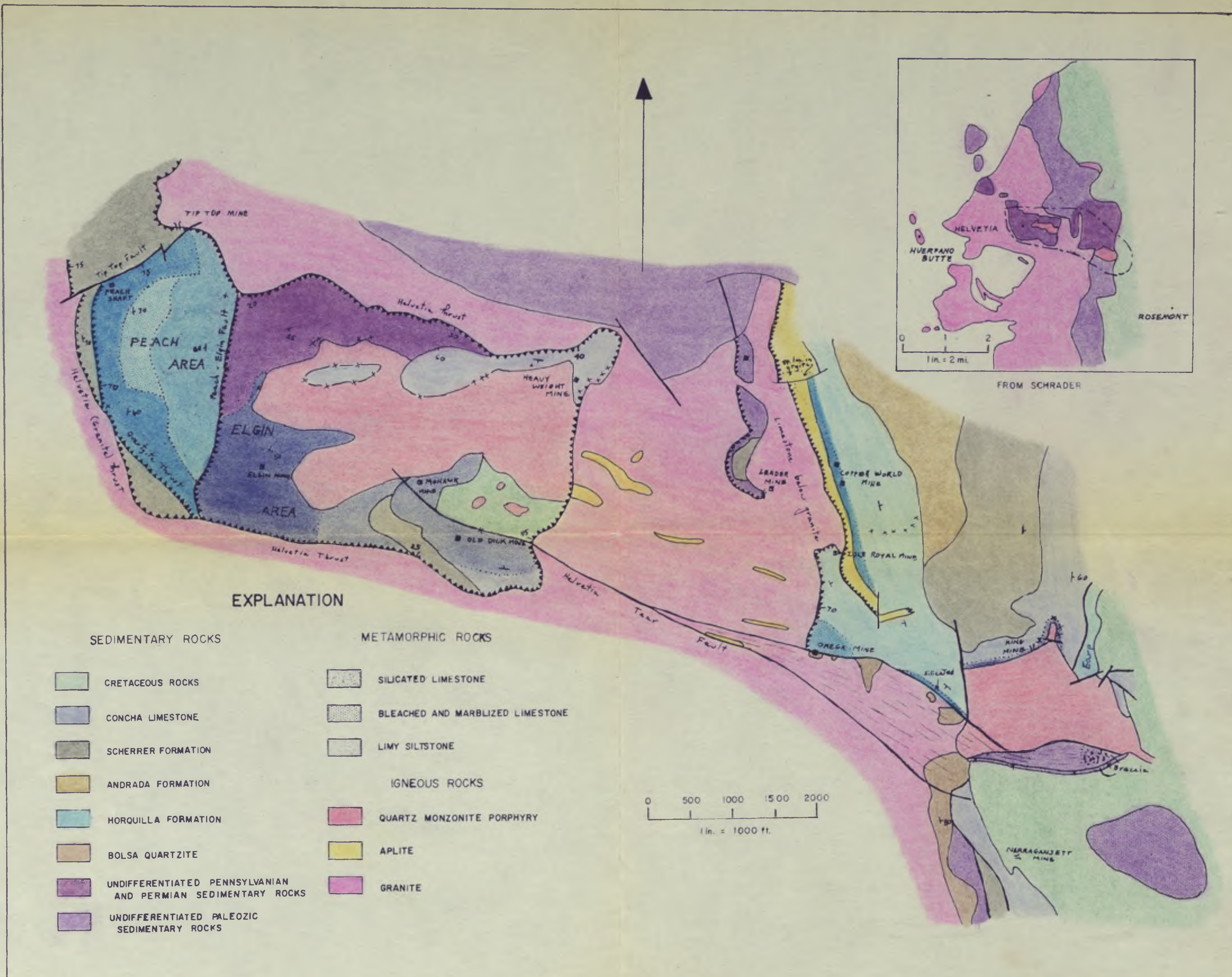
PRODUCTION FROM HELVETIA DISTRICT UP TO 1957 BY MINE[1]

NAME OF MINE	COPPER lb.	SILVER oz.
Narragansett & Daylight[2]	6,300,000	63,000
King & Bonnie Blue[3]	4,500,000	42,000
Tip Top (Alta I)	2,750,000	8,000
Isle Royal	2,400,000	?
Copper World	2,000,000	10,000
Elgin	2,000,000	100,000
Mohawk	1,180,000	26,000
Old Dick & American	950,000	10,000
Peach	900,000	45,000
Leader[4]	560,000	6,500
Omega	500,000	10,000
Heavy Weight	300,000	?
Bulldocer	300,000	?
Oregon Copper	250,000	?
Saratoga (Sweet Bye and Bye)	200,000	?
Old Pap Copper	160,000	?
Chicago	120,000	?
American I (Copper Duke)	100,000	?
Black Horse	100,000	?
Newman	90,000	?
Falls	35,000	?
Old Put Con.	15,000	?
Coconino	5,000	?
Excelsior	(5)	
Last Chance 2	(5)	
Humbug	(5)	
Hunter	(5)	
La Fayette	(5)	
South End	(5)	
American 2 (Noonday)	(5)	
Chance	(5)	
Silver Spur	(5)	
Recorder	(5)	
Exchange	(5)	
Indian Club	(5)	
Pilot	(5)	
Eclipse Copper (Eclipse)	(5)	
Olcott (Triangle)	(5)	
Eldon (Backbone)	(5)	
Broadtop & Alta Copper	(5)	

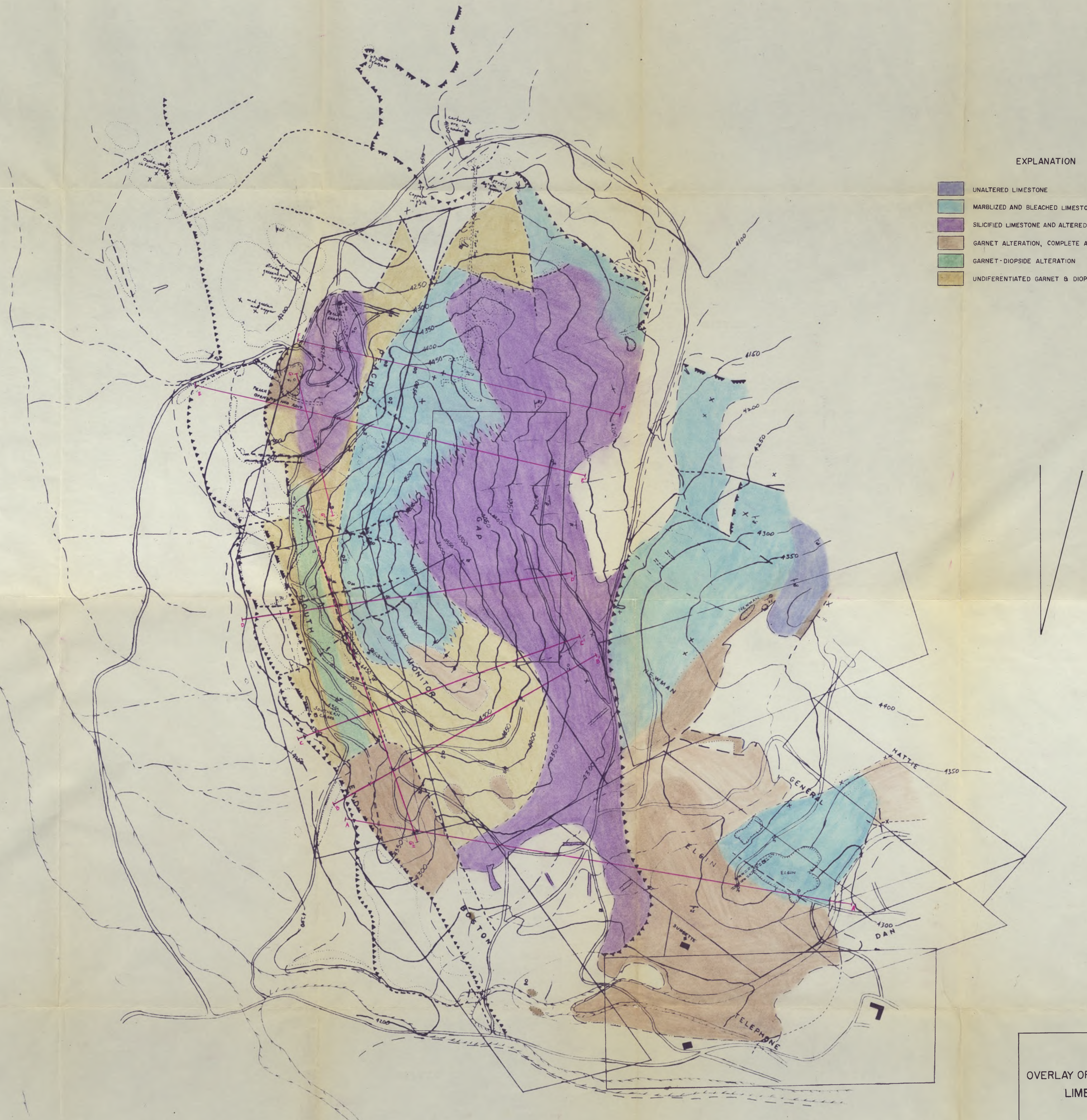
1. All figures are approximate. Total production from Helvetia District 1908-1953 from Arizona Metals Production and Minerals Yearbook: Gold, $33,301; Zinc, 1,100,580 pounds; Lead, 426,032 pounds. Approximate totals of copper and silver production up to 1957 are 25,000,000 pounds and 330,000 ounces, respectively.
2. Also 750,000 pounds combined lead and zinc.
3. Also 50,000 pounds zinc and 7 ounces gold.
4. Also 6.5 tons 90% MoS_2 concentrate and 21 ounces gold.
5. Less than 100,000 pounds or production unknown.

CORRELATION OF STRATIGRAPHIC COLUMNS, HELVETIA DISTRICT, ARIZONA

ERA	PERIOD	POPOFF 1941 FORMATION	POPOFF 1941 THICKNESS (FT)	JONES 1940 FORMATION	JONES 1940 THICKNESS (FT)	JOHNSON 1941 FORMATION	JOHNSON 1941 THICKNESS (FT)	CREASEY & QUICK 1943 FORMATION	CREASEY & QUICK 1943 THICKNESS (FT)	BRYANT 1956 FORMATION	BRYANT 1956 THICKNESS (FT)	LITHOLOGY	THICKNESS USED IN THIS PAPER
CRETACEOUS		SONOITA GP.	ABOUT 7000	CLASTICS	1000'S	SHALES AND ARKOSES	5000	CLASTICS				ARKOSE, CONGLOMERATES, VOLCANICS	ABOUT 7000
PALEOZOIC	PERMIAN	SNYDER HILL LS.	800	SNYDER HILL LS	500 - 750	SNYDER HILL LS	500	SNYDER HILL LS.		NACO GROUP: CONCHA LS.	355+	DARK GRAY FOSSIL LIMESTONE	600
PALEOZOIC	PERMIAN	MANSANO GP.	1300	MANSANO GROUP: SAN ANDREAS FM.	750 - 1000	MANSANO GROUP: SAN ANDREAS FM.	700	UPPER MANZANO EQUIV.		NACO GROUP: SCHERRER FM.	620	QUARTZITE WHITE DOLOMITIC LIMESTONE QUARTZITE	100 200 350
PALEOZOIC	PERMIAN			MANSANO GROUP: YESO FM.	1000-1400	MANSANO GROUP: YESO FM.	1000	LOWER MANZANO EQUIV.		NACO GROUP: ANDRADA FORMATION: EPITAPH & COLINA		LIMESTONES, MARLS, GYPSITE, SHALES, THIN QUARTZITES	1200
PALEOZOIC	PENNSYLVANIAN			NACO FM.	1200-1500	UPPER NACO FM.	700	NACO LS. (RESTRICTED)		NACO GROUP: ANDRADA FORMATION: EARP		LIGHT BROWN AND GREEN SILTSTONE	700
PALEOZOIC	PENNSYLVANIAN					LOWER NACO FM	800			HORQUILLA FM		INTERBEDDED LIMESTONE, WITH MINOR SILTSTONE AND SHALE	800
PALEOZOIC	MISSISSIPPIAN	ESCABROSA LS.	400			ESCABROSA LS.	700	ESCABROSA LS.				WHITE, COARSELY CRYSTALLINE MARBLE	
PALEOZOIC	DEVONIAN	MARTIN LS.	150			MARTIN LS.	200 - 400					GRAY LIMESTONE, WITH MINOR SHALE	
PALEOZOIC	CAMBRIAN	RINCON LS (?)	200			CAMBRIAN LS.	800					PINK TO GRAY LIMESTONE, THIN QUARTZITE	
PALEOZOIC	CAMBRIAN	ABRIGO FM.	400									THIN INTERBEDDED LIMESTONE & CHERT	
PALEOZOIC	CAMBRIAN	COCHISE FM.	150									LIMESTONE, SHALE, QUARTZITE	
PALEOZOIC	CAMBRIAN	BOLSA QTZITE	600			BOLSA QTZITE	520	BOLSA QTZITE				ROUGH TEXTURED, COARSE-GRAINED QUARTZITE	



SKETCH GEOLOGIC MAP OF PART OF THE HELVETIA DISTRICT, ARIZONA

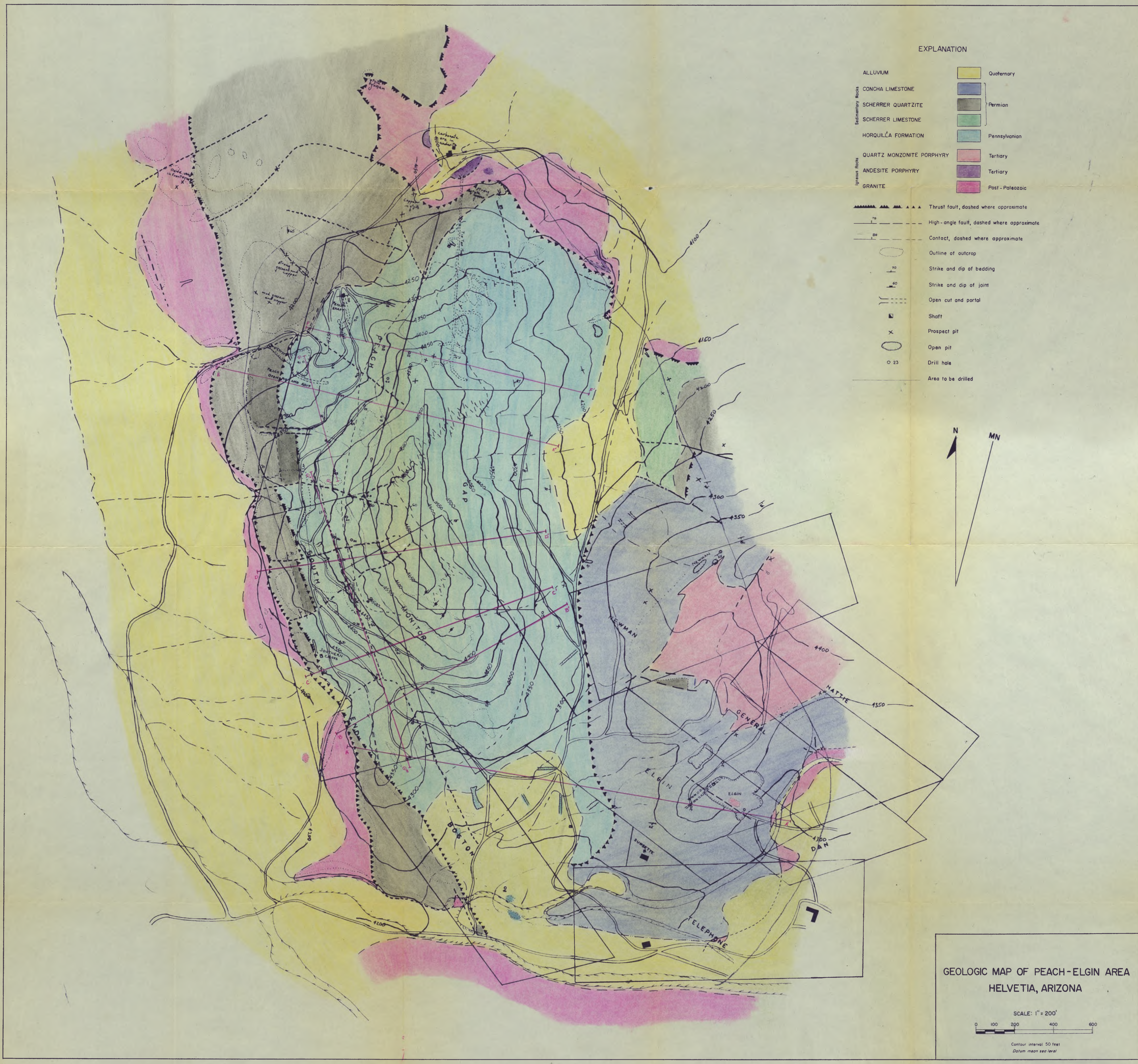


EXPLANATION

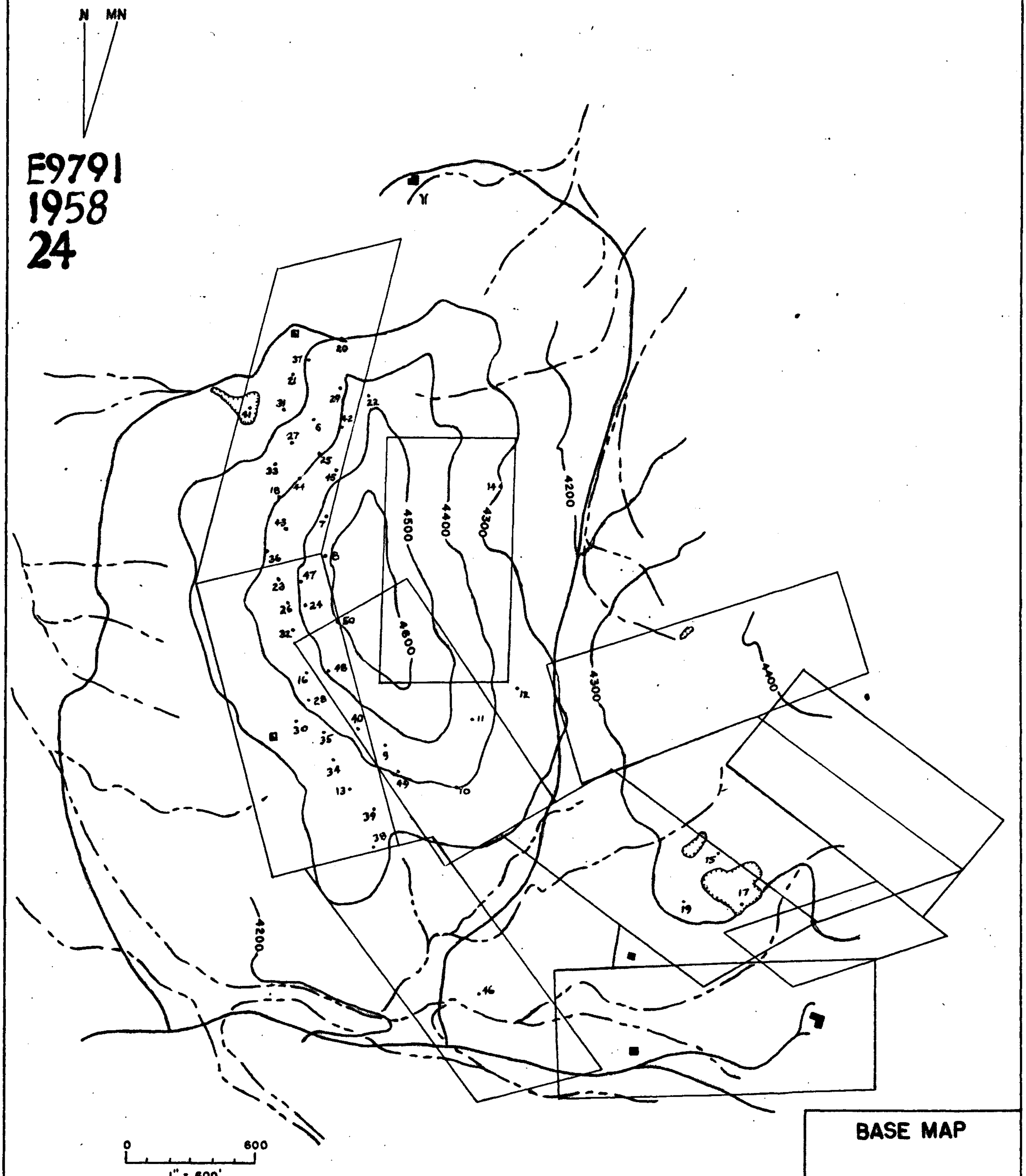
- UNALTERED LIMESTONE
- MARBLIZED AND BLEACHED LIMESTONE
- SILICIFIED LIMESTONE AND ALTERED SILTSTONE
- GARNET ALTERATION, COMPLETE AND PARTIAL SILICATION
- GARNET-DIOPSIDE ALTERATION
- UNDIFERENTIATED GARNET & DIOPSIDE ALTERATION

OVERLAY OF PEACH-ELGIN GEOLOGIC MAP
LIMESTONE ALTERATION

SCALE: 1" = 200'


EXPLANATION
ALLUVIUM
Quaternary
Sedimentary Rocks
CONCHA LIMESTONE
SCHERRER QUARTZITE
SCHERRER LIMESTONE
Permian
HORQUILLA FORMATION
Pennsylvanian
Igneous Rocks
QUARTZ MONZONITE PORPHYRY
Tertiary
ANDESITE PORPHYRY
Tertiary
GRANITE
Post - Paleozoic
Thrust fault, dashed where approximate
High - angle fault, dashed where approximate
Contact, dashed where approximate
Outline of outcrop
Strike and dip of bedding
Strike and dip of joint
Open cut and portal
Shaft
Prospect pit
Open pit
Drill hole
Area to be drilled
N
MN
PEACH
MONITOR
GAP
SOUTH
END
BOSTON
NEWMAN
GENERAL
HATTIE
ELGIN
DAN
TELEPHONE
GEOLOGIC MAP OF PEACH - ELGIN AREA
HELVETIA, ARIZONA
SCALE: 1" = 200'
0 100 200 400 600
Contour interval 50 feet
Datum mean sea level

OVERLAY MAPS OF THE PEACH-ELGIN AREA



BASE MAP

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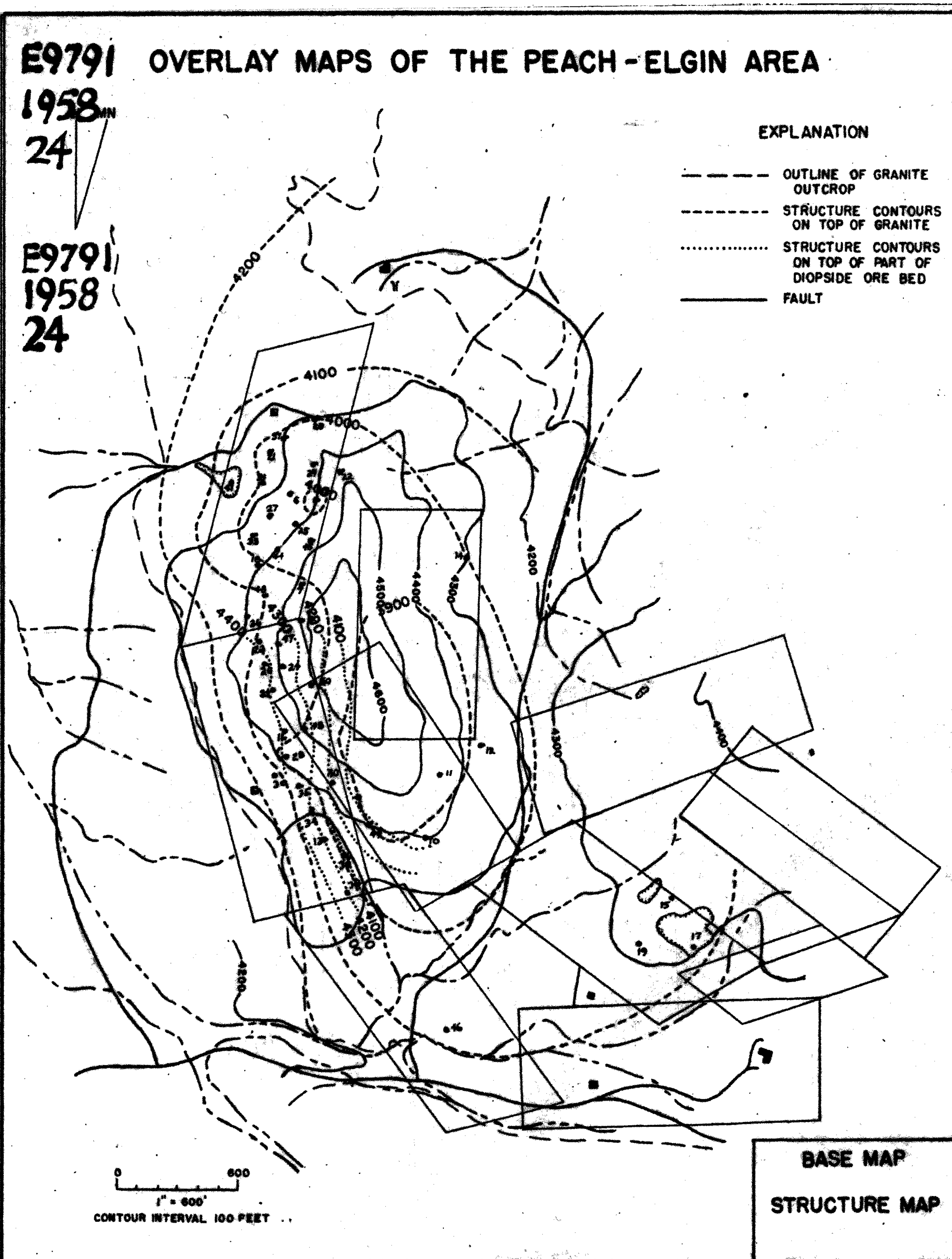
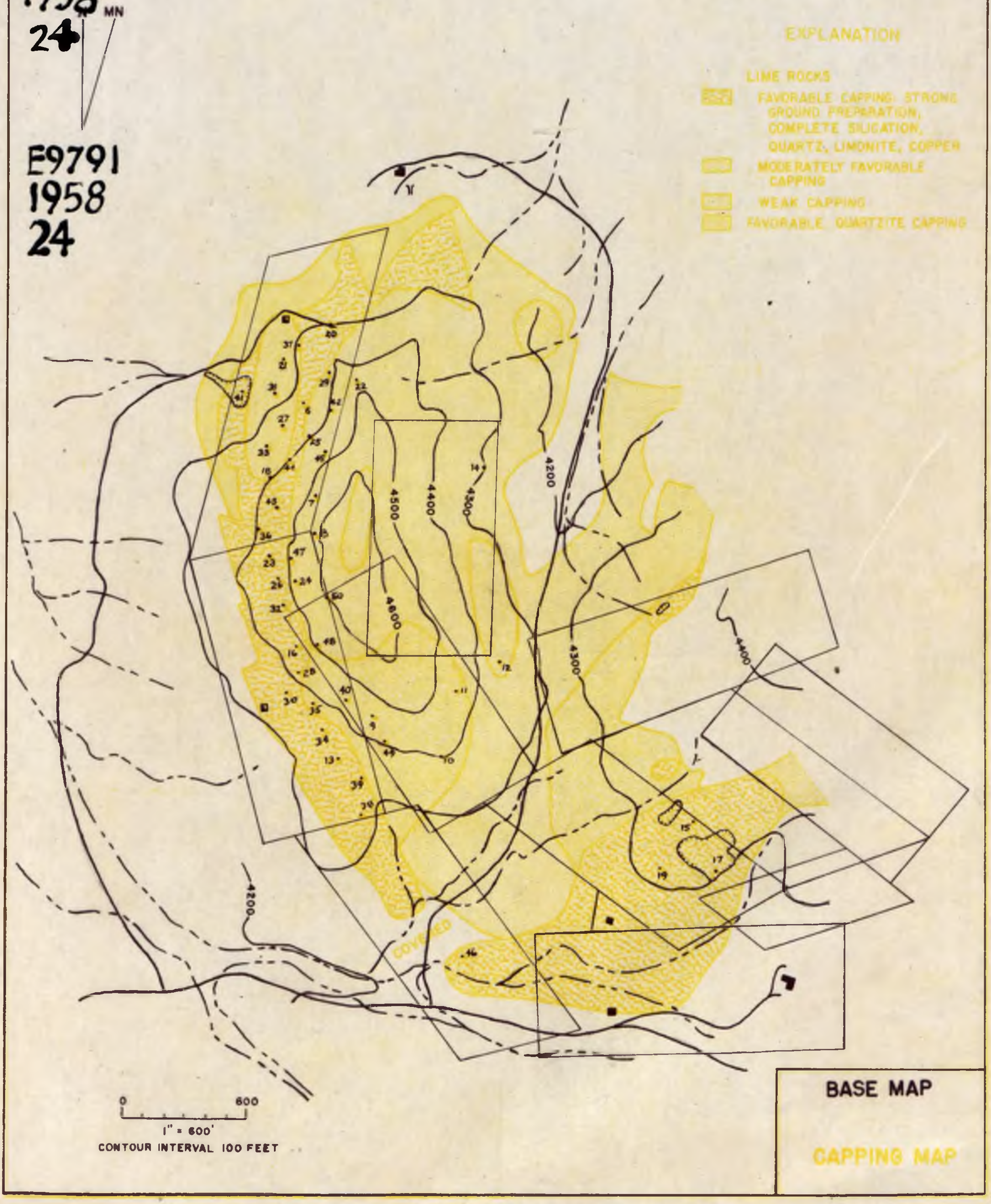
OVERLAY MAPS OF THE PEACH - ELGIN AREA



OVERLAY MAPS OF THE PEACH - ELGIN AREA



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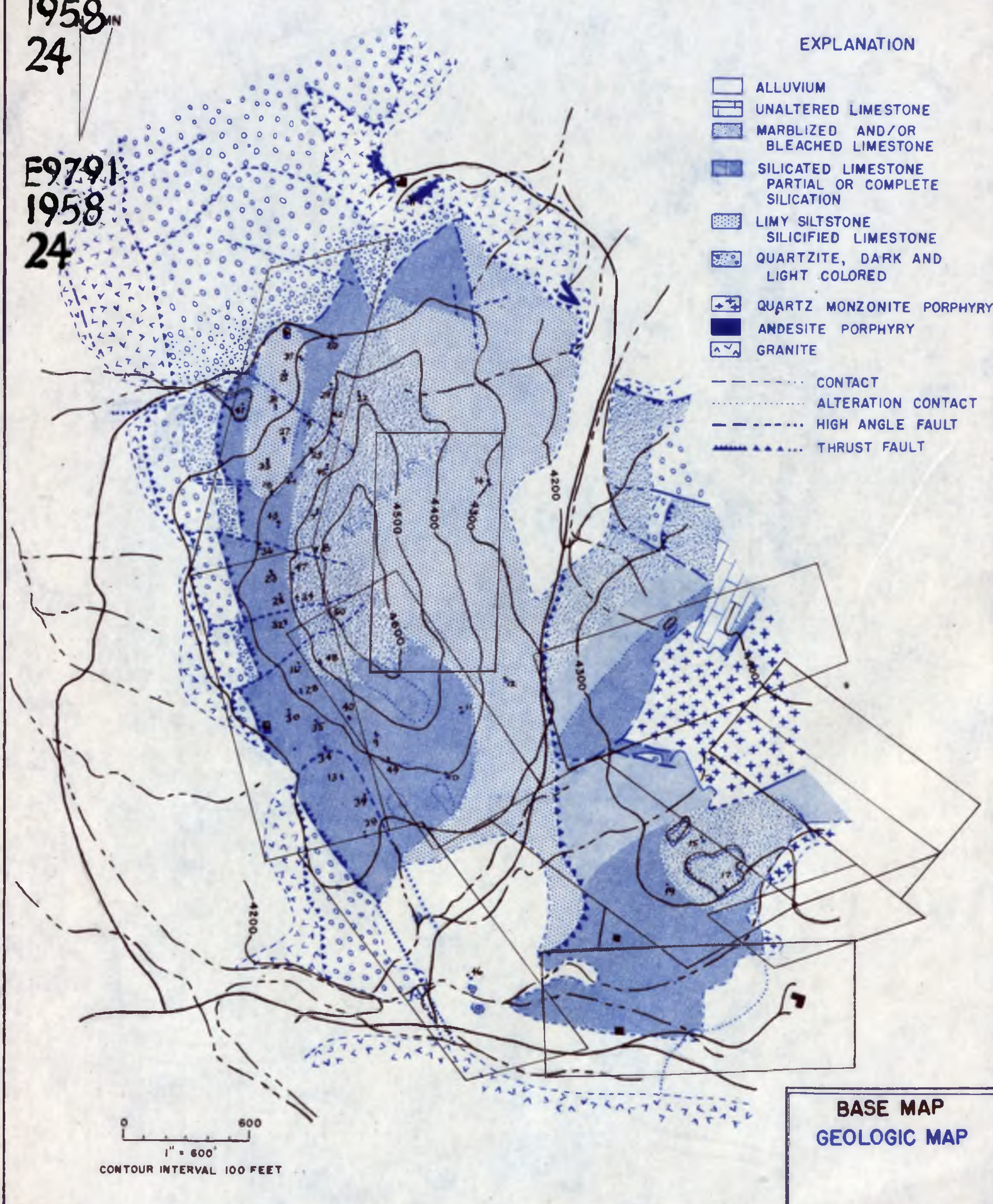
24

OVERLAY MAPS OF THE PEACH-ELGIN AREA



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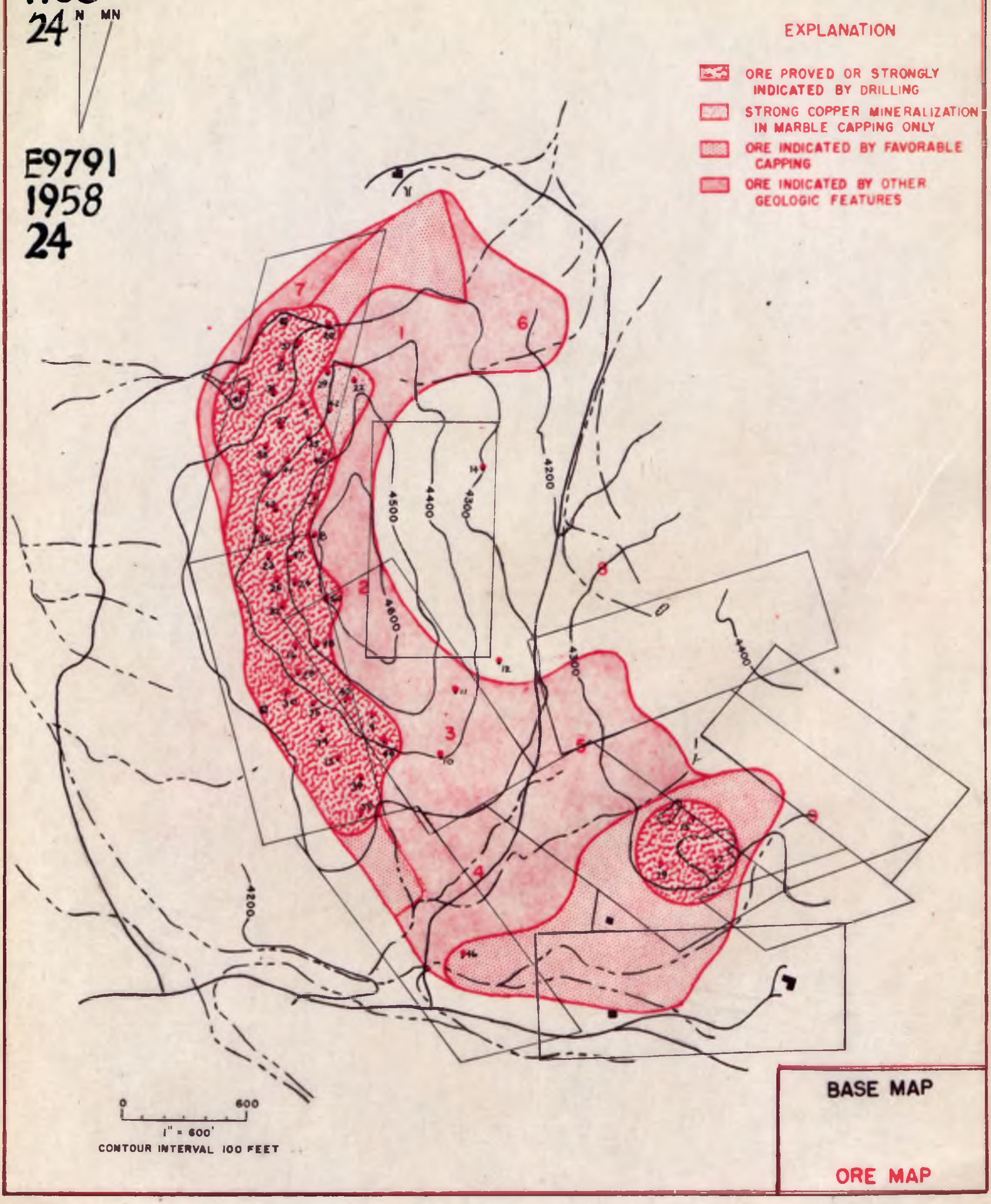

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