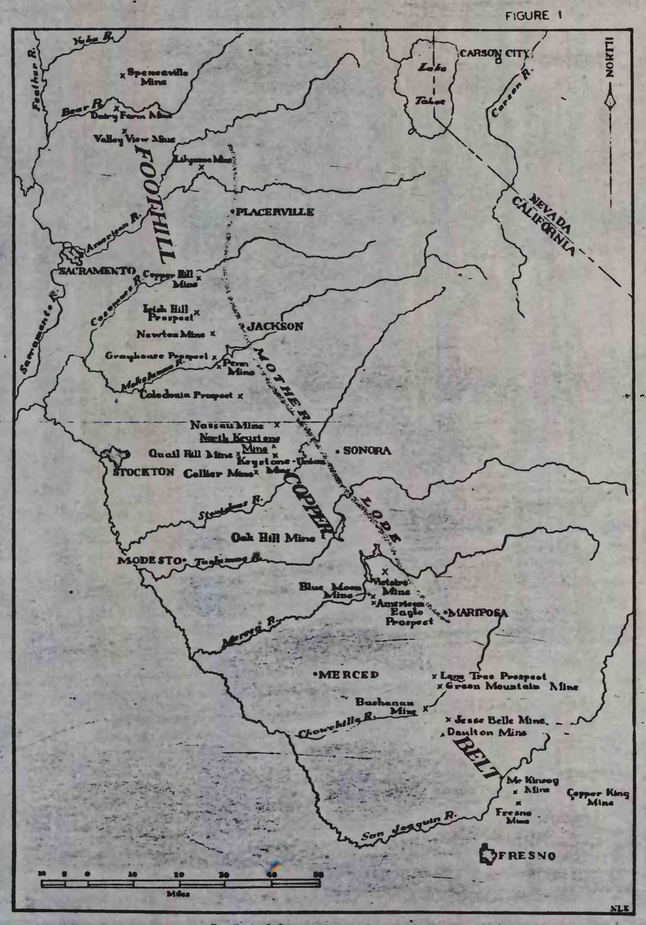
FIGURE 1



INDEX MAP, FOOTHILL COPPER BELT, CALIFORNIA

Heyl, George Richard, 1909 -

FOOTHILL COPPER-ZINC BELT OF THE SIERRA NEVADA, NORTH KEYSTONE MINE, COPPEROPOLIS, CALIFORNIA

By George R. Heyl and Jarvis B. Hadley

One of the more important producers of copper in the foothill belt is the North Keystone mine at Copperopolis, in western Calaveras County, Calif. The mine was reopened in 1942, after having been inactive since 1930, and is now operated by the Keystone Copper Corporation of Copperopolis.

The mine consists of six levels connected by a two and a half compartment vertical shaft 1,120 feet deep. These levels are spaced at 150, 375, 525, 675, 875, and 1,075 feet, with the mining activity at the present time restricted almost entirely to the deeper levels. From the shaft collar the ore is hauled by truck for milling at Hodson, a village 3 miles northwest of Copperopolis. The concentrates are shipped by rail from Farmington to Tooele, Utah, where they are smelted in the plant of the International Smelting & Refining Company.

During parts of 1943 and 1944, the mine and the area immediately adjacent to it were examined and mapped by George R. Heyl, Jarvis B. Hadley, George L. Quick, and Mortimer H. Staatz of the Geological Survey, United States Department of the Interior, as part of a comprehensive study of the most favorable portions of the foothill copper-zinc belt. This investigation is part of the Survey's program of providing geological information that will aid in developing known ore deposits of strategic minerals and will guide the search for new deposits. During part of 1943, the Bureau of Mines, also of the Interior Department, drilled four holes at the mine, in cooperation with the Survey, and the results obtained have been utilized in preparing this report.

The region in the vicinity of Copperopolis is underlain by a sequence of volcanic and argillaceous rocks of probable Jurassic age, which have been transformed by low-grade metamorphism to schists, greenstones, and slates. These rocks have a regional northwesterly strike and a steep easterly dip. Where stratification can be observed, it is generally closely parallel to the cleavage, but locally it may diverge considerably from this, suggesting the presence of folds in the area. Intruded into these rocks are bodies of granodiorite, diorite, hornblendite, gabbro, and serpentine, which commonly show the effects of shearing and crushing, and in many places have developed a schistosity.

A discontinuous zone of intense chloritization, which in detail crosscuts stratigraphic units, extends for almost 9,000 feet through the Copperopolis district and serves as the host rock for the copper ore bodies. This belt of alteration, which has a maximum width of approximately 300 feet, follows a zone of faulting that trends with the regional strike, the member faults being arranged en echelon. The North Keystone mine lies in the northern part of this chloritized belt.

The ore bodies are sulphide replacement deposits developed in chloritized slate and schist. They consist chiefly of chalcopyrite and pyrite, but bornite, magnetite, and specular hematite are present in minor quantities. Locally, small amounts of quartz, calcite, and epidote are present as gangue minerals. In addition to chloritization, the introduction of talc and sericitization are the most important alteration processes associated with the ore deposit.

In the North Keystone mine three main ore bodies are present, designated respectively the North, Middle, and South; these are shown on the accompanying longitudinal projection. They are lenticular in form and lie approximately parallel to the schistosity or cleavage of the country rock, with their longest dimension trending down dip. In detail they are composed of innumerable interconnected veinlets of chalcopyrite, which both follow and crosscut the cleavage and schistosity, and also include veins and streaks of massive chalcopyrite ranging in width from a few inches to about 4 feet, all of which contain pyrite as well. Because of considerable variation in the chalcopyrite content within the ore bodies, the copper tenor in parts of them may become so low that the material cannot be mined economically. Although the monthly averages of the grade of ore removed during the present operation has ranged between 4.063 percent and 1.963 percent copper, during the past year there has been a progressive decrease in ore tenor so that in more recent months the grade has averaged less than 2 percent. This is a result of the fact that unusually high grade ore occurring in the South ore body near the 675-foot level was mined during the earlier months of the operation, and when this was exhausted the overall tenor of the ore being mined decreased appreciably.

An envelope of coarse-grained pyrite surrounds the ore bodies in most places, and grades outward into country rock containing more sparsely disseminated pyrite. The tapering ends of these pyritic envelopes extend some distance beyond the ore bodies, and have been useful guides to their location.

Though, for the most part, the sulphide masses replaced the chloritized slate and schist in the hanging wall of the prominent fault, designated the Footwall fault, much smaller amounts of copper sulphides were deposited locally in the rocks west of this fault, the chief locus there being in the green feldspathic schist close to or at its contact with the slates lying west of it. Sulphides, together with magnetite and talc, also have been deposited at some places in the gouge of the Footwall fault itself, but none of these bodies has yet proved to be economically minable.

At the North Keystone mine the important ore controls that have been recognized can be summarized as follows:

(1) A prominent fault trending with the regional strike, and dipping, in general, from 60° to 70° northeastward; this is known as the Footwall fault.

(2) The local strike of segments of the Footwall fault, and probably analogous variations in the dip of the fault; this relationship is best shown by the map of the 675-foot level of the mine.

(3) Subsidiary faults and fissures in the hanging wall of the Footwall fault.

(4) The chloritized slate and schist, which seems to have afforded the most favorable environment for ore deposition.

(5) Where the granodiorite in the hanging wall closely approaches the Footwall fault, pinching down or out the chloritized slate or schist, ore or minable width is less likely to be encountered, although narrow stringers of chalcopyrite-bearing rock and ore are present in sheared, crushed, and partially chloritized granodiorite.

Previous to its present period of activity, the North Keystone mine was operated as an adjunct of the adjacent Keystone-Union mine, and consequently no production figures are known to be available for 1930 or earlier years. The production of the mine, since it was reopened in 1942, is summarized in the following table:

Production of the North Keystone mine

Year	Pounds of copper
1942	577,740
1943	3,986,980
1944	3,809,116*
Total.....	8,373,836

* Includes an estimated production of 365,000 pounds for the month of December 1944.

From a strictly geological viewpoint, it is probable that further ore reserves are present at the North Keystone mine in addition to those already located by mine development and diamond drilling. The zone of mineralization and the adjacent Footwall fault are strongly and continuously developed from the surface to a depth of 1,075 feet, and at this level show no indication of dying out. The larger ore bodies within this zone of mineralization have persisted down dip for 500 to 600 feet, and in the adjacent Keystone-Union mine, which has a similar geological environment, ore bodies were present at least to a depth of 1,200 feet. There is every indication, therefore, that the zone of mineralization at the North Keystone mine will continue for an appreciable distance below the 1,075-foot level, and will probably contain bodies of sulphides of sufficient grade to be classed as copper ore under present conditions.

It should be remembered, however, that the long-range outlook for the mine as a commercial operation is more fully dependent on the price of copper existing after the present emergency is passed, and on the status of mining costs in the future, than on the geological characteristics of the ore deposit. Only if the price of the metal remains sufficiently high to insure an adequate profit margin over the cost of mining and treating the ore, can this property be expected to operate under normal peacetime conditions.

NORTH KEYSTONE MINE, FOOTHILL COPPER-ZINC BELT, COPPEROPOLIS, CALIFORNIA