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To Ed Wisser with the compliments of the writer

THE GEOLOGY OF THE ENGELS AND SUPERIOR MINES, PLUMAS COUNTY, CALIFORNIA

WITH A NOTE ON THE ORE DEPOSITS OF THE SUPERIOR MINE

BY

CHARLES A. ANDERSON

UNIVERSITY OF CALIFORNIA PUBLICATIONS

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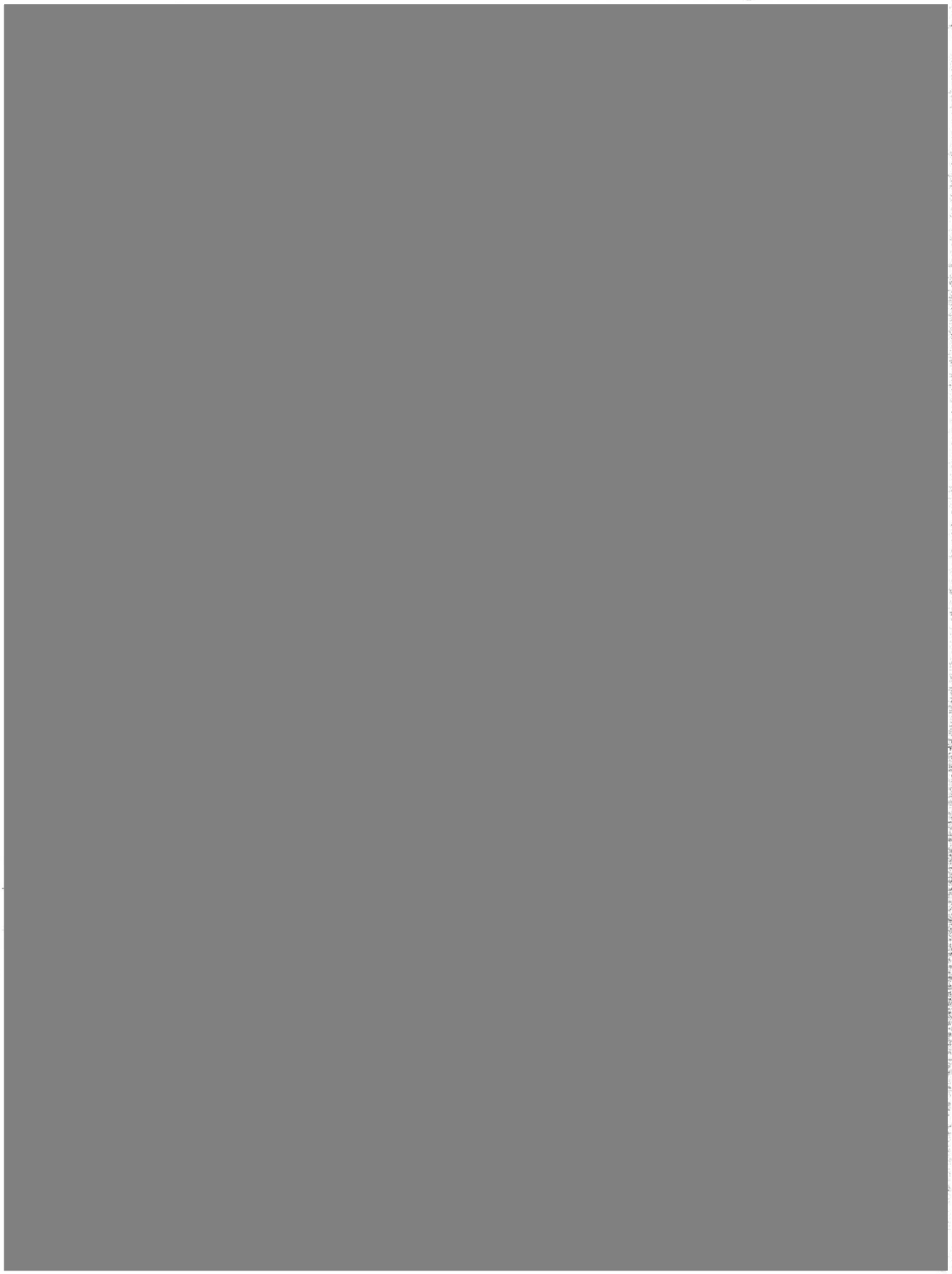

represents an ore shoot to the south of the *M* vein.

File: Engel Mine
California
Plumas County

above the Superior Mine

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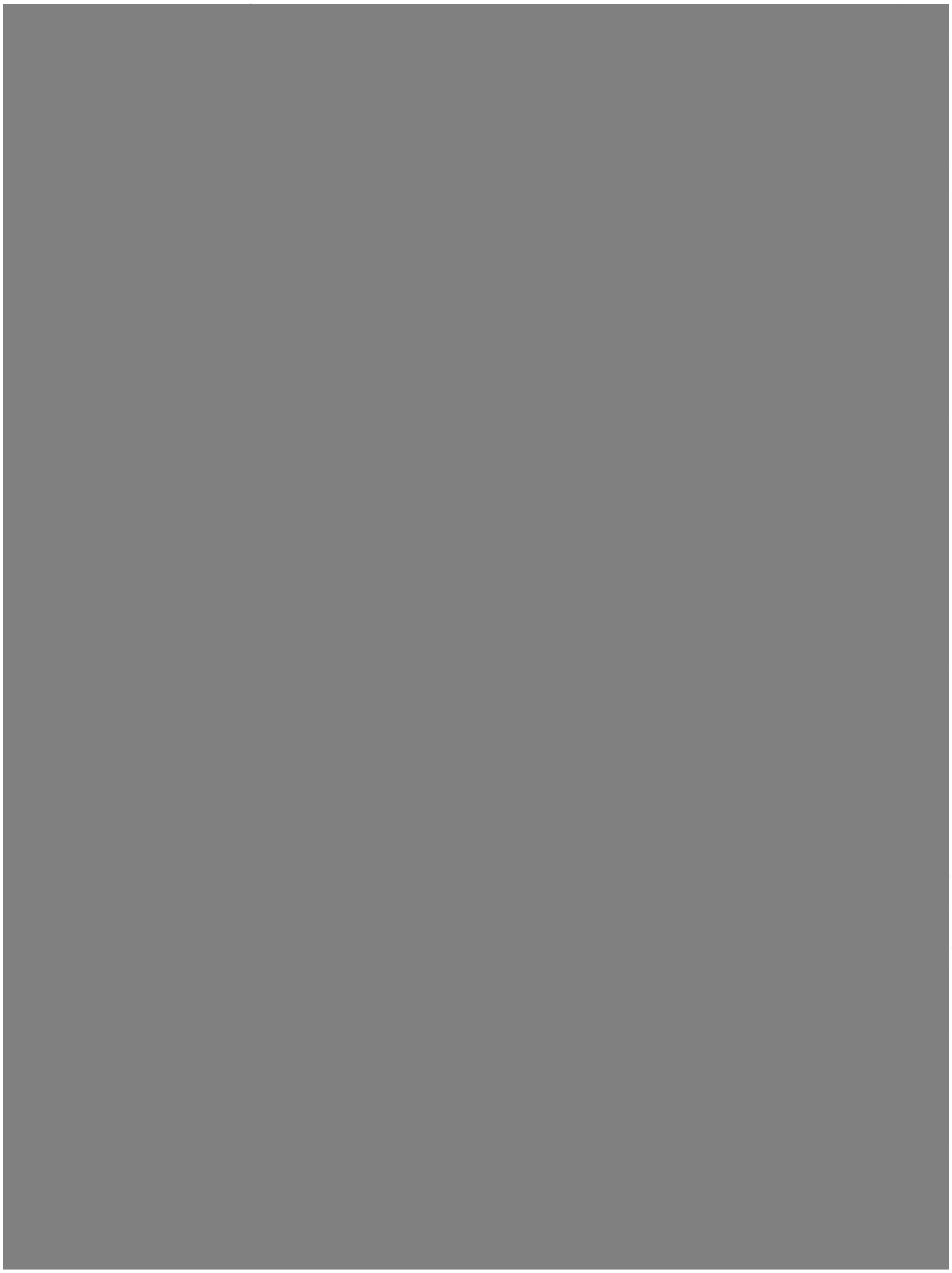

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THE ENGELS COPPER DEPOSITS, CALIFORNIA.

Reprinted from ECONOMIC GEOLOGY, Vol. XXV., No. 1, Jan.–Feb., 1930

THE ENGELS COPPER DEPOSITS, CALIFORNIA.[1]

ADOLPH KNOPF AND C. A. ANDERSON.

INTRODUCTION.

[redacted]

The Magmatic Origin of the Chalcopyrite and Bornite at Engels

The Editor:

Sir—In the article on the Engels mine by Mr. A. B. Parsons, in your issue of July 30, there appears a reference to a paper by H. W. Turner and A. P. Rogers on the ores of that mine, and subsequent articles written by L. C. Graton and R. P. McLaughlin. Mr. Parsons draws the inference that the conclusions of Turner and Rogers are wrong whereas Graton and McLaughlin are correct, referring especially to the formation of copper glance, or chalcocite, which in most copper deposits is undoubtedly a product of downward sulphide enrichment. A discussion of this matter requires the production of a mass of scientific data, which can only be digested by expert petrographers and metallographers. It is not the purpose of this letter to discuss the occurrence of chalcocite at the upper Engels mine, as it is of minor importance, and according to Mr. Parsons, chalcocite ore has given out in the lower levels of the main orebody. Suffice it to say that in most copper deposits where glance is an important constituent of the ore, pyrite is usually present. This mineral readily oxidizes, forming, as one result of the reactions, sulphuric acid, which leaches out the copper and silver of the ore and carries these metals in solution to lower levels, where they are precipitated forming the well-known zones of sulphide enrichment. Chalcopyrite and bornite oxidize less readily, and hence supply less acid. There are three reasons why no such strong zone of sulphide enrichment exists in the upper Engels mine:

(1) The absence of pyrite as noted above and hence the lack of abundant acid to leach out the metals and carry them to lower levels.

(2) The density of the orebearing rock making it difficult for the descending solutions to penetrate it.

(3) The lack of strong shearing or fissuring, so that spaces for downward percolation of waters were largely lacking.

For these reasons, the amount of secondary chalcocite in the Engels deposit is insignificant compared with its occurrence in many other copper deposits. It is probably safe to say that 95% or more of the copper produced at the Engels mine comes from bornite and chalcopyrite. These two minerals form the 'bread and butter' of the mine, and it is therefore of great scientific and economic interest to determine if the chalcopyrite and bornite are of magmatic or hydrothermal origin. If of magmatic origin it is very likely that the deposit may extend to a considerable depth and if one ore lens gives out it may be replaced below by another lens as in the similar Tweefontein mine in Africa. If of hydrothermal origin, it is probable that the ores will give out at a comparatively shallow depth, for the reason that there is no strong fissuring or shearing at the Engels deposit such as occurs at all deep sulphide metal mines of hydrothermal origin.

To discuss the origin of the ore, it might be well to define magmatic and hydrothermal deposits, although in nature there may be, and probably is, a gradation from one to the other. Most mining geologists of the present day including, I presume, Messrs. Graton and McLaughlin, ascribe nearly all metalliferous deposits, such as the copper, gold, and silver mines of the Western States, to magmatic waters arising from a magma in depth and depositing their valuable contents in fissures and in adjoining wall-rocks comparatively near the surface. Such deposits, however, would be called hydrothermal, since water is the chief agency in transporting the metals from depth to the veins where we now find them, and frequently (as in the Mother Lode gold belt) the veins are not in the igneous rock from which the metals came, but in older sedimentary or schistose rocks.

Magmatic deposits, on the other hand, may be designated as deposits originating in the magma in which we find them without being transported any great distance through fissures, sheared zones, or porous rocks. All magmas contain water, which in the gaseous form is a mineralizer; and other mineralizers may be present and active, and yet if the ores are deposited at their place of origin or nearly so, the ores being original in the magma, it will be perfectly proper to designate the deposit as one of magmatic origin, even though modified and rearranged by pneumatolytic or hydrothermal agencies, in contradistinction to one of plainly hydrothermal origin in which the metals are brought from remote sources by ascending waters. This definition will probably suit neither Tolman and Rogers nor Graton and McLaughlin, but is here used to emphasize the great difference between a deposit like that of the upper Engels mine where the ore-minerals occur in a fresh massive dioritic rock, and one, say, like the Butte deposits, which clearly occur along fissures extending to great depth.

Moreover, in the last analysis, if the present prevalent theory that nearly all gold-silver-copper deposits containing sulphides owe their origin to waters originating in magmas, all such deposits are in a broad way magmatic; but for practical purposes can readily be separated into two series:

(1) Hydrothermal: those in which the metals have been transported a considerable distance.

(2) Magmatic: those in which the metals and sulphides originally crystallized out in the parent rock at or nearly at the points where we now find them.

At one extreme we have the Butte copper veins, the gold veins of the Mother Lode, the silver veins of Tonopah, etc.; and at the other extreme, deposits like that of the Engels mine, the famous Sudbury pyrrhotite-nickel deposits, and the copper deposits of Namaqualand in South-West Africa.

The only expert petrographers and metallographers that have studied the Engels deposit, so far as I know, are Tolman and Rogers of Stanford University and Graton and McLaughlin. The original paper by Turner and Rogers has already been referred to. But at a later date Professors Tolman and Rogers obtained suites of specimens of ores from many other magmatic deposits and spent a year or more in carefully investigating them. This research work was published in a bulletin of Stanford University in 1916 and forms the best general review of the whole subject of magmatic deposits that has appeared in recent years. However, it is not referred to in the paper by Graton and McLaughlin published at a later date in 1917, in 'Economic Geology'.*

If now we take the papers published by the experts above referred to, we may note that they do not greatly differ concerning some of the main features of the origin of the chalcopyrite-bornite orebodies; and this is the only matter of practical importance in the discussion. Both consider that the ore was deposited after the silicates. Tolman and Rogers consider this to have occurred soon after the crystallization of the silicates, chiefly by the action of mineralizers (pneumatolytic) with some later hydrothermal action. Graton and McLaughlin divide the various processes, resulting in the formation of the ore, into four divisions, but state that these "four stages covering the time from initial magmatic conditions to the close of the primary mineralization, are merely convenient divisions of an uninterrupted sequence", and further state that "the orebody is in our opinion a direct result of igneous action; but was formed as a final concentration following the crystallization of the rock and not as a magmatic segregation".

If one may criticize the papers by Graton and McLaughlin, it may be said that as a whole they give the impression that the orebearing diorite of the Engels mine is a much altered rock, whereas from a petrographic standpoint it is usually quite fresh. By over-emphasizing what they consider evidences of hydrothermal action, one would draw the conclusion that the deposit is similar to the typical hydrothermal deposits as understood by mining geologists in general. A careful reading of their conclusions, however, suggests that that is not their meaning, but that it is a direct result of igneous action and not brought up from unknown sources. It may also be said that under the head of Intense Hydrothermal Period they emphasize the formation of chlorite, sericite, and epidote, as evidence of strong hydrothermal action. As a matter of fact these minerals, especially chlorite and sericite, are common throughout the Sierra Nevada granitic rocks, the sericite being derived largely from feldspar and the chlorite from biotite. An absolutely fresh granitic rock is a rarity anywhere in the world, as any competent petrographer will testify. Absolutely fresh granitic rocks are certainly rare in the Sierra Nevada and the sericite, chlorite, and epidote in them are no doubt the product of hydro-metamorphism, which implies hydrothermal action. It in no sense implies such *intense* hydrothermal action as is seen in vein deposits in general. On the contrary, it implies mild hydrothermal action. Otherwise we must regard the great granite batholith of the Sierra Nevada as having been subjected to intense hydrothermal action at many places.

In reference to the Superior deposit, also in a granular igneous rock (a form of grano-diorite), the statement is made that pyrite is absent. This may be true of the ore itself, but it is not true of the grano-diorite country-rock, as may be seen in the original lower Superior tunnel, where pyrite coats the joint-planes.

The stockholders of the Engels mine probably do not care what the origin of their copper ore is, so long as it is of commercial value and continues in depth or laterally; they are interested in the matter to this extent, however, that if the deposit is of magmatic origin, taking my rather wide definition of that term, they may be assured that the present ore lenses may extend to a considerable depth, and that other similar lenses may be found. If, on the other hand, it is of hydrothermal origin, as the term is usually used, the ores must soon give out, as the dense nature of the rock and the lack of shearing or fissuring, militate against a vigorous circulation of ascending waters.

H. W. TURNER.

San Francisco, August 12.

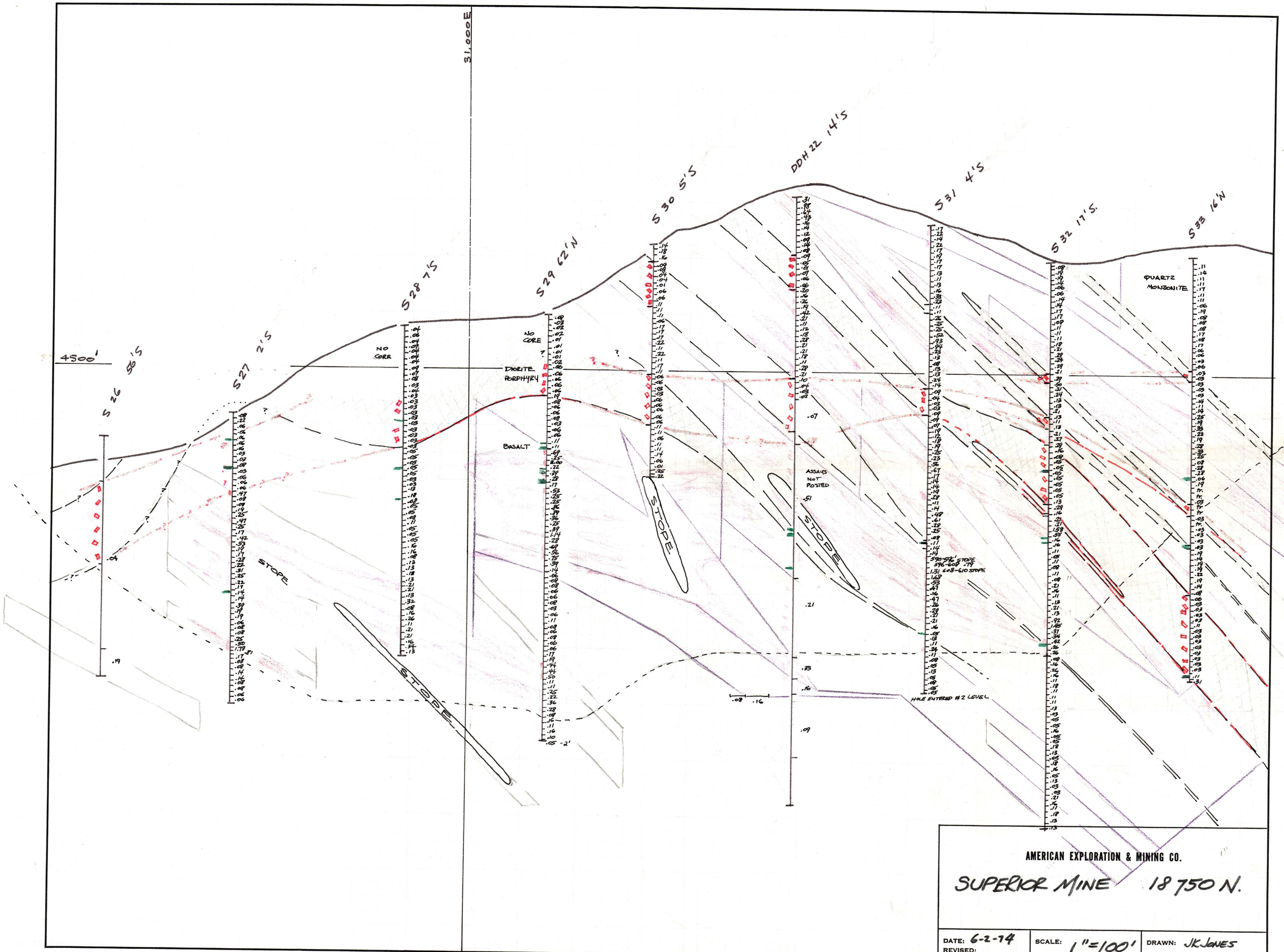
*In a later paper dealing chiefly with the formation of chalcocite, Graton and McLaughlin refer in a complimentary manner to the excellent bulletin by Tolman and Rogers and modify their views in some details, none of which are of importance as related to the main theme of this article, namely to emphasize the great difference between an ordinary hydrothermal deposit and that of the Engels mine.

The Tariff on Magnesite and Chrome

The Editor:

Sir—I am reliably informed by letter from Washington that the Fordney tariff bill now pending in the Senate, and which passed the House on July 31, provides a tariff on magnesite of $10 per ton, and places chrome on the free list. Both of these minerals are extensively used in the manufacture of steel, magnesite and chrome being used practically for the same purpose of making firebrick for use in melting-furnaces.

If the object of the Fordney bill is to give protection to the miners of magnesite and chrome, and to discourage the importation of these minerals from foreign countries, then this bill, if passed in its present form, will prove a fraud and a failure, for it is very evidently written to protect the interests of the steel manufacturers, who



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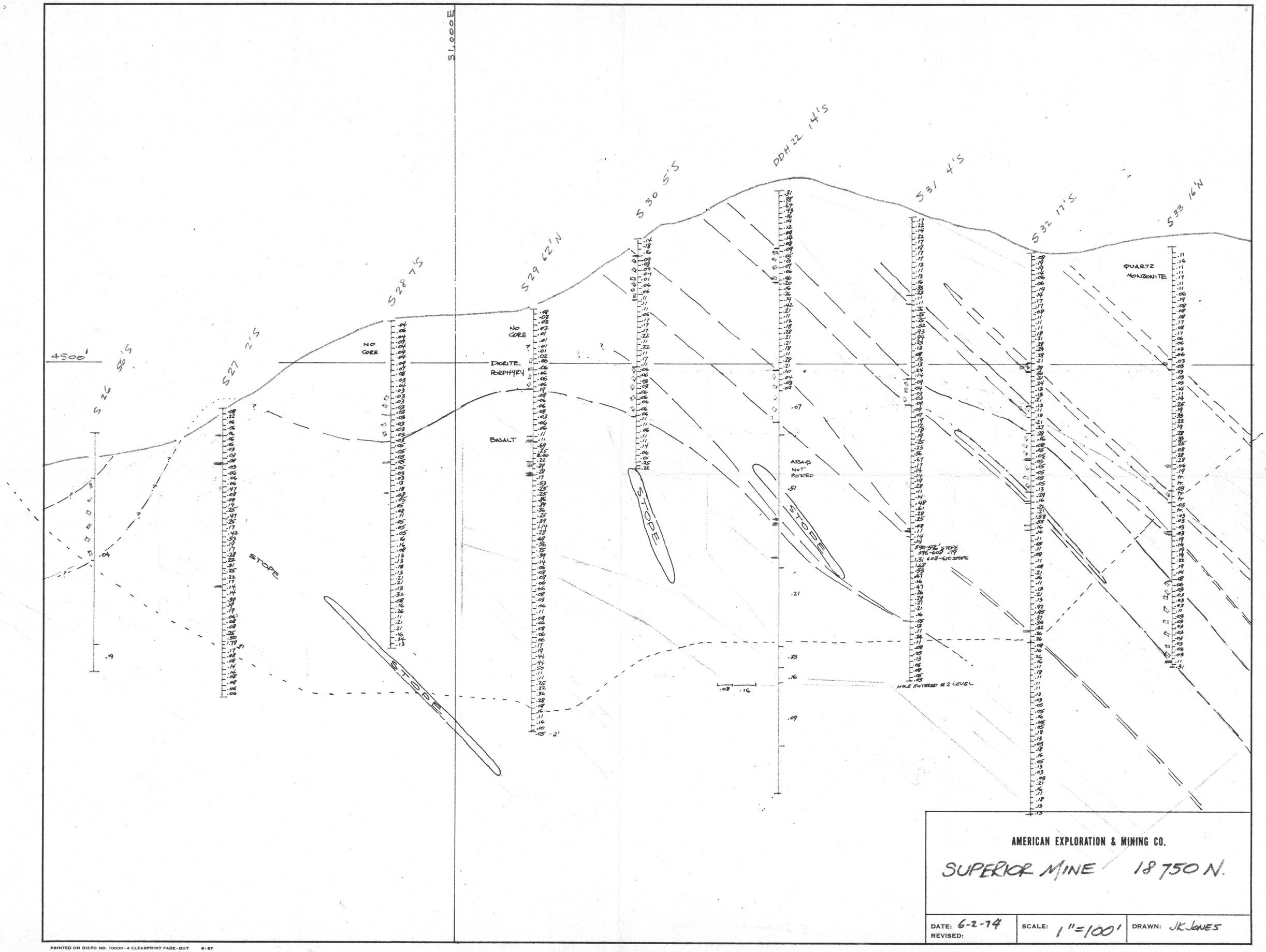

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