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Geology and Ore Deposits of the Golden Messenger Mine, Lewis and Clark County, Helena, Montana.

John C. Archibald Jr.

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GEOLOGY AND ORE DEPOSITS OF THE GOLDEN MESSENGER MINE,
LEWIS AND CLARK COUNTY, HELENA, MONTANA

by
John C. Archibald, Jr.

A Thesis
Submitted to the Department of Geology
in Partial Fulfillment of the
Requirements for the Degree of
Bachelor of Science in Geological Engineering

MONTANA SCHOOL OF MINES
BUTTE, MONTANA
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INTRODUCTION

The Golden Messenger Mine which is approximately twenty-three miles northeast of Helena, Montana, near York, on Trout Creek, (Plate I) has long presented several problems of both theoretical and practical interest. With the exception of a United States Geological Survey Bulletin No. 842, written in 1933 by Pardee and Schrader (14), in which the deposits of the Messenger Mine are briefly described, no published geological report exists. The need for such a detailed geological study has been keenly felt by the writer's father, Mr. J. C. Archibald, who is at present manager for the property. Upon his suggestion and with the approval of Dr. E. S. Perry, chairman of the Department of Geology of the Montana School of Mines a study of the geology and gold deposits of the mine has been undertaken.

The author is indebted for the assistance of Dr. E. S. Perry and Dr. G. F. Seager in the arranging of the material and subsequent microscopic work. He also thanks them for their kind assistance and suggestions in connection with the field work. The author's father, Mr. J. C. Archibald, rendered invaluable assistance both in a discussion of the problems encountered and also in making available the necessary mater-

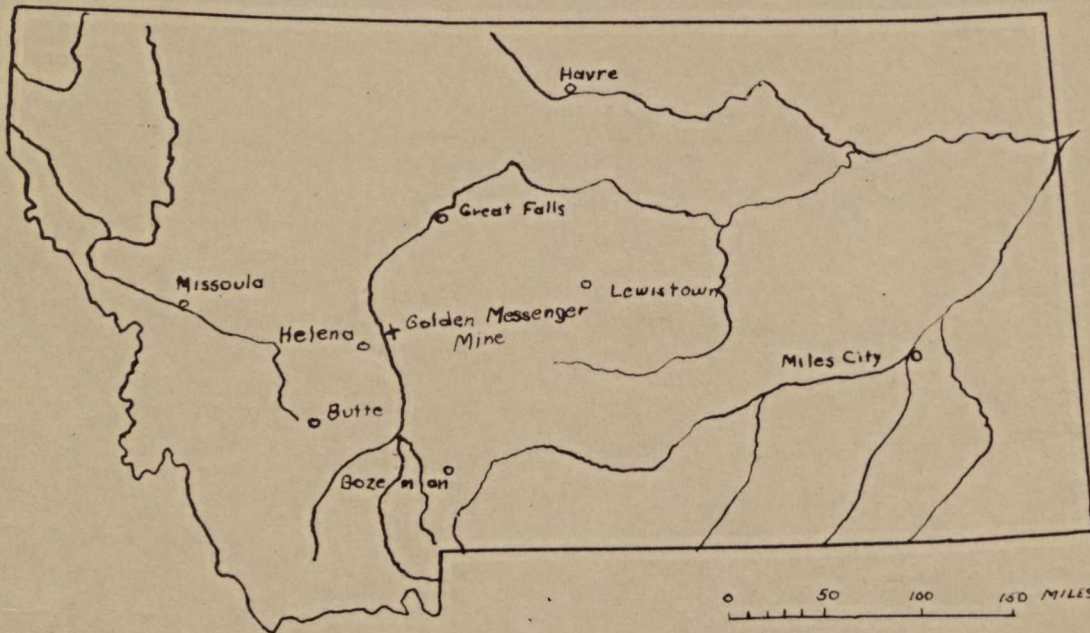


PLATE I

INDEX MAP OF MONTANA SHOWING
LOCATION OF GOLDEN MESSENGER MINE

ial. The author's brothers and wife assisted materially in the surveying of the area and in the gathering of specimens.

History and Production

In 1886, a prospector working in Kelly Gulch, found a piece of float rock, which upon assaying ran \$8 per ton in gold. This piece of float rock was traced to the outcrop and in a period of a few years from about 1890 to 1910 approximately \$50,000 worth of ore was extracted from the Little Dandy Mine which is on the east end of the Golden Messenger property. About 1900, John and Charles Friederichs and others bought up the present group of claims which comprises the Golden Messenger holdings. Included in these claims were those of the Little Dandy. The Columbia Gold Mining and Milling Company, which was incorporated in 1900 by the Friederichs brothers, built a small mill which a few years later burned to the ground. As a result the mine lay idle for a number of years. Later the LaCasse brothers, on lease, did some further underground development but no milling. The French Bar Mining Company next did some work, and finally in 1913 the York Mining Company built a thirty ton cyanide plant which was used on and off until the fall of 1934, when the present 135 ton cyanide plant was built. Birtchey and Leydig operated the property under a lease sometime near 1920 and were the first operators with the exception of those mining on the Little Dandy to make the mine pay. Further development work was done in 1927-1928 by the Golden Messenger Corporation which now owns and operates the property. Between 1928 and 1934 the development work was continued. In 1934 the property was taken over by the United Gold Mines Corporation.

A considerable amount of surface work was done in the way of trenching and test pitting by this company prior to re-equipping the mill. As a result of this extensive surface work, a large body of low-grade ore was developed. This ore was mined first in a large open pit and later, after more development work, the ore was followed down to the lower workings. The mine has operated steadily, from November 1934 to the date of the present writing. In February of the present year the mine returned to the Golden Messenger Corporation.

Prior to 1928, there had been about 34,000 tons of ore mined, reputed to assay 0.30 oz. gold per ton. Since 1928 the production has been in excess of 130,000 tons running about 0.18 oz. per ton with a net recovery of \$680,000. Most of the ore mined to date has come from the oxidized zone. However, in the last few months, it has been found necessary to mine the sulphide ores since the oxidized zone is practically exhausted.

Location and Accessibility

The Golden Messenger Mine is easily accessible from Helena along about twenty-three miles of good graded roads. During the winter, the roads are kept open except for a few days in the most severe weather. The mine is situated in Brown's gulch about a half mile from Trout Creek. It is in T. 11 N., R. 1 W. in Lewis and Clark County. The small community of York is a mile and a half down Trout Creek and has a population of a hundred and fifty. This is a transient population composed mainly of miners and their families.

Topography

The mine lies well up in the foothills of the Belt Mountains. The hills are well rounded, in all except the upper and lower ends of Trout Creek, where some rather resistant limestones are found. At the mouth of Trout Creek these resistant formations are interbedded with soft shale which give rise to a few small gullies between high ridges of limestone. Drainage is good; the side gulches such as Brown's gulch drain intermittently into Trout Creek, which in turn runs into Hauser Lake Dam on Missouri River. The region can be considered as being in the stage of early maturity.

Climate and Vegetation

Lorain (13) has characterized the climate as being semi-arid, since there is an average precipitation of 10 to 13 inches a year. Most of this precipitation is made up of winter snowfalls. ^{not true} The average yearly range in temperature is about 50 degrees, although temperatures sometimes drop as low as fifty degrees below zero and reach a maximum of 90 degrees above.

The vegetation is for the most part a more or less poor soil type. It consists of sage brush and a type of scrub pine, although in the Belt Mountains themselves there are large stands of pine and fir.

GENERAL GEOLOGY

The Golden Messenger Mine occurs in what is known as the Golden Messenger Dike. (Plate II). This quartz diorite body, (see description below) intrudes the pre-Cambrian Greyson shale (14). In addition to this igneous body, there are two others which are almost in direct

line with it, and of the same composition and age.

Sedimentary Rocks

Practically the whole of Trout Creek is underlain by a pre-Cambrian series, the Belt shales, with the exception of some middle Cambrian rocks at the mouth and a middle Paleozoic limestone at the source of the stream. A description of these sedimentary rocks follows:

Pre-Cambrian Rocks:--The Belt shales, which comprises the only pre-Cambrian rocks in this section, are composed of the Newland limestone, the Greyson shale, and the Spokane shale. The Newland limestone is an argillaceous, slaty, appearing rock, which is very impure containing some aeranaceous material and some magnesia. It is buff-colored in appearance with a very striking shaly cleavage. In appearance it differs but little from the other members of the Belt series which are exposed along Trout Creek. Pardee (14) estimated that the thickness is about 4,500 feet.

The Greyson shale, is a gray- to buff-colored rock, which lies conformably on the Newland limestone. The contact between the Greyson shale and the Newland limestone is poorly defined, one formation grading into the other. In places the shale is light gray in color and is coated with brown specks of siderite or limonite. In the middle of the shale are found some quartzitic ^{layers}. The shale weathers to a buff color. The thickness is approximately 3,000 feet.

The Spokane shale, which marks the top of the Belt series in this locality is conformable to the Greyson shale. This shale commonly is gray to buff in color and in the vicinity of the Golden Messenger con-

tains siliceous and calcereous veins which cut it and the Golden Messenger Dike at steep angles. The remainder of the area covered by this shale is non-calcerous and is in part composed of aeranaceous beds interbedded with shaly members. The thickness is in the neighborhood of 2,000 feet.

Cambrian Rocks:--The Cambrian formations lie unconformably on the Spokane shale. The lowest member of the series is the Flathead quartzite, on top of which lies the Wolsey shale, the Meagher limestone and other formations. The Flathead is characterized by the pinkish tinge of the resistant "reefs". The lowest beds show pebbles which characterize this formation in this region. The thickness is about 350 feet.

The Wolsey shale, which lies conformably on the Flathead quartzite, is poorly exposed since it occupies a saddle between the resistant Flathead on one side and the resistant Cambrian limestone on the other. It consists in this locality of a soft, muddy gray to olive green shale. Many of these layers contain fine scales of mica (Pardee 14). The thickness is about 300 feet.

Above the Wolsey shale lies a limestone probably a part of the Meagher formation. This is so correlated because it has the characteristic dark brown and gold colorations typical of the Meagher. Above this lies what is probably the Park shale and possibly above that occurs the Pilgrim limestone. The writer was unable to measure the section and Pardee (14) says only that above the Wolsey the formations have a total thickness of about 1,500 feet.

Middle Paleozoic Limestones:--At the head of Trout Creek is a large fault which brings either Mississippian or Devonian rocks in contact with the Newland limestone. These rocks are blue gray in color and prob-

ably Madison in age although no work was done to determine the age. The thickness in this locality was unmeasured.

Quaternary:--The next younger sedimentary rocks that occur are Quaternary in age. They consist of alluvium material in part gravel deposited at intervals along Trout Creek valley. The beds are very loosely consolidated and are made up mainly of material eroded from the Belt shales through which Trout Creek runs. The thickness was not measured, but probably does not exceed fifty feet.

Igneous Rocks

There is only one type of igneous rock cropping out in this area, a quartz diorite dike of probable Oligocene age (Pardee 14). The dike runs from Kelly gulch on the east in a west-northwest direction for a distance of about three miles. Its dip is for the most part vertical, although in some places it dips steeply to the north.

Megascopically the fresh rock appears to contain hornblende, quartz, and plagioclase feldspar. The rock itself has a greenish tinge, which upon weathering becomes brown or greenish brown. Upon microscopic examination, the rock is seen to be leucocratic, holocrystalline, and medium-grained. The minerals as determined by the petrographic microscope and their relative abundance are:

Hornblende	30%
Quartz	25%
Plagioclase	25%
Orthoclase	10%
Magnetite	9%
Pyrite, Apatite	1%

The Plagioclase is a calcic variety (Andesine) which has been altered rather highly to sericite and in some places has been partially kaolinized.

The quartz shows undulating extinction indicative of some strain. Much of the quartz and feldspar show excellent graphic intergrowth. The majority of the hornblende has been altered to chlorite with some attendant secondary magnetite. Primary magnetite is common. Apatite crystals are common, showing good euhedral characteristics. Pyrite is rather uncommon but does occur.

From the appearance and the texture, the rock appears to have been injected at some depth (plutonic) perhaps one thousand feet or more. At any rate, cooling was relatively slow, giving time for crystals to assume a medium-grain size. From the thin sections studied, the paragenesis seems to be as follows:

Apatite
Pyrite
Magnetite
Hornblende
Orthoclase
Plagioclase
Quartz

It is unfortunate that the specimens of the quartz diorite were taken from above the groundwater table, because it would have been interesting to note whether any alteration had taken place below the main oxidized zone, but no fresh rocks were available.

Alteration of the Intruded Shale

The contact between the shale and the dike is poor due to high amount of alteration of the shale. In places there is a zone twenty feet wide which has an intermediate appearance between that of the dike and that of the shale. No thin sections were made of this altered rock, and consequently the author is unable to describe it in detail. Megascopically it

appears that the temperature of intrusion must have been high, since the alteration is great. The presence of magnetite bears this out.

STRUCTURE

In general the region is characterized by one big fold and one major fault. The Belt shales exposed along Trout Creek are part of the York anticline, and the Cambrian beds at the mouth of Trout Creek are in a small syncline which runs parallel to the axis of the anticline.

The Scout Camp fault, (see map) which brings the middle Paleozoic limestones in contact with the Belt shales, is a large overthrust. According to Pardee (14) the movement was to the northeast, thrusting the York anticline upon Mississippian (Madison) rocks. This is probably a southward continuation of the Lewis overthrust fault, which is found in the northwest part of the state. Along the fault the Belt rocks are overturned due to drag and the limestones are crushed and brecciated.

In addition to large scale overthrust faults, numerous smaller faults, many of which are normal in character may be observed.

Fault Systems in the Dike

The fault systems of minor magnitude are roughly of two ages. Both appear to be due to tensional forces set up during cooling of the igneous mass. These fractures form what might be termed a "ladder type" of faulting. The first system is mineralized and forms the commercial vein system at the Golden Messenger Mine. Roughly the two systems of fractures run from east to west and from north to south, parallel and perpendicular to the contact of the dike with the shale. Those veins running east and west dip to the north, and those running north and south

dip to the west. Not a single exception to this rule of dip has been found.

The second set of fractures are unmineralized and tend to cause offsets in the veins. These fractures strike north and south and invariably dip to the east. The majority of them are normal faults. These fractures are probably also due to cooling, and consequently the mineralization of the first set of fractures must have taken place while the intrusive was still rather hot.

There is a possibility also that there were earth movements of a minor sort which would account for the presence of one reverse fault. This fault is the only one of its type that has been found, however, it is possible that some of the normal faults included in the second type may be included in this type. Such a condition could be caused by rotational stresses, set up in the area.

It is interesting to note that the Little Dandy vein, which was mined out in the early 1900's, is reputed to have had the same strike and dip as the intruded shale and to have run from the dike into the shale. This vein was supposed to have contained about an ounce in gold per ton of ore as an average.

ORE DEPOSITS

The ore deposits mentioned above occur in mineralized fissures and fractures in the intrusive. (See Plates III, IV, & V) The known distribution of veins is from the eastermost portion of the dike in Kelly gulch, all along the dike to its westermost portion. In places the veins are close together (Golden Messenger Mine) and in other places they are relatively far apart (section in between the Golden Messenger and the

Little Dandy mines, and between the Golden Messenger and the westernmost portions of the dike). The veins vary in width, ranging from stringers of a few inches thick to as much as ten or twelve or even fourteen feet thick in other places. The walls of the veins are determined by economic rather than by structural conditions, since the veins seem to grade into the country rock.

Two different types of ore are being mined at present, oxides and sulphides. The oxidized ore occurs above the No. 3 level and close to the water table, and sulphide ore lies below. The veins for the most part are continuous from the oxidized into the unoxidized zones. The break between these two zones is rather abrupt, and the two types have a widely divergent appearance. The oxide ore is reddish brown due to the presence of limonite, and the sulphide ore is white to gray in color.

Mineralogy

The mineralogy of the two zones differs widely and so will be discussed under two separate heads. The mineralogy of the zone of primary sulphides is interesting in that apparently the veins are largely replacement, since in places parts of the original diorite remain. There has been a secondary introduction of quartz along with some ankerite, pyrite, galena, sphalerite, and Pardee (14) reports the presence of chalcocite. All except the chalcocite can be observed megascopically. The paragenesis is probably as follows:

Quartz
Ankerite
Galena
Pyrite
Sphalerite
Chalcocite

The oxidized ore is characterized by having a large amount of limonite and quartz, with some feldspar (probably plagioclase), which, however, may be residual. Microscopically the limonite shows some pseudomorphic forms probably after pyrite. The amount of limonite appears to be large to have originated from the pyrite entirely, and it seems logical to suppose that the limonite is in part derived from the alteration of the hornblende of the diorite. Pardee (14) says that the gold occurs with the galena, but the author and the mine management believe that the gold occurs with the pyrite.

GENESIS

Of Sulphide Ore

The veins are without doubt of the replacement type, which were probably injected a little after the first set of fracturing took place. The lodes seem to grade out into the country rock, with a few stringers of ankerite and quartz grading out even into the shale. The reason for dating the veins so close to the original injection is the subsequent normal faults due to tension which in turn was caused by contraction while cooling.

Origin of Gold

In presenting this part of the paper, it might be well to say first that Pardee (14) feels that there was a supergene zone above the top of the present veins which has been eroded away. He further says that the absence of placers proves this point. The author feels that if this were the case, why didn't the gold in the hypothetical supergene zone, which was eroded away, form placers in Brown's gulch. In order to properly dis-

cuss this further the author will offer a general survey of literature dealing with the supergene enrichment of gold.

Theoretical Considerations of Supergene Enrichment

Bateman (1) has remarked on the Kennicott, Alaska, ores that climate is very important in the processes of supergene enrichment. A cold climate tends to slow the process down, while a warm climate will hasten oxidation and consequent enrichment. Grassmuck (4) says that in countries where there is a large amount of rain, the rate of enrichment is materially increased. In a country where glaciation has been rather recent, supergene enrichment will either be retarded or if the enrichment has taken place prior to glaciation, it may be easily removed, provided the zone of enrichment is not too deep.

Ransome (11) has given an excellent summary of conditions necessary or beneficial to enrichment. In this discussion he brings out the point that in countries where the relief is great, the possibilities for supergene enrichment of gold, all other things considered equal, will be greater than in a country where the relief is small. He further states, that in countries where the altitude is high, the supergene enrichment is more pronounced, due to favoring of oxidation under such conditions.

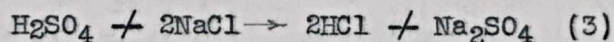
The groundwater table is important in enrichment of gold, in that it tends to mark the lowest boundary of oxidation, and therefore fixes the depth of leaching, and also marks the zone of enrichment, if there is any. There are cases of alteration below the groundwater table (Locke (8), pp. 49-63), but they are few and need not be considered in this case. After the enriched zone has formed three things may happen, (1) the water

table may rise and drown out the enrichment, or (2) the water table may drop, leaving the enriched zone high and dry, and finally (3) the water table may remain in the same place relative to the enriched zone.

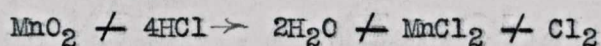
Solution of Gold:--The solution of gold can be accomplished in various ways, the more important of which are shown below. The table below has been taken with a few minor changes from Grassmuck (4):

1. Gold may be dissolved in the presence of a chloride and manganese dioxide in cold dilute solutions. Emmons (3).
2. In solutions of iron alum and cupric chloride with attendant hydrochloric acid gold may be slowly dissolved. Raising the concentration of the acid affects the solution of the gold more than raising the concentration of the alum and the chloride. McCaughey (10).
3. Gold may also be dissolved by alkaline sulphides, ammonium sulphide, and moistened hydrogen sulphide. Mellor (9).
4. Gold may be dissolved by mixtures of chlorides, bromides, or iodides. Emmons (3).
5. Gold is also dissolved by such substances as sulphuric or phosphoric acid in the presence of an oxidizer such as nitric acid or the higher oxides of lead and manganese. Lenher (5 & 6).

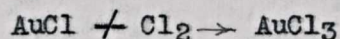
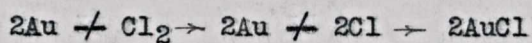
Of all the methods given for the solution of gold in nature, perhaps the first and last are the most common. In the first (and also in most of the others) pyrite is oxidized as shown by the equation below forming sulphuric acid which furnishes the acid conditions necessary for the solution of gold.



The MnO_2 reacts with the HCl formed in equation (3) above to give the following results (Lindgren 7):



The formation of chlorine (nascent) as shown in equation (4) above, is the oxidizer which dissolves the gold. The gold is supposed to act as shown in the following equations (Mellor 9):



In equation (1) ferrous sulphate was formed which is a strong precipitant of gold from chloride solutions and consequently the reactions shown in equation (2) must take place before any gold will be taken into solution and transported.

Pyrite is probably the most important single substance which must be present to have supergene enrichment. The pyrite furnishes both the necessary sulphuric acid and also forms one of the most important precipitants, ferrous sulphate.

The solution of gold by iron, alum, and cupric chloride, as well as that by means of alkaline sulphides, need not be commented upon since they rarely occur in nature in sufficient quantities to cause solution.

Such acids as sulphuric and phosphoric acids will dissolve gold in the presence of certain oxidizing agents as mentioned above. The possibility of the presence of phosphoric acid is more remote than that of the sulphuric acid, since as mentioned before the oxidation of pyrite tends to

the formation of sulphuric acid.

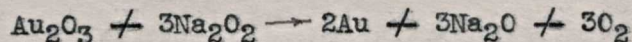
Transportation of Gold:--Gold to be transported must first necessarily be in solution. Then it must pass through either pervious rocks, or through a fractured zone. The wall rocks should not be chemically active, since active rocks such as limestones tend to precipitate the gold.

Precipitation of Gold:--Brokaw (2) gives the following table for the more common precipitations of gold:

- (1) Native elements, such as copper, silver, mercury, tellurium, etc.
- (2) Sulphides, tellurides, etc.
 - a. simple--most of the common sulphides such as pyrite, marcassite, and galena.
 - b. complex sulpharsenides and sulphantimonides such as polybasite.
- (3) Ferrous compounds
 - a. in solution derived from alteration of iron sulphides.
 - b. primary minerals such as siderite, ankerite, etc.
- (4) Manganous compounds
 - a. in solution derived from alteration of manganese minerals.
 - b. primary, rhodocrosite, etc.
- (5) Other inorganic substances such as sulphur dioxide, arsenious acid, etc.
- (6) Organic compound such as formic acid, oxalic acid, acetylene, glucose, amorphous carbon, etc.

Very little work has been done on the precipitation of gold from any solutions other than chloride solutions. In the precipitation from chloride solutions, ferrous sulphate has been considered the most important since it can be readily formed from the oxidation of pyrite.

In addition to the precipitation from chloride solutions, Lenher (as quoted by Grassmuck 4) has formulated the autoreduction theory of gold as shown in the equation below:



Any peroxides such as those of barium, calcium and hydrogen, may replace the sodium shown in the formula above. Such a theory could account for the deposition of gold as long as it remained in the oxidized zone, since only oxygen is necessary for the precipitation of gold in this case.

If a chloride solution of gold should be neutralized or made alkalic, the gold would immediately be precipitated. Consequently in an active gangue such as limestone, there would be no transportation of gold, as long as the limestone or lime remained.

Applications to the Problem at Hand

The total sulphide minerals in the veins (as mentioned under ore deposits) make up about 3% of the total, with pyrite making up about 2%. Manganese occurs in the ankerite in the form of manganous carbonate (about 0.8%). Chlorine has been found in the mine water in small quantities. From the above knowledge it would seem that conditions would be satisfactory for the solution of gold, except for the presence of manganous carbonate, which could easily be oxidized to manganic oxide.

To make the solution of gold possible it would be necessary to have a sufficient amount of chlorine to dissolve the gold and also to have attendant HCl. All ferrous compounds in solution would have to be oxidized to ferric compounds. The active CaCO_3 in the ankerite, would have to be leached out and the ferrous carbonate occurring in the veins would have to be removed.

There should also be a zone somewhere in the oxidized portion of the

vein where there would be enriched values present. No such case is found (See Plate V). If no such zone is found, why were not the conditions right for the solution of gold, since there are present practically all the necessary minerals needed for the solution of gold. Several things may account for this, which will be discussed below.

There is a strong possibility that there was not enough pyrite present to furnish the necessary amount of sulphuric acid either to further change the ferrous compounds to the ferric or to change the manganous compounds to manganic. Such a condition is very probable and should be given some weight.

Also the calcium carbonate in the ankerite would tend to precipitate the gold as quickly as it was taken into solution. A long period of time would be necessary for such a large amount of calcite to be leached away, and also while this was being leached away the pyrite would have been completely oxidized, and the sulphuric acid removed.

It is very probable that such a state of affairs took place.

Precipitating agents for the dissolved gold forms a long list. Ferrous carbonate, manganous carbonate, and calcium carbonate all occur in the ankerite. The preponderance of these precipitating agents is probably what has kept the gold from being transported after being once dissolved.

CONCLUSIONS AS TO ORIGIN

In conclusion, it is the opinion of the writer that the veins are replacement veins along fractures in the quartz diorite caused by contraction, and that these veins were formed before the complete cooling of the intrusive. There is no evidence of supergene enrichment in the

way of an enriched zone, and it appears probable that the hypothesis advanced by Pardee is not correct. The reasons for lack of enrichment are given above, but may be summarized as follows. Although there was present at one time a sufficient amount of solvents for gold, the active wall rock containing calcium carbonate and manganous and ferrous compounds was not leached away until the gold solvents were removed in solution.

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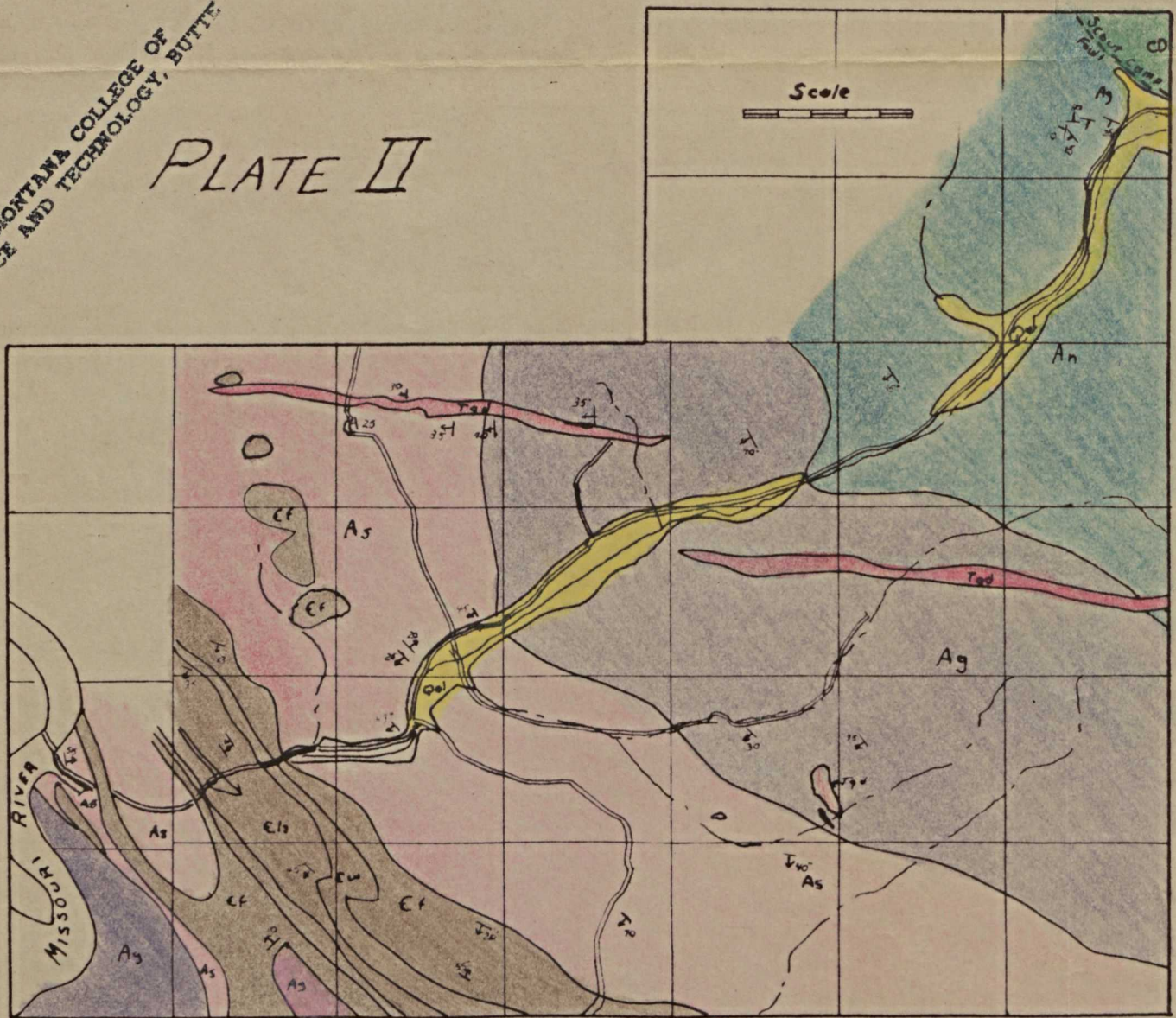
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PLATE II



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| Qal Recent Alluvium | Ef Cambrian Flathead Quartzite |
| Ted Tertiary Quartz Diorite | As Algonkian - Spokane Shale |
| CD Carboniferous-Devonian Undifferentiated | Ag Algonkian Greyson Shale |
| Els Cambrian Limestone Undifferentiated | An Algonkian Newland Limestone |
| Ew Cambrian Wolsey Shale | --- Faults |

GEOLOGIC MAP
OF
TROUT CREEK AREA