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GEOLOGY OF THE CUCOMUNGO SPRING PROSPECT, ESMERALDA COUNTY, NEVADA

The Cucomungo Spring molybdenum prospect is in southern Esmeralda County, Nevada, about 14 miles southwest of Lida. The prospcet lies almost at the center of the Magruder Mountain 15-minute quadrangle near Uncle Sam Spring, Uncle Sam Creek, Poison Spring, and the headwaters of Alum Creek.

Of principle interest in the prospect is a large area of strongly altered and mineralized granite. The granite has been rather completely altered hydrothermally to sericite and quartz; abundant clay is probably partly of hydrothermal origin but mostly of weathered origin. The altered area has been mineralized with pyrite and molybdenite. Weathering and erosion of the soft mineralized rock has produced a yellowish-streaked badlands. The altered area is so spectacular in appearance and location that it is advertised as a tourist attraction called "the Big Molly". The view of northern Death Valley is outstanding from the prospect.

Little geologic information has been published on the area. The Cucomungo deposit is briefly described by John H. Schilling in Nevada Bureau of Mines Report 2, "An Inventory of Molybdenum Occurrences in Nevada", pp. 17-18. A four-page unpublished descriptiin by John Schilling is more detailed. The geologic map of Esmeralda County by John Albers and John Stewart, U. S. Geological Survey Mineral Investigations Field Studies Map MF-298, on a scale of 1:200,000 is excellent though not of sufficient detail to distinguish structure and rock units in the prospect area. U. S. Geological Survey Bulletin 1251-H, "Geology of the Magruder Mountain Area, Nevada-California", by Edwin H. McKee is inaccurate and of insufficient detail.

Discussions with John Schilling, Nevada Bureau of Mines geologist, have been most helpful. Mr. Schilling gave us copies of geologic maps, drill sample analyses, geochemical maps, an I. P. report, and other data on the Cucomungo Spring prospect which have been released from the files of Freeport Sulphur Company, Bear Creek Mining Company, and Molybdenum Corporation of America. In addition, Mr. Schilling has salvaged drill cores and cuttings from the prospect; these are available for inspection at the Nevada Bureau of Mines.

The exploration history of the Cucomungo Spring deposit is summarized by Schilling in his unpublished report and in the various company reports. The earliest activity was in the mid 1930's by Gus Roper who drove an adit northeast from the floor of Alum Creek. In 1938 and 1939, Freeport Sulphur extended the adit to 840 feet and drilled 6 rotary holes shown on their assay map. Two of the holes were in the adit area; four were in the heart of the badlands area near Poison Spring. Bear Creek conducted topographic, geologic, geochemical, and geophysical surveys. They drilled 15 diamond drill holes during the period 1958-1961. Some of the holes were more than 800 feet deep. In 1967, Molycorp drilled 19 rotary holes mostly to depths between 200 and 400 feet. The Sorenson claims, which include most of the prospect, are presently controlled by Geochemical Surveys.

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This/is based upon two months of geologic mapping and field study of the Cucomungo Spring prospect and the surrounding region during the summer of 1969. A topographic map accompanying this report shows certain geologic features to which this report refers. My geologic map of the Cucomungo Spring prospect is to be used in reading of this report. Mapping was on aerial photographs at a scale of 1 inch equals 1000 feet. As the geology was transferred to the base map by inspection, the map is not accurate.

Geologic Setting

The general geology of the region is shown on the geologic map of Esmeralda County. Briefly, the geologic history of the region was as follows: Precambrian(?) and early Paleozoic formations were intruded by large granitic stocks of middle Jurassic age. High angle and thrust faulting occurred before, during, and after intrusion of these stocks. Mineralization occurred shortly after intrusion of the stocks, probably during the/stages of cooling of the intrusives. A long period of deep erosion followed. In Tertiary time, volcanic flows and pyroclastic layers were deposited. Late Tertiary faulting produced mountain ranges and valleys, many of which are preserved in today's topography. Lakes occupied the intermontane areas, and thick deposits of lake sediments composed partly of pumice and other pyroclastics were deposited. Late elevation of mountain blocks along Recent faults, erosion, deposition of alluvium, and extrusion of basalt flows and of pyroclastic material has produced the present topography.

The earliest rocks found in the Cucomungo Spring area are xenoliths of gneiss and schist preserved in the Uncle Sam porphyry stock. Dark gray biotite schist is exposed about a mile southwest of Cucomungo Spring. Phyllite is exposed about 5 miles east of Cucomungo Spring. These rocks show that the area was subjected to dynamothermal metamorphism at an early time prior to intrusion of the stocks.

Most of the metasediments of the prospect area are marble, skarn and hornfels. They were produced mainly by thermal metamorphism caused by intrusion of the stocks, though the original sediments may have been slightly affected by dynamothermal metamorphism prior to intrusion of the stocks.

The stocks range in composition from granite to quartz monzonite. Nearly all are porphyritic with a wide range of textures. Relatively small areas of metasedimentary rocks are preserved between stocks.

Early structural deformation was intense and complex, though the record of early orogenies is so fragmentary that details have not been deciphered. High angle faults and thrust faults have been truncated by intrusive contacts showing that some of the faulting preceded intrusion of the stocks. Some high angle faults and thrust faults have offset intrusive masses showing that some of the faulting post-dated intrusion.

The large mountain block consisting of the Silver Peak, Palmetto, Sylvania and other ranges and including the Cucomungo Spring prospect was elevated during the Tertiary. Almost no Tertiary lake beds were deposited on this mountain block, and Tertiary volcanic deposits are rare due to nondeposition or erosion.

Rocks

On the geologic map of the Cucomungo Spring prospect only 4 rock units, excluding alluvium, are shown. Metasediments were intruded by the Uncle Sam and Cottonwood stocks; these were overlain by volcanic rocks. The rocks are described below.

Metasediments

The oldest rocks of the area, as mentioned, are the metamorphosed sedimentary formations. Some of these may have been subjected to an early stage of weak dynamothermal metamorphism resulting in phyllite and schist. Most are thermally metamorphosed by intrusion of the stock. The most widespread rocks are marble and hornfels. Skarn is rarely present locally. Bedding is well preserved and it strikes at sharp angles to contacts with granitic rocks. No attempt has been made to divide these rocks into formations as this would probably not aid in deciphering the geology of the molybdenum prospect.

Uncle Sam quartz monzonite porphyry

Quartz monzonite porphyry exposed near Uncle Sam Spring is named Uncle Sam quartz monzonite porphyry. This rock is distinctive in appearance and may be readily distinguished from other intrusive rocks. In the prospect area, this porphyry is the only formation exposed along the southwest side of Uncle Sam fault. This fault is traceable for many miles because the distinctive Uncle Sam porphyry of the southwest block is faulted against other rocks on the northeast block. Uncle Sam porphyry is not known anywhere on the northeast side of the fault.

The distinctive characteristics of the Uncle Sam porphyry are its medium to dark gray color and the very large somewhat widely distributed euhedral orthoclase phenocrysts. Geologists recognize this as "Sierra Nevadian type" intrusive rock. Other granitic rocks of the area are lighter gray and have generally smaller phenocrysts.

Megascopically, the rock has a medium-grained phaneritic groundmass composed of nearly equal proportions of light gray minerals and of black biotite. The light colored minerals are feldspar and quartz; the biotite occurs as clusters of small crystals. Orthoclase phenocrysts are 1 to 1½ inches in length, are in euhedral crystals having sharp rectangular cross sections, and are somewhat widely distributed; they probably comprise only 10% of the rock. There are no grains of intermediate size between the medium-grained groundmass and the very large phenocrysts. Upon weathering, the phenocrysts stand out in relief against the soft often crumbly groundmass. Xenoliths of schist and gneiss are present in parts of the Uncle Sam stock.

Petrographic examination (sample no. CZ-71--fresh Uncle Sam porphyry collected from the floor of Alum Creek) shows the Uncle Sam to be quartz monzonite porphyry. The groundmass consists of orthoclase and plagioclase in nearly equal amounts, of abundant quartz, and of some hornblende and sphene. Grain boundaries are serrated due to deuteric intergrowth of quartz and orthoclase; myrmekite is common along orthoclase borders. Some of the quartz grains consist of aggregates of smaller quartz grains. Biotite in small grains and in grain clusters has been partly resorbed by feldspar. Hornblende has been almost completely replaced by biotite and is perforated with quartz and orthoclase; iron oxide dust is plentiful. Coarse crystals of sphene are fairly

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common. The rock, as a whole, is fresh; it has not been hydrothermally altered. Only a very minor amount of clay and sericite is present.

Cottonwood granite porphyry

The rock composing a large stock near the head of Cottonwood Canyon is named Cottonwood granite porphyry. Here the rock is fresh, but in the area of the molybdenum prospect the Cottonwood granite has been strongly altered to sericite, quartz and clay minerals. Megascopic and microscopic descriptions of fresh Cottonwood granite are given below; the altered rock is described later.

The Cottonwood granite porphyry is a coarse-grained, phaneritic, light gray biotite granite having feldspar phenocryts that usually are only 2 or 3 times as large as groundmass grains. It is distinguished from the Uncle Sam porphyry by its lighter color (due to less biotite), coarser-grained groundmass, and smaller phenocrysts. Variations in texture and composition are common. In some places the rock is fine-grained, has less biotite, and is not porphyritic. No schist or gneiss xenoliths are present.

Microscopic examination (sample CZ-63--fresh rock collected at head of Cottonwood Canyon) shows the Cottonwood to be on the borderline between granite and quartz monzonite. Plagioclase, which is sodic, is present but not in sufficient proportion to classify the rock as quartz monzonite. The groundmass is coarsely phaneritic. Minerals of the groundmass in order of abundance are orthoclase, quartz, microcline, sodic plagioclase and biotite. Quartz grains are large and are discrete crystals rather than aggregates of smaller crystals. Microcline occurs as grains in the groundmass and also as the phenocryts. Biotite is clean (not altered) but has ragged borders, and it is not very abundant. No other mafic minerals are present. Grain boundaries are largely subhedral and sharp. The rock of this sample has not been hydrothermally altered.

Volcanic rocks

During middle or late Tertiary time, volcanic rocks were deposited on the deeply eroded and irregular topography of the prospect area. The volcanics are mainly preserved as cappings on high peaks. However, in some places the volcanics are preserved in early valleys that have not been subjected to recent erosion. The alluvial flat east of Cucomungo Spring is an early valley underlain with volcanics.

The lowest volcanics consist of soft bedded tuff. In the prospect area the tuff is only a few tens of feet thick, but northwest of the prospect the tuff thickens locally to several hundred feet.

The tuff is overlain by andesite flows. The andesite is locally vesicular. The black peak southeast of the junction of Uncle Sam and Alum Creeks is capped with basalt which overlies a thin sequence of tuff beds. This may be a part of the same volcanic flow sequence, though it could be a remnant of a later flow sequence present several miles to the southeast. I saw no evidence that this is a cinder cone.

The volcanic rocks are post mineral and thus have no direct bearing on mineral distribution. However, the volcanics are important in that they may cover potential bodies of ore.

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Structure

The most important structures of the prospect area are the contacts between igneous rock units and metasediments. The contacts were studied to determine their nature and thus to determine their bearing on mineral deposits.

Intrusive Contacts

Poison Spring is in strongly altered Cottonwood granite. A few hundred feet east of Poison Spring the altered granite is in contact with metasediments. Here the contact is very straight as it cuts across the topography, an indication that it is nearly vertical. There are no granite apophyses in the metasediments. A dike in the metasediments appears to be cut off at the contact, though this can not be confirmed due to alluvial cover in the area of the intersection. Such features suggest a high angle fault. However, as the contact is traced to the northwest and southeast, it becomes very irregular. The irregular pattern shows that the contact is intrusive and not a fault. Several large xenoliths of metasediments in the granite near the contact confirm the intrusive nature of the contact.

A core hole drilled by Bear Creek Mining Company, DH-12AA, is in the metasediments east of the contact (see geologic map). The collar of the hole is about 300 feet higher in elevation than the outcropping contact. The drill core consists of hornfels and marble to a depth of 252 feet at which point somewhat altered Cottonwood granite was encountered and continued to the bottom of the hole at 263.5 feet. Thus, the granite-metasediment contact is nearly at the same elevation in the drill hole and on the outcrop. The nearly vertical contact at the surface must flatten out abruptly at depth. This is further indication of the great irregularity of the contact, a fact supporting its intrusive origin.

Several hundred feet west of Poison Spring the altered granite is in contact with another area of metasediments. Though some segments of the contact are straight indicating nearly vertical plane surfaces suggesting fault origin, other parts of the contact are of very irregular pattern indicating intrusive origin. Small isolated patches of Cottonwood granite are present in the metamorphics near the contact; these are probably apophyses having concealed connections with the Cottonwood stock. The irregular contact and the apohyses are strong evidence for the intrusive nature of the contact.

Other evidence indicates that the Cottonwood granite intruded the metasedimentary sequence. Xenolithic masses of metasediments, some of which are large, such as the one shown on the geologic map about 2000 feet northwest of Poison Spring, are present in the stock. The metasediments on the northeast and southwest sides of the stock, and those of the xenoliths, are similar in composition, degree of metamorphism, and appearance. Also, the strike of bedding in the metasediments is the same on each side of the stock and in the xenoliths, the strike being about N.70° W. If the contacts between the granite and metamorphics were faults, the strikes of bedding on each side of the granite would probably not be parallel.

The intensity of thermal metamorphism in the metamorphic rocks on each side of the Cottonwood stock (and in the xenoliths) does not visibly increase toward the granite contacts. This led to a preliminary belief that the contacts were faults. However, now that the intrusive character of the

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contacts is recognized, the absence of obvious increase of metamorphic intensity near the contacts is thought to show that the thermal metamorphic environment was widespread and uniform rather than narrow and variable. This widespread metamorphism is supported by the occurrence of thermally metamorphosed rocks far from exposed granitic contacts elsewhere in the area, and it may account for the talc deposits found in metamorphosed dolomite far from granitic contacts. As a number of stocks were intruded in the area at about the same time as the Cottonwood stock, it seems likely that the sedimentary rocks of the entire region were heated more or less uniformly.

il The directions and degrees of dip of the contacts on the northeast and southwest sides of the Cottonwood stock in the altered area are important to mineral exploration. The contact northeast of the stock dips at moderately low angles to the northeast. This is indicated by the shallow depth to granite in diamond drill hole DH-12AA, which has already been mentioned. Also, it is shown by the pattern of the contact on the topography on the geologic map.

The contact on the southwest side of the stock also dips to the northeast. A dip of 65° was measured on the contact at a point about 2500 feet west-northwest ~~west~~ of Poison Spring. Core hole number DH-14AA, which is on the southwest side of the contact and very close to the contact, did not strike Cottonwood granite. This indicates a dip ranging between vertical and northeastward. Information from core holes DH-2AA, DH-3AA, DH-4AA, and DH-8AA will be helpful in confirming the northeastward dip of the contact. The degrees of dip would be measureable on a geologic map on which the contact were plotted accurately from the aerial photographs by photogrammetric methods; the dip would be determined by the trace of the contact across topographic features. Inspection of the contact as shown on the present inaccurate geologic map justifies the general conclusion that the contact dips northeastward at a steep angle.

Uncle Sam fault

The molybdenum prospect is limited on the southwest by Uncle Sam quartz monzonite porphyry which here is barren of mineralization. The contact of the Uncle Sam porphyry with the rocks of the molybdenum prospect is very important to exploration of the prospect. Much time and effort were devoted to the study and mapping of this contact to determine whether it is an intrusive contact or a fault. For reasons given below, it was identified as a fault; it is named Uncle Sam fault for Uncle Sam Canyon. The canyon owes its existence indirectly to the fault.

The Uncle Sam fault, mapped for a length of 14 miles, is shown on the Magruder Mountain quadrangle map accompanying this report. The fault undoubtedly extends much farther in both directions. The structure was mapped for this long distance in order to determine its characteristics.

Essentially, the fault represents the northeastern contact of the Uncle Sam porphyry with other rocks. For the entire length of the mapped contact, Uncle Sam porphyry occupied the southwestern side. I did not see Uncle Sam porphyry anywhere to the northeast of the fault during reconnaissance of the region. Though Uncle Sam porphyry lies adjacent to the fault in a band of varying width, other rocks such as met-sediments and other granitic stocks lie in the southwestern block of the fault at distances from the fault. A few of these other rock types are indicated on the topographic map near where the California border crosses Cucomungo Canyon.

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In the prospect area only metasediments lie adjacent to the fault on the northeast side. However, farther southeast Cottonwood granite lies along the fault. A narrow zone of sericitized Cottonwood granite was noted in the light-colored saddle through which the fault passes about $2\frac{1}{2}$ miles southeast of Poison Spring.

Through the prospect area the Uncle Sam fault has a sinuous map pattern in-
dicating considerable variation in dip. Where it crosses Cottonwood Canyon, the
fault is nearly vertical. On the noses a few hundred yards northwest of the junc-
tion of Alum and Uncle Sam Creeks, the fault is nearly horizontal. From here
northwestward for a mile the contact has a gentle dip to the northeast. A dip of
20° northeast was measured where the fault crosses a canyon about 2500 feet west
of Poison Spring. Core hole DH-14AA, on the hill slope northeast of the junction
of Alum and Uncle Sam Creeks, encountered Uncle Sam porphyry at a depth of 461
feet; the identification of the porphyry was confirmed petrographically. This
indicates a northeastern dip of about 20° for the fault. Such variation of dip
and low angle of dip suggest an intrusive rather than a fault contact. Indeed,
the contact was mapped by both Bear Creek Mining Company and Molybdenum Corpora-
tion of America as an intrusive contact. But, the evidence that the contact is
a fault is conclusive.

Evidence that the Uncle Sam contact is a fault is as follows:

1. Different rock types occur on each side of the fault. Uncle Sam porphyry
occurs on the southwest side throughout it mapped extent; other rock types and
no Uncle Sam porphyry occur on the northeast side. This fact, taken alone,
could support an intrusive origin for the contact, but when considered with
other evidence, it supports a fault origin.

2. The contact has a relatively straight trend for 14. Such a long straight
trend is more typical of a fault, especially of a high angle fault, than of an
intrusive contact. Stocks along the northeast side of the fault, such as the
Cottonwood stock, are sharply cut off by the contact.

3. No apophyses of Uncle Sam porphyry extend across the contact to the north-
east side. If this were an intrusive contact, apophyses would probably be pre-
sent.

4. Aplite dikes in the Uncle Sam porphyry are abruptly cut off at the con-
tact. This is noted in several places along the contact many miles apart. If
the contact were intrusive, aplite dikes would cross the contact.

5. Sericite and quartz alteration in Cottonwood granite is cut off abruptly
at the contact. It does not extend across the contact into the Uncle Sam por-
phyry.

6. The texture of the Uncle Sam porphyry does not change near the contact.
Where Cottonwood granite is in contact with Uncle Sam porphyry, there is no
change in primary texture of the Cottonwood close to the contact. If the con-
tact were intrusive, border facies may be expected in the intrusive rocks.
Cottonwood granite commonly, though not invariably, has a fine grained border
facies near intrusive contacts

7. The rocks on both sides of the contact are brecciated.

8. The Uncle Sam porphyry is commonly very deeply weathered to soft crum-
bly rock near the contact. Uncle Sam Canyon and White Cliff Canyon several

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miles to the northwest (see topographic map) were eroded from such crumbly Uncle Sam porphyry adjacent to the fault. This deep weathering could be due to brecciation. Another possibility is that the deep weathering occurred prior to faulting, and in parts of the Uncle Sam fault that are thrusts, the northeast blocks moved across the land surface preserving parts of the ancient weathered rock.

9. Fine grained material, probably fault gouge, is often seen where the contact is well exposed.

10. Diorite dikes occupy the contact in many places in the Cottonwood Canyon area.

11. Foreign rock fragments and horses may be present along the contact. Core hole DH-14AA, which started in metasediments and passed through the contact into Uncle Sam porphyry, penetrated 14 feet of altered and mineralized Cottonwood granite near the base of the metasediments. This was probably a horse dragged from below by the fault. Below the altered Cottonwood there were 24 feet of soft crumbly brecciated metasediments before the Uncle Sam was penetrated.

Several of the above criteria are strong evidence of faulting. The abrupt termination of hydrothermal alteration at the contact, the termination of the aplite dikes at the contact, brecciation on either side of the contact, and diorite dikes along the contact are indisputable evidence of faulting. All the other criteria strengthen the case for faulting, though some taken alone could also support an intrusive contact. I feel that the evidence proves the contact to be a fault.

The Uncle Sam fault is complex. As mentioned, parts of the fault are nearly vertical and other parts have gentle dips to the northeast. The relatively straight course of the fault suggests a generally steep dip with only local areas of low dip. Attempting to classify the fault as normal or reverse would serve no purpose and may be confusing. Of most importance is the nature of movement along the fault. The gentle northeastern dips of the fault in the area of the molybdenum prospect and several miles to the northwest suggest that the fault was a thrust in which the northeastern plate moved southwestward upon the footwall block. This, of course, assumes that the present direction of dip indicates the direction of movement, the northeast dip indicating movement of the thrust plate from the northeast. This assumption, though reasonable in the absence of other evidence of direction of movement, is not infallible. A similar northeast-dipping thrust fault has been mapped a few miles to the northwest where it crosses the Palmetto Wash highway, according to John Schilling (oral communication).

Thrust faults often pass into high-angle faults abruptly. My conclusion is that the Uncle Sam fault is a high-angle fault having portions that were low-angle thrust faults. Deeper parts of the fault were high-angle; surface or near surface parts were probably low-angle thrusts. The thrust sheets may have slid upon an ancient land surface.

Long straight faults often suggest rifts having strike-slip movement. Though Uncle Sam fault is certainly a major fault with relatively straight trend, irregularities of the fault attitude seem to rule out any significant strike-slip movement.

The history of the Uncle Sam fault is probably long and complex. The fault is probably very ancient and has had a number of periods of movement through ...logic time. It is a very deep fault that consitutes a major "zone of weak-

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ness". Some of the stocks of the area may be aligned along the fault suggesting that magma rose along the fault zone; geologic mapping of the stocks is needed to confirm this. The prominent zone of alteration in the Cottonwood granite lies parallel to the Uncle Sam fault and, in places, adjacent to the fault. The hydrothermal solutions responsible for the alteration, and also solutions responsible for molybdenum mineralization, may have ascended along the Uncle Sam fault. Post-mineral movement of the fault removed any altered or mineralized rock originally formed on the southwestern or footwall side. Late movement of the fault is shown by the dikes of fresh diorite that occupy the fault zone in the Cottonwood Canyon area.

The attitude of the Uncle Sam fault in the molybdenum prospect area has important bearing on ore potential. As mentioned, the fault has low angles of dip in the prospect area. Uncle Sam porphyry on the footwall side of the fault in barren of molybdenum mineralization. If the fault maintains a gentle dip under the mineralized part of the prospect, it will provide a shallow floor under which no mineralization would be found. This would seriously diminish the possibility of finding a large body of ore. Study of drill cores will be particularly valuable in determining whether the fault steepens to provide a greater thickness of potential mineral ground.

Hydrothermal Alteration

The Cottonwood granite is hydrothermally altered to sericite, quartz, and clay minerals in the vicinity of Poison Spring. The rock is soft and weathers easily. Concentrations of quartz stringers found throughout in apparent random distribution weather to resistant ribs and masses. Parts of the granite are not completely altered and still show feldspar crystals fresh enough to preserve bright cleavage surfaces; these fresher parts are somewhat more resistant to weathering. Sericite and quartz produced by hydrothermal activity are concentrated along early fractures forming veinlets and veins. Much of the rock between such veins has been converted to soft clay through hydrothermal and weathering activity. Large primary quartz crystals have not been altered and remain as ¼ inch diameter grains evenly distributed throughout the soft sericite-clay matrix of strongly altered rock. Small and large angular masses of quartz throughout the altered area indicate that the area was severely fractured after quartz-sericite alteration.

The most intensely altered area extends from the northwestern rim of Alum Creek Canyon southeastward for about 4000 feet; its width averages 1500 feet. The area is limited on the northeast and southwest sides by the metasediments that flank the Cottonwood stock. This is the area eroded to a badlands topography. Alteration extends farther to the northwest and southeast but is less intense, and the altered zone is narrower.

Clay was formed by decomposition of feldspar by both hydrothermal and weathering action. The proportion of clay formed by each process is problematical. Though some clay was produced by hydrothermal alteration, petrographic study shows relatively small amounts of clay in many deep zones. Much of the clay was probably formed as a result of weathering.

Origin of clay by deep weathering is favored by two factors. First, the deposit is very rich in disseminated pyrite; acid solutions produced by the weathering of pyrite facilitated decomposition of feldspar to clay. Second, the deposit was subjected to a long period of weathering during the Tertiary prior to deposition of the volcanics; the volcanic rocks preserved the soft weathered material until Recent erosion stripped back the volcanic cover and cut into the soft rock.

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Fresh pyrite present high in the deposit near the Tertiary erosion surface
could indicate that weathering was not deep. However, weathering seems to have
been intense and deep in some zones and shallow in others. The quantity of
secondary quartz ~~present~~/in particular zones determined the depth of weathering;
pyrite surrounded by impervious quartz did not weather, but unprotected pyrite
was destroyed. Thus, in some zones weathering was deep and in siliceous/was
shallow.

Abundant pyrite is confined to the area of badlands topography. Sericite
alteration extends farther, but pyrite and badlands weathering are absent. The
Association of pyrite and badlands topography is further indication that deep
weathering of pyrite produced the clay alteration rather than hydrothermal activity.

Three samples of the strongly altered rock were collected from different parts
of the altered area for laboratory examination (CZ-59, CZ-64, CZ-65). All are
white with light orange-yellow mottling due to iron oxide. Small pores apparently
were produced from the solution of pyrite. The original granitic texture is poorly
preserved except for the large quartz grains. Feldspars are white and somewhat
soft due to partial decomposition; some feldspar crystals are sufficiently presevesd
to show bright cleavage surfaces. Secondary quartz and sericite are very common.
The secondary quartz seems to have soaked through all the rock and is truly
pervasive; in these samples quartz and sericite are not concentrated in veinlets.

Petrographic examination of the three samples shows the character of the original
rock and of the alteration. The most common preserved primary minerals are quartz
and potash feldspar in large grains. Grain boundaries are sharp and serrated,
not granular; they suggest replacement. Almost no microcline was noted. However,
one grain of potash feldspar has a few areas showing microcline twinning, a fact
suggesting that microcline may have originally been abundant and was altered to
orthoclase. Original biotite was altered almost completely to sericite. No other
mafic minerals are present. Original plagioclase was not abundant; it was almost
completely altered to sericite. Enough of the original minerals and textures are
preserved to confirm the identification of the altered rock as Cottonwood granite.

Most striking in the thin sections is the evidence of typical quartz-sericite
alteration. Sericite is abundant and occurs as veinlets along grain boundaries
as replacements of biotite and plagioclase, and as partial replacements of ortho-
clase. Silicification is pervasive. Fine granular quartz is mixed with sericite.
Quartz in veinlets is not common. Some of the secondary quartz is hard to distin-
guish from primary quartz, though the secondary quartz consists mainly of aggregates
of smaller quartz grains. Yellow opaque minerals may be iron oxide or ferrimolybdate.
Very little clay alteration is evident in the thin sections.

Samples of altered Cottonwood granite were selected from drill cores and studied.
Sample 7A-667 from a depth of 667 feet from drill hole 7AA is granite that has been
only modrately altered. Megascopic examination shows medium grainded fresh ortho-
clase and quartz with a very few small grains of altered biotite. Disseminated
pyrite is common. Microscopically, the rock shows quartz, orthoclase, and
plagioclase in moderate abundance. Very little biotite is preserved. Much of the
quartz is in aggregates of tiny grains. Some of feldspars are altered moderately
to sericite; some clay minerals are present. ¶ Sample 9A-505 from a depth of 505
feet in core hole 9AA shows pervasive quartz-sericite alteration of Cottonwood
granite. The megascopic appearance is of gray primary quartz grains in a matrix
of finely crystalline sericite and quartz with scattered pyrite grains and yellow
oxide stains. Under the microscope the feldspars are patchy due to alteration to
sericite. A little microcline is preserved. Biotite has been completely altered

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to sericite; some biotite has been replaced by pyrite. Quartz and sericite predominate.

Sample 12A-259 taken from 259 feet in core hole 12AA is Cottonwood granite that shows relatively weak quartz-sericite alteration. The original minerals of the granite are mostly preserved. Sericite selectively replaces plagiocalse. Microcline is abundant; areas of potash feldspar without twinning that occur within microcline grains suggest that some of the abundant potash feldspar of the strongly altered rock originally may have been microcline. Grain boundaries are quite serrated. A few shards of preserved biotite show green chloritic alteration, and much iron oxide dust outlines former grains. Potash feldspar is somewhat perthitic.

A sample of hornfels (CZ-60) was collected only 20 feet from the granite contact along the southwest side of the strongly altered area. The purpose of taking this sample was to observe the effect of the alteration upon the hornfels. Megascopic examination shows faint banding that suggests sedimentary lamination in siltstone. Under the microscope the rock is seen as a mosaic of quartz and dark colored mica that is probably chlorite. The rock consists of quartz with scattered small grains of chlorite. Quartz is clean with no inclusions; chlorite has not been altered. Foliation (sedimentary lamination?) is preserved. Small fractures trending across foliation are filled with a fine aggregate of feldspar with very little quartz. Some pyrite is present. As the mafic mineral is fresh it seems that this rock has not been affected by the hydrothermal alteration that caused moderate quartz-sericite alteration in granite a few tens of feet away (sample CZ-59, which has been mentioned, was collected in the altered granite only 20 feet from the hornfels contact and 40 feet from sample CZ-60). The hornfels must have been in equilibrium with the hydrothermal solutions that altered the granite.

Mineralization

The mineralization of the molybdenum prospect area was examined in the field but was not studied in detail. Pyrite, molybdenum minerals, and copper minerals were noted.

Pyrite is most highly concentrated in the area of badlands topography. No systematic changes in pyrite concentration were noted there, though there are local variations in concentration. Pyrite is present in the holes drilled into the altered granite on the northwestern rim of the badlands area. Cuttings on the ground at Molycorp drill hole SM-14, which is about a mile ~~northeast~~ northwest of Poison Spring, have a small amount of pyrite.

Visible molybdenum minerals are present only in the badlands area. Molybdenite occurs in the secondary quartz as linings of vugs, as linear streaks that appear to be healed fractures, as disseminated grains, and as sheets that follow the edge of quartz veinlets. Weathering of molybdenite has led to the formation of secondary minerals such as yellow hydrous molybdenum oxide, ferri-molybdite, and a deep blue complex molybdenum mineral, probably a molybdenum sulphate. The secondary minerals form halos and coatings around molybdenite masses.

The concentration of molybdenum minerals changes greatly and erratically throughout the altered area. Some areas, such as that near Poison Spring, have abundant visible molybdenum minerals. Several large areas a few hundred square feet in size are particularly conspicuous because they are covered with coatings of dark blue molybdenum sulphate. According to Fremont Sulphur's assay maps of surface samples taken in parts of the altered areas, overall molybdenum concentration is too low

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to be commercial. Some limited areas, however, have high enough molybdenum values to be classed as ore if the tonnages were great enough for low-cost mining methods. A grade of about 0.2% molybdenum would yield ore worth about $6 per ton, ore that could be mined economically by large-tonnage open pit mining.

Molybdenum values from drill samples of the three companies are generally low. There is no systematic change in molybdenum content with depth. Concerning the Cucomungo Spring prospect, John Schilling states (unpublished report), "As is common in many molybdenite deposits; there has been relatively little leaching or secondary enrichment, and the grade of the molybdenum remains constant from the surface to a depth of at least 800 feet".

Copper minerals were not recognized in the altered granite. Malachite, azurite, and chrysocolla in thin coatings are present in small concentrations 1500 feet west of Poison Spring in the metasediments. The secondary copper minerals were derived ffom chalcopyrite deposited in garnetized limestone. One of the copper concentrations is exposed in a road cut, a sample of which (CZ-9) has 20,000ppm copper and 10,000 ppm zinc. Prospect pits were sunk on these copper showings along the ridge crest in the late 1800's or early 1900's.

The relationships of minerals to each other and to hydrothermal alteration are important to exploration. Visible molybdenum minerals are confined to the area of altered Cottonwood granite. Specifically, molybdenite is closely associated with the secondary quartz formed by quartz-sericite alteration. Molybdenite deposition probably started during the final stage of quartz formation. Fractures that formed in the quartz facilitated the circulation of molybdenum solutions and the deposition of molybdenite shortly after quartz was formed.

Significant pyrite mineralization is also confined to the altered Cottonwood granite. As with molybdenite, pyrite is most highly concentrated in the badlands area and diminishes in concentration toward the southeast and northwest along the altered zone; pyrite is absent or inconspicuous in the metasediments flanking the altered granite. The similar concentrations of pyrite and molybdenite suggest that they are closely associated in origin. However, such association is not obvious in hand specimens in which pyrite and molybdenite are present but do not occur together. John Schilling feels that the two minerals are not genetically associated in the Cucomungo Spring deposit; in the unpublished report he states, "Pyrite also is disseminated through the altered rock and in the quartz veins, but apparently has no relation to the distribution of the molybdenite". At the Questa Mine, New Mexico, which is very similar to the Cucomungo Spring deposit, pyrite mineralization and molybdenite mineralization were independent.

Copper mineralization is not obviously associated with pyrite or molybdenite mineralization. However, geochemical evidence mentioned later indicates close association of copper and molybdenum.

Conclusions based on the relationships of various minerals are as follows:

1. Molybdenum mineralization started toward the end of the formation of secondary quartz and continued after the end of quartz formation. The secondary quartz was formed during quartz-sericite alteration of the Cottonwood granite.

2. Though pyrite and molybdenite have similar distributions, the two minerals may have formed independent of one another.

3. In exploration for molybdenum, zones of quartz-sericite alteration and also any zones of silicification within the Cottonwood stock should be prime targets.

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As pyrite formation may have been independent of molybdenum formation, the presence of pyrite may not be a good guide to the presence of molybdenite.

Geochemistry

A detailed geochemical survey made of the molybdenum prospect included residual soil samples collected on an approximate 500-foot grid pattern and bedrock samples taken where bedrock was exposed near soil-sample stations. Geochemical maps plotted for molybdenum in soil, molybdenum in bedrock, zinc in soil, copper in soil, and silver in soil show important geologic characteristics of the molybdenum prospect. These are listed as follows:

1. Zones of mineral concentration are elongated northwest-southeast.

2. Metal content of soil and bedrock changes abruptly at the Uncle Sam fault. Values of molybdenum, copper, zinc, and silver are moderately high in the metasediments on the northeast block of the fault, but values of these metals are conspicuously low in the Uncle Sam porphyry on the southwest side of the fault. The contrast of metal values is so sharp that the Uncle Sam fault may be traced readily on the geochemical maps. This geochemical evidence shows that the Uncle Sam contact is a fault.

3. As expected, high molybdenum values occur in the long northwest-trending zone of alteration in the Cottonwood granite. The highest values are in the badlands area. The zone extends from the southeastern limit of sampling on the east side of Cottonwood Creek to the alluvial flat about 2½ miles to the northwest. Molybdenum values diminish toward the northeast in fresh Cottonwood granite.

4. Molybdenum values are moderately high in the metasediments lying adjacent to altered Cottonwood granite on the northeast and southwest walls of the stock. This is further evidence of the intrusive nature of the contact on each side of the stock. Had the contacts been faults, mineral content would have changed abruptly at the contacts. Molybdenum mineralization was probably genetically related to the stock; during the final stage of cooling of the stock, contraction produced fracturing that facilitated the ascent of mineralizing solutions. During molybdenum mineralization of the altered part of the stock, molybdenum passed into adjacent metamorphic wall rock.

5. Zinc and copper values are high in the metasediments on each side of the altered part of the Cottonwood stock. These undoubtedly represent metal zones concentric to the central core of molybdenum mineralization.

The above comments on geochemistry concern the geology of the prospect. Geochemical information having direct bearing on exploration targets is mentioned later.

Examination of Nearby Areas

Besides a general geologic reconnaissance of the entire region, several specific areas were examined to determine the nature of mineralization and to determine any bearing they may have to the Cucomungo Spring prospect.

White Cliff Canyon about 2½ miles northwest of Cucomungo Spring (see topographic map) is a spectacular large erosional amphitheater having badlands topography resembling that of the molybdenum prospect. The Uncle Sam fault passes along the head of the eroded canyon. Uncle Sam porphyry at the head of the canyon is weathered to gray soft granular rubble. The bulk of the canyon is carved from

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white soft deeply weathered granite that resembles the Cottonwood granite. Remnants of fresh rock show no hydrothermal alteration. The soft material consists mostly of clay. No sericite is present; no secondary quartz is present; no molybdenum minerals were noted. Iron stains and heavy alum concentration in spring water from the clay area suggest that pyrite may have been concentrated in this area. The clay was probably formed by deep weathering of granite facilitated by sulphuric acid released by the decomposition of pyrite. This could have formed at an early geologic age, and the soft area may have been overridden and preserved by the Uncle Sam thrust sheet. Recent erosion of the thrust sheet exposed the area and created the badlands topography.

Three residual soil samples were collected from White Cliff Canyon to determine any metal content. Sample CZ-68 taken from an iron oxide vein in deeply weathered Cottonwood-like granite on the south rim of the canyon had 75 ppm molybdenum and 150 ppm lead. Two samples of yellowish iron oxide material from the floor of the canyon, CZ-69a and CZ-69b, had insignificant amounts of molybdenum and other base metals. A sample of residual soil from unstained weathered rock in the floor of the canyon, CZ-69c, had no base metal values of significance. Three of the samples collected represented material from the most highly stained parts of the canyon. As metal values were geochemically low, further exploration of White Cliff Canyon is not recommemded.

Copper Canyon about 2 miles southwest of Poison Spring is crossed by a northwest-trending zone of quartz-sericite and clay alteration. Several prospects along this zone show the presence of copper and molybdenum mineralization. A stream sediment geochemical survey of Copper Canyon and its main tributaries showed low values of molybdenum and other base metals. However, molybdenum values of 5-10 ppm indicated the places where the survey crossed the altered zone. Examination of several prospects showed mineralization confined to small veins. Copper Canyon probably has little potential for major ore discovery. However, the altered zone may be worth further investigation.

The portion of Cucomungo Canyon that extends for several miles in a southwest direction from Cucomungo Spring is very straight and may be classed as a lineament. The Cucomungo Canyon lineament may be traced on the aerial photographs for several miles northeast of Cucomungo Spring where it is marked by an alluvium-bedrock contact and minor drainages. This lineament is paralleled by others such as one followed by the lower part of Copper Canyon. These lineaments lie at right angles to the Uncle Sam fault, the Last Chance Canyon fault, the Copper Canyon altered zone. and the general northwest-trending structural grain of the region.

If the Cucomungo Canyon lineament is a fault, the area of its intersection with the Uncle Sam fault may be an interesting target for molybdenum exploration. The intersection is concealed under the alluvial flat near Cucomungo Spring. Examination of Cucomungo Canyon, however, showed that the canyon does not follow a fault. Several unbroken geologic contacts were traced across the canyon and are shown on the topographic map. Heavy arrows on the map indicate the Cucomungo Canyon lineament.

Cucomungo Canyon lineament, though not a fault, is probably a strong fracture. This and parallel fractures are complementary to the large northwest-trending faults of the area. The intersections of these large fractures with deep and ancient faults may have produced fracturing along which minerals could have ascended, providing that the fracturing predated mineralization. If other geologic factors are favorable, the areas of intersection of northeast-trending lineaments and northwest-trending faults are probably favorable loci for

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metal concentration.

Molybdenite occurs in three localities shown on the topographic map close to the Cucomungo Spring deposit. The molybdenum prospect in Copper Canyon, which has been mentioned, is briefly described by Schilling in Nevada Bureau of Mines Report 2, "An Inventory of Molybdenum Occurrences in Nevada", p. 18, under the heading "McBoyle Prospect." This prospect is 5 claims staked by M. D. MacBoyle, the Molly and Exchequer claims.

The second molybdenite occurrence is at the Sylvania Mine on the boundary between secs. 22 and 23, T. 6 S., R. 38 E. about 5 miles northwest of the Cucomungo Spring deposit (the Sylvania Mine is shown at the wrong locality on the published topographic map --- this has been corrected on the accompanying copy of the map). Here molybdenite occurs with scheelite, galena, sphalerite, and copper stains in skarn and marble along a granite contact within several tens of feet of the Uncle Sam fault. The Sylvania Mine is owned by Don H. Clair who lived on the property (address - Dyer, Nev.).

The third molybdenite occurrence is the Les Brown molybdenite prospect about 1½ miles southwest of Cucomungo Spring. Molybdenite is found in milky quartz veins cutting Uncle Sam quartz monzonite porphyry. The veins are nearly vertical and strike north. Molybdenite occurs as linings of small vugs, as small disseminated grain clusters, and as discontinuous linear streaks along early fractures in the quartz that have healed. Though quartz veins are common in this area, molybdenite seems to be confined to a small concentration. Some of the veins are of optical quartz mined during World War II; feldspar crystals in some of the veins show the quartz veins to be pegmatitic in origin. Chalcopyrite intergrown with molybdenite was noted but is rare. Yellow crystals near some of the molybdenite-lined vugs are probably ferrimolybdite. Sericite is present sparingly in the quartz and is found along the sides of some quartz veins. The pegmatitic quartz veins were probably associated with a nearby Cottonwood-like granite stock that intruded the Uncle Sam porphyry. Molybdenum mineralization here, as in the Cucomungo Spring deposit, started during quartz deposition and continued afterwards.

These three molybdenite occurrences have no direct bearing on the Cucomungo Spring deposit except to show that ascending mineralizing solutions in the region commonly carried molybdenum; this is a molybdenum-rich province.

Exploration Recommendations

This geologic study indicates that further exploration of the Cucomungo Spring molybdenum prospect is warranted. Geologic conditions favoring the occurren of a large low grade ore deposit are present. Geochemical surveys confirm some of the geological conclusions and indicate specific areas of exploration. Records of prior exploration of the prospect, especially of deep drilling, show that parts of the prospect have already been tested; drilling results have been discouraging. These tested parts of the prospect should be avoided during the early stages of exploration even though testing was not thorough. Should further exploration show promising results near an area of old drilling, exploration in previously tested ground may then be justified. Several favorable areas are present besides those that have already been tested.

The favorable ground for molybdenum exploration is the hydrothermally altered

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zone of the Cottonwood granite. As molybdenite is closely associated in origin with secondary silica, the best guides to molybdenite are silicification and quartz-sericite alteration.

The favorable ground, or the zone of alteration, has certain geologic limits. It is bounded on the northeast by unaltered Cottonwood granite and metasediments. It is limited on the southwest by metasediments. Though the metamorphic rocks along the sides of the altered part of the Cottonwood stock have geochemically significant quantities of molybdenum, these rocks may not have been fractured sufficiently to make ore deposits. The Uncle Sam fault dips under the altered area; it forms a footwall limit or floor to favorable ground. These limits describe a more or less prism-shaped mass of favorable ground extending in a northwest direction. The northwestern end of the prism lies concealed under the alluvial flat near Cucomungo Spring. The southeastern limit is probably a short distance east of Cottonwood Canyon where the altered zone becomes narrow. Further geologic study, geochemical surveys, and drill core inspection will define the limits of the favorable mass of ground more accurately.

The geochemical maps showing molybdenum in soil and molybdenum in bedrock indicate four untested areas of particular interest in the prospect area. The most obvious is the area of very high molybdenum content extending for about a mile through the badlands area. This area has been only partly tested by Freeport's drill holes and by several of Bear Creek's drill holes. Study of available drill information is needed before planning any further drilling in this area.

The second favorable area is probably the most promising. It is the portion of the altered Cottonwood granite concealed under the andesite cap on the hill about 3500 feet northwest of Poison Spring. Bear Creek drilled on the top of the andesite hill (DH-6AA) to a depth of 300 feet but did not get out of andesite. Quartz-sericite alteration is strong where it passes under the southeastern edge of the andesite cap. The alteration is weaker and narrower but nevertheless present where it emerges from under the northwestern edge of the andesite. As the andesite covers an area of about 2000 feet by 2500 feet, at least 70% of which includes the altered zone, there is ample space for a large ore body to be concealed under the andesite cap.

Molycorp drilled several holes in altered granite on the southeast and northwest sides of the andesite cap. Molybdenum values in these holes were low. The geochemical maps, however, offer encouragement. Moderately high molybdenum values found in the altered granite on the northwestern flank of the hill indicate that high molybdenum values persist under the andesite capping.

The third area of interest is the alluvial flat beyond the northwesternmost exposures of the altered zone. As the altered zone passes under the alluvium, and as geochemical values of molybdenum are moderately high in the last exposures of the altered zone, there seems a chance that an ore body could be concealed under the valley. This is the alluvial flat that covers the intersection of the Uncle Sam fault and the Cucomungo Canyon lineament. The Cottonwood stock ends under the alluvium; only metasediments are found under late andesite northwest of the alluvium. Cottonwood granite and metasediments under this valley are overlain with andesite covered with alluvium; this accounts for the absence of geochemical quantities of molybdenum in this area. The depth to granite here is not excessive. Molycorp drilled two holes in this valley. SM-12 went through the alluvium into andesite but was discontinued at a depth of 143 feet, short of the andesite-granite contact, due to drilling difficulties. SM-11 reportedly

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was in granite but had very low values of molybdenum to the bottom at 130 feet. This hole is located off the northeastern flank of the altered zone as projected under the alluvium.

The fourth area of interest is the southeastern end of the altered zone near Cottonwood Canyon. Moderately strong molybdenum values are shown on the geochemical maps to the end of the surveyed area. Geochemical coverage should be extended to the southeast to the end of the molybdenum anomaly.

Specific recommendations for exploration of the Cucomungo Spring prospect are as follows:

1. Claims should be staked to cover the area of exposed altered granite northwest of and adjoining the Sorenson claims. Twelve claims are sufficient. Consideration should be given to extending the staking to include the part of the alluvial flat to the northwest under which the altered granite is expected.

2. Bear Creek's drill cores and Molycorp's drill cuttings should be logged. The two principle types of inforamtion to be sought are the subsurface attitudes of the Uncle Sam fault and the contacts of the Cottonwood stock; and the extent of quartz-sericite alteration.

3. The geology and the geochemical stations should be transferred from the aerial photographs to the base map photogrammetrically to provide an accurate map. Dips of outcropping contacts can then be computed, and the true positions of geochemical anomalies will be known. The present maps are inaccurate because information can not be transferred by simple projection from photos to base map with accuracy in areas of high topographic relief.

4. At this stage of the exploration, induced polarization surveys probably would not be helpful. Pyrite is abundant and would be indistinguishable from molybdenite. I. P. traverses may possibly be useful at the northwestern and southeastern limits of the exposed altered zone. However, further geochemical work would be of greater value and should precede any decision to use I. P.

5. Further detailed bedrock and redidual soil geochemical surveys should be made in specific areas. Geochemistry and geology will be the most valuable tools for the location of drilling targets. Some of the molybdenum anomalies should be confirmed and the limits more accurately determined. Several detailed traverses of bedrock and soil samples should be made in the altered granite on the north and northwest flanks of the andesite north/of Poison Spring. The geochemical survey should be extended southeastward for at least a mile to determine the southeastern limit of the molybdenum anomaly.

west /

6. Drill targets should be selected using all available information. Drilling techniques should be designed to yield a maximum amount of geologic information as well as reliable samples for determining mineral grade. As some of the highest molybdenum values will be found in soft clay-sericite material, drilling and sampling techniques must be tailored to provide proper recovery of molybdenite from such zones and to eliminate contamination of low-value samples from high molybdenum zones. Drill samples should be logged very frequently by a geologist to obtain critical information and to avoid useless drilling beyond zones of possible ore.

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Exploration of the Cucomungo Spring prospect should be undertaken with a realization of the chances for success and failure. Three major companies have explored the prospect and failed to find ore. They tested at least part of the most favorable area. However, untested potentially good portions remain. The favorable geology and geochemistry give encouragement. In spite of the unfavorable odds, further exploration seems justified.

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