University of Nevada

Reno

The Geology of the Montgomery Creek Mining District and the R & S
Mine Area, Benton Quadrangle, California–Nevada

A thesis submitted in partial fulfillment of the requirements for
the degree of Master of Science in Geology

by

Paul Renken

April 1980
The thesis of Paul Renken is approved:

I wish to thank fellow graduate students B. K. Means and Donald Johnson for their aid in the study of thin sections and the interpretation of the petrographic evidence presented within this thesis.

My thanks also extend to Larry Reasons and Dr. J. S. Geology for his willing and informal aid in interpretation of various analytical and geologic problems.

Special consideration is extended to the company for her professional techniques in preparation of analytic data for mineral samples.

Thesis Advisor

Department Chairman

Dean, Graduate School

University of Nevada

Reno

April 1980
I wish to thank fellow graduate students Dennis Geason and Donald Hudson for their aid in the study of thin sections and the interpretation of the petrographic evidence presented within this paper.

My thanks also extends to Larry Garside of the Nevada Bureau of Mines and Geology for his willing and informal aid in interpretation of various analytical and geologic problems.

Special consideration is extended to Jennifer Kramer of the Anaconda Company for her professional techniques in preparation of geologic maps for submittal herein.
ABSTRACT

Marble, quartzite, and interbedded calc-silicate hornfels of the Cambrian age Poleta is exposed in the Benton 15' quadrangle. Recrystallized calcite with minor amounts of magnetite, hornblende, biotite, and limonite are the usual minerals present in the marble. Metasomatism introduces large amounts of limonite, chlorite, sericite, lead, and silver in bedded replacements and fissures of quartz-calcite, in fractures within propylitically altered rocks and in jasperoid breccia.

Intrusion of quartz monzonite has suspended the carbonate as roof pendants atop the plutonic rocks. Garnet skarn has developed locally along intrusive contacts.

Uranium values above background occur in pegmatites and calc-silicate hornfels in the White Mountains and in pumiceous rhyolite tuff in the Benton Range.

Additional sulphide mineralization may extend beneath volcanics in the Benton Range and beneath zones of alteration in the White Mountains.
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### SUGGESTIONS

1. Graduate students interested in plant pathogenesis.
2. Undergraduate students interested in plant biology.
3. Faculty members interested in plant pathology.
4. Scientists working in related fields.

### REFERENCES CITED


### Table 1

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<tr>
<td>Pathogen</td>
<td>detection</td>
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<tr>
<td>Host</td>
<td>resistance</td>
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*Note: This table is an example and should be replaced with actual content.*
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This study is concerned with rock units located on the 1935 S. J. Geological Survey G-21 series geologic map sheets (Index Map compiled by Dunbar and others). These maps were published in the original series of the Newberry, Nevada, and Reno quadrangles of Washoe County and the Bear Lake of Virginia-Creek quadrangles to the west of Nevada State 71 and 67, and in the same series of the quadrangle west of Montgomery Town on the east of the A & P lines in the Fernley Charge in 1935. The accompanying material is part of northern A, 102-2-12 Plate 14.

The material within may be reached by unimproved roads and along roads in 1938 Nevada-California 71. Spring, Nevada, 50 miles to north west, Fernley, 50 miles to the north west, and Reno, California, 10 miles to the north west.

Capitol.

Even though the geological formations of the study area are only represented by a limited amount of information, their geology is considered and described by the use of its map, geology, and structure. The geology was separated into distinct units related to significant geologic structures. The study area
INTRODUCTION

Location and Access

The Benton 15' Quadrangle lies along the California-Nevada border at the north end of the White-Inyo Mountains and includes portions of Mineral and Esmeralda Counties in Nevada and part of eastern Mono County in California (Figure 1).

This study is concerned with those rocks labeled as Cm on the 1972 U. S. Geological Survey GQ series geologic map number 1013 produced by Crowder and others. These rocks occur in two major areas: on the west flank of the northern White Mountains of Mono County (from the mouth of Morris Creek southward to the mouth of Marble Creek) in T1 and 2S, R32E MDB&M, and in the north portion of the quadrangle west of Montgomery Pass in the area of the R & S mine in the Benton Range in T1N, R32E including sections 2 and 11 and parts of sections 1, 3, 10, & 12 (Plate 1).

The mapped areas may be reached by unimproved roads and jeep trails from Nevada-California Highway 6. Tonopah, Nevada lies 70 miles to the east, Lee Vining, California 50 miles to the northwest and Bishop, California 40 miles to the south.

Purpose

Even though the Cambrian carbonates of the study areas are only separated by a few miles of valley alluvium, their geologic setting and aspect of modification are now quite different. The carbonates of the Benton Range study area reflect changes induced by volcanic activity while those carbonates of the White Mountains study area reflect changes made by intrusive activity. The changes in
carbonate mineralogy as a result of these different environments and descriptions of the skarns and mineral deposits developed in those carbonates are the main purpose of this study.

Topography, Climate, and Vegetation

Steep slopes dropping into valley alluvium cut by perennial and intermittent streams make up the topography of the study area. Elevations within the study areas range from 5800' in Benton Valley to 10,400' in the White Mountains of the southern study area and from 6300' in Benton Valley to 7900' in the Benton Range in the northern study area. Fish Lake Valley lies over the crest of the White Mountains to the east of Montgomery Pass while Owens Valley lies directly to the south of Benton. Boundary Peak, the second highest elevation point in the state of Nevada, lies 6 miles to the east of Benton Station.
Vegetation consists of sage, tumbleweed, and desert grass in the valley while pinyon pine and juniper are common from elevations of 6,400' to 10,000'. Bristlecone pine can be found in some of the sheltered drainages within the White Mountains study area.

The climate of the area is semi-arid, receiving most of its annual precipitation in the form of winter snows which reach down to base level and cover the mountains to several feet in thickness. West and south facing slopes lose their snow cover by mid-March while shaded higher elevations of the study areas may allow snow to linger occasionally to June. Temperatures may range from near zero at higher elevations in the winter to 100+ degrees in the valley during mid-summer. Occasional mid-summer thunderstorms produce local dangerous flash floods while spring thaws produce occasional debris flows, slides, and rock falls.

Previous Work

Previous mapping on a scale of 1:62,500 had been done by Crowder, et al (1972) for the entire quadrangle. Descriptions of batholithic rocks in the area have been published by Anderson (1937) and Evernden and Kistler (1970). Tertiary geology and volcanics have been studied by Taylor (1965) and Gilbert (1941) while Pleistocene glaciation features have been studied by La Marche (1965). Ross (1961) published a Nevada Bureau of Mines Report on the geology and ore deposits of Mineral County. Radiometric analyses of some batholithic rocks of the area were reported on by Cupp and Mitchell (1978). Unpublished aeromagnetic and gravimetric data has been compiled on a 1° x 2° scale by the U. S. Geological Survey (1971) and by Healey (1976) respectively.
Methods of Study

Field mapping and collecting of approximately 100 rock samples was performed in the fall of 1979. Follow-up field work and verification of conclusions were made in the spring of 1980. Rock analyses were made on various samples in the winter of 1979-80 using the X-ray diffractometer, X-ray fluorescence spectrometer, petrographic microscope, and fire assay. Field radiometric analysis data was compiled on selected samples using a portable scintillometer. Uranium chemical analyses were performed by the U. S. Bureau of Mines using a fluorometric method similar to that used by Cupp and Mitchell (1978).
The White Mountains lie at the northern end of the Inyo Mountains batholith; a series of intrusives of granite, granodiorite, quartz diorite, and quartz monzonite which Evernden and Kistler (1970) have dated as old as 160 million years of age. Crowder, et al (1972) obtained dates of 157 million years of age for quartz monzonite, quartz diorite and granodiorite of Jurassic age and dates of 80-90 million years for quartz monzonite of Cretaceous age within and east of the study areas.

Resting as roof pendants upon these rocks are limestone, quartzites, dolomites, and siltstones of Lower to Upper Cambrian age which have been for the most part metamorphosed to marbles, calc-silicate hornfels, mica schist and phyllite. Absent in the study area but conformably overlying Cambrian rocks to the north and southlie rocks of Ordovician quartzite, shale, limestone, dolomite, and sandstone including members of the Pogoip Group, Eureka Quartzite, and Ely Springs Dolomite. Sequences of Devonian, Carboniferous, Permian, and Triassic marine sedimentary units follow. Total stratigraphic thickness if all units were present in one area exceeds 10,000 feet, but uplift and erosion have isolated only individual sequences of several thousand feet at any particular location. Just north of Montgomery Pass and out of the study area the Ordovician sedimentary sequence is unconformably overlain by early Triassic volcanic sediments and extrusive rocks which exceed thicknesses of more than 800 feet of section (Larson and Langenheim, 1973).

Mesozoic geology is dominated in the White Mountains by intrusive plutons of diorite and quartz monzonite, the oldest of which, in the Blind Spring Hills area, are given Triassic age (210 million years K-Ar date) by Evernden and Kistler (1970). The Inyo batholith, of which a portion is exposed in the White Mountains,
has been dated by them to be the second oldest complex of the Sierra Nevada batholithic complex.

Benton Valley lies at the west extremity of a structural feature identified by Ekren (1976) as the Warm Springs Lineament. This east-west lineament of left lateral strike slip (Taylor, 1965) is certainly pre-Basin and Range in age with an absolute age as yet undetermined. It is possibly Paleozoic and marks the existence of a zone of deep crustal weakness. Figure 2 shows the position of this feature as item 2 with Warm Springs being the eastern extremity of the lineament. Four similar features are also identified. Lineament identification is based upon fault offsets, major terminations of structural trends, and abrupt lithologic and topographic irregularities (Ekren, 1976).

Taylor (1965) believes uplift of the White Mountains began before Miocene time and ceased temporarily before Pliocene time as witnessed by a peneplanation surface upon the Jurassic age quartz monzonite of Pellesier Flats in the White Mountains and steep depositional contacts dipping to the south of the Miocene age Esmeralda formation of interbedded volcanic flows and lacustrine sediments in the Benton Range.

Regional uplift began anew in lowermost Pliocene time and is marked by the development of gentle open folds with gentle south or east plunging axes in the Esmeralda formation. Pliocene age block faulting caused the north end of the White Mountains to rotate upon a north-south axis, causing asymmetric relative tilting of the mountain block to the east, forming much steeper western escarpments than eastern. This block faulting is believed by Backman (1978) to have formed Owens Valley. Dating of lacustrine Waucobi Lake beds near Big Pine, California establishes an age of incipient uplift of 2.6 million years ago, or mid to upper Pliocene. Since that time roughly 2,300 meters of vertical elevation have been added with uplift rates of up to 1 meter per thousand years.
Position of the Warm Springs Lineament and other similar features. WM - Warm Springs (Ekren, 1976).
along the White Mountains and northward to Mono Lake.

Pleistocene age glaciers produced glacial moraines at higher elevations in the Inyo Mountains, particularly in sheltered east draining streams just east of the Montgomery Creek Mining District (La Marche, 1965). Old alluvial fans, terraces, and benches can be found in Fish Lake Valley and Owens Valley derived from melting of accumulated glaciers and snow fields at the end of the Pleistocene. Many of the apparent catastrophic disgorgings of debris from major canyons like that from Montgomery Creek probably date from this period of time.

The entire area remains actively seismic at present with occasional historic faulting events with surface rupture occurring along zones developed during the Pliocene. Hot spring activity can be found 8 miles to the southeast in Fish Lake Valley, near Mono Lake 20 miles to the north, and 2 miles east of Montgomery Pass. Seismic records of activity and heat flow measurements 20 miles east of Mono Lake made by the University of Nevada Seismology Laboratory suggest a molten magma at relatively shallow depths in that area at the present time.

**STRATIGRAPHY**

Within the study areas only Cambrian age marble, quartzite, and phyllite represent Paleozoic sediments. These rocks often occur as roof pendants atop Jurassic age intrusive rocks which in the White Mountains lie in turn upon Cretaceous intrusive rocks. Tertiary volcanics overlie Cambrian sediments and Jurassic intrusive rocks alike in the Benton Range study area.

**Metasediments**

**Poleta Formation**

Coarse grained, recrystallized marble with interbedded quartzite and calc-
Silicate hornfels of the Cambrian Poleta formation is exposed in both study areas as shown on Plate 1. This is the same formation as Ross' (1961) Miller Mountain formation and Crowder, et al. (1972) Cm unit.

White, yellow, and brown are the colors of the marble of the Poleta formation. When present, sericite and chlorite produce greenish tints (in calcareous rocks) to brown in heavily oxidized gossans. In surveyed section 22 north of Montgomery Creek, altered marble shows coarse hypidiomorphic granular textures and cannot be distinguished from Jurassic age plutonic rock at a distance. These rocks under the petrographic microscope show strong sericite development and growth of albite plagioclase.

Lamination and soft sediment crenulations are common in the formation. Coarse clastic sediments are rare to absent. A boulder conglomerate found in the east portion of section 11, northeast of the R & S mine, in the Benton Range study area consists of well-rounded white marble boulders to one foot in diameter in a rock matrix of white, coarse-crystalline marble.

Correlation

Difficulty in identifying the rocks as Poleta formation was encountered due to the metamorphism of the entire formation and the lack of worm trails or fossil Archaeocyathids in this area which are common in Poleta formation rocks east of Bishop, California to the south (Nelson, 1962). It was not until work was completed in the Benton Range study area that stratigraphic correlations became apparent.

Just north of the R & S mine approximately 20 feet of silicified limestone, in this case jasperoid, is in direct contact with overlying phyllite of the Cambrian Harkless formation. Marble lying conformably beneath the jasperoid is
coarse, recrystallized, white to blue-gray, and thinly laminated, which correlates with Stewart's (1970) upper member of the Poleta formation in the Inyo Mountains to the south. The basal gray shale of the Poleta formation reported by Stewart east of Bishop, California to the south could not be found in either study area and is assumed to be absent. Massive quartzite approximately 100 feet thick is common in the White Mountain portion of the study area. This probably represents an extremity of the quartzite and argillite of the Miller Mountain formation (Larson and Langenheim, 1973) found further to the north in Mineral County.

Harkless Formation

Lying conformably atop the Poleta formation in section 11 of the Benton Range is massive brown phyllite of the Harkless formation (Cph). Two to five millimeter spots of chlorite are characteristic constituents in a rock matrix of chlorite, biotite, calcite, quartz, and iron oxide dust. Interstitial sericite is a common alteration mineral. Coloration varies from yellow through shades of red and brown to black. Weathering produces slaty fragments with iron oxide crusts and occasional rounded spalling features reminiscent of the weathering of pillow basalts. Crowder, et al (1972) report the occurrence of interbedded shales though none were found during field mapping.

Depositional Environment

The depositional setting of the entire Cambrian section is inferred by Stewart (1970) to be of the off-reef carbonate zone with westerly tidal currents of deposition; as evidenced by the presence of fossils of reef dwelling plants and animals and lithologic westerly dips. The lack of fossils, except possible detrital remains, and the presence of fairly thick beds of metamorphosed laminated siltstones and quartzites outside the mapped areas in Queen
Canyon north of Morris Creek suggest a further seaward zone of deposition of the Cambrian section in this area.

PLUTONIC ROCKS

Jurassic Quartz Monzonite and Granodiorite

G. H. Anderson (1937) made a thorough study of alteration and related phenomena of Jurassic age plutonic 'granite' of Pellesier Flat. Crowder, et al (1972) considered the 'granite' of Anderson to actually be of granodiorite to quartz monzonite composition, while Taylor (1965) considers it to be of quartz diorite composition. Independent tests of samples by this author taken within the southern area using the X-ray fluorescence spectrometer and petrographic microscope are in greater agreement with compositions ranging from quartz monzonite to quartz diorite rather than granite. Most of the rock seen in the field is of granodiorite composition.

White Mountains Area

Hornblende-biotite quartz diorite and quartz monzonite are the rock names assigned to the majority of Jurassic age plutonic rock (Jagp) exposed in the study area, with gradational areas of granodiorite and diorite schlieren gneiss being common. Cataclastic mylonite is found just south of the mouth of Morris Creek.

Medium grained, (2mm average) hypidiomorphic granular texture predominates with euhedral plagioclase of An\textsubscript{16-25} cores to An\textsubscript{38} rims being the norm for quartz diorite (Taylor, 1965). Green and brown hornblende make up 15% of the rock while poikilitic granular quartz, plagioclase, and biotite with accessory apatite, sphene, and magnetite make up the remainder of the rock. Rutile in
chlorite may be found occasionally. Analyses of these dioritic rocks showed elevated values of alumina and of titania from those values obtained by Anderson (1937) and Crowder, et al (1972). Diorite schlieren lenses ranging in size from 3 inches to 3 feet in length are locally abundant and are usually aligned parallel to lithologic contacts with Cretaceous quartz monzonite (Kab). Large euhedral crystals of K-spar may be found locally within schlieren and dispersed through the quartz diorite.

Alteration is widespread due to later intrusion of Cretaceous quartz monzonite. Sericitic alteration of plagioclase and K-spar is common. Occasional perthitic orthoclase may be found. Myrmekite is not as abundant in this area as Anderson (1937) would have one believe. Biotite alters to green chlorite, occasionally showing anomalous interference colors. When in contact with roof pendants of Poleta formation marble, biotite schist and calc-silicate hornfels develops along the contact and can be found in lenses as far as 100 feet away from the contact such as in the granodiorite found in the NE\(^{4}\) of section 12 north of Marble Creek. This is shown in Figure 3. These lenses apparently developed from alteration of dioritic lenses within the granodiorite and not from engulfed blocks of metasediments. No evidence of incorporated blocks of metasediments either altered or unaltered could be found along the Cmp-Jagp contacts. Iron and calcium content rises abruptly in strongly metasomatized rock due to the introduction of interstitial calcite and limonite, apparently from solutions which may have been hydrothermal.

Fine grained, simple quartz-aplite dikes of injected Cretaceous quartz monzonite (Kab) or remobilized Jurassic granodiorite (Jagp) are common. Aplite dikes derived from the Cretaceous quartz monzonite are obvious injection features as seen in the north wall of Montgomery Creek. Remobilized Jurassic granodiorite
Figure 3. Calc-silicate hornfels (H) and biotite schist (BS) near the contact of Jurassic granodiorite (JAGP) and Cambrian marble (CMP), NE%. of section 12 north of Marble Creek (Marble is not shown in photo).

(apparently caused by the Cretaceous intrusive event) may be seen as small aplite dikes on the jeep trail in section 14 south of Morris Creek. Gradational wall contacts of the dike to country rock and the localizing of mafic constituents to the center or the fringes of the dikes are interpreted as evidence of remobilization. Occasional fracture fillings of epidote may be found also. Calcite veins locally cut all textural features.

Joint patterns within the Jurassic rock and in nearby contact rocks are generally parallel to lithologic contacts, suggesting joint control was a function of stresses placed upon the rock by the intruding Cretaceous pluton.

Benton Range Area

Two plutonic rock types grossly different in appearance are identified on Plate 1 and are believed to be of Jurassic age in this study area. Plutonic
rocks (Jagp) which outcrop in section 11 are white, silicic granite intrusives characterized by large euhedral crystals of pink orthoclase (up to 7 mm) with fresh quartz and muscovite of up to 5 mm in a hypidiomorphic granular matrix of sericitic K-spar, sodic plagioclase, and interstitial muscovite (Taylor, 1965).

The other intrusive (Jai) is a stock of green color in section 2 of coarse, granular texture altered to basic granular hornfels by local andesitic dikes. Hornblende, biotite, and albite make up the general components of the rock with accessory magnetite, euhedral apatite, and a little natrolite. Biotite shows heavy alteration to chlorite with radial aggregates of mica formed after orthoclase. Similar lithologic character (Crowder, et al, 1972 and Taylor, 1965) to the Jagp in the White Mountains and to the stocks exposed in section 11 of the Benton Range mapped area suggests this intrusive to be contemporary to those of Jurassic age.

Cretaceous Quartz Monzonite

Cretaceous age quartz monzonite (Kab) intrudes Jurassic age plutonic rock throughout the White Mountains study area. Taylor (1965) considers this rock to be biotite granite. Crowder, et al (1972) show the rock to be primarily quartz monzonite.

Plagioclase (An\textsubscript{15}), orthoclase, and quartz are the primary components of this coarse, hypidiomorphic granular rock (Taylor, 1965). Mafic constituents make up a much smaller percentage of this plutonic rock than that of Jurassic age, which gives this rock a much lighter color. Very little change in hand specimen appearance can be seen between samples of the pluton taken throughout the study area. A few veins of aplite of similar composition can be found to cross the pluton.
Aplite and Pegmatites

Numerous aplite masses and pegmatites have been injected into the overlying Jurassic rocks. Their composition is summarized by Anderson (1937) in Table 1. Many aplites near the contact area with Jurassic quartz diorite are parallel to the strike of the contact. Most cross-cut wallrock foliation and narrow with distance from the pluton. Composition of the aplites remains relatively constant with distance from the pluton though some tend to become more siliceous and occasionally become quartz veins, particularly near entry into the carbonate rocks.

Of the small number of pegmatites found in the study area, all were of similar appearance and composition to the aplites. They are distinguishable from the aplites by their very coarse texture, the development of garnet-actinolite skarn in the contact zone host rocks, and higher scintillometer counts in the field than aplites.

Table 1. Composition of aplites and pegmatites derived from Cretaceous plutonic rocks (from Anderson, 1937).

<table>
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<th>Constituents</th>
<th>Aplites</th>
<th>Pegmatites</th>
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<td>(15)</td>
<td>(16)</td>
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<tr>
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<td>Granite aplite in intermediate granite</td>
<td>Aplite in Pelliser granite</td>
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<td>1.22</td>
<td>7.20</td>
</tr>
<tr>
<td>Ratio Na₂O/K₂O</td>
<td>0.95</td>
<td>0.98</td>
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</tbody>
</table>
VOLCANIC ROCKS

Volcanic rocks are only exposed in the Benton Range study area. Pumiceous rhyolite tuff (Trg) correlated to Taylor's (1965) lithic pumice tuff of the younger volcanic series is the lowermost Tertiary volcanic rock exposed in section 10 of the Benton Range study area (Plate 1.). This rhyolite is approximately 40' thick and is composed of quartz, sanidine, andesine, brown biotite, and spherulitic, radiating chalcedony in a microfelsitic groundmass of iron, sanidine, and amygdaloidal opal. Dark, subrounded pumice fragments to 3 inches in diameter mottle the rock in hand specimen. A lower contact for the unit could not be found. The unit is anomalously radioactive in the field, giving scintillometer counts of approximately 250 cps.

Immediately overlying the pumice tuff and beneath the andesite flows in section 11 is up to 40' of waterlaid, laminated, diatomaceous, rhyolite tuff (TrTd) containing horizontal narrow veins of green perlite. Color ranges from white to light gray. The rock weathers to a fine white powder. This unit is believed to be equivalent to the rhyolite of West Queen Canyon (Trw) identified by Crowder, et al (1972) and to be roughly contemporaneous in age with the overlying andesite.

Porphyritic augite-hornblende-pyroxene andesite (Ta, Tai, Tap) of late Pliocene age (Taylor, 1965) covers most of the Benton Range study area. The unit is normally reddish brown to brownish gray in color. Two separate types are identified; an olivine bearing variety (Ta) of plagioclase, hornblende, olivine, and biotite in a felsitic groundmass of brown glass, and a mound-forming olivine poor variety (Tap) of the same color and mineralogy. Andesite dikes (Tai) of similar mineralogy found in the southwest portion of section 2
may have been feeders for the flows (Crowder, et al, 1972).

Pink biotite rhyolite flows (Tr) and dikes (Tri) of post-andesite age cover portions of sections 1 and 12 east of the R & S mine. Sanidine and andesine phenocrysts, euhedral biotite, and rare spherulitic chalcedony are enclosed in a groundmass of dark iron dust and glass. Most phenocrysts are weathering to kaolinite clay (X-ray diffraction results). A vertical dike of the same material crosses the crest of the hill of elevation 7646 in section 1 and has been prospected for mercury mineralization.

Remnants of vesicular, high potash, olivine basalt flows (Tb) are the last volcanic rocks to be extruded in the study area. This unit reportedly interfingers with post-andesite rhyolite (Tr) near Montgomery Pass and is therefore considered to be contemporary in age to the rhyolite (Crowder, et al, 1972).

QUATERNARY SEDIMENTS

Occasional landslides of Quaternary age (Qls) may be found in the White Mountains study area. Weathered and broken intrusive rocks are generally involved in the downslope movement. Annual spring thaws are believed to have caused separation of the broken rock mass seen south of Montgomery Creek (Plate 1.).

Valley fill (Qal) of fine clay, coarse sand, rocks, and boulders comprise the alluvium of Benton Valley. Intermittent heavy rains add occasional mud slides and debris flows to the alluvium. Their channels take on the appearance of man-made water diversions.

Evidence of Pleistocene age alluvial deposits within the study areas is lacking due to obliteration and burial by younger detritus.
STRUCTURE

Folding

Minor folds and bedding crenulations occur in all of the marble exposed in the mapped areas. A small recumbent S fold of roughly 3' in width may be seen in altered marble in the north wall of Montgomery Creek just east of the mouth of the canyon and above the old creek bed. Most folding and bedding deformation in the marble is soft sediment deformation before metamorphism as evidenced by non-parallel folding between lamellae. Contorted foliation and bent shears are common in the Jurassic quartz monzonite and granodiorite in the southern study area and were probably formed during metamorphism and uplift of that unit.

Plutonic rocks do not show foliation in the Benton Range study area.

Only occasional minor folds appear in the volcanic rocks of the Benton Range study area. That folding which does occur is in volcanic flows and sediments in the Esmeralda Formation to the east of the study area.

Faulting

Active, high-angle, range front faults on the order of several hundred feet displacement are the most common faults found in both study areas. These faults tend to roughly parallel one another, such as in a part of the White Mountain Shear Zone in section 2 north of Marble Creek or in the Benton Range just south of the R & S mine on Plate 1, forming step-like blocks upward into their respective mountain ranges. In every case the valley side block is down relative to the range block. The faults are generally open fractures which post-date the
mineralization events in both study areas. The faults west of and cross-cutting the workings of the R & S mine in Plate 1 do however pre-date the mineralizing event in this area and are filled with quartz veins, dike rocks and mineralized breccias. Post-mineralization displacements can also be recognized on these faults.

In the SE¼ of the NW¼ of section 11 in the Benton Range study area complex high-angle faulting of fairly small displacements occurred prior to mineralization. These faults were filled with dike rocks and quartz veins containing sulphides which produced an undetermined small amount of Au-Ag-Pb-Cu ore.

The White Mountain Shear Zone along the west face of the White Mountains in the southern study area either terminates against or is deflected into the west part of the Warm Springs lineament near the south end of the Benton Range study area. The increasingly northeastward strike of range front faults north of Montgomery Creek suggests the conjunction of these two structural features.

Dolomite cemented, mixed rock, breccia is suggestive of gravity sliding involving the Poleta formation downslope off of the Jurassic age granodiorite pluton north of Montgomery Creek on the second ramp of the jeep trail in section 14. Similar evidence south of Montgomery Creek is lacking or obscured by talus. All contacts of Poleta marble south of Montgomery Creek are undulatory, gradational, or, as in the case of figure 4, at high angles to underlying plutonic rock. Gravity sliding of the Poleta formation is therefore considered a localized phenomena and not characteristic of the formation as a whole. Roof pendants of Poleta formation atop Jurassic age granodiorite are common of the formation in the south study areas.
Figure 4. High-angle contact between Jurassic granodiorite (JAGP) and Cambrian Poleta formation marble (CMP). BSH—Biotite schist and micaceous hornfels 4' in width, NE 1/4 section 12, north of Marble Creek.
Marble

All carbonates of the study areas have undergone regional metamorphism. This metamorphism has marmorated the pre-existing laminated to massive carbonate rocks, developed calc-silicate hornfels facies rocks from interbedded siliceous siltstones, and indurated fine grain sandstones to quartzites.

Figure 5 is a thin section which shows typical marble of the Poleta formation. The texture is that of a massive recrystallized carbonate of compacted calcite grains and occasional dolomite with accessory minor amounts of siderite, hematite, pyrite, magnetite, biotite, and rare sphene, hornblende, and chlorite.

Figure 5. Photomicrograph of marble. Width of field 3.38 mm. P-pyrite C-calcite S-sphene. Overall color of photo is greener than true color.

Pyrite (lower right, opaque) may be euhedral, or, in this photo, angular to
subrounded with limonite and hematite crusts. Voids of weathered pyrite en- 
crusted with limonite are common. Bimodal calcite grain size is typical of 
this marble. Some grains may show crushing, shearing, or distortion due to 
shearing during metamorphism.

Interlayered beds of calc-silicate hornfels consist of euhedral to rounded 
grains of chlorite, biotite, hornblende, plagioclase, minute euhedral apatite, 
pyrite, and interstitial quartz with minor amounts of muscovite, diopside, 
sphene, hematite, and limonite. Sericite after muscovite as well as sericiteti- 
zed plagioclase may vary in abundance from sparse to plentiful. Most mafics 
are well broken to ground up and in many cases lineated into schistosic bands. 
Biotite is for the most part altering to chlorite with green pleochroism. 
Sphene is always an early formed grain ground up into rounded fragments; des­
troyed by subsequent dynamic forces during metamorphism.

Quartzite is composed of massive, varicolored, fine grained, equant, sand 
grains in silica cement with occasional interstitial biotite. Occasional 
lamellae of deposition may be seen.

Skarn

Skarn has developed in selected areas near and often parallel to the con- 
tact between the quartz monzonites of Jurassic and Cretaceous age and occasion- 
ally extends into marble. Two types of skarn have developed; a wallrock zone 
along or related to quartz-aplite pegmatites in and south of Montgomery Creek, 
and a skarn apparently related to aluminum rich metasomatism without visible 
quartz veins in the northwest quarter of section 12 north of Marble Creek.

Metasomatic Skarn

In the NW¼, section 12 north of Marble Creek on Plate 1 in the White Mountain
study area can be found a green granular rock of schistosic habit which in hand specimen appears to be hornfels. Under the petrographic microscope the rock is seen to be primarily calcite, with abundant pyrite (opaque), chlorite, highly altered muscovite, sodic plagioclase, and globular quartz (Figure 6). Fire

assay showed 0.11 oz/ton silver, probably reporting to the presence of cerusite identified by the X-ray diffractometer. Veinlets of a highly birefringent unidentified micaceous mineral (2V + 60°) and pyrite crosscut the matrix with cleavage planes of the mineral and orientation of pyrite perpendicular to the strike of the vein.

Strong metasomatism of the marble apparently drew the mineral forming constituents into the vein from the wallrock producing the horizontal striations. The close correlation of this mineralogy and pegmatite formed skarn mineralogy found further to the north, suggests a close affinity of this mineralogy and metasomatism to pegmatites and pegmatite genesis.
Pegmatite Produced Skarn

Plate 1 shows a zone of garnet-actinolite development associated with quartz-aplite pegmatites in wallrock of Jurassic intrusive rock and Poleta formation marble extending from just north of Montgomery Creek southward for approximately 1 mile into the Poleta formation. The zone varies in size from greater than 100 feet across in the north wall of Montgomery Creek to less than 10 feet across in the major canyon south of the mines of Montgomery City. In the next canyon south, the zone parallels two massive quartz-aplite veins which fail to outcrop further to the south. Typically, veins and coarse grained pegmatites of quartz-aplite composition have filled fractures and engulfed blocks of Jurassic intrusive rock. Actinolite of excellent crystal groups, grossular, garnet, and diopside are the abundant constituents of the produced skarn. Some of the actinolite developed around brown hornblende cores. Epidote appears to be a late mineral introduced into open fractures. The pegmatite may or may not contain considerable interstitial calcite. Pyrite is a common accessory mineral in the garnet-actinolite rocks but not in the quartz-aplite pegmatite. No tungsten mineralization could be found although old claims had been posted on this zone in the past.

The distribution of what may be grossular garnet lends some evidence to the genesis of the pegmatite skarn. The probable minerals present in the Jurassic plutonic rock before metamorphism and the high temperature conditions associated with the Cretaceous pluton support the forming of and the identification of the garnet as grossular. Garnet can be found alone filling narrow fractures cut by quartz-aplite veins in the Jurassic schlieren gneiss just west of the pegmatite zone in the north wall of Montgomery Creek. Strong bleaching of the wallrock extends approximately 3 inches either side of the fractures. A boundary zone of quartz diorite lies between the fracture fillings and the
pegmatites. Blocks of schlieren quartz diorite surrounded by pegmatite have altered to actinolite and garnet. The lenses of schlieren however resisted garnet replacement probably due to their tight granular packing, prior mafic-rich constituency, and lower permeability. No evidence of metamorphosed marble xenoliths was found near the pegmatite zone. Garnet-actinolite-quartz rock is also found surrounded by strongly sericitized marble within the Poleta formation along strike of the quartz veins in unsurveyed section 35, suggesting mineralization similar to that of garnet pipes found at Cold Hill, Utah (Nolan, 1935).

The proposed genesis of the garnet-actinolite skarn in Montgomery Creek is shown in Figure 7. The first stage shows the Jurassic schlieren gneiss as it may have looked prior to development of the Cretaceous pluton magma chamber. The second stage shows formation of a quartz diorite armor on the Jurassic pluton side of the contact and the formation of a CO$_2$, Ca, Mg, gas bubble along the Jagp-Kab contact as rising temperatures partially remobilized older intrusive rock, driving liquified feldspars and quartz away from the contact and forming euhedral K-spar within Jagp schlieren several yards westward from the contact. Along the contact schlieren constituents were concentrated in the quartz diorite. Excessive gas pressure broke through the quartz diorite armor as shown in Stage 3 allowing some of the gas to escape from the bubble into relatively cool fractures where CO$_2$ infiltrated into the wallrock causing bleaching. Dropping CO$_2$ pressure allowed garnet to form and reseal the fractures. Remaining gas and quartz-aplite from the magma began to assimilate blocks of quartz diorite broken loose from the roof of the magma chamber along the contact during the gas phase. Stage 4 shows infiltration of gas depleted aplite into new fractures formed in the schlieren gneiss as a result of later swelling of the Cretaceous magma chamber. Figure 8 shows the resulting appear-
Figure 7. Theoretical development of the quartz-aplite pegmatite zone of Montgomery Creek.
ance of the north wall of Montgomery Creek as a result of these events.

Figure 8. Pegmatite zone in the north wall of Montgomery Creek, looking north. G-quartz-aplite pegmatites and garnet, QD-quartz diorite armor.
White Mountains Area

Rich silver ore was discovered just south of Montgomery Creek in what would become known as the Montgomery or White Peak District in the spring of 1863. Due to the changing of the Mono County seat from Aurora, Nevada to Bridgeport, California in September of that year, the claims were not recorded by the approximately 50 claimants at that time until June of 1864 (Mono County Recorder's Office).

Irelan (1888) reports that $60,000 worth of ore had been produced from the district by 1888 with early ore being shipped to Reno or San Francisco and later production being treated at small mills at Benton. In July of 1865 two prospectors from Cold Hill had discovered ore assaying $1.50/ton Au and $138-$603/ton Ag (Anonymous, 1865a) somewhere within the nebulous boundaries of the district with other rich assays including values of 2 to 4 per cent copper reported later in July (Anonymous, 1865b) and in December (Anonymous, 1865d). The number of prospectors in the district had grown to 200 with development of the district supporting 3 mills, 1 arrastra, and 1 smelting furnace charging as much as $75 per ton for custom work (Anonymous, 1865c). The district had been abandoned by late 1866.

New claims were again posted between 1910 and 1915 (Mono County Recorder's Office) when Tom L. Rigg located the Black Warrior mine north of Montgomery Creek. Field evidence shows the new claims remained active until 1918.

Recent activity has developed in the area of the mine at the top of the jeep trail in section 14 of Morris Creek.
Irelan (1888) reported the ore to be in quartz veins averaging 3 feet in width in limestone and occasionally in granite which struck northeast and dipped at a low angle to the northwest at a contact between hanging wall limestone and footwall limestone conglomerate. The veins were strata conformable and were generally of podiform or 'pinch and swell' habit (Figure 9) containing an argentiferous mix of lead, copper, iron, and zinc sulphides with only a trace of gold. The lowest workings were 130 feet in depth.

Figure 9. Pinch and swell mineralized quartz vein, NE corner of section 34, Montgomery District. View is to the northwest with hammer pointing at angle and direction of dip of the vein and perpendicular to strike. Q-quartz, LS-limestone and marble.

Anglesite and cerussite formed as the result of oxidation of galena. Microcrystalline quartz, geothite, and minor pyrite are also present. Chalcopyrite is lacking from the vein material throughout the district except when veins are in quartzite. Interstitial calcite may be abundant. Halloysite, illite, chlorite, and sericite are in zones of alteration up to 5'
wide when ore takes the character of fracture fillings such as in the mining area just north of the Black Warrior mine of Plate 1. Similar veins may be found at Gold Hill, Utah (Nolan, 1935).

Propylitic alteration (Barnes, 1967) with development of chlorite, biotite, sericite, albite, K-spar, and montmorillonite is strong in quartzite and interbedded hornfels in the zone identified on Plate 1; particularly along the range front just north of the jeep trail. Here rock in an area approximately 500 yards wide has been subjected to strong magnesium metasomatism, resulting in complete destruction of the quartzite rock texture to coarse gravel in a clay-like matrix which weathers into varicolored bands of friable, sandy gossan. Jurassic age granodiorite and schlieren gneiss close by has undergone similar metasomatism. The adit at the top center of section 14 north of the jeep trail was driven along the contact of a remnant block of quartzite resting upon a 3 foot vein of friable quartz. Disseminated chalcopyrite extends 2 feet into the wallrock quartzite. Powdery melanterite forms wall-lining crusts within the adit due to weathering of abundant sulphides in the wallrock.

The quartzite beds are of north strike and vertical dip in this area. Ore bearing fluids preferentially chose the partings between lamellae of the interbedded hornfels to move upward from depth and to disperse laterally along strike, depositing chalcopyrite in the center of narrow fractures in the hornfels or passing interstitially into the quartzite where vein temperatures were sufficient to force solutions into the wallrock. The carbonates in contact with the quartzite are not mineralized near the more intense zones of alteration, suggesting either the fluids did not migrate out of the quartzite or that temperatures near the alteration were too high to allow
ore-bearing sulphides to precipitate.

In the Montgomery Creek area ore in carbonates is always in the hanging wall limestone of a vein and never in the footwall conglomerate (Ireland, 1888). No conglomerate could be found on the surface in this area. Conglomerate was found at the periphery of the zone of propylite alteration on the second ramp of the jeep trail in section 14 south of Morris Creek. Here mixed clasts of granodiorite and marble have formed a hoodoo of cobble sized, hydrothermal dolomite cemented breccia with a massive marble capstone. This breccia apparently formed from local downslope gravity sliding of the Poleta marble atop the Jurassic granodiorite during uplift of the range and prior to or during the period of ore forming hydrothermal activity. Whether the deposition of the dolomite was presulphide or postsulphide could not be determined but it is suspected to be a postsulphide event since no sulphides could be found with the dolomite. Only occasionally did fluids succeed in reaching carbonates to form replacement ores. If this scenario for the breccia is true, the mineralizing fluids must have utilized a range front fracture at depth to reach favorable host rock in the vertical standing quartzite and moved along bedding or rock contacts to reach carbonate host rocks, and not have been derived in a straight line directly from the Cretaceous age quartz monzonite to the east; a situation similar to that of some zinc ores of the Hanover District, New Mexico (Newhouse, 1942).

Hydrothermal alteration of carbonates away from the propylitic alteration zone shows widespread sericite development and occasionally, as in Figures 10 and 11, combines with chloritic alteration and silicification. Albite along rims of early pyrite can be seen at upper right. Notice the
small blebs of disseminated opaque chalcopyrite in the matrix. Sericite webwork and interstitial chlorite comprising 50% of the rock surround and interfinger with microcrystalline masses of granular quartz and albite. This mineralization differs from that of the simple quartz veins in that quartz and chalcopyrite are disseminated into the rock rather than veined, and albite is a significant accessory mineral. This alteration suggests higher temperatures of formation than for the simple vein ores in carbonate.

Figure 10. Photomicrograph of hydrothermal alteration of carbonate, uncrossed polars. Width of field 3.38 mm. P-pyrite S-sericite C-chlorite Q-quartz Photo color is greener than true color.

Benton Range area

Sometime between 1910 and 1919 the R & S mine was developed in silver-bearing jasperoid of approximately 30' in thickness at the top of the Poleta formation in the northeast corner of section 11, T1N, R32E in the Benton Range. Fifteen carloads of ore (of unknown value) were shipped to the McNamara mill at Tonopah, Nevada. Ore assays averaged 2% lead, trace
Figure 11. Photomicrograph of hydrothermal alteration of carbonate, crossed polars. Width of field 3.38 mm. P-pyrite S-sericite C-chlorite Q-quartz Photo color is greener than true color.

gold, and 0–30 ounces silver to the ton in jasperoidal calcite and limonite breccia. Ore grade was insufficient at the time to warrant further development (Nevada Bureau of Mines & Geology, Mining District Open-Files). The property is currently claimed by Palosky Exploration of Hawthorne, Nevada.

Figure 12 shows the mineralogy of this jasperoid. Opaque limonite, hematite, and geothite make up 75% of the rock while clear to milky chalcedonic quartz is disseminated through the rock as blebs and microveinlets. Figure 13 is an enlargement of Figure 12 and shows amber jarosite surrounding individual grains of iron oxide dust. Chalcedony and cerussite also can be seen to line the quartz filled voids. Pyrite is not present, nor are leached gossans present in outcrop.

The jasperoid is formed by the silicification of the upper unit of the
Poleta formation directly beneath phyllite of the Harkless formation. Un-
silicified Poleta formation marble lies directly beneath jasperoid to the
north of the mine. No sulphide mineralization could be found in unsilici-
fied marble near the mine.

Silica for making jasperoid was derived from a potassic rhyolite dike
which outcrops for approximately 40 feet on an east-west strike above the
adits in the jasperoid. Hand specimen appearance of the rhyolite is very
coarse grained, with large muscovite crystals. Petrographically, pheno-
crysts of sanidine, orthoclase, muscovite, and sericitized albite lie in a
groundmass of muscovite, K-spar, iron oxides, and quartz. This rhyolite

Figure 12. Photomicrograph of jasperoid ore of the R & S mine. Width
of field 3.38 mm. Q-quartz, chalcedony L-limonite, sili-
cified limestone, and goethite.
is similar in composition to the post-andesite dike shown in cross-section 1 on Plate 1 (though much more coarse) and is considered to be of similar age and derivation. Emplacement of the dike was controlled by a branch of the east-west trending step fault which drops the south side of the fault toward Benton Valley and exposes the cliff face of quartz monzonite to the west of the mine.

One-half mile to the west in the west half of section 11 along strike of this fault lie a number of adits and prospects driven in vuggy, comby, quartz veins (of less than 100' in length and less than 1' wide) and jasperoid in siliceous marble. North striking faults intersect here and have brecciated the Poleta formation, providing the permeability necessary for silica-bearing solutions to penetrate the carbonate. A little further to the west along the fault a silicified vein breccia of little surface ex-
posure contains mixed pumiceous, andesite, rhyolite, and calcite clasts. A grab sample of this rock from a mine waste dump yielded 1.5 oz/ton Ag and .01 oz/ton Au when fire assayed. Small outcrops of jasperoid similar to those at the R & S mine occur also and suggest an age of the vein breccia similar to that of the rhyolite dike found at the R & S mine.

Chalcopyrite, pyrite, limonite, galena, and fibrous clusters of boulang-erite? are disseminated in the rock matrix.

Along the north trending faults lie prospects for gold in minor fractures filled with latite crosscutting Poleta marble. The latite does not alter the wallrock carbonate. No mining activity has occurred on these prospects since 1964.

On the hill crest in the center of section 1 lie a number of prospects for cinnabar. A rhyolite dike of sanidine, biotite, and andesine phenocrysts altering to clays in a fine grain groundmass of sanidine and spherulitic chalcedony strikes east-west through a rhyolite flow of similar composition. The dike walls are sharp and distinct against the rhyolite flow rock. No mercury mineralization could be found although renewed prospecting activity has taken place recently.

In the canyon in the west ½ of the SW 4 of section 11 lie the Diatone claims which were located in 1978. Several adits, shallow excavations with some production, and bulldozer cuts have been made to obtain a bulk sample to test the diatomaceous earth properties of laminated, water-laid, diatomaceous, rhyolite tuff containing horizontal veins of pistachio green perlite. The tuff lies conformably beneath the younger andesite of Taylor (1965) and overlies pumice tuff in the SW 4 of section 11. It is considered to be of roughly contemporary age to the andesite and to diatomaceous earth
units mapped by Robinson, et al (1973) in the northern portion of Fish Lake Valley to the east. The cover of volcanics over most of the outcrop area of this unit and the much larger, easier mined sources of diatomaceous earth in Fish Lake Valley cast doubt upon the economic viability of this rock.

Uranium Reconnaissance and Analysis

Pegmatites found in the Jurassic age quartz monzonite are in some cases uranium bearing in the White Mountains. Ross (1961) made tentative identification of samarskite and euxinite in a pegmatite north of Morris Creek at the Lucky Susan prospect believed to be in section 35, T1N, R32E. Cupp and Mitchell (1978) failed to find the prospect when sampling for their study.

Uranium mineralization is also known south of the study areas at the Claw prospect in section 32, T2S, R33E (Cupp and Mitchell, 1978). Beta-uranophane and uraninite are reported in a roof pendant of banded marble, magnetite schist, actinolite schist, and biotite schist in granite. Uraninite occurs as disseminated automorphic euhedral replacement growths along opaque calc-silicate bands in marble. Minor uranium mineralization is also reported from pegmatite dikes. Other areas nearby of epidote, fluorite, beryl, and garnet mineralization of contact metamorphic origin with trace chalcopyrite and iron oxides recorded radiation counts only slightly higher than those for the plutonic rocks.

Cupp and Mitchell (1978) believe the genesis of this deposit to be of a remobilized pre-existing deposit. Similar deposits of this genesis are found by Robbins (1978) at Spokane Mountain, Washington, by Hegge and
Rowntree (1978) in the East Alligator River Region of Australia, and by Dahlkamp (1978) at the Key Lake deposits of north Saskatchewan. Due to the proximity of these uranium occurrences to the study areas and the similar rocks and minerals involved in these deposits, a search and analysis was made of potential uranium mineralization within the study area.

Samples analyzed for this study were crushed to -100 mesh and allowed to digest in acid for 5 days, then analyzed with a fluorimeter similar to the method used by Cupp and Mitchell (1978).

Table 2 gives a summary of uranium analysis results obtained from rock samples in and near the study areas. For comparison of values, according to Cupp and Mitchell (1978) sample 21004 was taken from a pegmatite in Jurassic age quartz monzonite somewhere near Marble Creek. Sample RS 19 was taken from veined hornfels in section 2 south of Montgomery Creek. Sample RS 8 is from marble at the intrusive contact in the canyon north of Marble Creek. Sample RS 43 is from light gray pumiceous tuff labeled Trg on Plate 1 in the southwest corner of section 11 in the Benton Range area.

Table 3 summarizes the range of scintillometer readings for rocks within the study areas using a Model SC-132 Mount Sopris Instrument Co. scintillometer.
Table 2. Analysis results for uranium content of selected rocks within and adjacent to the study areas. Twenty thousand series from Cupp and Mitchell (1978).

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<td>T1S, R32E</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>NW%, SE%, sec. 14</td>
<td>RS 34</td>
<td></td>
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<td>T1S, R32E</td>
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<tr>
<td>NW%, NE%, sec. 14</td>
<td>RS 35</td>
<td></td>
<td>160</td>
<td>0.9</td>
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<tr>
<td>SE%, NW%, sec. 11</td>
<td>RS 43</td>
<td>volcanic</td>
<td>250</td>
<td>4.1</td>
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<tr>
<td>T1N, R32E</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Center, section 2</td>
<td>RS 46</td>
<td></td>
<td>100</td>
<td>1.7</td>
</tr>
</tbody>
</table>

--- = no reading taken
Table 3. Range of scintillometer counts for rocks of the study areas.

<table>
<thead>
<tr>
<th>Rock Type</th>
<th>Range (cps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intrusive</td>
<td>100 - 200</td>
</tr>
<tr>
<td>Marble</td>
<td>40 - 80</td>
</tr>
<tr>
<td>Metasediments</td>
<td>140 - 220</td>
</tr>
<tr>
<td>Pegmatite, vein, and altered</td>
<td>80 - 240</td>
</tr>
<tr>
<td>Volcanic</td>
<td>100 - 250</td>
</tr>
</tbody>
</table>

From the accumulated results and observations the following conclusions are made:

1. The probability for a sizable ore deposit of uranium within the study areas is low.

2. Anomalous (higher than background) uranium occurrences can be found in the study areas in the following:
   A. pumiceous rhyolite tuff (Trg) in section 11 of the Benton Range
   B. calc-silicate hornfels throughout the mapped areas
   C. just north of Marble Creek in interbedded hornfels and skarn near the Jagp intrusive contact
   D. in a few small pegmatites within the Jagp intrusive

3. Uranium anomalies are rare in the study areas in the following:
   A. unaltered batholithic rocks
   B. recrystallized marble
   C. unaltered and/or non-rhyolitic volcanic rocks
   D. massive quartzite
   E. in association with epithermal base and precious metal ores
Whether or not the pegmatite zone of garnet-actinolite mineralization seen in Montgomery Creek contains local uranium ores along it could not be determined. If the rocks of similar type at the Claw prospect to the south are representative of the probability of uranium mineralization in this area, then the probability is low.

No data was available nor was consideration given to the possibilities of uranium enrichment in sub-alluvial zones in the valley away from the range front. This possibility should not be overlooked due to the presence of Pliocene lacustrine sediments and the anomalous uranium found in the pumiceous rhyolite tuff (Trg). Groundwater leaching could have transported uranium into valley fill sediments from the plutons to the east or from the volcanics of Montgomery Pass and the Benton Range. Rogers, et al (1978) note the tendency of $^{4+}$ to form fluoride and carbonate ion complexes during aqueous transport. Fluorspar mineralization is found 3 miles east of Montgomery Pass. These mineralized areas flow into the north end of Benton Valley. The abundance of fluorine and carbonate available for complexing $^{4+}$ here at the north end of Benton Valley could produce enrichment of uranium in Pliocene age sediments beneath the alluvium.
The potential for sizable ores of base and precious metals being found in carbonates of the study areas is summarized in a simplified manner with Figure 15. Most of these examples are dependent upon structure and local favorable conditions for isolation of ore-bearing fluids in favorable host rocks.

Type A with some modification may be representative of the zone of propylitic alteration in impure quartzite south of Morris Creek where supergene sulphide enrichment may lie at depth in the footwall of the range front fault. Type B very closely resembles veins and structure of the Montgomery District while Type C is prevalent of ore in fault breccias from the R & S mine in the Benton Range where Type E conditions may be encountered also. Uranium mineralization may have developed under structural conditions in metasomatized carbonates similar to Type D or in suballuvial sediments near either study area.
Figure 14. Idealized structure of ore potential in the study areas. All except C from Locke (1926).

A. A small relic of an alteration border outcropping and indicating ore below. 1, surface; 2, fault; 3, ore bed; 4, alteration border.

B. Separated outcrops of fractures and favorable beds pointing toward hidden favorable intersections below. 1, surface; 2, bottom of oxidation; 3, favorable rock bed, slightly mineralized; 4, mineralized fissure; 5, ore.

C. A small brecciated outcrop of ore indicating a larger hidden host unit below. 1, barren cover; 2, plutonic rock; 3, hidden ore host; 4, brecciated ore.

D. Outcrop of 'metasomatic halo' indicating ore along hidden halo boundary. 1, surface; 2, 'metasomatic halo'; 3, ore; 4, garnet; 5, intrusive rock.

E. Outcrop of jasperoid which denotes a jasperoid enlargement making a roof for ore. 1, surface; 2, jasperoid expanding in a favorable horizon; 3, ore.
EXPLORATION SUGGESTIONS

Considerable economic mineralization may remain undiscovered, particularly for sulphide ores that have been supergene enriched.

Permeability along the copper mineralized fractures in quartzite in section 14 south of Morris Creek is excellent for downward transport of oxidized sulphide minerals to the water table where reductive conditions would produce a zone of supergene copper ore with significant silver content. This mineralization may be localized in a highly altered, porous portion of Jurassic granodiorite similar to that found just north of the jeep trail. Drilling directly down dip in the propylitic alteration zone in unsurveyed section 14 north of the jeep trail will answer several uncertainties; namely: presence or absence of supergene sulphide: ore of Ag-Pb-Zn-Cu at depth, extent of Cambrian quartzite down dip along the range front, correlation if any of mineralization to range front faulting, presence or absence of a buried mineralized dike or intrusive.

Supergene enriched sulphide ore may be localized below leached gossans of the zone of propylitic alteration at depth along the Cmp-Jagp contact just north of the Black Warrior mine. Development of workings on vein mineralization and alteration was not carried on to great depths. Disseminated values of sulphides in unmined altered rock of the mine workings may be economic at the present time. The source of mineralization in this area is unknown and may be controlled by local permeability along the contact. These ores may have been ultimately derived from the same source as those found in quartzites to the west.

Localized, small, high-grade deposits of copper sulphides may have
developed on the carbonate side of the zone of garnet-actinolite skarn north and south of Montgomery Creek. Local concentrations of uranium are possible though improbable in the same area. These deposits may be connected to high grade quartz-sulphide veins of silver, lead, and zinc. Considerable Pb-Ag ore of jasperoidal - limonite - carbonate breccia may lie along strike of the front range fault near the R & S mine in section 11 of the Benton Range study area. The area covered by volcanics immediately west of the R & S mine as well as the area covered by Harkless formation to the east of the mine should be drilled to determine whether or not the hanging wall of the fault is mineralized. Trace element tests and core logging may discover additional metals and sulphides in jasperoidal ore of zinc, copper, antimony, gold, and possibly molybdenum and tungsten. Extension to depth of the mineralizing rhyolite dike above the R & S mine adits suggest the possibility of a mineralized porphyry intrusive of Jurassic age or a zone of sulphide enrichment previously undiscovered near the water table, particularly on the hanging wall side of the fault where a combination of volcanic cover and range front faulting may conceal additional sulphide mineralization. Host rock and ore minerals found at the R & S mine are similar to those found in rocks overlying many porphyry copper-molybdenum deposits of the world.
REFERENCES CITED


Dahlkamp, Franz J. 1974, Geologic Appraisal of the Key Lake U-Ni Deposits, Northern Saskatchewan: Econ. Geol., vol. 73, no. 8 p. 1430-1449.


