Characterization of Alkaline Rock-Hosted Precious and Base Metal Mineralization in the Nogal Mining District, Lincoln County, New Mexico.

by

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Thesis

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Abstract

Alkalic rocks are known to host a wide variety of mineral deposits, including large tonnage gold deposits. Recently, detailed geochemical data and new genetic models have made alkalic-hosted gold deposits attractive exploration targets. Recently published geochemical data for the alkalic igneous centers of Lincoln County, New Mexico has provided new insight into the origin of these rocks and their possible mineral potential. This study uses stable isotope, fluid inclusion, and geochemical data collected from a mining district in Lincoln County, New Mexico to characterize the mineralizing fluids and associated vein alteration. Data from this study, in combination with new and existing geologic and geochemical information, are used to postulate a genetic model for two gold deposits in the district, as well as the geologic events leading to mineralization of the area.

The Nogal Mining District is located in the Sierra Blanca mountains of south-central New Mexico. The district contains four types of mineralization: 1) Au-bearing veins and breccias; 2) Ag-Pb-Zn veins; 3) Disseminated Mo-Cu occurrences; and 4) Au placers. These deposits have historic production of Au, Ag, Pb, and Zn in excess of $1,000,000 with no current production. The geology of the district is dominated by andesite flows and flow breccias, that have been intruded by three hypabyssal alkaline stocks. Geochemical data suggest that two different pulses of igneous activity occurred in the district.

Fluid inclusion data shows that the gold deposits of the district have formation temperatures ranging from 230°C to 480°C with an average salinity approximately 6 wt. eq. percent NaCl. However, two gold deposits, the Waterdog and the Helen Rae, contain inclusions with salinities of 23 to 50 wt. eq. percent NaCl. The Ag-Pb-Zn deposits range in formation temperature from 230°C to 350°C with an average salinity of 4 wt. percent NaCl.

Oxygen isotope data indicate that fluids responsible for gold mineralization were magmatic dominated fluids for most deposits ($\delta^{18}O_{fluid}$ = 9.5 to -5.0) and that fluids of Ag-Pb-Zn mineralization were mixed magmatic-meteoric fluids ($\delta^{18}O_{fluid}$ = 3.5 to -5.7 per mil). Fluids responsible for disseminated Mo-Cu mineralization were similar to the Ag-Pb-Zn fluids ($\delta^{18}O_{fluid}$ = 1.1 to -5.0 per mil). Calculated $\delta^{34}S_{fluid}$ of the deposits was -1 ± 1 per mil, indicating a magmatic source for the sulfur.

Two distinctly different forms of alteration are present in the district. The first is a broad, regional hydrothermal alteration of the andesites, caused by isotopically depleted waters, similar to the mineralizing fluid responsible for Ag-Pb-Zn mineralization. The second type of alteration is vein alteration associated with gold mineralization. This type of alteration is superimposed over the broad, regional alteration and is characterized by an enrichment in K, oxygen isotopic re-enrichment, and a depletion of Na, Mg, and Fe in the rocks near the vein.

From this data, four events are presented in an effort to reconstruct the geologic events leading to mineralization of the Nogal district. Formation of deep northeast trending basement faults occurred during the Laramide. The andesites of the area were erupted from these deep basement faults during subduction-related volcanism (37.3 to 37.0 Ma). Later (31 to 26 Ma) early Rio Grande rifting sparked another phase of igneous activity. Early in this phase (31 to 30 Ma), many stocks were intruded into the volcanic pile leading to hydrothermal alteration of the andesites. During this time, one of the intrusions produced Mo-Cu disseminated mineralization. Simultaneously, the reactivation of a structure in the district coupled with abundant hydrothermal fluids lead to the formation of the Ag-Pb-Zn deposits. Fluids from late-stage intrusions (around 26 Ma) migrated along older northeast trending structures. These fluids were dominately magmatic in origin, as meteoric water was less abundant at this time. These fluids formed the gold deposits of the district.

Acknowledgements

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I would like to thank the property owners of the district for access to their holdings. Thanks goes to Randy Ruff for his work on the gas data. Thanks goes to my committee: Dr Andrew Campbell, my advisor, for being patient with me and always being there to bounce ideas off of; Dr. William Chavez, for help on the photomicrographs and for just having an upbeat attitude; and Dr. David Norman, for help with the fluid inclusion stage and the gas data. This manuscript has benefitted from discussions with Randy Ruff, Alan Porter, and Ernie Scharkan. My sanity has benefitted from "discussions" with Terry Pollock, Ernie Scharkan, Aaron Cross, Ed Fry and Rebecca Brown.

To my family and friends: I couldn't have done it without you!

To Rebecca Brown: See what kind of trouble I get myself into when you're not around.

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Introduction

Alkalic rocks are known to host a wide variety of mineral deposits and have generated a great deal of interest in academic, as well as mining circles for over 100 years. Although alkalic rocks are areally and volumetrically minuscule (less than 1% of all igneous rock) in North America, they account for close to 13% of total lode gold production in the U.S. and Canada (Mutschler et al., 1991). In addition, large (1 million oz.) deposits are common (Mutschler et al., 1991). Recently, exploration successes at Cripple Creek, Colorado and Ortiz, New Mexico, as well as continued production from deposits like Zortman-Landusky in Montana have focused attention on alkalic rocks along the eastern margin of the North American Cordillera. The unique chemistry of alkaline rocks has lead to many different petrologic classification schemes and theories as to their origin. Detailed geochemical data collected from many suites of alkalic rocks has brought forth a more coherent understanding of these rocks and their origins. These new genetic models make alkalic related precious metal prospects attractive exploration targets (Mutschler et al., 1991). One of the key elements in defining or re-defining the mineral potential of an alkalic area is detailed geochemical data from the area (see Mutschler, 1985). Yet, some areas containing alkaline igneous rocks have not been studied in such a fashion or these studies are only now becoming available. Such is the case for the alkalic igneous centers in Lincoln County, New Mexico. While their overall alkalic nature has been recognized since the early 1900's (Lindgren et al., 1910), only recently has detailed geochemical data has become available for the area (Allen and Foord, 1991; Allen and McLemore, 1991; and Phillips et al., 1991). In light of these and other studies, a re-evaluation of the area's mineral potential seems warranted.

This study focuses on the nature of the fluids associated with precious and base metal mineralization, in the largest alkalic complex in Lincoln County, New Mexico. This project stems from a previous study by Campbell et al.(1991) that detailed the existence of highly saline fluids associated with gold deposition in one deposit. The principle goals of this study are: to characterize the ore forming fluids from throughout the district using stable isotope and fluid inclusion techniques; and to characterize fluid-rock interactions related to mineralization using petrographic, stable isotope, and geochemical methods. A secondary goal is to present possible genetic models for select gold deposits using the results of this study. From this, a coherent picture of ore genesis in the district will also be developed and the district's mineral potential discussed.

Location and Geologic Setting

The Nogal mining district is located in the Sierra Blanca Mountains of south-central New Mexico (Fig. 1). The

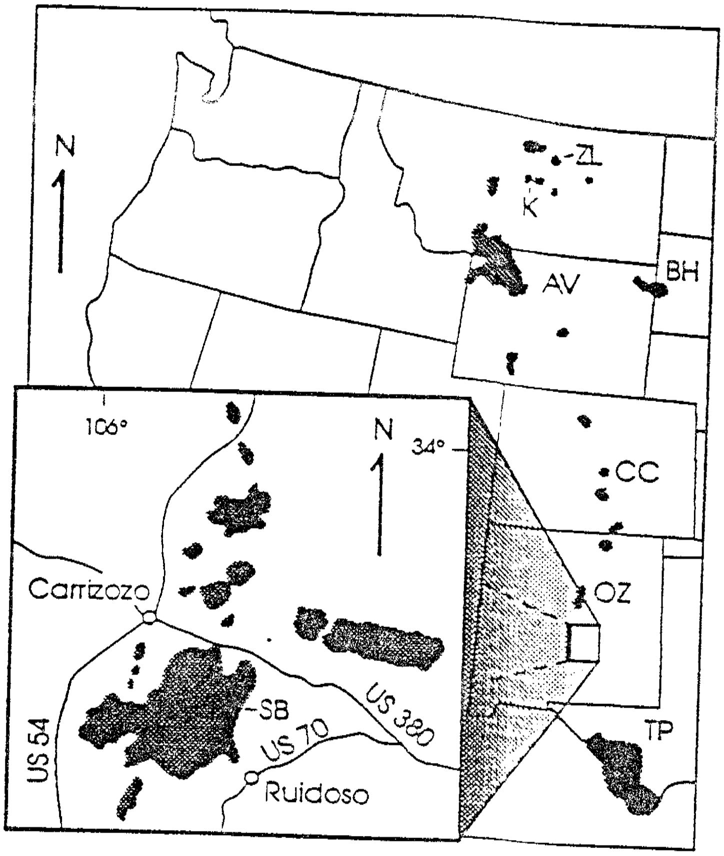
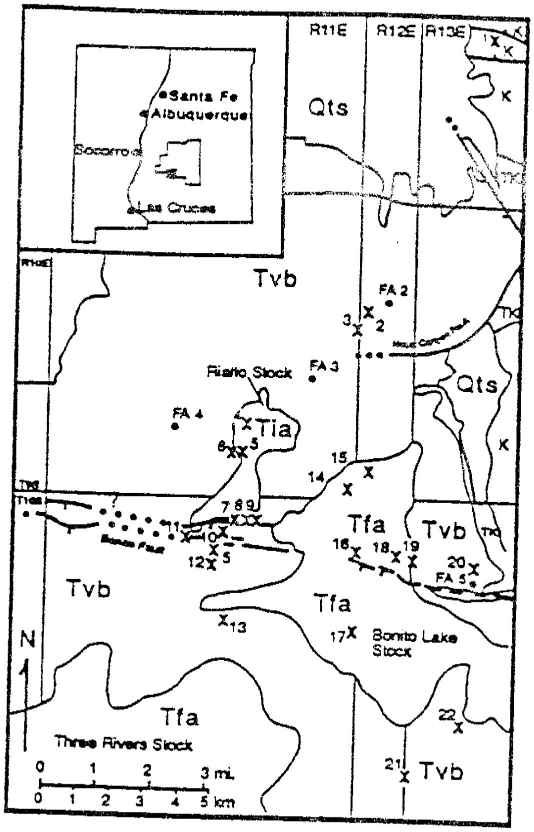


Figure 1. Map of the Rocky Mountain Alkalic Provence (RMAP). Modified from Mutschler et al., 1985. Inset - Map showing the rocks of the Lincoln County Porphyry Belt (LCPB). Modified from Cather, 1991a. AV - Absaroka volcanic field; BH - Black Hills; CC - Cripple Creek volcanic field; K - Kendell mining district in the Judith Mountains; OZ - Ortiz Mountains; SB - Sierra Blanca Igneous Complex; TP - Trans-Pecos volcanic field; ZL - Zortman-Landusky mining districts in the Little Rocky Mountains.

earliest reported discovery from the area was of placer gold in 1865 (Lindgren et al., 1910). The first lode claim was located in 1868, but active exploration and production did not commence until the 1880's. Production from the district's mines has been sporadic and Thompson (1973) estimated that only about $1,000,000 in lead, zinc, silver, and gold have come from the area since its discovery. Recent years have seen renewed interest in the area with several sites being targeted for exploration (Fulp and Woodward, 1991 and Mining Record, 1992). Previous studies in the area have dealt with the mineral resources of the district (Lindgren et al, 1910; Griswold, 1959, Griswold and Missighi, 1964; Thompson, 1973; Campbell et al., 1991; Eng, 1991; Fulp and Woodward, 1991; and Ryberg, 1991), the tectonic and the petrology of the area (Thompson, 1972; Giles and Thompson, 1972; Allen and Foord, 1991; and Cather, 1991a), and a wilderness study (Segerstrom et al, 1979).

The igneous complex that forms the Sierra Blanca mountains is one of eleven porphyritic alkalic igneous centers that comprise the Lincoln County porphyry belt (LCPB; Kelly and Thompson, 1964). In turn, the LCPB is part of the Rocky Mountain Alkalic Provence (Carmichael et al., 1974), which includes Laramide and post-Laramide alkalic rocks along the eastern Rocky Mountain front from Canada to Mexico (Figure 1). The igneous centers of the LCPB are emplaced along, and around, the intersection of two major structures, the north-trending late Pennsylvanian Pedernal uplift and the east-west trending Capitan lineament (Kelly and Thompson, 1964); and the area lies at the eastern-most extent of both Laramide deformation and Rio Grande rifting. In their study of the geology of the LCPB, Allen and Foord (1991) compiled geochronological and geochemical data indicating two different periods of igneous activity which correspond to arc magmatism (38-36 Ma) and later rift magmatism (26-15 Ma). The region was subjected to northeast-southwest directed compression during the late Laramide (Price et al., 1987), which coincides with the fabric of the Precambrian basement of the area and appear to have re-activated old basement fractures. This is important, as it appears that deep structural flaws are needed in order to tap deep-seated alkalic magmas (Allen and Foord, 1991). During this compressional event, the Sierra Blanca basin was formed and was partial filled by locally derived clastic sediments (Cather, 1991b). Into this basin, the Sierra Blanca volcanics erupted starting around 37 Ma. The Sierra Blanca Igneous Complex is the largest alkalic center in the LCPB, covering almost 600 km^2 (Allen and Foord, 1991).

The geology of the Nogal district is dominated by the Oligocene Sierra Blanca volcanics (Figure 2). The volcanics are up to 1000 m thick and have been divided into several different formations. The basal formation is the Walker



1-Vera Cruz, Au,b
2-Helen-Rae-American, Au, v
3-Rockford, Au,v
4-Rialto (Fulmer), Mo, b
5-Parson's (Hopeful), Au, b
6-Jenny Linn,?, b
7-Renowned OK, Ag-Pb-Zn, v
8-Crow, Ag-Pb-Zn, v
9-Martha Washington, Ag-Pb-Zn,v
10-Spur Ag-Pb-Zn,v
11-Argentine, Ag-Pb-Zn,v
12-Maud, Ag-Pb-Zn,v
13-Great Western, Au,b
14-Breccias of Waterdog, Au?, b
15-Waterdog, Au, Cu-Au , b
16-Soldier, Ag, s
17-Rock No.1, Ag-Pb-Cu, s
18-Hope-Ag, s
19-Mineral Farms, Au-Pb-Zn,s
20-Mayberry, Ag-Pb-Zn, v
21-Silver Plume, Ag, v
22-Blue bird, Cu
FA 1-5 whole rock sample locations

v-vein
b-breccia
s-shear zone

Qts	Surface Sediments
Tfa	Felsic Alkalic Porphyries (syenite to alkali granite)
Tia	Intermediate Alkalic porphyry (hornblend-biotite monzonite to biotite-monzonite)
Tvb	Volcanic flows and flow breccias of Sierra Blanca Volcanics, andesite to trachyte
TK	Synorogenic sediments of the Cub Mountain formation
K	Shales, sandstones, coal and limestone of Mesa Verde group
——	Contact
—┴—	faults, tick showing down thrown side

Figure 2. Geologic and index map of the Nogal mining district. Modified from Woodward, 1991 with additions from Segerstrom et al., 1979.

Andesite, which is comprised of 700 m of andesite flows and flow breccias. It erupted between 37.3 and 37.0 Ma based on crosscutting relationships with dikes in the area that have been dated (Allen and Foord, 1991). Unconformably overlying the Walker Andesite in the district are 300 m of trachyte and quartz trachyte flows referred to as the Nogal Peak Trachyte. Ages on these flow are less well constrained and fall between 30 and 26.5 Ma (Allen and Foord, 1991). To the northeast of Nogal Peak, and overlying the Walker Andesite, are 240 m of latite flows, referred to as the Church Mountain Latite. Thompson (1972) gives a K-Ar age date of 31.8 ± 1.3 Ma for the Church Mountain Latite. This latite may be the lateral equivalent of the Nogal Peak Trachyte, but due to erosion such correlation is impossible. These trachytes and latites clearly represent a later and different stage of volcanism than was responsible for the andesites. The chemistry of the later volcanics is similar to that of the late syenite and alkali granite of the Three Rivers stock (Allen and Foord, 1991).

Hypabyssally intruding the Sierra Blanca Volcanics are the Rialto stock, the Bonito Lake stock, and the Three Rivers stock. All three stocks are coeval with the volcanics and consist of multiple intrusive phases (Thompson, 1972 and Allen and Ford, 1991). The Rialto stock is located near the center of the district. The stock has been classified as a hornblend-biotite monzonite (Thompson,

1972) and as a syenodiorite (Griswold and Missaghi, 1964 and Allen and Foord, 1991). Mineralogically, the rock is 90 percent orthoclase and plagioclase with minor amounts of quartz, ferromagnesian minerals, sphene, apatite, rutile and magnetite (Thompson, 1972). The stock has been intruded by small bodies of biotite-monzonite (Thompson, 1972). Alteration of the stock is extensive, with even the freshest samples being altered. The age of the stock is unknown. Brecciation with associated disseminated molybdenum and copper mineralization, along with its resultant hydrothermal alteration, are found in the northern half of the stock. The Bonito Lake stock is located in the east-central part of the district. The rocks of the Bonito Lake stock have been classified as a hornblend-biotite syenite (Thompson, 1972) and as a syenite to a quartz-syenite (Allen and Foord, 1991). It is composed of orthoclase and plagioclase with abundant microperthite and minor magnetite, apatite, zircon and pyroxene (Segerstrom et al., 1979). Chloritic alteration of the mafic minerals is pervasive throughout the stock (Allen and Foord, 1991). Thompson (1972) reported a K-Ar age date of 26.6 Ma from biotite, but complex intrusive relationships and alteration of the stock make this date a minimum (Allen and Foord, 1991). Argillization and silicification have occurred along the northern boundary of the stock, and has been accompanied by the formation of pyrite, molybdenite and chalcopyrite.

The Three Rivers stock is located in the southernmost part of the district. It has been divided into an arfvedsonite-aegirine syenite dated at 29.9 Ma, a younger porphyritic syenite of similar composition, a quartz syenite dated at 29.3 Ma, and an alkali granite dated at 26.7 Ma (Allen and Foord, 1991). The northern and eastern margins of the stock have been hydrothermally altered, with silicification and deposition of pyrite and molybdenite occurring.

Trace element geochemistry strongly suggests that two distinctly different pulses of magmatism were responsible for the alkalic rocks of the area (Allen and Foord, 1991). The first, or older event occurred between 38.2 and 36.5 Ma and is coincident with waning subduction of the Farallon plate beneath North America. This phase produced the alkaline, quartz-undersaturated flows of the Walker Andesite in the district. The second, or younger event occurred between 30 and 26.5 Ma during the early phases of Rio Grande rifting. This phase is responsible for the later, saturated to oversaturated, trachyte and latite flows and alkali granite stocks of the area. The data also indicates that some portion of both the Rialto and Bonito Lake stocks belongs to the older alkalic pulse and that the stocks are of a complex parentage (Allen and Foord, 1991). However, the majority of intrusive activity occurs with the later pulse, based on chemical composition. In compiling data on mineralization associated with alkalic rocks Mutschler et al.(1985) show that significant gold enrichment above crustal averages is a common characteristic of alkaline-related gold deposits. Geochemical data shows that the rocks of the Sierra Blanca are enriched in gold relative to background crustal values, and are even comparable to crustal gold values seen at Cripple Creek, Colorado (Allen and Foord, 1991).

The area is cut a few district-wide faults, although for the most part the faults are small and localized. Faulting in the district is normal and shows minor displacements, less than 30 m. These faults strike in three directions: northeast-southwest, east-west and northwest-southeast. Mineralization in the area trends predominately in two directions: northeast-southwest and east-west. The largest district-wide structure is the east-west striking Bonito Fault which is also the structure that localizes silver-base-metal mineralization . The Bonito Fault, a splay off of the Capitan lineament (T. Thompson, per. comm.), is not a discrete fault in most of the district, but rather a complex series of small faults and fractures that form a shear zone. The stratigraphic throw along the fault zone in the district is not over 46 m (Segerstrom et al., 1979). The gold deposits are aligned on a northeast-southwest "trends". While these "trends" are not mappable surface structures, it is clear that gold mineralization is favored along that strike bearing.

Mineralization

There are four known styles of mineralization in the Nogal District (Figure 2): (1) disseminated Mo-Cu deposits, (2) gold breccia-vein deposits, (3) silver-base metal vein deposits, and (4) placer deposits (which will not be discussed).

Disseminated Mo-Cu Mineralization

Disseminated molybdenum and copper mineralization occurs in the northern half of the Rialto stock. Additional disseminated Cu-Mo mineralization occurs along the northern and eastern contact of the Three Rivers stock with the volcanics (not discussed here, see Giles and Thompson, 1972). Mineralization in the Rialto stock is localized in, and around, a small breccia pipe that formed at the contact of the older hornblend-biotite monzonite with the younger biotite monzonite. The breccia consists of small (less than 10 cm), subangular pieces of highly altered monzonite cemented by quartz and pyrite. Mineralization consists of pyrite, quartz, molybdenite, and copper sulfides. Pyrite and quartz occur early and throughout mineralization. Molybdenite occurs as smears and as euhedral grains in open space fracture filling in quartz. Molybdenum content decreases outward from the pipe (Thompson, 1973). Copper sulfides are abundant and are disseminated over a wider area than is the molybdenum, leading Thompson (1973) to suggest that the area should be explored for a low-grade copper deposit. The rocks around the mineralization have been extensively hydrothermally altered by silification, sericitization, kaolinization, and pyritization (Thompson, 1973). This alteration is irregularly distributed around the deposits with an inner zone of argillic alteration containing localized areas of silicification and pyritization, and an outer propylitic zone. The deposit has also undergone some supergene alteration that has produced a large zone of oxidation (Thompson, 1973). The deposit has been explored by two adits and numerous drill holes, but the molybdenum grades are spotty and the area lacks sufficient tonnage (Griswold and Missaghi, 1964). The Rialto deposit has been classified as a breccia-type molybdenum deposit (Griswold and Missaghi, 1959; Thompson, 1968; Giles and Thompson, 1972) and is included by Westra and Keith (1981) in their classification of alkalic molybdenum stockwork deposits.

Gold Breccia-Vein Deposits

Gold deposits occur throughout the district in various rock types. These deposits also exhibit two different morphologies: fissure veins and hydrothermal breccias. For example, the breccia of the Vera Cruz is hosted in Mesa Verde group sandstones and shales that have been locally metamorphosed by the Vera Cruz laccolith; whereas the vein deposits of the Helen Rae-American, and the breccia of the Great Western are hosted in the Walker andesite. The veins of the district are narrow (1 to 2 m) fracture-filling systems emplaced along northeast trending normal faults of minor displacement (1 to 30 m). Gold veins are localized in the area around the Helen Rae-American and the Rockford. The veins have variable strike lengths, from a few tens of meter to several kilometers. These veins do show some crustiform textures with early and continuous quartz formation, followed by sulfide deposition and late stage carbonate formation.

The breccia deposits appear as pipes or conical bodies intruding into the country rock. These breccia pipes are less 200 m in diameter with the exception of the Waterdog, which appears to be a large area (3 km^2 ?) of extensive alteration and localized brecciation associated with an intrusive event. The breccia clasts consist of small (less than 10 cm), angular to subangular pieces of highly altered country rock that has been re-silicified. The country rock clasts are so altered as to hinder the identification of the primary rock types. Mineralization occurs with the interstial quartz as either sulfides or oxides.

The mineralogy and ore paragenesis of the different styles are very similar and can be considered the same. Hypogene minerals, in paragenetic order, include quartz, pyrite, sphalerite ± bornite and tetrahedrite, galena, gold-

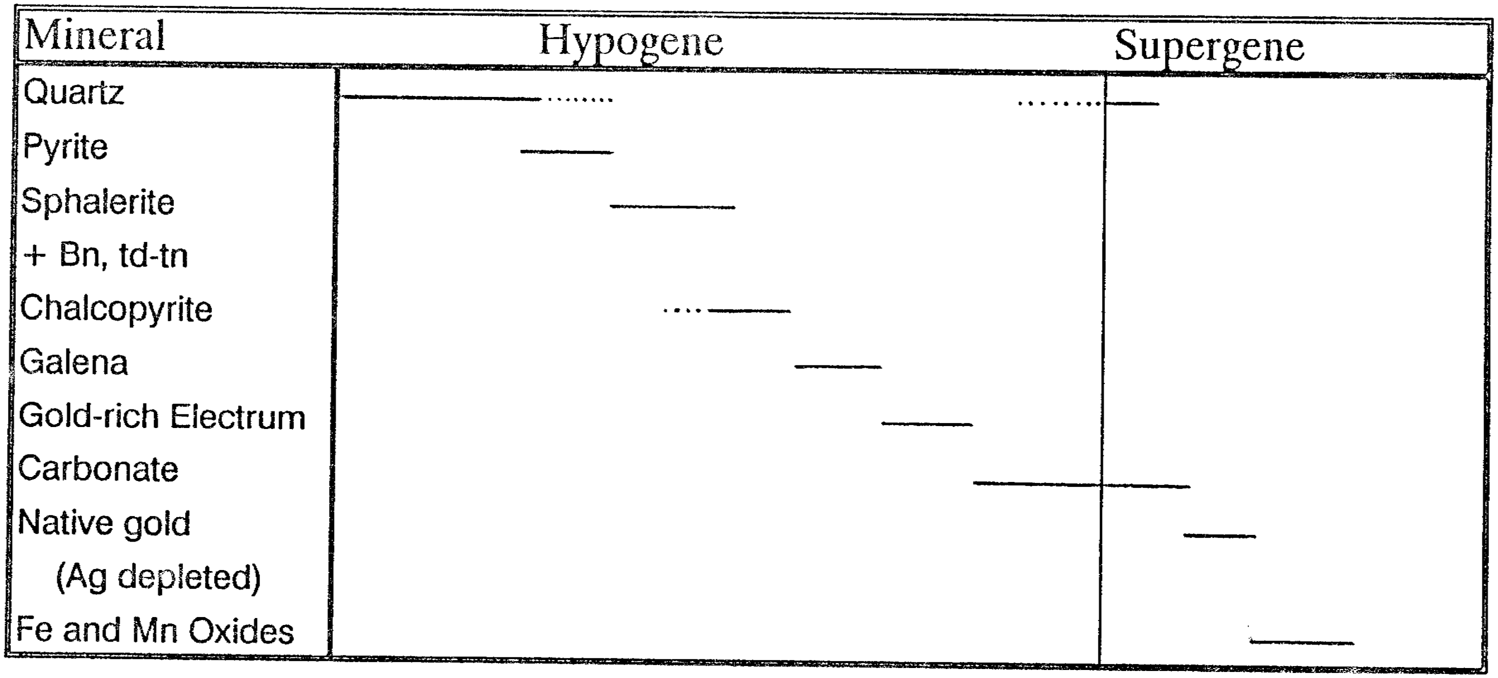


Figure 3. Composite paragenetic diagram for Au deposits. Compiled from Campbell et al., 1991 and Eng, 1991. Bn = bornite, Td = tetrahedrite, Tn = tennantite.

rich electrum, and carbonate (Figure 3; Campbell et al., 1991 and Eng, 1991). Quartz is by far the most abundant mineral in these deposits and occurs throughout the vein paragenesis. Sulfide mineralization is minor, comprising only 2 percent of the mineralized material in most deposits. Wall rock alteration associated with vein mineralization is usually minor and very erratic in its occurrence. It commonly consists of a small (0 to 12 cm) zone of visible sericite and pyrite away from the vein, but locally can consist of argillic alteration extending up to 10 m from the vein. Alteration associated with the breccias is characterized by intense silicification and brecciation of the surrounding country rock. All of these deposits have undergone some supergene alteration, which has resulted in the formation of secondary quartz, Ag-depletion rims on native gold, and iron and manganese oxides. All gold deposits, both vein and breccia, are aligned along two N 28° E trends (Figure 4). One of these "trends" aligns the Parsons breccia with the Rockford, Helen Rae-American and Vera Cruz deposits to the north. To the south, the trend passes near the Argentine mine, which produced some gold (Thompson, 1973), and ends at a small un-mineralized (?) breccia body near the Three Rivers stock. The other recognizable "trend" connects the Great Western breccia body to the breccias of the Waterdog deposit. This alignment of the gold deposits was noted as far back as Lindgren's 1910

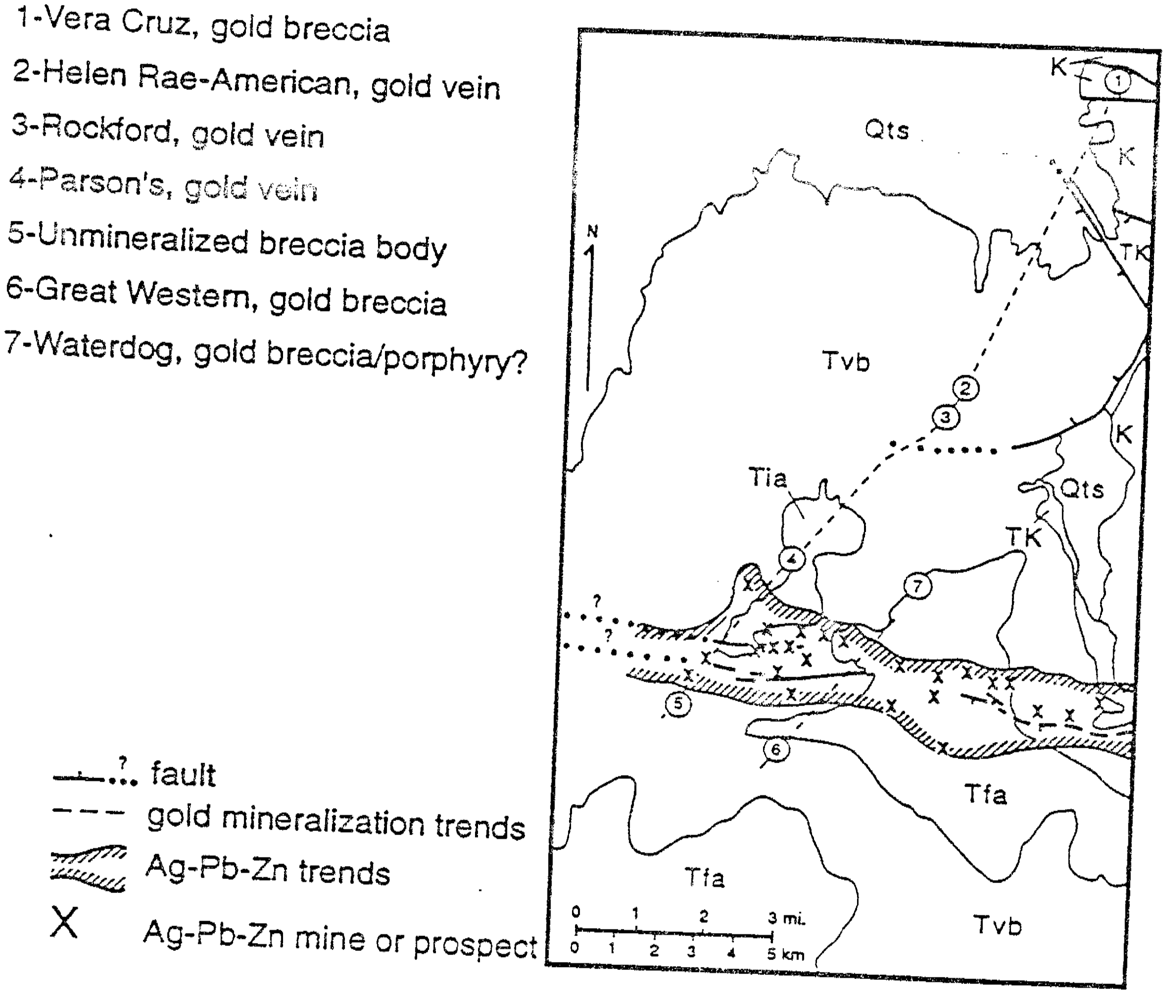


Figure 4. Modified geologic map showing the distribution of gold and Ag-Pb-Zn deposits.

study. These deposits are, and have been, the main source of exploration activity in the district. The Great Western has a total of 150,000 ounces of known Au reserves (Fulp and Woodward, 1989) and current exploration of the Vera Cruz has led to the discovery of extensive mineralization with gold grades as high as 0.9 ounces per ton over a 10 foot interval (Mining Record, 1992). Additional potential may also exists at the Helen Rae-American and at the Waterdog deposits. At the Helen Rae-American, significant historic gold production has occurred from relatively shallow workings (Griswold, 1959). At the Waterdog, the rocks have been extensively bleached, re-silicified and oxidized. This, along with anomalies of Cu, Au, Ag and Te, have lead Fulp and Woodward (1991) to postulated the existence of an Cu-Au alkalic porphyry deposit at depth below the Waterdog.

Silver-Lead-Zinc Deposits

The Ag-Pb-Zn deposits are localized in the central part of the district (Figure 4). They occur as narrow (1 to 2 m) fracture-fillings along fault and fracture traces of the Bonito fault zone, within the Walker andesite. The only exception is the Mayberry deposit, which is emplaced along a small north-northeast trending dike. Most of the mineralized structures are not laterally continuous along strike, existing only a few meters either side of the workings and are part of the Bonito Fault zone. The only exception to this is the Crow Vein, which outcrops as a vein for up to 2 kilometers and contains the workings of the Crow, Renowned O.K. and Martha Washington mines. The veins contain early quartz followed by sulfides and late stage barite; carbonate is only seen in the last stage at the Mayberry and the Silver Plume. Carbonate mineralization in these deposits is only seen at the Mayberry and the Silver Plume. Eight polished thin sections from three sites were used to come up with a generalized mineral paragenesis for these deposits. The minerals in paragenetic order are: quartz, pyrite, argentiferous galena, chalcopyrite, sphalerite, minor barite, ± carbonate, and later secondary covellite and tetrahedrite (Figure 5). This paragenesis is in agreement with Thompson's (1973). Quartz is quite abundant, comprising up to 50 percent of the vein material, and seen throughout the paragenetic sequence. While chalcopyrite precedes sphalerite, it also rims sphalerite and is intermixed with it. No native silver was seen in any of the samples. This suggests that the galena is the silver bearing mineral, except at the Silver Plume where silver occurs as cerargite. Thompson (1973) noted that zinc to lead ratios decrease away from the Rialto Stock, leading him to conclude that the stock was the source of the mineralizing fluid.

From the paragenetic work, two important differences distinguish these deposits from the gold deposits. The first is the abundance of sulfides in the Ag-Pb-Zn deposits

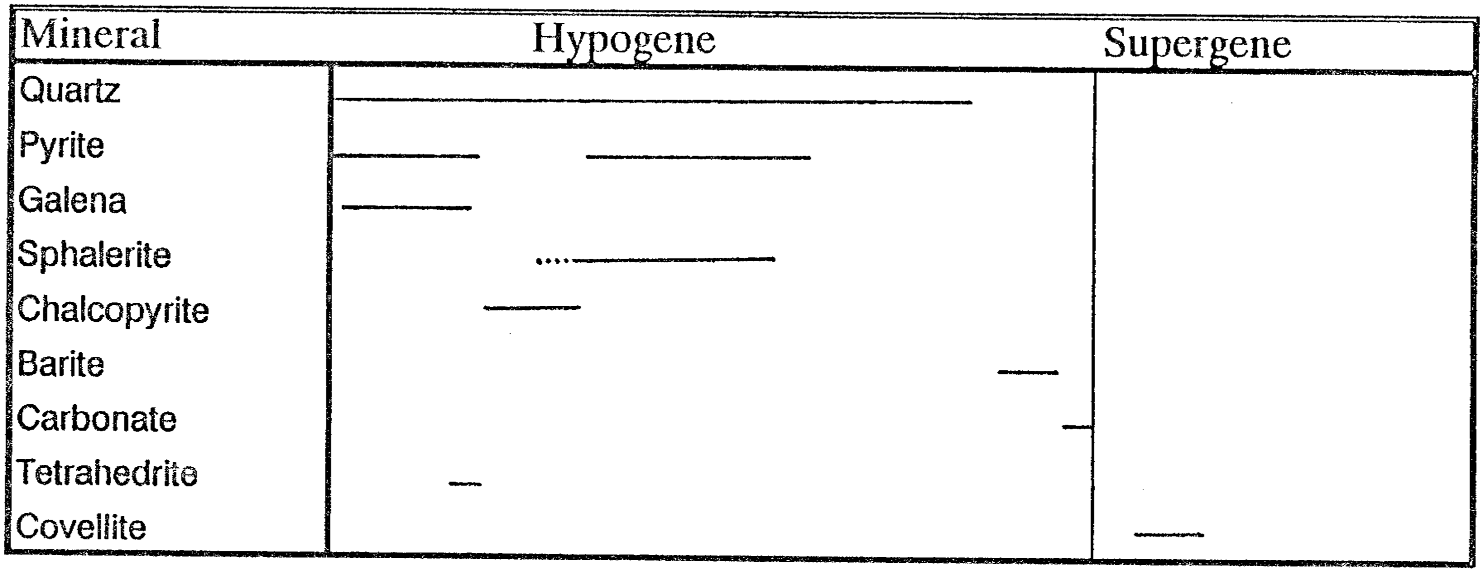


Figure 5. Composite paragenetic diagram for the Ag-Pb-Zn deposits.

is 50 to 75 percent of the vein material as compared to 2 percent sulfide material in the gold deposits. The second is the lack of any gold in the Ag-base metal deposits. Wall rock alteration associated with the Ag-base metal mineralization is similar to that seen with the gold deposit. However, the visible alteration, comprised of sericite and pyrite, is somewhat more extensive (up to 1 m from the vein). In addition, post-mineralization movement along these vein structures has lead to extensive oxidation, as well as the development of fault gouge in the deposits.

A small group of deposits differs from the other Ag-base metal deposits in mineralogy, texture and style to warrant their description as a sub-group, and they appear as a separate deposit type in the data set. These deposits occur along northeast and northwest shear zones in the Bonito Lake stock. Mineralization consists of abundant quartz and barite with lesser amounts of argentiferous galena, sphalerite and pyrite. They exhibit little or no visible wall rock alteration, which if present consists of minor sericite and pyrite. Little, if any production has occurred from these areas and most are just prospects. In general, the working of the Ag-base metal deposits are limited, with only the Crow and Renowned O.K. being moderately developed. While some rich pockets of silver were discovered in the late 1950's, little work has been done on the deposits since the late 1960's or early 1970's

(Alan Porter, per. comm., 1991). These deposits lack the high silver grades and large tonnages needed to sustain even a medium sized operation.

Sampling and Analytical Procedures

Sampling

Samples were collected from twenty mine sites or prospects in the district, and from three drill cores (Figure 2). Where possible, samples were collected in place. However, due to the dilapidated nature of most of the mine workings, this was often impossible and samples had to be collected from the dumps. Since most of the samples were collected from dumps, care was taken in sampling to insure that a representative sample was obtained. The three cores were from a hole drilled at the Vera Cruz and from two holes drilled in the Rialto stock, NP-4 and N-20. Drill core and their accompanying log are stored at the New Mexico Bureau of Mines and Mineral Resources in Socorro, New Mexico. Promising intervals of mineralization in the core, based on the core logs, were examined and those suitable for fluid inclusion and stable isotope work were used.

Since paragenetic control from sample sites was somewhat weak, efforts were made to analyze different phases of a mineral, both petrographically and isotopically. Quartz was the only abundant mineral that had a wide distribution and showed different textures. It was found that early stage quartz was clearer and more amenable to fluid inclusion work and later stage quartz was cloudy, or milky, and contain no inclusions. The differences in appearance were used to separate the different types of quartz for isotope analyses. Appendix A contains detailed descriptions of the sample sites, hand samples and fluid inclusion sections.

Fluid inclusion and stable isotope data are divided into four deposit types in this study. These four are the different deposit types described in the last section: disseminated Mo-Cu mineralization, gold deposits, Ag-base metal vein, and shear zone deposits. This classification is based on style of mineralization and deposit mineralogy. Two deposits, the Jenny Linn and drillhole NP-4, were originally thought to be related to gold mineralization at the Parsons, due to their proximity to the Parsons and because they are in the same brecciated part of the Rialto stock that contain the Parsons. No evidence was found that indicated that these deposits were related to gold mineralization, or any other style of mineralization noted in this study. Consequently, they were combined with the Fulmer(Rialto) deposit and drillhole N-20 to form a group called "Deposits of the Rialto". This was done as the deposits share a common host rock (the Rialto stock) and the deposits occur in a similar textural style (breccias).

Analytical Procedures

Fluid inclusion thermometric analyses were made on a Linkham THMS-600 stage with a TP-91 electronic controller. The stage was calibrated using a synthetic CO_2 inclusion, a synthetic water inclusion, caffeine crystals and potassium dichromate crystals. The stage was accurate within 0.1°C at 0.0°C and 4°C at 400°C.

Oxygen was extracted from quartz and whole rock samples with chlorine trifluoride and converted to CO_2 according to the procedures described by Clayton and Mayeda (1963) and Borthwick and Harmon (1982). Isotopic measurements were made on a Finnigan MAT Delta E mass spectrometer. The data is reported as per mil deviation ($\delta^{18}O$ ‰) relative to SMOW. NBS-28 quartz was used as a standard test and yielded an average $\delta^{18}O_{SMOW}$ of 9.72 per mil, compared to the reported value of 9.64 per mil. Oxygen isotope analyses of NBS-28 were reproducible to better than ± 0.1 per mil. Duplicates of most quartz samples were run and were found to be reproducible to ± 0.3 per mil.

Carbon and oxygen isotope compositions were determined for several carbonate samples using the phosphoric acid technique (McCrea, 1950). Carbon isotope compositions are reported in standard delta notation ($\delta^{13}C$ ‰) relative to PDB. Oxygen values are reported as an acid corrected $\delta^{18}O$. A calcite of a known value was analyzed as an in-house standard and compared to NBS-18 and NBS-20. Precision of the oxygen and carbon isotope analyses is better than ± 0.1 per mil.

Sulfur isotope analyses were performed on monomineralic sulfide samples. The sulfide samples were oxidized to SO_2 by roasting them in the presence of cupric oxide. Any SO_3 was converted to SO_2 by passage over hot copper wool. Recovery of converted sulfide samples was greater than 97 percent. Samples were run against NBS 123 sphalerite standard then corrected to CDT, and are reported in standard delta notation ($\delta^{34}S$ ‰). Canyon Diablo Troilite, a synthetic galena and a galena of known value were run as secondary standards. The NBS-123 sphalerite had a measured value of 17.4 ± 0.1 per mil based on repeat analyses, compared to the given value of 17.32 per mil $\delta^{34}S$. The accuracy of secondary standards was less than ± 0.4 per mil. The precision of the sample analyses was less than ± 0.2 per mil based on repeat analyses.

Alteration Study

Regional Alteration

The multiple intrusive and extrusive events of the area have left the majority of the rocks altered to some degree. Both the type and extent of alteration in the district is highly variable.

The volcanic rocks of the Walker Andesite have been weakly propylitically altered on a regional basis (Giles and Thompson, 1972 and Thompson, 1972). Thompson (1972) concluded that this hydrothermal alteration of the andesites was related to the intrusive events in the area. Four unweathered andesite samples were collected in the district (FA 1-3 and FA 5; see Figure 2 for location). Petrographic and chemical analysis of FA 1 and FA 2 was performed as part of the vein alteration study and was not performed on the other andesite samples. Sample FA 1 shows alteration of the K-feldspars with the mafic minerals being heavily altered and replaced by epidote and chlorite. Sample FA 2 shows minor alteration of the K-feldspars (less than 10%), while the mafic minerals are heavily altered. The chemical composition of FA 2 can be considered as the baseline andesite composition from the Sierra Blanca complex, with respect to the regional alteration of the andesites. These samples were also used to compare the isotopic values of the regionally, propylitically altered andesite to the isotopic values of rocks associated with vein alteration (see next section). The samples ranged in composition from 5.9 per mil to 0.0 per mil $\delta^{18}O$. Samples FA 2 and FA 5 were collected near the periphery of the volcanics and have isotopic compositions of 5.6 and 5.9 per mil $\delta^{18}O$ respectively. The remaining samples, FA 1 and FA 3, were collected in the interior of the complex and have isotopic compositions of 3.9 and 0.0 per mil $\delta^{18}O$ respectively. These whole rock isotope values are all depleted relative to an average oxygen isotope value of 6.2 per mil $\delta^{18}O$ for andesites, trachytes and syenites as determined by Taylor (1968). To calculate the isotopic composition of alteration fluids that would have been in equilibrium with these rocks, the fractionation between K-feldspar and water was assumed to be representative of water/whole rock fractionation. A temperature of 240^{o}C was chosen as a representative for the propylitic alteration, or regional low-grade greenschist facies metamorphism of the andesites (Turner, 1981). Alteration fluid $\delta^{18}O$ values of -0.7 to 6.6 per mil $\delta^{18}O$ were calculated using the K-feldspar-water fractionation equation (Matsuhisa et al., 1979). See Table 1 for a summary of isotopic and chemical data from these samples.

The trachyte and latite flows, overlying the Walker Andesite, are free of the regional, hydrothermal alteration and have not been intruded by any dikes (Griswold and Missaghi, 1964; Giles and Thompson, 1972 and Thompson, 1972). Samples FA 4a and FA 4b were collected on the slopes of Nogal Peak, in the trachyte flows. These samples had isotopic values of 6.1 and 8.9 per mil $\delta^{18}O$ respectively.

All the stocks exhibit some form, or forms, of alteration, which is highly variable in extent. The stocks contain areas of strong localized alteration, such as those associated with Cu-Mo mineralization in the Rialto and Three Rivers stocks, and gold mineralization in the Bonito Lake stock. They also contain broad areas of potassic and propylitic alteration, such as in the Bonito Lake stock

(Allen and Foord, 1991). Much of this broad alteration in the stocks may be deuteric in nature, as Thompson and Giles (1972) have shown that all the intrusive phases of the Three Rivers stock have undergone deuteric alteration.

Vein Alteration

In order to better characterize the alteration associated with vein mineralization, samples were examined from one gold deposit (the Helen Rae) and one Ag-base metal deposit (the Crow). Unweathered samples were taken every six inches out to three feet, then taken every three feet or so (where possible) out to 30 feet from the vein. The vein alteration traverse samples were prepared and analyzed petrographically, isotopically, and chemically (Table 1).

Petrographically, samples from both traverse sites show a progressive sericitization of feldspar phenocrysts and groundmass and the loss of mafic minerals as the vein is approached. These losses are accompanied by the addition of chlorite, calcite, quartz, pyrite, and iron oxides. At the Helen Rae, a steady progression of alteration is seen from 30 feet from the vein to 18 feet from the vein. This is characterized by the alteration of the feldspar phenocrysts and the mafic minerals. Between 15 and 18 feet from the vein, the feldspar groundmass becomes completely altered and the mafic minerals disappear. At this point to within a foot and a half of the vein, alteration is characterized by

Table 1: Isotopic and Chemical Data from the Vcin Alteration Study

Sample	HR 1	HR 2	HR 3	HR 4	HR 5	HR 6	HR 7	HR 8	HR 9	HR 10	HR 11	HR 12	HR 13	HR 14	HR 15
Distance from Vein(ft)	0.5	1	1.5	2	2.5	3	6	9	12	15	18	21	24	27	30
Delta 18 O	7.6	6.1	6.0	5.4	4.8	5.4	5.0	4.3	4.4	4.0	4.0	3.7	3.7	3.2	2.6
SiO2 %	45.793	38.204	40.885	46.393	44.587	45.145	44.931	46.603	46.026	41.874	47.651	46.947	47.265	47.744	46.742
Al2O3 %	15.070	14.157	14.617	16.091	17.196	16.482	15.738	14.757	15.671	14.231	17.468	17.692	19.106	18.104	18.078
Fe2O3 %	7.197	8.476	8.906	8.332	9.736	9.184	8.424	7.705	8.728	7.416	9.956	9.679	9.930	10.033	10.186
MgO %	1.791	4.802	2.029	5.676	3.274	2.594	5.676	7.723	7.373	8.436	5.612	5.909	5.126	5.228	6.364
CaO %	10.134	11.325	11.888	6.061	9.655	8.315	6.686	7.813	8.290	8.894	8.200	9.105	7.736	9.028	8.273
Na2O %	2.627	2.269	2.370	4.321	3.644	2.014	3.854	4.661	6.029	4.373	2.890	3.104	3.663	3.623	3.942
K2O %	3.478	3.293	3.108	1.696	2.306	4.129	2.567	1.200	0.960	1.479	2.240	1.393	1.623	1.637	1.190
TiO2 %	1.039	0.962	1.010	1.131	1.191	1.119	1.093	0.975	1.045	0.948	1.172	1.218	1.207	1.213	1.258
MnO %	0.151	0.188	0.187	0.135	0.156	0.177	0.137	0.172	0.170	0.193	0.144	0.171	0.154	0.175	0.170
P2O5 %	0.454	0.410	0.425	0.471	0.497	0.499	0.466	0.428	0.458	0.398	0.487	0.504	0.534	0.515	0.498
LOI %	12.075	16.677	13.453	10.232	8.990	10.703	11.182	10.326	8.624	11.038	4.670	4.201	3.921	3.639	3.624

Sample	CR 1	CR 2	CR 3	CR 4	CR 5	CR 6	CR 7	CR 8
Distance from Vein(ft)	0.5	1	1.5	2	2.5	3	8	13
Delta 18 O	5.3	4.9	3.8	3.3	2.8	2.7	1.9	2.1
SiO2 %	63.991	63.333	61.909	61.696	62.812	60.97	60.713	57.188
Al2O3 %	17.512	17.263	16.265	16.909	16.969	16.726	16.617	16.993
Fe2O3 %	3.319	4.246	4.829	4.636	5.073	4.510	3.663	6.375
MgO %	0.983	0.837	1.151	1.496	2.467	0.656	1.490	2.708
CaO %	0.298	0.607	1.235	1.806	2.062	1.191	1.231	2.422
Na2O %	3.274	4.012	4.897	4.650	5.177	5.675	6.478	4.699
K2O %	5.710	5.064	4.269	3.687	3.433	4.059	3.342	2.073
TiO2 %	0.812	0.844	0.804	0.798	0.860	0.761	0.813	1.258
MnO %	0.113	0.062	0.103	0.124	0.118	1.909	1.751	0.129
P2O5 %	0.306	0.324	0.379	0.4	0.472	0.399	0.432	0.65
LOI %	3.266	2.939	2.12	1.961	1.903	2.903	2.443	2.382

FA 1	FA 2
0.7	5.6
54.201	47.100
17.279	19.978
7.969	10.250
4.101	3.747
4.839	6.847
4.009	3.789
3.699	0.924
1.482	1.485
0.174	0.145
0.629	0.622
2.248	3.539

severe alteration of the feldspar phenocrysts, the complete alteration of the groundmass, and the addition of opaque minerals, chlorite, and abundant calcite. At eighteen inches from the vein, alteration becomes so complete that even the ghost remnants of the feldspar phenocrysts can no longer be recognized. At the same time, chlorite disappears from the alteration assemblage and the amount of Fe oxides and other opaques in the rock decreases. Quartz is only seen in the samples immediately adjacent to the vein.

At the Crow, samples show a steady, progressive alteration that differs from that at the Helen Rae. From thirteen feet from the vein inward, the rocks show a progressive increase in seriticization of feldspars, from 20 percent at 13 feet to 80 percent immediately adjacent to the vein. This is accompanied by a progressive increase in the amount of quartz, chlorite, Fe oxides and opaques. Both quartz and chlorite are seen in the sample taken 13 feet from the vein, with quartz constituting upwards of 20 percent of the sample; and the abundance of these mineral in the samples only increases further as the vein in approached.

Isotopically, both vein traverses show enrichment near the vein and a progressive isotopic depletion outward from it. At the Helen Rae, whole rock samples ranged from 7.5 per mil near the vein to 3.6 per mil $\delta^{18}O$ thirty feet from the vein (Figure 6). Starting six inches from the vein at

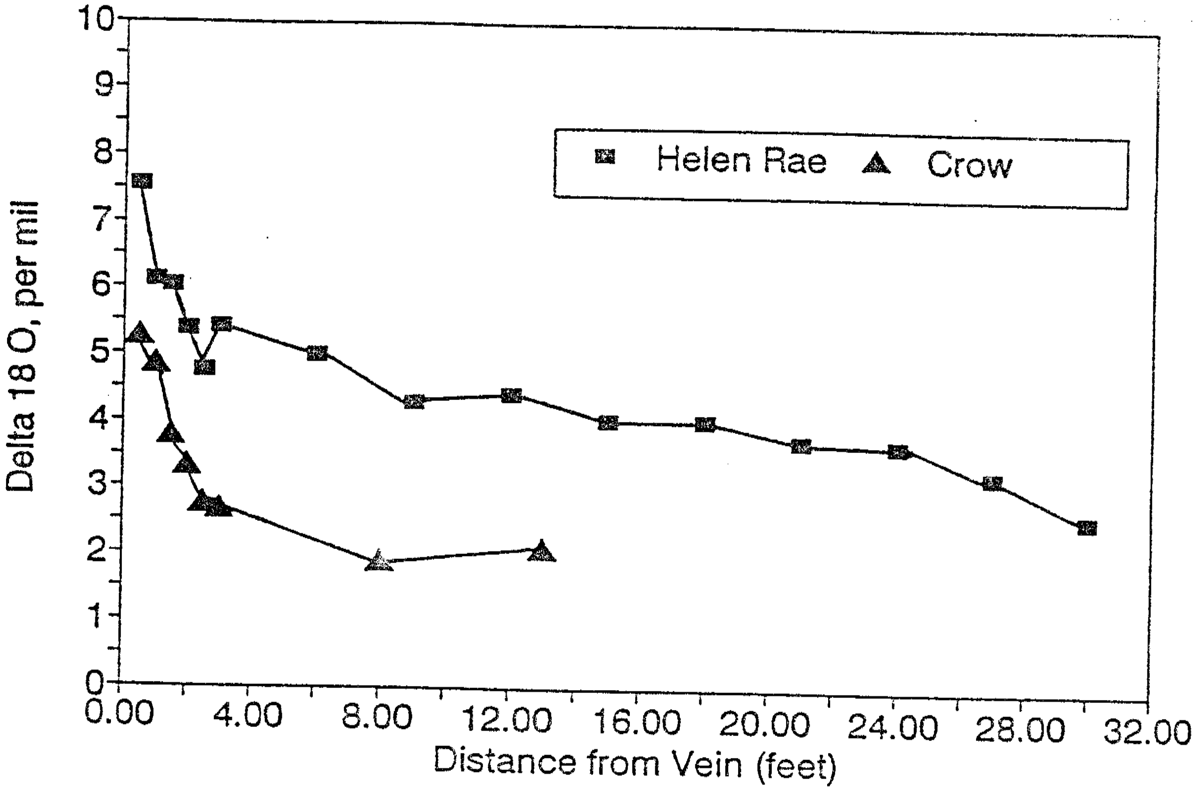
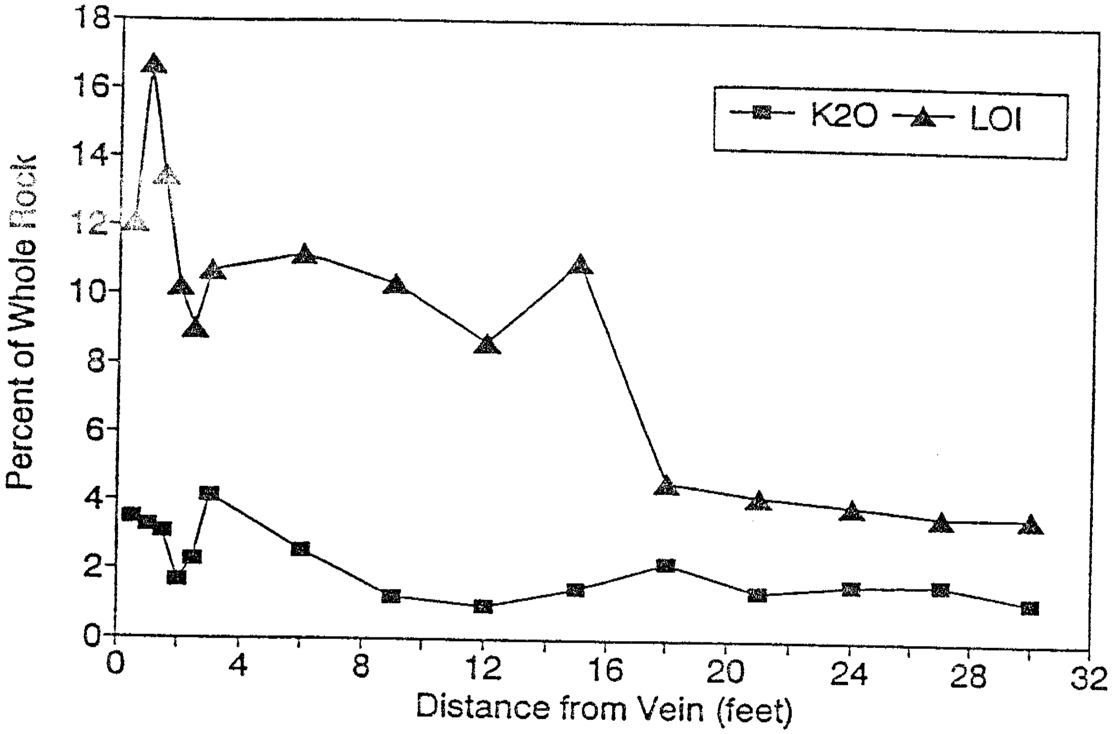


Figure 6. Profile of whole rock $\delta^{18}O$ values from vein alteration traverses.

7.5 per mil $\delta^{18}O$, the isotopic composition of the samples quickly drops to 4.7 per mil $\delta^{18}O$ only to rebound slightly to 5.4 per mil $\delta^{18}O$ before gradually decreasing. This dip corresponds to sample HR 5, which is petrographically slightly less altered than surrounding samples and more like sample HR 9 at 12 feet from the vein. From three feet to thirty feet out from the Helen Rae vein, the isotopic content of the rocks gradually decreases from 5.4 per mil $\delta^{18}O$ to 3.6 per mil $\delta^{18}O$. At the Crow, the samples ranged from 5.3 per mil near the vein and gently curve down to 2.1 per mil $\delta^{18}O$ thirteen feet from the vein (Figure 6). Figure 6 shows that the $\delta^{18}O$ values at the Crow are all depleted relative to the corresponding samples at the Helen Rae.

The samples were analyzed by XRF for their major oxide content (Table 1). The Helen Rae samples show major oxide compositions that are highly variable within three feet of the vein, becoming less variable farther out and are finally stable past eighteen feet (Figure 7). The loss on ignition (LOI) also shows this same pattern. The data indicates that K_2O and CaO is enriched near the vein, where as Fe_2O_3, MgO, and Na_2O are depleted near the vein. The SiO_2 content varies sharply in places, but overall is constant from near the vein out to thirty feet. The Crow samples show the major oxide composition sharply vary out to three feet, become stable out to eight feet and then varying again out to thirteen feet (Figure 8). At the Crow, K_2O is also



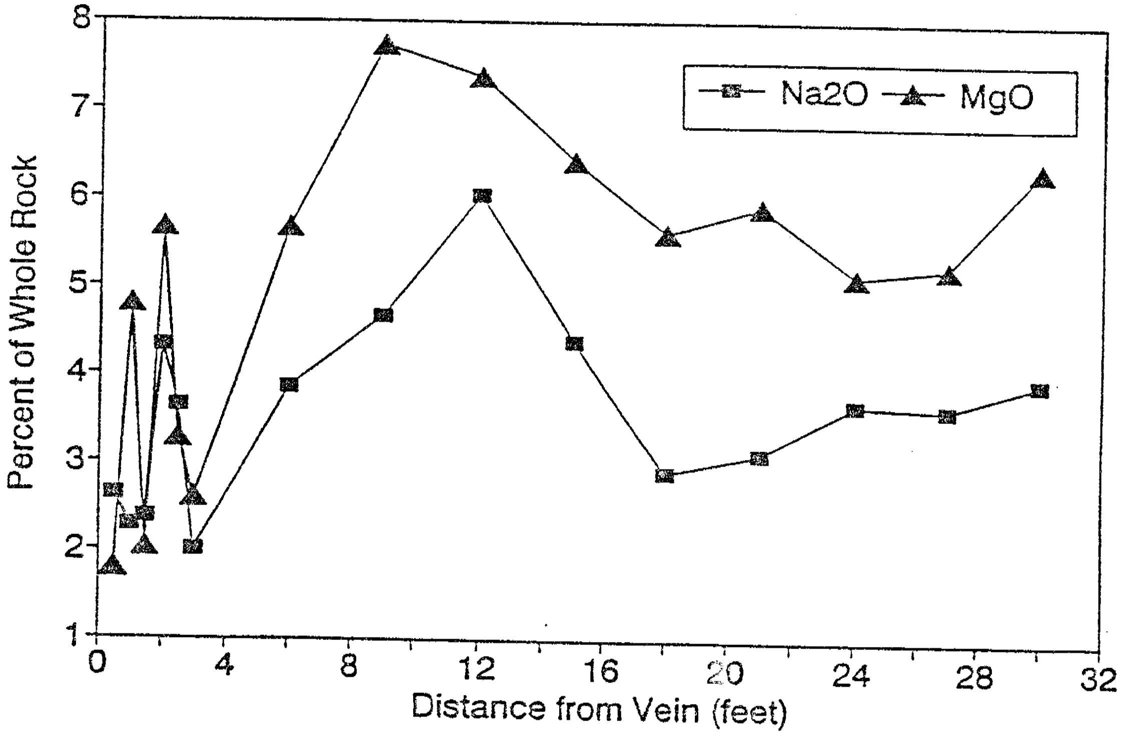


Figure 7. Profiles of selected major oxide content from the vein alteration traverses at the Helen Rae (Au).

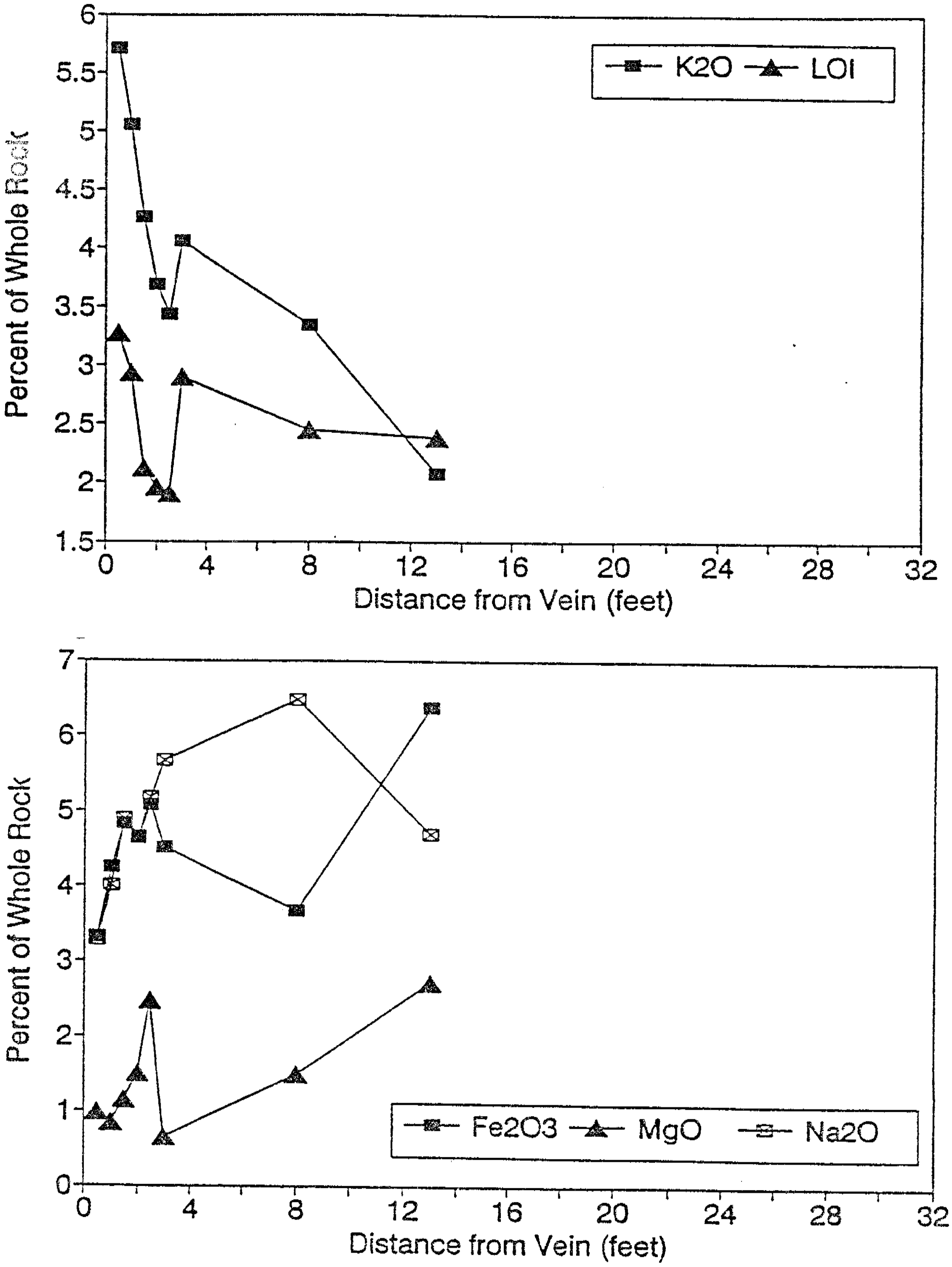


Figure 8. Profiles of selected major oxide content from the vein alteration traverse at the Crow (Ag-Pb-Zn).

enriched near the vein and Fe_2O_3, MgO, Na_2O, and CaO all are depleted near the vein. The LOI pattern is similar to the K_2O pattern and is lower than the LOI at the Helen Rae. Oxide compositions were normalized to Al_2O_3 to determine relative enrichments or depletions due to alteration. Elements from both sites retained their un-corrected distribution patterns, with the exception of SiO_2 from the Crow. Figure 9 shows the difference between SiO_2 and SiO_2/Al_2O_3 values from the Crow.

Fluid Inclusion Data

Description

Samples of quartz, sphalerite, and calcite from twenty-one different sites were used in this study. From these sites, seventy-six doubly-polished sections were prepared but only forty-four contained acceptable fluid inclusions for analysis. Roedder's (1984) recognition characteristics of primary versus secondary were used in this study. Inclusions ranged in size from 50 μm to 4 μm with an average size of 18 μm. Inclusions 8 μm or larger were used for analysis. In most deposits, the predominant fluid inclusions are two phase aqueous inclusions with liquid dominant over vapor (Type I). However, in quartz crystals from the Waterdog breccia other types of inclusions occur (see Figure 10), such as: two phase vapor dominant inclusions (Type II); three phase (H_2O liquid + vapor + halite; Type III); and multi-phase (H_2O liquid + vapor +

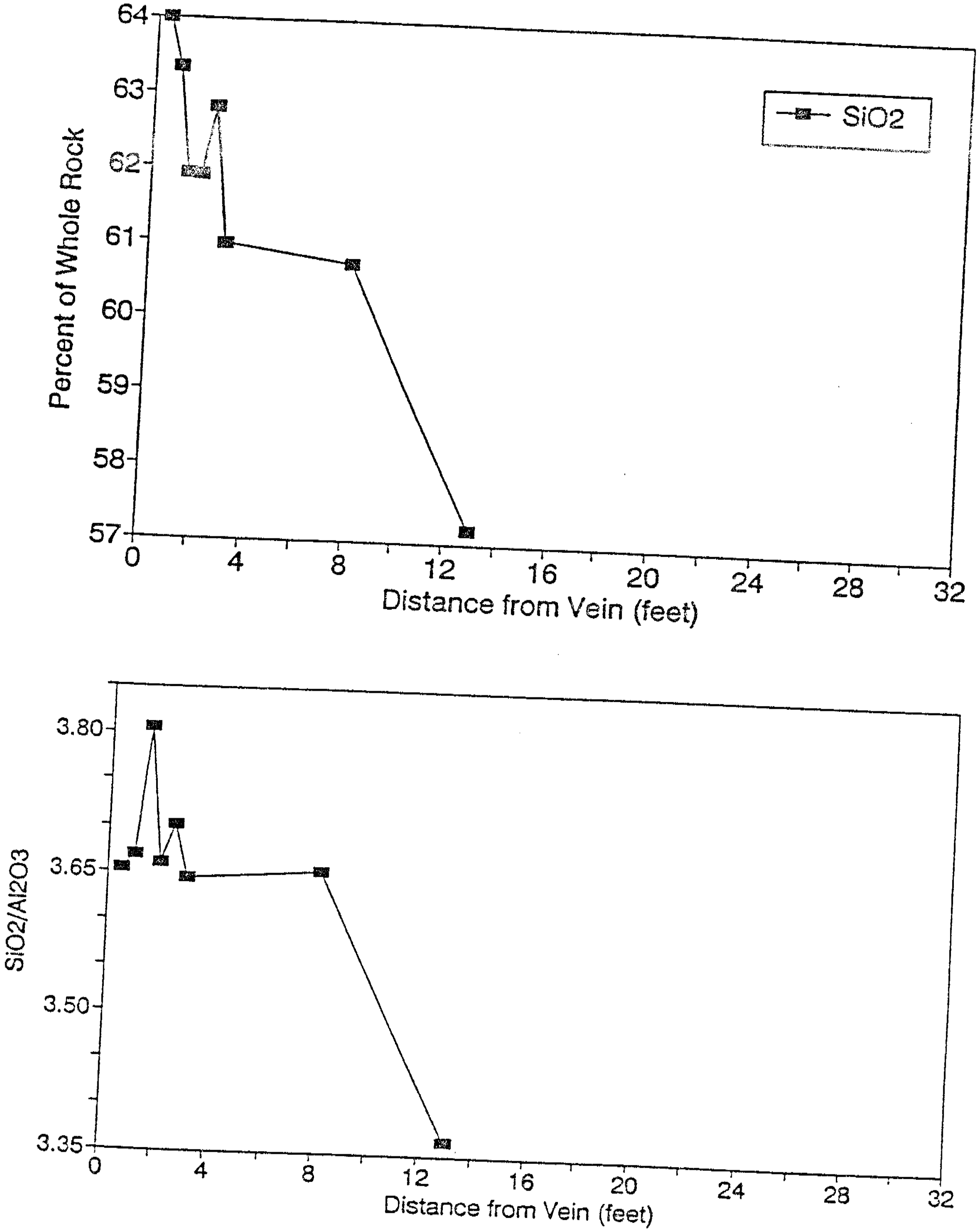
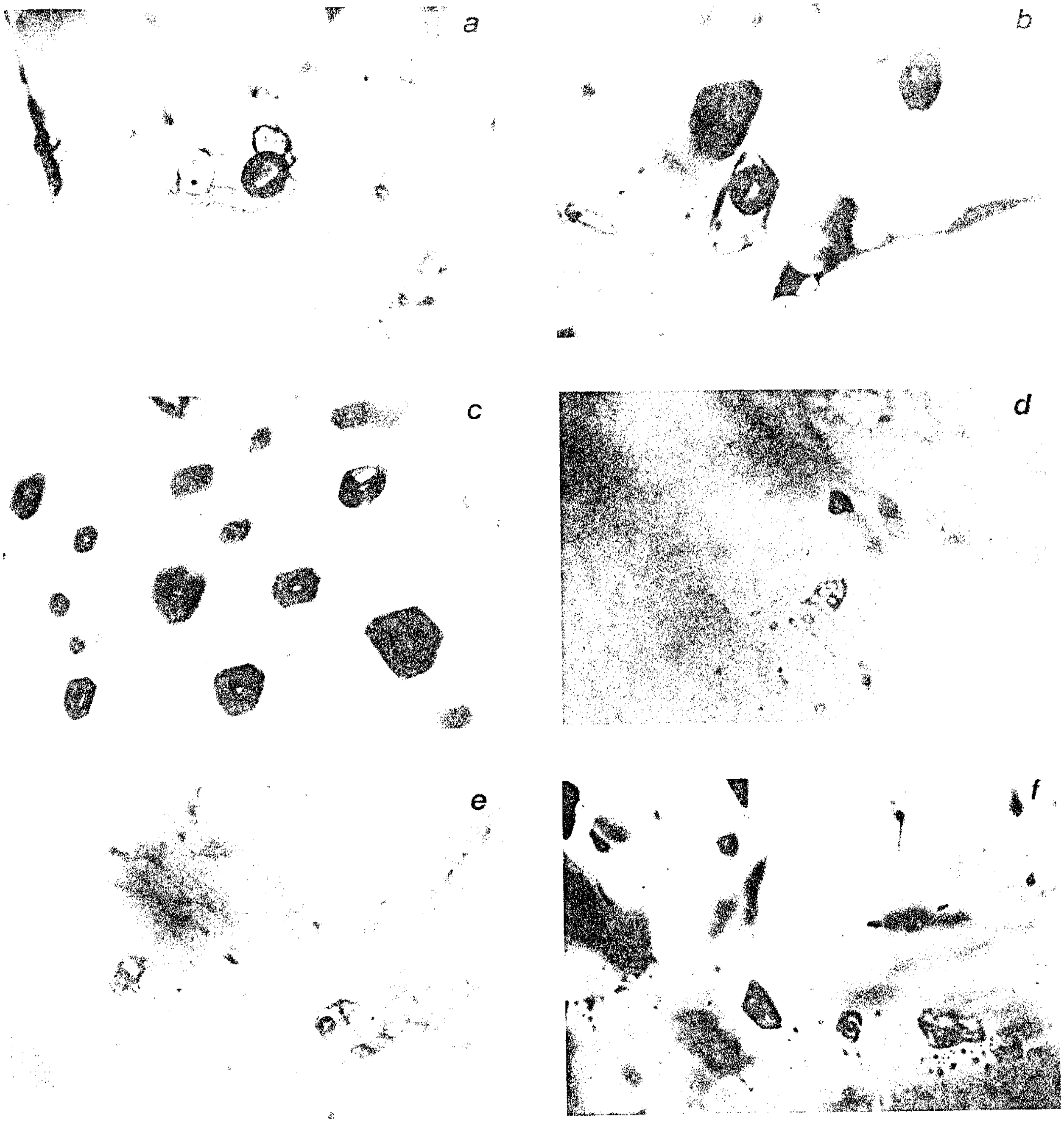


Figure 9. Top - Profile of SiO_2 content of vein alteration samples from the Crow. Bottom - Ratio of SiO_2 to Al_2O_3 in the same samples.

Figure 10. Plate of fluid inclusion types: (a) Type IV primary inclusion from the Waterdog, x20; (b) Large type I secondary inclusion from the Waterdog, x20; (c) Vapor dominated (type II) secondary inclusions from the Waterdog, x20; (d) Type IV primary inclusion from the Helen Rae, x40, unpublished photo from Campbell et al., 1991; (e) Type I primary inclusions from the Rockford, x10; and (f) Type I primary inclusions from the Jenny Linn, x10.


a
b
c
d
e
f

halite + sylvite ± up to 3 unidentified daughter minerals; Type IV).

Geothermometry and Fluid Composition

In this study, 419 homogenization temperature were measured from 44 different slides, representing 34 samples. On average, between 18 and 24 measurements were made on primary and secondary inclusions from each deposit. Homogenization temperatures for all inclusions measured range from 100°C to 538°C, with primary inclusions in quartz ranging from 188°C to 538°C. A representative homogenization temperature for each deposit was obtained by determining the mode Th from a histogram. For deposits that did not contain suitable fluid inclusion material, the average temperature for that deposit type is used for isotope calculations. Of the 419 Th measurements, 264 paired Tm measurements were made. Salinities for types I and II inclusions were determined by the freezing point depression method and were converted to weight percents using Bodnar's (1992) revised freezing point depression chart. Salinities for types III and IV were calculated on FLINCOR using the halite dissolution temperatures (Brown, 1982). Salinities range from 2 to 50 eq. wt. % NaCl. Ore stage quartz from the Helen Rae was unobtainable, so fluid inclusion data for the Helen Rae-American is taken from Campbell et al. (1991). Table 2 lists the mean homogenization temperature and salinity for each deposit, Appendix E gives a detailed

Table 2: Mean Th and Salinity Data by Deposit

Sample Location	Mineral	Type of Inclusion	Mean Th degrees C	Salinity eq.wt.% NaCl
Gold Deposits				
Vera Cruz	Qtz 1	I, Pri	310	5
Helen Rae	Qtz 1	I, Sec	160	4
Rockford	Qtz 1	I, Pri	230	6
Parsons	Qtz 1	I, Pri	250	3
Waterdog	Qtz 1	IV, Pri	490	45
		III, Pri	450	40
		I+II, Sec	320	6
Silver-Lead-Zinc Deposits				
Martha Washington	Qtz 1	I, Pri	240	6
Crow	Qtz 1	I, Pri	250	3
Renowned O.K.	Qtz 1	I, Pri	290	4
		I, Sec	157	
Spur	Qtz 1	I, Pri	300	3
Maud	Qtz 1	I, Pri	240	6
		I, Sec	190	
Argentine	Qtz 1	I, Pri	270	8
		I, Sec	210	6
Mayberry	Sph	I, Sec	180	11.5
	Qtz 1	I, Pri	230	3
		I, Sec	160	5
Silver Plume	Calcite	I, Pri	220	2.5
Deposits Related to Porphyry Mineralization				
Jennie Linn	Qtz 1	I, Pri	200	6
		I, Sec	220	3
Drillhole NP-4				
435 ft.	Qtz 1	I, Pri	240	3
533 ft.	Qtz 1	I, Pri	255	5
Drillhole N-20 164 ft	Qtz	I, Pri	350	?
Shear Zone Deposits				
Rock No. 1	Qtz 1	I, Pri	357	10
		I, Sec	140	9
Soldier	Qtz 1	I, Pri	240	10
		I, Sec	175	10
Hope	Qtz	I, Pri	260	

summary of fluid inclusion data, and Appendix F lists individual inclusion data points by site.

Homogenization temperatures for primary inclusions in quartz from the gold deposits range from 224°C to 538°C. An average temperature for these deposits of 260°C, excluding data from the Waterdog (Figure 11). Individual gold deposits have mean homogenization temperatures of: 310°c at the Vera Cruz; 250°C at the Helen Rae-American; 230°C at the Rockford; 250°C at the Parsons; and 480°C at the Waterdog. The salinities of these deposits range from 2.6 to 9.4 eq. wt. percent NaCl with a mean salinity of 5 eq. wt. percent NaCl, except the primary inclusions of the Helen Rae (Figure 12). The primary, type III inclusions at the Helen Rae vary from 18 to 35 eq. wt. percent NaCl (Campbell et al., 1991). Secondary inclusions from the Helen Rae were measured in this study and have a mean Th of 160°C and a mean salinity of 4 eq. wt. percent. C-axis sections of euhedral quartz crystals from a breccia body on the Waterdog contain many large, high temperature-high salinity inclusions. Type III inclusions have an mean Th of 450°C and type IV inclusions an mean Th of 480°C. Type III inclusions from the Waterdog range in salinity from 38 to 42 eq. wt percent NaCl, and the type IV inclusions vary from 40 to 50 eq. wt. percent NaCl (Figure 12). Secondary Type I and Type II inclusions were also measured in the quartz from the Waterdog. They appear to be co-genetic with each other; having a mean Th of 320°C

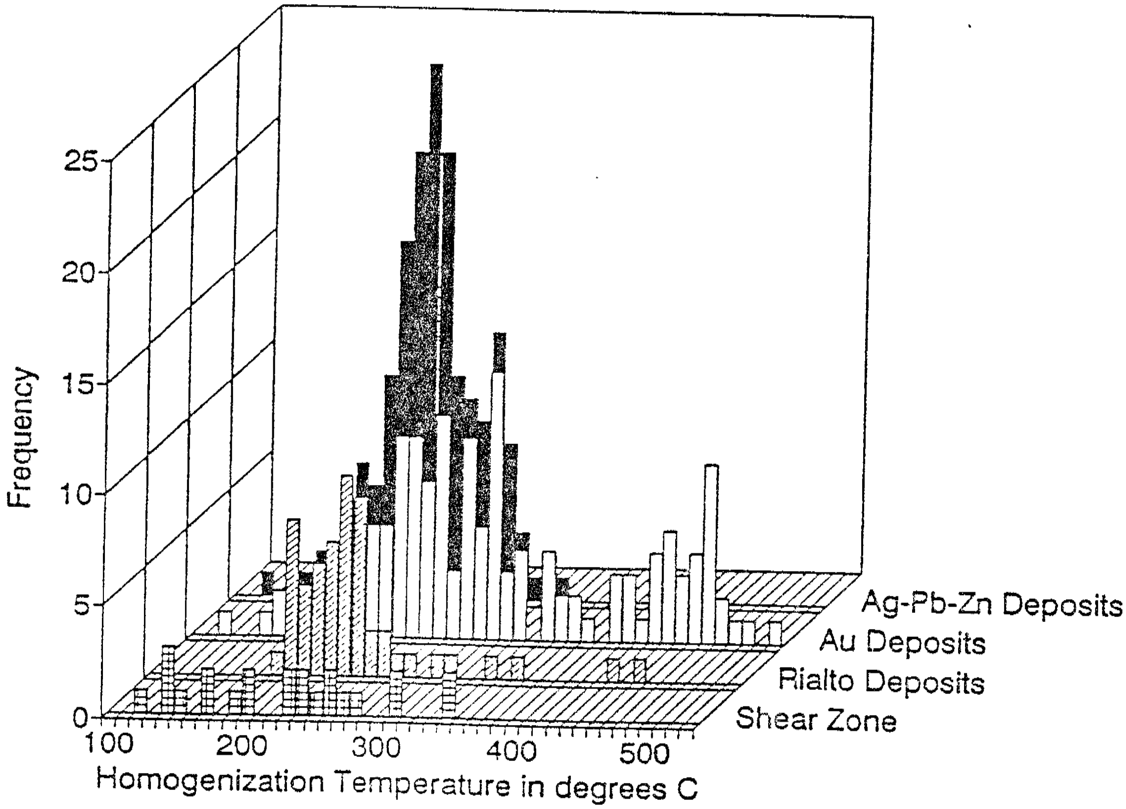


Figure 11. Fluid inclusion Th histograms by deposit type.

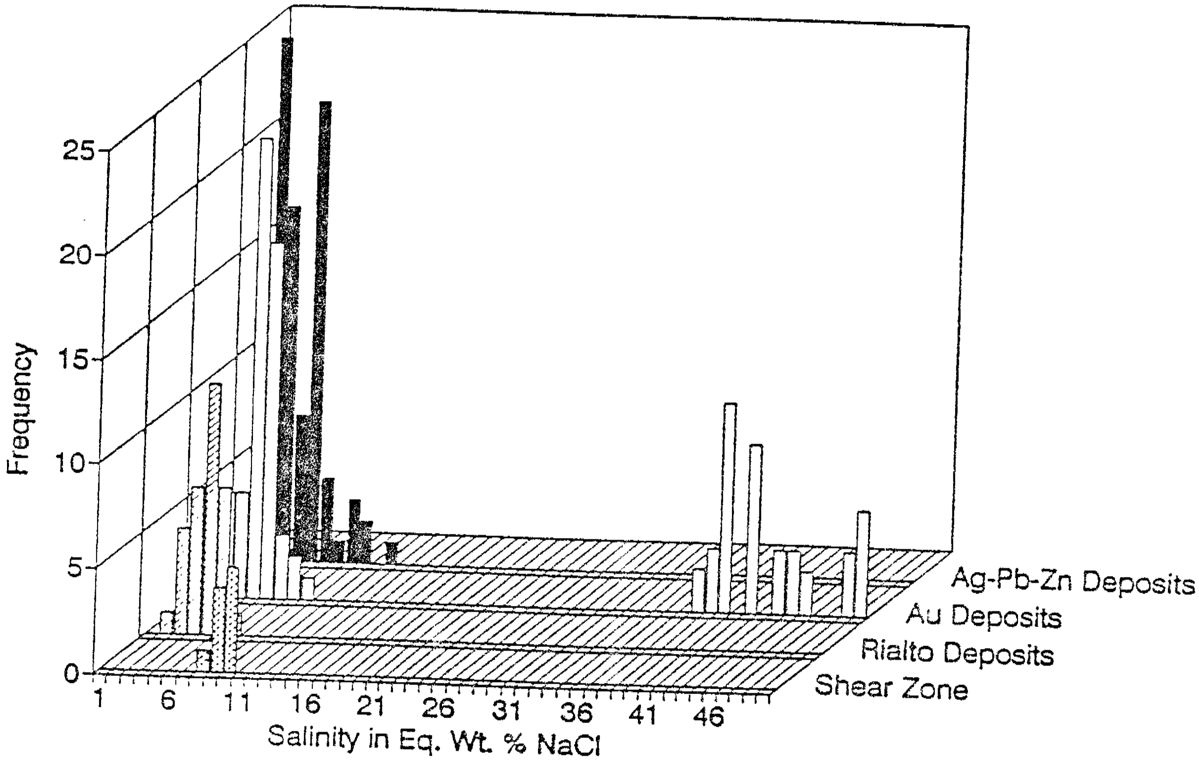


Figure 12. Fluid inclusion salinity histograms by deposit type.

and a mean salinity of 6 eq. wt. percent. Material from the Great Western was not suitable for fluid inclusion analysis and was assigned an average temperature of 260°C for the purpose of isotopic calculations.

Homogenization temperatures for primary inclusions in vein quartz from the silver-lead-zinc deposits range from 188°C to 416°C with an average temperature for these deposits of 240°C (Figure 11). Deposits have mean homogenization temperatures of: 240°C at the Martha Washington; 250°C at the Crow; 290°C at the Renowned O.K.; 300°C at the Spur; 240°C at the Maud; 270°C at the Argentine; and 230°C at the Mayberry. The salinities of these deposits range from 2.4 to 18 eq. wt. percent NaCl with a mean of 4 eq. wt. percent NaCl (Figure 12). Secondary inclusions in sphalerite from the Mayberry were measured. They have a mean Th of 180°C and an average salinity of 11.5 eq. wt. percent NaCl. Calcite from the Silver Plume contained inclusions that have a mean Th of 220°C and an average salinity of 2.5 eq. wt. percent NaCl. Quartz from the Silver Plume was not suitable for fluid inclusion analysis.

Inclusions in quartz from the shear zone deposits range in temperature from 127°C to 359°C (Figure 11). Quartz from the Rock No.1 contained two primary inclusions with a mean Th of 357°C, as well as several secondary with a range in Th from 127°C to 205°C. Quartz from the Soldier contains primary inclusions that have a mean Th of 240°C. Two questionable primary inclusions were measured in quartz from the Hope prospect; they have an average temperature of 280°C. Inclusions from these deposits have an average salinity of 10 eq. wt. percent NaCl (Figure 12).

Temperature from quartz of the porphyry related deposits range from 194°C to 460°C (Figure 11). Inclusions in quartz from the Jenny Linn have a mean Th of 220°C and an average salinity of 6 eq. wt percent NaCl. Euhedral quartz crystals where collected from the 435 ft. and 533 ft intervals of the NP-4 drillhole. The 435 ft. interval has a mean Th of 240°C and an average salinity of 3 eq. wt percent NaCl. The 533 ft interval has a mean Th of 255°C and an average salinity of 5 eq. wt percent NaCl. A small quartz veinlet from the 164 ft. interval of the N-20 drillhole near the Fulmer(Rialto) was looked at for fluid inclusions. The quartz contained badly decripitated inclusions, some with daughter minerals. This quartz yielded questionable Ths ranging from 323°C to 460°C and averaging around 350°C. Samples from the Fulmer(Rialto), proper, were not suitable for fluid inclusion analysis and the quartz was assigned an estimated temperature of 350°C.

Inclusion Gas Data

Samples from three gold deposits (Helen Rae, Rockford, and the Waterdog) and from three silver-base metal deposits (Crow, Spur, and the Mayberry) were crushed and their gas content measured on a quadrapole mass spectrometer. Data from these crushes was corrected for background and converted to mole percents (Table 3). The H_2S-SO_2 ratio of each sample is considered the approximate ratio in the fluids during sulfide deposition, and was used to calculate the total δ^{34} S from sulfide minerals of these deposits.

Stable Isotope Data

Samples of quartz, sulfide, and carbonate mineralization, along with whole rocks associated with mineralization were isotopically analyzed. Table 4 lists the isotopic value of quartz, sulfides, and carbonates. Appendices B, C, and D give detailed summaries of the isotope data for the different minerals.

Oxygen Isotopes

Oxygen isotopes from the quartz of the gold deposits have a range of 3.9 to 12.5 per mil δ^{18}O. No statistical difference in the stable isotope data or the fluid inclusion data was seen between gold breccia deposits and gold vein deposits. Quartz from the breccias of the Vera Cruz, Waterdog and Great Western, and primary vein quartz from Helen Rae all have a δ^{18}O over 10 per mil. Primary vein quartz from the Rockford, to the south of the Helen Rae-American, has an average δ^{18}O value around 8 per mil. The lowest δ^{18}O for quartz from a gold deposit is 3.9 per mil from the Parsons breccia. Secondary quartz from the Helen Rae and the Waterdog have δ^{18}O values of 7.4 and 9.4 per mil, respectively.

Table 3: Gas Analyses from Fluid Inclusions

	Gold Deposits			Ag-Pb-Zn Deposits		
	Waterdog	Helen Rae	Rockford	Crow	Spur	Mayberry
H2O	99.54234	97.22558	97.37252	98.37692	97.02027	95.77710
N2	0.20971	1.34510	1.07340	0.26198	0.39125	0.59387
CO2	0.12216	1.24988	1.12822	1.21301	2.40828	2.94960
O2	0.01794	0.00480	0.08836	0.00613	0.00271	0.21894
SO2	0.00165	0.01876	0.01574	0.00013	0.00047	0.01181
H2S	0.00647	0.00489	0.02753	0.00116	0.00844	0.05740
CH4	0.07439	0.11622	0.22973	0.12218	0.12885	0.25989
CnHn	0.00265	0.02477	0.06449	0.01152	0.02427	0.03350
Ar	0.00298	N/A	N/A	0.00139	0.00090	0.00696
He	0.01971	N/A	N/A	0.00559	0.01457	0.09029

Oxygen isotopes of quartz from the silver-base metal vein deposits have a range of 2.2 to 10.7 per mil $\delta^{18}O$. The quartz from these deposits contain several different textures and possible stages, consequently there is a variation in the $\delta^{18}O$ value of quartz from within any given deposit. The variation in quartz values from any individual deposits is about 3 per mil with an average $\delta^{18}O$ for all deposits of around 5.5 per mil. Certain samples of quartz from the Renowned O.K., the Spur and the Silver Plume have higher $\delta^{18}O$ values than is typical for this deposit type as a whole: 10.7 per mil at the Renowned O.K., two samples with an average of 8.0 per mil at the Spur, and 9.6 per mil at the Silver Plume.

Quartz from porphyry mineralization at the Fulmer(Rialto) has a $\delta^{18}O$ of 6.1 per mil and the quartz from the porphyry related deposits have $\delta^{18}O$ values ranging from 7.0 to 10.2 per mil. Quartz from the shear zone hosted deposits has $\delta^{18}O$ values between 9.0 and 15.3 per mil. The Rock No.1 is at the low end of the range at 9.0 per mil and the Soldier is at the high end at 15.3 per mil.

The isotopic content of the fluids responsible for quartz deposition were calculated using the appropriate homogenization temperatures from each deposit and the quartz-water fractionation equation of Matsuhisa et.al. (1979; See Table 4)

TABLE 4: SUMMARY OF ISOTOPE DATA

Location	Mineral	Temperature	D 18 O Min	D 34 S Min	D 18 O H2O	D 13 C	D 34 S H2S	Tot D 34 S
Samples from the Gold Deposits								
Vera Cruz	Qtz	310	12.2		5.7			
	Pyr	310		5.6 - 6.1			4.3 - 3.8	
Helen Ree	Qtz I	280	12.4		4.5			
	Qtz II	210	7.4		-3.5			
	Cal	180	13.9		3.2	-0.1		
	Gal	250		-4.7			-6.4	18.1
American	Qtz	250	9.7		0.6			
	Cal	180	13.1		2.4	-0.8		
Rockford	Qtz	230	8.7 - 7.7		-1.1 - -2.1			
Parsons	Qtz	250	6.8 - 3.9		-2.1 - -5.0			
Great Western	Qtz	290	13.7 - 10.7		5.2 - 2.2			
Waterdog	Qtz	480	12.0		8.5			
	Qtz II	240	8.4		0.0			
	Sph	480		-2.8			-2.8	0.3
Samples from the Silver–Lead–Zinc Deposits								
Martha Washington	Qtz	240	7.0 - 4.7		-2.4 - -4.2			
	Gal	240		-6.7			-3.3	
Crow	Qtz	250	5.5 - 3.2		-1.5 - -5.7			
	Pyr	250		-3.1			-4.6	-1.7
	Sph	250		-2.8			-3.2	-0.5
	Ccp	250		-5.8			-6.6	-2.6
	Gal	250		-5.8			-3.5	-0.7
Renowned O.K.	Qtz	290	10.7 - 2.2		3.5- -6.0			
Spur	Qtz	300	8.3 - 4.8		1.7- -2.0			
	Sph	300		-2.7			-3.0	-1.8
	Gal	300		-6.3			-3.4	-2.2
Maud	Qtz	240	7.8 - 4.1		-1.5 - -5.0			
Argentine	Qtz	270	6.5		-1.5			
	Pyr	270		-3.4			-4.7	
Mayberry	Qtz	230	8.1 - 5.3		-2.3 - -4.5			
	Cal	180	18.8		8.2	-1.3		
	Sph	230		-6.1			-6.4	-1.0
	Gal	230		-4.6			-6.0	-0.7
Silver Plume	Qtz	240	8.7		0.3			
	Cal	220	16.3		7.8	-1.0		
Samples from Cu–Mo Porphyry Deposit and Related Areas								
Rialto (Fulmer)	Qtz	360	6.4		1.1			
	Pyr	360		-0.4			-1.4	
	Mo	360		-1.1			-1.1	
Jenny Linn	Qtz	220	8.4 - 7.0		-2.0 - -3.4			
Drillhole NP-4								
436 ft	Qtz	240	10.0		0.7			
	Pyr	240		-2.0			-3.8	
533 ft	Qtz	250	7.3		-1.5			
579 ft	Qtz	250	8.7		0.0			
	Pyr	250		-0.2			-1.8	
	Sph	250		-4.0			-6.3	
Samples from Shear Zone Deposits								
Rock No.1	Qtz	380	9.0		4.0			
Soldier	Qtz	240	15.2		5.8			
Hope	Qtz	280	10.4		2.8			
	Pyr	280		-5.7			-7.0	

In addition to whole rock sample analyzed for the alteration study, samples of whole rock closely associated with mineralization were also analyzed for their oxygen isotopic composition (Table 5). These are whole rock samples taken from hand samples of mineralization. Samples from the Rialto stock (Fulmer, Parsons, and Jenny Linn) range from 5.2 to 6.2 per mil $\delta^{18}O$. Whole rock samples from the Bonito Lake stock (Waterdog and Hope) have $\delta^{18}O$ values from 4.8 to 7.6 per mil. Samples of whole rock from mineralization in the Walker Andesite (American and the Bluebird prospect) have values ranging from 7.9 to 9.9 per mil $\delta^{18}O$.

Sulfur Isotopes

Monomineralic samples of sulfides were collected from many of the deposits. Sulfide samples from the gold deposits were limited: pyrite from the Vera Cruz breccia has an average δ^{34} S of 5.3 per mil; galena from the Helen Rae has a $\delta^{34}S$ of -8.7 per mil; and sphalerite from the Waterdog has a $\delta^{34}S$ of -2.6 per mil.

Sulfides from each of the silver-base metal deposits had similar isotopic compositions with the exception of the sulfides from the Mayberry. Pyrites have an average $\delta^{34}S$ of -3.2 per mil. Sphalerites from these deposits have an average $\delta^{34}S$ of -2.7 per mil, except at the Mayberry where the $\delta^{34}S$ of sphalerite is -6.1 per mil. Galenas have an average $\delta^{34}S$ of -5.5 per mil, except at the Mayberry where

Table 5: Oxygen Isotope Data From Whole Rock and Alteration Samples

Sample location	Sample Number	Run Number	Sample size in mg	D 13 C	D 18 O	D 18 O Qtz Min
Rialto Stock						
Fulmer	9251-F1	SI-7-10	11.1	-25.7	6.2	6.4
		SI-7-11	10.8	-25.7	6.4	
Parsons	9251-P1	SI-4-12	10.3	-25.7	5.9	6.6
		SI-5-8	10.3	-25.6	5.7	
Jenny Linn	9251-JL1	SI-6-8	11.1	-25.6	5.8	7.5
		SI-6-9	10.1	-25.7	5.2	
Bonito Stock						
Waterdog breccia	6031-BB1	SI-4-9	10.7	-25.7	7.6	12.1
		SI-5-9	11.0	-25.8	7.6	
Near Waterdog	3222-B1	SI-7-9	10.6	-25.8	4.7	5.6
		SI-7-8	10.5	-25.7	5.0	
Hope prospect	7181-H1	SI-6-11	11.5	-25.6	4.8	10.4
		SI-6-10	10.5	-25.7	5.2	
Walker Andesite						
American	7260-A1	SI-5-11	10.8	-25.8	6.4	9.7
		SI-5-10	11.8	-25.6	8.7	
Bluebird prospect	6121-SP3-WR	SI-119-7	10.3	-25.2	9.9	N /A
		SI-119-8	10.8	-25.3	8.9	
	6121-SP4	SI-125-9	10.4	-25.4	7.9	
Alteration Samples						
	FA 3	SI-13-8	13.1	-25.1	4.0	
	FA 4-1	SI-12-8	11.1	-25.3	6.1	
	FA 4-2	SI-12-9	12.4	-25.2	8.9	
	FA 5	SI-13-9	11.1	-25.1	5.9	

the $\delta^{34}S$ is -8.6 per mil. Chalcopyrite from the Crow has a $\delta^{34}S$ of -5.8 per mil.

Pyrite and molybdenite from the Fulmer(Rialto) were analyzed. The pyrite has a $\delta^{34}S$ of -0.4 per mil and the molybdenite a $\delta^{34}S$ of 0.0 per mil. Pyrite from the 435 foot interval of the NP-4 drillhole has a $\delta^{34}S$ of -2.0 per mil. Pyrite from the 579 foot interval of the NP-4 drillhole has a $\delta^{34}S$ of -0.2 per mil and sphalerite from the same interval has a $\delta^{34}S$ of -8.0 per mil. A single sample of pyrite from the Hope prospect, of the shear zone deposits, has a $\delta^{34}S$ of -5.7 per mil.

The $\delta^{34}S_{H2S}$ of the mineralizing fluids were calculated with the appropriate homogenization temperature for each deposit and the mineral-H_2S fractionation equations of Ohmoto and Rye (1979; See Table 4). Sulfide minerals were slightly out of equilibrium with each other, and thus could not be used as sulfide geothermometers. Homogenization temperature from inclusions in quartz were used, thus the temperatures must be considered only approximate. From this data and the fluid inclusion gas data, the total $\delta^{34}S$ of the mineralizing fluids was calculated for each deposits that has gas data. The calculations used the equation given by Ohmoto (1972):

$$\text{Total } \delta^{34}S = \delta^{34}S_{H2S} \bullet X_{H2S} + \delta^{34}S_{SO2} \bullet X_{SO2}$$

$$\text{where } X_{H2S} = x_{H2S} / \; x_{H2S} + x_{SO2}$$
$$\text{where } X_{SO2} = x_{SO2} / \; x_{H2S} + x_{SO2}$$

The $\delta^{34}S$ of the SO_2 was calculated from the SO_4^{2-}-H_2S fractionation equation of Ohmoto and Lasaga (1982) and the homogenization temperature from each deposit. The calculations gave an average total $\delta^{34}S$ of -1 ± 1 per mil, except at the Helen Rae where a total $\delta^{34}S$ of 18.1 per mil was calculated (Table 4). Gas analyses from the Helen Rae are similar to those of the nearby Rockford with the exception of H_2S content, which is dramatically lower than the H_2S content of the Rockford. A total $\delta^{34}S$ of 18.1 per mil is representative of the Permian sulfates that underlie the region, which could be a potential source for sulfur. However, this number from the Helen Rae seems unrealistic for the deposit and is uncharacteristic for the district. The H_2S/SO_2 ratio from the Helen Rae should be consider inaccurate.

Carbon and Oxygen Isotope from Carbonates

Vein carbonate samples from four deposits were analyzed for their carbon and oxygen isotopic composition. Late vein carbonate from the Helen Rae has a $\delta^{13}C$ of -0.1 and a $\delta^{18}O$ of 13.9 per mil. Carbonate from a barren portion of the American has a $\delta^{13}C$ of -0.8 and a $\delta^{18}O$ of 13.1 per mil. Late stage carbonate is found at the Mayberry and has a $\delta^{13}C$ of -1.3 and a $\delta^{18}O$ of 18.8 per mil. Vein carbonates are abundant at the Silver Plume, where two different phase can be distinguished. The early carbonate has a $\delta^{13}C$ of -1.0 and a $\delta^{18}O$ of 16.5 per mil, where as the later carbonate has a

$\delta^{13}C$ of -1.0 and a $\delta^{18}O$ of 16.0 per mil. The oxygen isotopic values of the carbonates were converted to fluid values using the appropriate temperatures and fractionation equations given by Friedman and O'Neil (1977).

Discussion of Results

Fluid Characteristics

Based on the analyses presented earlier, two different mineralizing fluids can be recognized. The fluids responsible for gold mineralization are distinct from those that are responsible for base metal mineralization in the district.

The fluids responsible for gold mineralization have isotopic compositions ranging from 9.5 to -5.0 per mil $\delta^{18}O$ (Figure 13), with the Vera Cruz, Helen Rae, Great Western and the Waterdog having a narrower range from 2.2 to 9.5 per mil $\delta^{18}O$. Calculated $\delta^{34}S_{H2S}$ values range from 4.3 to -6.4 per mil, with sphalerite from the Waterdog yielding a total $\delta^{34}S$ of 0.3 per mil. Carbonates from the Helen Rae-American have $\delta^{13}C$ values of -0.1 to -0.8 per mil and calculated $\delta^{18}O$ fluid values of 2.4 to 3.2 per mil. The salinities of the inclusions associated with these deposits vary greatly from 3 to 50 wt. percent NaCl.

Fluid values for the Ag-Pb-Zn deposits range in $\delta^{18}O$ from 3.4 to -5.7 per mil, with only quartz from the Renowned O.K. and the Spur being above -1.0 per mil (Figure 13). The related shear zone-hosted Ag-Pb-Zn deposits show fluid

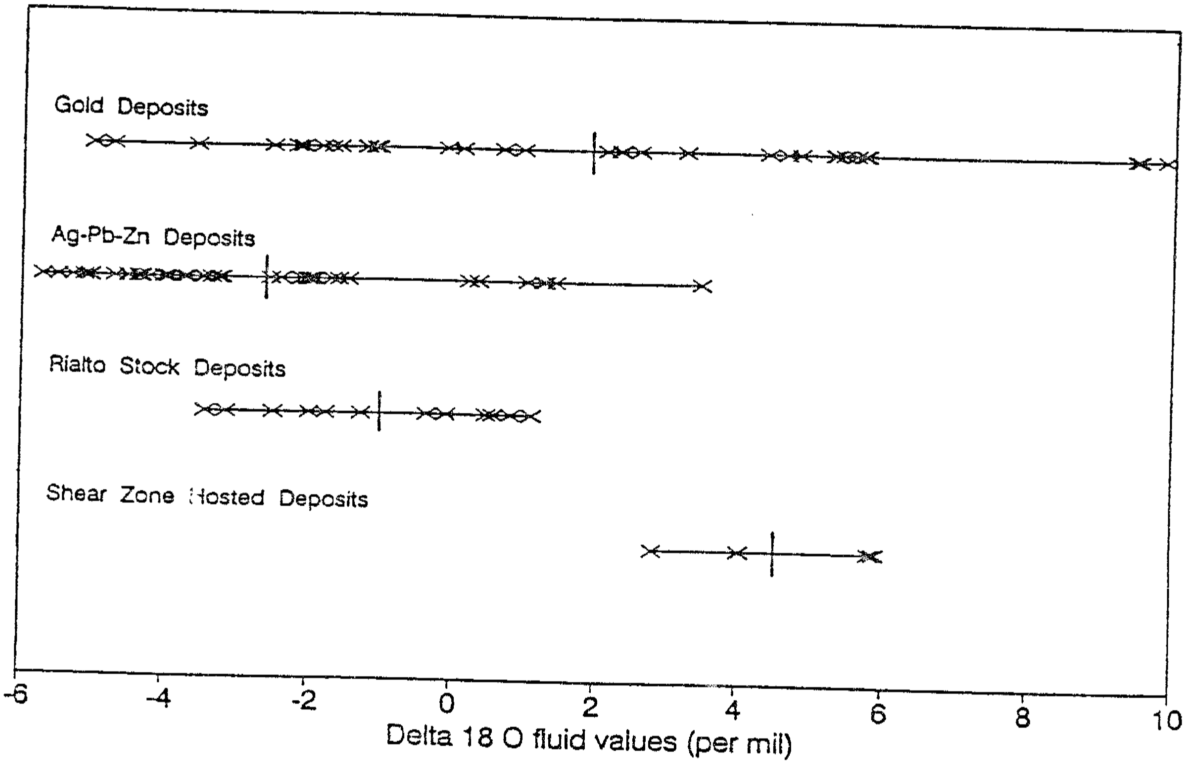


Figure 13. Plot of δ^{18} O fluid values by deposit type, an average fluid value for each deposit type is denoted by a vertical line.

values from 2.8 to 5.8 per mil δ^{18} O (Figure 13). Sulfides from these deposits have calculated $\delta^{34}S_{H2S}$ values ranging from -3.3 to -6.4 per mil. Total $\delta^{34}S$ values calculated from sulfide mineral and gas data from the Crow, Spur and the Mayberry give a $\delta^{34}S$ for the fluid of -1 ± 1 per mil. Carbonates from the Mayberry and the Silver Plume have a $\delta^{13}C$ of -1.0 to -1.4 per mil and calculated $\delta^{18}O$ fluid values of 7.5 to 8.3 per mil. These deposits have low salinities, ranging from 3 to 6 wt. percent NaCl.

Quartz from the Fulmer (Rialto) Mo-Cu disseminated porphyry mineralization has a fluid value of 1.1 per mil $\delta^{18}O$, while other deposits in the stock have values of between -3.4 and 0.7 per mil $\delta 18$ O (Figure 13). The calculated $\delta^{34}S_{H2S}$ of the sulfides from these deposits range from -1.1 to -8.3 per mil. While fluid inclusion data from the Fulmer (Rialto) Mo-Cu deposit was not available for this study, the other deposits of the Rialto stock have salinities of 3 to 5 wt. percent NaCl.

While the characteristic of gold deposits vary widely, it is clear that these fluids are different than the fluids responsible for base metal mineralization in the district (Table 6). It is also clear that the fluids of the Ag-Pb-Zn deposits are similar to those of the Mo-Cu deposit and related deposits of the Rialto stock. These characteristics not only differentiate the fluid types, but also suggest

Table 6: Characteristics of Precious and Base Metal Deposit in the Nogal Mining District

Attributes	Au Deposits	Ag-Pb-Zn Deposits
Recoverable metals	Au > Ag	Zn > Pb > Ag
Mineralization Style	Open-space veins or breccias	Open-space veins
Host Rock	Walker Andesite, Rialto Stock, Bonito Stock, Mesa Verde Group	Walker Andesite
Hydrothermal Alteration	Vein envelope or pervasive Propylitic Weak Argillic Carbonatic	Pervasive Propylitic Weak Phyllic
S (as S2-) abundance	Relatively low (>2%)	High (50-75%)
Ore stage fluids		
Temperature	224 - 538 C (ave = 260 C)	188 - 416 C (ave = 240 C)
Salinity	2 - 50 wt% NaCl	2 - 18 wt% NaCl
D 18 O fluid (in per mil)	-5.0 - 9.5 (ave = 1.9)	-5.7 - 3.4 (ave = -2.6)

very different origins for the gold and the base-metal deposits of the district.

Based on these characteristics, four gold deposits appear to have been derived from fluids with a substantial magmatic input or an equilibrated water component. At the Waterdog breccia, characteristics such as high Ths (450-480°C), high salinities (45-50 wt % NaCl), and high δ^{18} O fluid values (9.5‰) are similar to fluids associated with porphyry-style mineralization (Sheppard et al., 1974 and Beane, 1982). Vein material from the Helen Rae has moderate temperatures (190-365°C), high salinities (18-35 wt % NaCl), and enriched oxygen isotope values (4.5‰). These characteristics are similar to those of Salton Sea fluids (Field and Fifarek, 1985). However, given the similarities to the fluids of the Waterdog deposit, these characteristics suggest a similar source for the fluids was responsible for gold mineralization at the Helen Rae. The total δ^{34}S of 0.3 per mil from sphalerite of the Waterdog indicates a magmatic source for the sulfur in these deposits. Lower temperatures and salinities of secondary fluids from these deposits suggests dilution of the ore fluids by meteoric water. Mineralization at the Vera Cruz is hosted in a breccia pipe in Mesa Verde Group sandstones and shales, and is related to a shallow laccolith. While the fluid of the Vera Cruz are not overly saline (8-9 wt % NaCl) compared to the Waterdog or Helen Rae, it is isotopically heavy (5.7‰), suggesting a magmatic component. Pyrite from the Vera Cruz has uncorrected $\delta^{34}S_{H2S}$ values of 3.8 to 4.3 per mil, indicating fluid interaction with the country rock. The Great Western breccia deposit has heavy oxygen fluid values (2.2 to 5.2 ‰) suggesting an origin similar to the other deposits, but the lack of fluid inclusion data makes this hypothesis tentative. The Rockford and the Parsons deposits are different than those of the other gold deposits, appearing more characteristically epithermal.

Gold veins occur only two places in the district, at the Helen Rae-American and at the Rockford. The veins of the Rockford have a similar strike and composition to those at the Helen Rae, immediately to the north. While the veins are not directly connected to those of the Helen Rae-American, they can be traced to near the American vein. The veins of the Rockford and Helen Rae-American may represent smaller parts of a single large mineralizing system. The fluids of the Rockford are lower in temperature (230°C) and salinity (6 wt % NaCl) than those of the Helen Rae, and have fluid values of -1.1 to -2.2 per mil $\delta^{18}O$. If the two vein systems share a common origin, then the difference in fluid composition at the Rockford may indicate that the veins of the Rockford are more distant from the magmatic source than at the Helen Rae. Thus, they would show a more mixed magmatic-meteoric origin than the fluids of the Helen Rae.

The Parsons gold breccia, emplaced in a highly altered and brecciated part of the Rialto stock, has $\delta^{18}O$ fluid values of -2.1 to -5.0 per mil. These depleted fluid values suggest that the ore fluids was exchanged meteoric water.

Fluid compositions of the Ag-Pb-Zn deposits and the deposits of the Rialto stock indicate that these deposits formed from more meteoric-dominated fluids, as opposed to the magmatic-dominated fluids of the gold deposits. Thompson (1973) suggested that the Rialto stock was the source of ore fluids, based on Pb-Zn ratios. The similarity between the fluids of the Ag-Pb-Zn deposits and the fluids of the Rialto stock deposits is further evidence that the stock may indeed be the source of the ore fluids. However, the ore fluids of the Rialto stock must have been diluted by abundant meteoric water, based on the depleted $\delta^{18}O$ fluid values and low salinities found in this study. In fact, only two deposits show any sign of a heavier, possibly magmatic fluid, and then only as a small pulse during mineralization. At the Renowned O.K., a vein quartz has a $\delta^{18}O$ fluid value of 3.5 per mil, while at the Spur some vein quartz has a fluid $\delta^{18}O$ values of 1.0 to 1.4 per mil.

Given the structural setting and fluid compositions of the Ag-Pb-Zn shear zone-hosted deposits of the Bonito Lake stock, a magmatic dominated system with some meteoric input seem likely.

Isotope data from the carbonates yields $\delta^{13}C$ values of -0.1 to -1.0 per mil. These are representative of epithermal vein carbonate values, but could also represent a mantle carbon source or carbon leached from underlying marine limestones (Field and Fifarek, 1985). The $\delta^{18}O$ fluid values from the carbonates are heavy (2.4 to 8.2 ‰) and with the exception of the Helen Rae, the $\delta^{18}O$ fluid values of carbonate is heavier than that of vein quartz in these deposits. The significance of the heavy $\delta^{18}O$ fluid values is unclear. However, a difference can be seen by deposit type. The gold deposits have lower fluid values than those of the Ag-Pb-Zn deposits, and are closer to the $\delta^{18}O$ of the vein quartz.

Alteration

The alteration study shows two distinctly different types of alteration present in the district.

The first type of alteration is the district-wide propylitic alteration of the andesites. Limited petrographic work has confirmed the weak and variable nature of this alteration that has been described by others (Lingren, 1910; Griswold and Missighi, 1964; and Thompson, 1972). Widely spaced sampling throughout the district shows the broad, but variable nature of this hydrothermal alteration. Isotope analyses of unmineralized whole rock have $\delta^{18}O$ values of 0.0 to 5.9 per mil. Thompson (1972) argued that the alteration occurred during the intrusion of the stocks into the volcanic pile, but did not go on to postulate the origin or composition of the altering fluid.

Calculated fluid compositions, based on K-feldspar-water fractionation at 240°C, range from -0.7 to -6.6 per mil $\delta^{18}O$ with an average near -4.0 per mil. A fluid composition near -4.0 per mil $\delta^{18}O$ suggests that the hydrothermal fluids were partially exchanged meteoric waters. These waters most likely infiltrated the volcanic pile during the interim between igneous phases and are isotopically similar to the fluids of the Ag-Pb-Zn deposits.

Alteration at the Crow (Ag-Pb-Zn deposit) is weakly phyllic in nature, with alteration appearing to extend no more than 8 feet from the vein. Alteration mineralogy suggests that the fluid was a weakly acidic to low K-near neutral fluid that reacted slightly with the rocks, and only near the vein. The rocks retain their original textures, with feldspars slightly to moderately sericitized and biotite rimmed by chlorite. Quartz is abundant in the samples near the vein, and steadily decreases away from the vein. Geochemical data indicates that SiO_2 content of the samples is constant away from the vein, suggesting that the quartz is a product of remobilization/alteration.

Isotopically, the whole rock $\delta^{18}O$ values steadily decrease away from the vein (5.3 to 2.1 ‰). This may be indicative of a magmatic fluid component being incorporated into the hydrothermal fluids and being channelized into the vein structures. Chemically, the vein shows a slight enrichment in potassium and a depletion in iron, magnesium and sodium.

The nature of the vein alteration fluids and their similarity to the fluids responsible for propylitic alteration of the andesites suggests that the two alteration fluids may have shared a common origin. The channelizing of a fluid into vein structures would be expected to promote more extensive alteration near the vein. The weak nature of alteration around the Crow vein and its steady, but rapid transition into the surrounding propylitic alteration are suggestive of the behavior of a single fluid in two different environments. If the two fluids are one in the same, then base metal mineralization can be time constrained to have occurred during regional alteration of the andesite; which has been inferred to have happen during intrusion of the stocks around 30 Ma.

The second type of alteration present in the district is sericitic or mild argillic alteration associated with gold vein mineralization. Vein alteration at the Helen Rae is characterized by extensive sericitic and carbonate alteration 15 to 20 feet out from the vein. The alteration mineral assemblage is composed of sericite(illite) + chlorite + calcite + pyrite + Fe oxides. The alteration of the rock is quite intense within 6 feet of the vein, completely obliterating rock texture. Mineralogy and mineral textures indicates that the fluids responsible for gold vein alteration were moderately acidic. Isotopically, the rock shows an enrichment near the vein from 3.6 to 7.5 per mil $\delta^{18}O$, with quartz only occurring near the vein. This indicates that the rocks associated with vein alteration have been re-enriched from their previously depleted values, associated with regional propylitic alteration of the andesites. The major oxide content of the whole rock samples fluctuates wildly near the vein, only to even out at 18 feet and become similar to that of the unmineralized andesite. Geochemistry data shows an slight enrichment of potassium near the vein, coupled with a depletion of sodium and magnesium. Potassium enrichment of fluids associated with gold mineralization have been noted in other alkaline-related deposits such as Cripple Creek, Colorado (Thompson et al., 1985) and the Gilt Edge deposit in South Dakota (Groff, 1990).

Gold vein alteration is different than that of the district-wide alteration or of alteration associated with the Ag-Pb-Zn deposits. This is further prove of different fluid sources for the gold deposits and base metal deposits. Furthermore, gold vein alteration is overprinted on top of the district-wide propylitic alteration. This indicates that gold mineralization occurred after the broad alteration of the andesite, and thus after Ag-Pb-Zn mineralization.

Genetic Models for Gold Deposits

The unique character of the fluids from the Waterdog and Helen Rae set these deposits apart from all others in the district. Since these deposits are unique in the area and many of their characteristics are known, the deposits are compared against a genetic model for alkaline-related gold deposits.

Mutschler et. al. (1991) presents a genetic model for alkaline rock-related gold deposits. Epithermal and porphyry-style end-members were defined and characteristics for each end-member listed. The example of alkalic epithermal mineralization used in the article is Cripple Creek, Colorado, while the Allard stock, Colorado, is used as the porphyry-style end member for this genetic model. Characteristics such as metal content, style of mineralization, alteration facies, volatile concentration, and fluid composition are given for each of the end-members. Table 6 lists these characteristics for Cripple Creek and the Allard stock, as well as those of the Waterdog and Helen Rae deposits.

The Helen Rae is a gold-rich, sulfide-poor open-space vein system, with associated propylitic and minor K-metasomatic alteration. Ore fluids of the Helen Rae were of moderate temperature (250°C), high salinity, and dominated by magmatic water. The Helen Rae has some characteristics that are similar to those of the Cripple Creek model and the

Table 7: Comparison of Characteristics of the Helen Rae and Waterdog and End Member Deposits of an Alkaline Rock-related Precious Metal Deposit Type Model

Attributes	Epithermal Au Systems Cripple Creek model	Porphyry Cu-Precious Metal Syste Allard stock model	Helen Rae	Waterdog
Recoverable metals	Au > Ag (precious metals usally sole or major product)	Cu > Ag > PGEs or Au (precious metal usually a by-product)	Au > Ag	Cu > Au (?)
Mineralization	Largely open-space vein fillings	Disseminated, pegmatitic, skarn	Open-spaced vein filling	Breccia, disseminated (?)
Au-bearing species	Tellurides, native Au	Native Au (in sulfides)	Native Au (in sulfides)	Native Au (in sulfides)
Hydrothermal Alteration	Vein envelope or pervasive Propylitic K-metasomatism Carbonatic Redox (Phyllic, solfataric)	Pervasive Propylitic K-metasomatism Carbonatic Redox (Phyllic)	Vein envelope of Propylitic Phillic Carbonatic	Pervasive Propylitic Argillic Silicic Phyllic
S (as S2-) abundance	Relatively low	High	Low	High
Volatile element Concentrations				
Te	Very high	Moderate	?	Low (?)
Tl	High	Low	?	?
Hg	Generally high	Low	?	?
As, Sb	Generally high	Varible	?	?
Ore stage fluids				
Temperature	< 210 C	300 - 800 C	190 - 365 C	371 - 536 C
Salinity	Low,(<5wt% NaCl)	High	18-38 wt% NaCl	30-40 wt% NaCl
CO2 content	High	High (often saturated)	Low	Low
H2O	Meteoric dominated	Magmatic dominated	Magmatic dominated	Magmatic dominated
Pressure	1->350 bars	350-1000 bars	?	?

Allard stock model. Based on these characteristics alone, the Helen Rae appears to fall somewhere between the two model end-members, and may represent a deposit that formed at an interval between shallow porphyry mineralization and deep epithermal mineralization. Figure 14 shows that the fluids of the Helen Rae were intermediate in nature between those of the Waterdog and the rest of the deposits in the district. The Helen Rae-American-Rockford(?) system may be the surface expression of mineralizing fluids from a porphyry deposit a depth leaking through the overlying andesite. An aero-magnetic map of the White Mountain Wilderness (Segerstrom et al., 1979) indeed shows an elongate anomaly surrounding the Helen Rae-American and the Rockford that might represent an intrusive at depth. Since no drilling or geochemical studies have been conducted on the Helen Rae, the true nature of the mineralization of this area is not complete known. This deposit may represent an as yet unknown and unstudied interval of the ore deposit continuum.

The Waterdog deposit is a disseminated and brecciated mineral deposit that contains Cu, Au and sulfides. The area around the deposits shows concentric propylitic, phyllic, silicic, and argillic alteration (Fulp and Woodward, 1991). Ore fluids of the deposit were of high temperature, high salinity, and from magmatic dominated water. Figure 14 shows the difference between the fluids of the Waterdog and

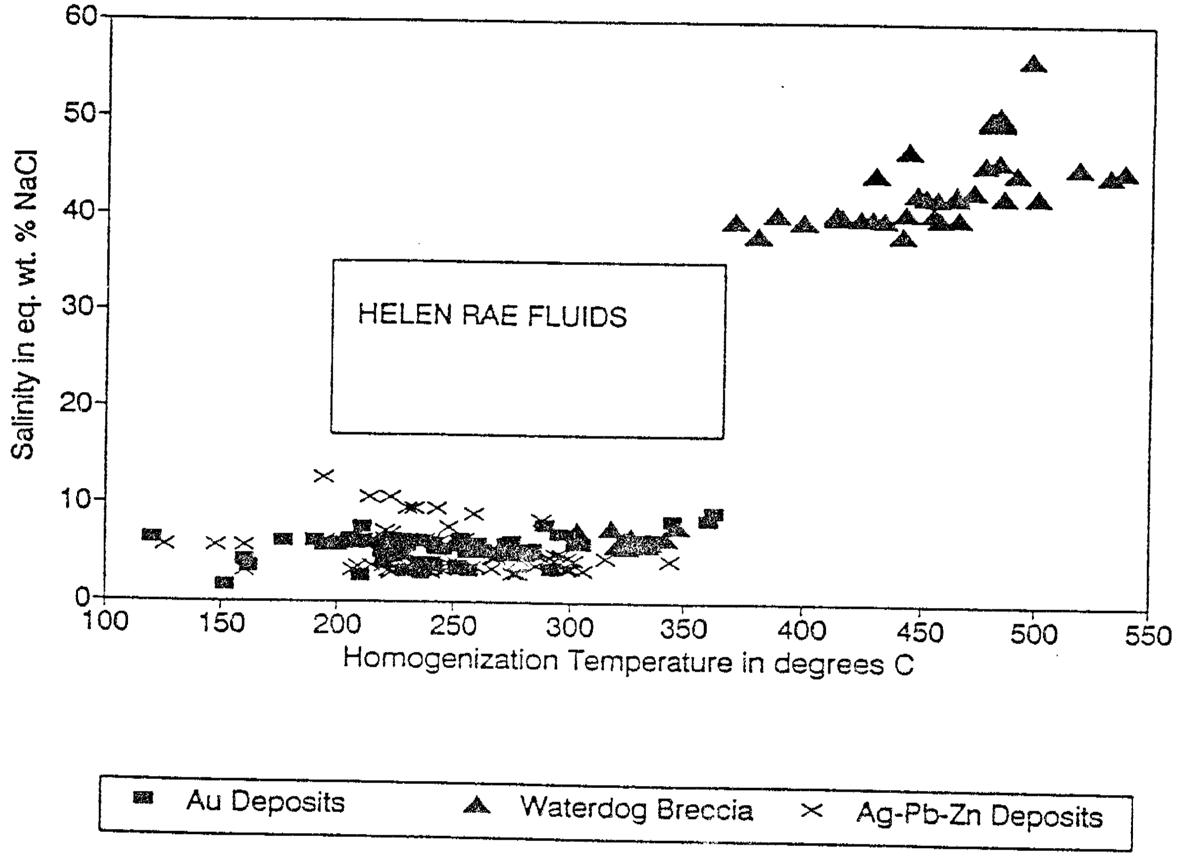


Figure 14. Th-salinity plot of all inclusion data from Au and Ag-Pb-Zn deposits. Box represents the range of fluid compositions of the Helen Rae gold deposit, taken from Campbell et al., 1991.

those of the rest of the district. These characteristics of the Waterdog clearly show that the deposit resembles an alkalic porphyry deposit, similar to the Allard stock model.

Conclusions

Evidence from this study combined with that of previous studies can be used to create a coherent picture of the geologic events that lead to mineralization in the Nogal mining district.

An early and important event in the region was the formation of the Sierra Blanca basin and northeast-trending basement faults, during the Laramide. Regional compression associated with subduction resulted in re-activation of ancestral structures of the area, the Pedernal Arch and the Capitan Lineament, to form the Sierra Blanca basin. This compression also re-activated northeast-trending faults and fractures in the basement rocks of the region. These deep basement faults were crucial to the emplacement of the alkalic igneous rocks of Lincoln County, as they provided conduits for deep-seated alkaline magmas, generated from subduction and later rifting, to reach the surface. Alkaline magma formed the Walker Andesite between 37.3 and 37.0 Ma. During this time, some part of the Rialto and Bonito Lake stocks were intruded along the same northeast-trending faults and into the volcanic pile (Figure 15 - phase 1).

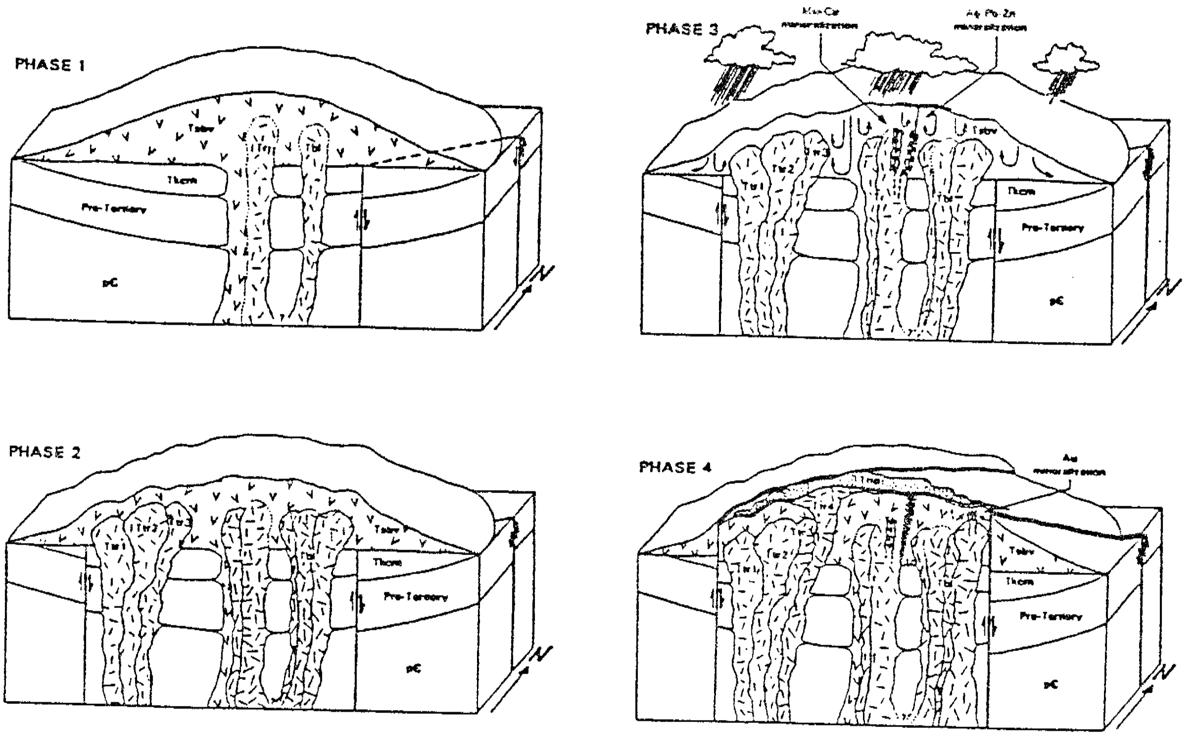


Figure 15. Schematic drawings of the geologic events leading to mineralization in the Nogal district. Phase 1 - extrusion of the Walker Andesite (Tsbv) and the intrusion of the early phases of the Rialto (Tr) and Bonito Lake (Tbl) stocks along NE trending fault, at 37.3-37.0 Ma. Phase 2 - intrusion of the Three Rivers stock (Ttr1-3) and the remaining phases of the Rialto and Bonito Lake stocks, at 31-29 Ma. Phase 3 - development of base metal mineralization and propylitic alteration of the andesites by meteoric dominated hydrothermal fluids, during phase 2 intrusive activity. Phase 4 - eruption of the Nogal Peak Trachyte (Tnp), along with the last phase of intrusion of the Three Rivers and Bonito Lake stocks, at 28-26.5 Ma. At this time, gold mineralization occurred from magmatically dominated fluids, along NE trending structures.

The next major event leading to mineralization occurred between 37 and 31 Ma when subduction-related compression ended and the region began to experienced the onset of Rio Grande rifting. Onset of rifting brought new alkalic igneous activity to the area, and between 31 Ma and 30 Ma the Rialto, Bonito Lake, and part of the Three Rivers stock were emplaced into the volcanic pile (Figure 15 - phase 2). The emplacement of part of the silica undersaturated Rialto stock was accompanied by disseminated Mo-Cu mineralization. Mineralization occurred in a brecciated part of the stock, when fluids of the stock mixed with the abundant meteoric waters that had infiltrated the volcanic pile (Figure 15 - phase 3). Emplacement of these intrusions heated the volcanic pile and contained waters, resulting in a hydrothermal system in which fluids propylitically altered the Walker Andesite.

During this alteration event, hydrothermal fluids infiltrated fractures in the Walker Andesite along the east-west Bonito Fault. Rising along these fractures were magmatic fluids from the Rialto stock. These magmatic fluids were mixed and diluted by the copious meteoric fluids heated by the intrusions. The mixing of the two fluids resulted in the deposition of the Ag-Pb-Zn deposits in the fractures (Figure 15 - phase 3).

Between 30 and 26 Ma the Nogal Peak Trachyte and the Church Mountain Latite erupted, while the last phases of the

Three Rivers stock and part of the Bonito Lake stock were emplaced. Tectonic relaxation of the area associated with rifting allowed the older northeast-trending structures to provide ready conduits for molten rock and magmatic fluids. Fluids from these shallow intrusions rose along the structures to form the veins and breccias of the gold deposits. The fluids of the gold deposits did not initially encounter the abundant fluids that were responsible for the Ag-Pb-Zn deposits, and only toward the end of the hydrothermal systems did meteoric fluids start to dominate the gold-bearing, magmatic fluids. This difference may be due to a number of different possibilities, such as: less meteoric water in the volcanic pile caused by the trachyte and latite flows; decreased permeability of the andesite due to earlier hydrothermal alteration; and smaller and deeper hydrothermal systems that did not allow for volumetrically important meteoric input.

This study, in characterizing the fluids of the area, has described alkaline rock-hosted mineral deposits similar to those of Cripple Creek, Colorado; Zortman-Landusky, Montana; the Black Hills, South Dakota; and Ortiz, New Mexico. While the deposits of the Nogal district share many common features with these other deposit, such as geologic setting, timing of geologic events, geochemistry of the rock, and style of mineralization; there are some notable differences. The deposits of the Nogal district do not contain any fluorite in the mineralization, nor any significant REE, Nb-Ta mineralization, which is common in these deposits. The district contains modest base metal mineralization and no telluride minerals, a trait not shared by the other deposits. These deposits show significant potassium enrichment, while the deposits of the Nogal district show weak enrichment in K. The question becomes: what do these differences mean and do they reflect the economic potential of the Nogal District's mineral resources?

This study has also characterized two gold deposits in the district. While one of the deposits looks very similar to porphyry-style mineralization, the other appears to represent an intermediated between that and epithermal mineralization. From the evidence available and the characteristics of other alkaline-related deposits, it appears that the Helen Rae represents a system at the boundary between shallow porphyry and deep epithermal mineralization.

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Appendix A: Site, Hand Sample and Fluid Inclusion Section Description.

Explanation of Sample Numbering

6031-CR1-A1

Specimen number within a certain sample collection. Number denote different section of the sample.

Sample number from site.

Site of collection, mine or prospect.

Year of collection, e.g. 1991 = 1.

Day of collection.

Month of collection.

All isotope and fluid inclusion sample numbers correspond to each other, as well as to the hand samples.

Abbreviations of Collection Sites

A - American mine
AG - Argentine mine
BB - Breccia body of the Waterdog prospect
CR - Crow mine
F - Fulmer tunnel (Rialto)
GW - Great Western mines
HR - Helen Rae mine
H - Hope prospect
JL - Jennie Linn mine
MW - Martha Washington mine
MA - Maud
MB - Mayberry mine
MF - Mineral Farms mine
P - Parsons mine
RN - Renowned O.K.
RK - Rock No. 1
R - Rockford prospect
SP - Silver Plume mine (including the Bluebird prospect)
SD - Soldier mine
S - Spur mine
VCD - Vera Cruz drillhole

Note: Minerals are listed in order of abundance, not in their paragenetic order. Mineralogical determinations done on hand samples only, except where noted.
* - indicates sample was used in the fluid inclusion study

Argentine

Location

The Argentine mine can be found in the SE1/4 sec.4, T.10 S., R.11 E. on a ridge between Argentina and Turkey canyons. The workings are reported to consist of a shaft and an adit with a stope (Thompson, 1973), but only the adit was visited. The adit was choked with debris and was in poor condition, owing to the fact that little if any work has been done at the site since the late 1960's.

Hand Samples

The site had nothing that appeared to be a tailings pile, however a couple of samples were found near the portal of the adit.

7191-AG1-A - A large piece of vein quartz. Parts of the sample have a cockscomb texture with the quartz being clear to slightly milky. The remainder of the sample is dark, highly silicified wall rock (?) with extremely minor (<1%) flecks of sulfides. The quartz and pyrite were used in the isotope study.

7191-AG1-B - A piece of highly altered rock. Alteration appears to be argillic in nature. The rock is banded with alternating layers of brownish-red and white.

Fluid Inclusion Sections

* 7191-AG1-A1 - A section of the cockscombed vein quartz. Only the center of the section is clear. Quartz is very grainy and has some minor fracturing. Only very tiny secondary and small pseudosecondary inclusions were seen, and then only in the clearest quartz.

* 7191-AG1-A2 - A small section of slightly milky quartz with a clear quartz rim. Some inclusions in the rim quartz, but still very small and mostly pseudosecondary in appearance. A cubic object was seen in the milky quartz. It is not galena, as the sample is pure quartz.

* 7191-AG1-A3 - Almost the same cut as A1, but at a different angle. One area of clear quartz has several large inclusions trapped between crystal boundaries.

Bluebird

Location

The Bluebird prospect is located in the SW 1/4 sec 29, T.10 S. along the road to Monjeau Peak. The workings consist of two prospect pits, an upper and lower, that are separated by a quarter of a mile. Samples were collected as part of the Silver Plume, as the pits are along the projected NE strike of the Silver Cut vein and adjoin the Silver Plume block.

Hand Samples

6121-SP3 - Collected from the lower pit. Rock is highly silicified Bonito stock with minor fleck of sulfides and streaks of copper carbonates. Sample was considered whole rock for the isotope study.

6121-SP4 - Collected from the upper pit and identical to SP3. Sample was considered whole rock for the isotope study.

Fluid Inclusion Sections

No material was found that was suitable for fluid inclusion work.

Crow

Location

The Crow mine is located in the NE 1/4 sec. 3, T.10 S., R.11 E. up Tanbark Canyon. The workings of the Crow consist of a shaft, a stoped adit, a small millsite and an abandon house. The workings are along a quartz-base metal vein in andesite, known as the Crow vein. The vein has experienced some post-ore movement, from which gouge ore has developed.

Hand Samples

6031-CR1-A - Vein sample collected 10 meters up a raise in the adit. Sample contains badly sheared, crystalline vein quartz with flecks of pyrite in very altered wall rock. The quartz was used in the isotope study and was marked as "6031-CR1".

6031-CR1-B - A piece of massive vein quartz collected from the raise.

6031-CR1-C - Ore sample collected from the raise. Sample contains galena, sphalerite, chalcopyrite and pyrite in quartz. The chalcopyrite was used in the isotope study.

9251-CR1-A - Ore sample found on a dump near the adit. Sample contains quartz, sphalerite, galena, chalcopyrite and pyrite. The quartz, sphalerite and galena were in the isotope study.

9251-CR1-B - Sample of banded quartz with galena and pyrite. The quartz, galena and pyrite were used in the isotope study.

9251-CR1-C - A piece of vein quartz with small cubes of galena collected from the dump. Sample was used for gas analysis.

9251-CR1-D - Ore sample collected from the dump. Sample contains quartz, altered wall rock, sphalerite, galena and pyrite. The sphalerite was used in the isotope study.

Fluid Inclusion Sections

* 6031-CR1-A - Quartz is clear to partly cloudy and very fractured. Very few inclusions were seen in the section. Small secondary inclusions were seen in the clearest quartz.

* 6031-CR1-C - A few inclusions were seen in the clear quartz near the sulfide minerals. The inclusions were very small and looked to be primary.

* 9251-CR1-A - Section is similar to 6031-CR1-C, in that a few inclusions were seen near the sulfide minerals. Section contains ruby-red sphalerite which has numerous dark inclusions.

* 9251-CR1-B - Section contains clear to milky quartz with large inclusions. Most appear to be secondary, but some may be primary inclusions. There is a favorable zone for inclusions near the cloudy quartz.

9251-CR1-C - Inclusions, mostly secondary, are seen only in the clearest areas of the cloudy vein quartz. Most inclusions are very small.

* 9251-CR1-D - A few small secondary inclusions were seen in the clearest quartz near the sulfides.

Drill Hole NP-4

Location

Drill hole NP-4 is uphill from the Jenny Linn at the sharp turn in the road in the NE 1/4 sec. 34, T.9 S., R.11 E. The drill hole is in the brecciated portion of the Rialto stock near its contact with the andesite.

Hand Samples

The samples used in this study came from drill core provided by the New Mexico Bureau of Mines from a drilling project carried out by the Continental Materials Corporation in 1981. The core log of the hole was looked at and favorable intervals were chosen and visual inspected. Only intervals with abundant quartz and/or sulfide mineralization were chosen.

NP-4 435′ - Core is highly altered and silicified. It contains a few large euhedral quartz crystals, very small flecks of pyrite and stringers of a sulfide mineral. The quartz and pyrite were used in the isotope study.

NP-4 533′ - Core is similar to 435′, but contains more crystalline quartz and stringers of sulfides. The quartz was used in the isotope study.

NP-4 579′ - Core is similar to 435′, but much more silicified. Sample contains small vugs filled with small quartz crystals, pyrite and sphalerite. Quartz, pyrite and sphalerite were used in the isotope study.

Fluid Inclusion Sections

* NP-4 435′-A - C-axis section of a euhedral quartz crystal. The crystal is badly fractured and inclusion are seen only in the clearest quartz. The inclusions are mostly secondary with isolated primary or pseudosecondary inclusion present. Growth bands are visible, but no inclusion are seen along them.

NP-4 435′-B - Similar to A, but from a different crystal.

* NP-4 533 - Similar to 435′-A, but somewhat more fractured and not as clear.

Drill Hole N-20

Location

Drill hole N-20 is located in the Rialto claim block (Fulmer) in the SE 1/4 sec. 27, T.9 S., R.11 E. Core is from the heavily altered part of the Rialto stock.

Hand Samples

Core samples of N-20 came from the same project as NP-4 and were evaluated in the same manner.

N-20 164′ - Core is of highly altered and extremely silicified rock. Sample contains a quartz stringer (4 mm thick) with a hematite coating. Disseminated pyrite is present throughout the sample.

N-20 237′ - Core is similar to 164′, but is more silicic and contains no hematite. Sample was used for oxygen isotope work.

Fluid Inclusion Sections

* N-20 164′ - Inclusions are seen in the clearest quartz. Most appear to be primary or pseudosecondary. A number of inclusions contain red bubbles, and a few contain both a clear and a red bubble.

Fulmer

Location

The Fulmer adit is located in the SE 1/4 sec. 27, T.9 S., R.11 E. due east of Nogal Peak. Workings on the site include the Fulmer Tunnel, an upper adit, several drill roads, and a dump. The adits are in a heavily altered portion of the Rialto stock.

Hand Samples

9251-F1-A - Sample of altered rock with fracture fillings of quartz, molybdenite, and pyrite. The molybdenite is crystalline and was sent off for rhenium-osmium dating. Quartz, molybdenite and pyrite were used in the isotope study.

9251-F1-B - Sample is a piece of slightly altered stock taken from the dump. Micas appear to be somewhat chloritized. The thin section shows abundant molybdenite flecks in the rock.

Fluid Inclusion Sections

9251-F1-A - Scattered secondary inclusions in only the clearest quartz, with most being very small. Numerous dark, inclusion-like features in the quartz.

Great Western

Location

The workings of the Great Western property are located in unsurveyed national forest land. The mines can be reached by a steep road off of Big Bear Canyon. The workings on the property consist of three adits and a pit or glory hole. The two adits on the map and the pit date back to work done in the late 1940′s or early 1950′s. A third adit on the north side of the hill was driven for Pioneer Metals Corporation in 1988. All the workings are in a breccia pipe in the Walker andesite.

Hand Samples

At the time the site was visited, Pioneer's adit was flooded with mud and the other adits were collapsed. Since access was limited, samples was taken from dump pile near Pioneer's adit and from the old pit above the adits.

6071-GW1-A - Piece of breccia with angular clasts suspended in a silica matrix. Clasts appear to have been bleached then silicified, with no identification of parent rock possible. Surface oxidation gives sample and dump piles a deep red color. The sample was used in the isotope study.

6071-GW1-B - Piece of massive silica with no clasts. Sample contains a number of reddish purple fractures. The sample was considered whole rock for the study.

6071-GW2 - Sample is identical to GW1-A except that it was collected from the pit at the surface, above the adit.

Fluid Inclusion Sections

6071-GW2 - Sample too cloudy to see much. Very few inclusion seen, most too small to measure.

Helen Rae - American

Location

The workings of the Helen Rae and American mines are located in sec 13, T.9 S., R.13 E. up the Dry Gulch drainage. The workings of the Helen Rae include several shafts, an adit, a drainage tunnel, an old mill, and an open stope 150 meter long. The workings of the American consist of several shafts and adits, along with the ruins of an old mill. Both mines apparently work the same vein, but from different sides of an intervening ridge. The area around the mines contain many quartz-calcite and barite veins in the Walker andesite. Most workings are inaccessible.

Hand Samples

7240-HR1 - Piece of clear crystalline to massive quartz with pyrite. Sample was collected from the Helen Rae mill. The quartz was used in the isotope study and for gas analysis.

7240-HR3 - Vein sample collected from the 60′ level of the shaft. Sample contains abundant galena with minor amounts of quartz, calcite and wall rock (?). The galena was used in the isotope study.

7250-HR4 - Vein sample collected from the 45′ level of the shaft. Sample contains quartz, galena, and minor calcite. Taken from mid-section of the vein. The calcite was used in the isotope study.

7250-HR8 - A mass of small euhedral quartz crystals found in a vug in a rock near the open stope. The quartz was used in the isotope study.

7260-A1 - Sample of fresh quartz-calcite vein taken from a newly blasted adit. Sample contains quartz, calcite and rhodochrosite. Altered wall rock contains blebs or stringers of pyrite and galena. The quartz and calcite were used in the isotope study.

8160-V1 - A piece of banded chalcedony taken from the Vindicator drainage tunnel. Bands are purple, red, and green in color. The milky white chalcedony was used in the isotope study.

8170-HR1 - Sample of vein material found in the muck of the shaft. Sample contains quartz, calcite, rhodochrosite, pyrite, galena, and disseminated sphalerite. The quartz and calcite were used in the isotope study.

Fluid Inclusion Sections

* 7240-HR1 - Section shows very small secondary inclusions. A few veils of secondary inclusion are present in the section. A number of solid, rhombohedral inclusions are also present in the sample.

* 8170-HR1 - Very few inclusions can be seen. Most are in the clearest quartz and calcite, and appear to be secondary in origin.

Hope

Location

The Hope prospect is in sec. 1, T.10 S., R.12 E. off of Kraut Canyon near Bonito Lake. The workings consist of two adits spaced 10 meters apart horizontally and 3 meters vertically. The adit follows a vein at N 15 W, while the upper adit apparently follows the same structure to the southeast. At the time the site was visited, the lower adit was flooded and the upper adit caved. The site, which is in the Bonito stock, is heavily altered.

Hand Samples

All samples were collected from the dump or near the adits.

7181-H1-A - Sample is a piece of wall rock that is partially covered by a core of massive quartz and a rim of bleached, vuggy quartz with small blades of barite, abundant pyrite and minor galena. Samples of wall rock, outer rim quartz and pyrite were used in the isotope study.

7181-H1-B - Sample of highly altered wall rock. Sample lacks the abundant mica that the local wall contains. The feldspar phenocrysts are completely altered to sericite. A small (1 to 2 mm) stringer of quartz and pyrite runs through the sample.

7181-H1-C - A piece of potassically altered wall rock with abundant biotite. Sample contains a very small stringer of quartz. This rock type composes the majority of rock in the dump at the site.

3222-H1 - Sample is massive quartz with pyrite, similar to 7181-H1-A. It is not nearly as bleached and is lacking both barite and galena.

Fluid Inclusion Sections

7181-H1-A - No inclusions were seen in the section.

7181-H1-B - No inclusions were seen in the section.

* 3222-H1 - Only very small secondary inclusions were seen in the clearest quartz. Most of the sample in too fine-grained and cloudy.

Jenny Linn

Location

The remains of the Jenny Linn adit are located in the extreme NE 1/4 sec. 34, T.9 S., R.11 E. about 200 yards due west of the Parsons mine and just north of the Parson's City townsite. The workings of the Jenny Linn are a collapsed adit with an overgrown dump. The adit is in the brecciated part of the Rialto stock.

Hand Samples

9251-JL1 - The sample was found on the dump and consist of a mass of quartz crystals on wall rock. The quartz is clear to cloudy with the largest crystals being about 1 cm across. Both the clear and cloudy quartz were used in the isotope study.

Fluid Inclusion Sections

* 9251-JL1 - Two sections were made from massive quartz. Sections show abundant primary and secondary inclusions in the clearest material. Some inclusions appear to be more vapor-rich than others.

Martha Washington

Location

The Martha Washington mine site is located in the NW 1/4 sec. 2, T.10 S., R.11 E. up George Washington Canyon. The mine site consists of debris covering a shaft and a small tailings pile. The map indicates an adit, but none was found. The Martha Washington was located on the eastward extension of the Renowned O.K.-Crow Vein system in the Walker Andesite. Down the canyon from the mine is the remains of the Old Chinaman mine, as well as several unnamed prospects.

Hand Samples

All samples were collected from the dump at the mine site.

7191-MW1-A - Sample consists of two euhedral quartz crystals twinned at 90 degrees and surrounded by massive quartz with minor sulfides. The sample has been heavily oxidized. The euhedral crystals were used in the isotope study

7191-MW1-B - Consists of massive, milky vein quartz with minor galena and sphalerite. Similar in appearance to vein material from the Crow and Spur mines. The galena was used in the isotope study.

7191-MW1-C - A piece of silicified vein material with abundant quartz and minor sulfides and oxides.

Fluid Inclusion Sections

* 7191-MW1-A1 - A section of quartz crystal and surrounding quartz. The crystal is badly fractured and at least three different episodes of fracturing can be made out. Questionable primary inclusions, if any, are hard to pick out in the clearer part of the crystal. Some inclusions are seen in the surrounding vein quartz, but all appear to be secondary in nature. Galena is the only remaining identifiable sulfide left in the sample.

* 7191-MW1-A2 - Cut of the same crystal as A1. Quartz is not as clear as A1 and the sample contains fewer inclusions that appear to be non-secondary in nature. One clear section of quartz contains what appear to be abundant, large primary or pseudosecondary inclusions.

* 7191-MW1-A3 - A cut of the quartz twin of A1 and A2. The crystal is clearer than the one in A1 and A2, but contains few over all inclusions.

7191-MW1-B - Milky quartz with small areas of crystalline quartz. Section contains galena with minor sphalerite and pyrite in massive quartz. Very few inclusions with most being very small and secondary in nature.

Maud

Location

The Maud mine is located in the SW 1/4 sec. 3, T.10 S., R.11 E. up Big Bear Canyon. The workings of the Maud consist of two adit, an upper and lower, along the same vein. At the time of the study, the lower adit was collasped and flooded and the upper adit was barely accessible. The workings are along a west-trending vein in the Walker andesite, which is similar to the veins of the Crow system and the Spur.

Hand Samples

3222-MA1 - Sample found on the floor of the upper adit. It is a piece of vein from roof. Sample consisted of vein quartz with disseminated sulfides. The quartz was used in the isotope study.

Fluid Inclusion Sections

* 3222-MA1-A - Section was cut normal to the C-axis of many small quartz crystals that grew together. Cores of crystals are clear and all have milky rims. Small inclusions are seen in only the clearest quartz.

* 3222-MA1-B - A section taken from the vein quartz. The quartz is very clear and show very few inclsions, most too small to measure.

Mayberry

Location

The Mayberry mine is located in the NW 1/4 sec. 8, T.10 S., R.13 E. in an intermittent drainage off of Philadelphia Canyon. The workings of the mine consist of a shaft with a stoped adit. The vein, which strikes to the northeast, is emplaced between the Walker andesite and a northeast trending andesite porphyry dike. An extension of the vein south of the drainage is not readily visible, and maybe offset up to 10 meters to the east. Grab samples of ore assayed out at 18% Zn, 9% Pb, 8 oz./ton Ag and 0.2 oz./ton Au.

Hand Samples

6091-MB1-A - Sample of massive vein quartz with sulfides, pieces of altered rock, and later quartz veins running through the sample. The sulfides appear to be sphalerite, galena, chalcopyrite and pyrite. The massive vein quartz was used in the isotope study.

6091-MB1-B - Sample is massive quartz with small cubes of pyrite. The quartz has a greenish tint to it.

6091-MB1-C - Sample is a piece of altered rock with a clear quartz vein running through on side of it. The altered rock contains small cubes of pyrite. The quartz was used in the isotope study. Sample was used for gas analysis.

6091-MB1-D - A piece of vein quartz with sulfides, altered rock, and massive barite. The sulfides are sphalerite, galena and chalcopyrite.

6091-MB1-E - A piece of cloudy vein quartz with minor sulfides. The quartz was used in the isotope study.

6091-MB1-F - An ore sample with quartz, sphalerite, galena, chalcopyrite, pyrite and barite. The quartz looks grainy, but mostly clear. The sphalerite is black to apple green and was used in the isotope study.

6091-MB1-G - Vein sample from the dump. Sample contains massive quartz, abundant galena, massive barite and minor chalcopyrite. The galena was used in the isotope study.

3222-MB1-A - Sample of vein-breccia from the dump. Angular fragments of altered wall rock are cemented by a clear quartz and a minor carbonate.

3222-MB1-B - A piece of wall rock that is veined with calcite, taken from inside the adit.

3222-MB1-C - A piece of calcite and clear quartz with a later calcite crust, on top of the quartz. The late calcite was used in the isotope study.

Fluid Inclusion Sections

6091-MB1-A - Inclusions seen in only the clearest quartz. Inclusions are mostly secondary with a few possible primary inclusions scattered about. Sphalerite is translucent in places and contains some very small inclusions.

6091-MB1-B - The quartz of the sample is too cloudy except for isolated patches of clear quartz.

* 6091-MB1-C - Numerous inclusions seen throughout the quartz. Most appear to be secondary in nature, but a few large isolated primary were noted.

6091-MB1-D - Inclusions are only seen in the clearest quartz. Inclusions are secondary with no unambiguous primary inclusions seen.

* 6091-MB1-F - Similar to MB1-A, inclusions were seen in the clearest quartz. The clearest quartz in the sample runs

as a thin band next to the sulfide minerals. The green sphalerite contains many visible inclusions. These inclusion are mostly secondary, but a few possible primary inclusions were noticed.

3222-MB1-A - A few small inclusions seen in the quartz. Most apear to be secondary, but some maybe of a primary origin.

* 3222-MB1-C - Inclusions are seen in the quartz and are scattered thoughout the section.

Mineral Farms

Location

The Mineral Farms mine site is located in the extreme SW 1/4 sec. 6, T.10 S., R.13 E. up Mineral Farms Canyon. The workings of the mine consist of a shaft with a dump. The mine is located on the eastern contact of the Bonito stock with the Walker andesite. Thompson (1973) states that the area is a shear zone between the stock and the andesite, but this relationship is unclear.

Hand Samples

7181-MF1 - Sample is massive, bladed barite collected from the dump.

Fluid Inclusion Sections

No material suitable for fluid inclusion work was found.

Parsons

Location

The Parsons or Hopeful mine is located in the extreme NE corner of sec. 34, T.9 S., R.11 E. The Parsons or Hopeful mine is not the mine marked of the map as the "Parsons", but is rather to the north of that mine by about 3/4 of a mile. The workings of the Parsons consist of a glory hole and its related underground adits and raises. The rocks around the mine are part of a brecciated portion of the Rialto stock which is highly altered. The ruins of the millsite can be seen a quarter of a mile west of the mine, in the old townsite of Parson's City.

Hand Samples

6051-P1 - The sample is a piece of massive quartz taken in place from the underground workings. This is the only known outcrop of quartz in place, inside the workings. The quartz was used in the isotope study.

9251-P1-A - The sample has been altered, fractured and then partially silicified. It has been oxidized and the only remaining sulfide is flecks of galena(?). The sample was found on a dump near where the tram line to the mill would have been. The quartz was used in the isotope study.

9251-P1-B - Highly altered rock with no visible phenocrysts. Sample is covered with small black flecks of some type of sulfide or metal oxide. Fractures in some areas are filled with turquoise.

Fluid Inclusion Sections

* 6051-P1 - Abundant secondary and primary or pseudosecondary inclusions in the clearest quartz. Best quartz for inclusions is that which has a moderately pitted surface. All inclusion types are good sized.

* 9251-P1-A1 - Large secondary inclusion with a few isolated primaries in the clear quartz.

* 9251-P1-A2,A3,A4 - Same as A1, but the quartz is not nearly so clear. Most inclusions are secondary with very rare primary or pseudosecondary inclusions seen.

Renowned O.K.

Location

The Renowned O.K. mine is located in the NE 1/4 sec. 3, T.10 S., R.11 E. directly west, across the road, from the Crow mine. The workings of the Renowned O.K. consist of a adit with a stope and winze. Heavily weathered dumps conceal additional underground workings to the east of the adit (Griswold, 1959). At the time the site was investigated, the stope had partially collapsed burying the winze. The stope was not investigated further due to "bad air" in the workings. The vein consists of quartz with pyrite stringers and is located within a gouge zone. The wall rock is andesite, but the farthest workings are reported to be in a latite porphyry (Griswald, 1959).

Hand Samples

6051-RN1-A and B - Sample of heavily altered and fractured vein material from the gouge zone. Sample consists of vein quartz with pyrite flecks on altered wall rock. Isotope sample RN1-A was a euhedral quartz crystal pulled from the sample. Isotope sample RN1-B was taken from the more abundant, bleached vein quartz. The sample looks similar to Crow sample 6031-CR1-A, but is more altered and sheared.

6051-RN1-C - Piece of vein quartz that is not as bleached and sheared as RN1-B.

6051-RN2 - Vein sample taken a meter closer to the stope than RN1 was. Some oxides and minor sulfides in the vein material. The quartz looks similar to RN1-C.

6051-RN3 - Vein quartz collected near the portal. The sample is not as sheared and altered as most of the rock in the mine.

Fluid Inclusion Sections

Sections 6051-RN1-C, RN2-A and RN2-B were looked at for inclusions. The quartz in all samples was too cloudy and fractured. Only about a dozen inclusions were seen in the three samples.

* 6051-RN3 - Section contains numerous inclusions in the clearest quartz. Inclusions appear to be secondary with no truly unambiguous primary inclusions seen.

Rockford

Location

The Rockford prospect is located in secs. 13 and 24, T.9 S., R.12 E. up Rockford Canyon, off of Nogal Canyon. Workings consist of several adits along northeast trending quartz veins in andesite. A mill for the site was located at the head of Rockford Canyon. The quartz veins of the Rockford may have some relation to the quartz veins of the American-Helen Rae mines, a mile to the northeast.

Hand Samples

7180-R1 - The rock is composed of pieces of clear to slightly milky, crystalline quartz surrounded by oxidized vein material. Sample was found on the dump of a small adit near the mill site, at the head of Rockford Canyon. Gas analysis was performed on the quartz, which showed it to contain large amounts of CO_2 and SO_2. The quartz was used in the isotope study.

4122-R1-A,B,C - Samples collected from the dumps of adits up the canyon from the mill. All samples look like 7180-R1.

Fluid Inclusion Sections

* 7180-R1 - Numerous pseudosecondary and secondary inclusions throughout the section. The quartz is very fractured and inclusions of primary origin are questionable.

Rock No. 1

Location

The workings of the Rock No. 1 are in unsurveyed forest service lands up Rodamaker Canyon, near Bonito Lake. The workings consist of a short adit and a collasped shaft in the Bonito Stock.

Hand Samples

4122-RK1-A - A piece of vein with quartz and galena found on the dump of the adit. Subhedral, clear quartz crystals are present.

4122-RK1-B - A piece of massive vein quartz found near the shaft.

Fluid Inclusion Sections

* 4122-RK1-A - Some small inclusions are seen in the clearest crystals. Most are too small to measure and appear to be secondary, but the section shows some larger primary or pseudosecondary inclusions.

Silver Plume

Location

The Silver Plume mine and related workings are located in the NE 1/4 sec. 31, T.10 S., R.13 E. along Krause Canyon. The workings on the property consist of a 45 meter long adit with rails and ore cars, a collapsed shaft and several prospect pits along the projected NE strike of the vein.

Hand Samples

The vein on the property, known as the Silver Cut, is a quartz-calcite vein with minor sulfides in the Walker andesite. Griswold (1959) reported the ore mineral of the vein to be cerargyrite, a silver chloride. Samples cut from the vein developed reddish-pink spots, characteristic of cerargyrite, several days after being collected. The vein shows some post-ore movement and is cut down the middle by a dike of unknown composition.

6121-SP1 - Sample cut directly from the vein, 20 meters inside the adit. The sample is composed of brecciated chunks of wall rock cemented by two types of calcite. The first type of calcite is massive and very milky. The second type is crystalline and forms a rim around the rest of the material. Both types were used in the isotope study. The sample shows a few small reddish-pink spots.

6121-SP2 - Sample of vein taken in place from the surface exposure at the shaft. The sample is mostly milky quartz with small islands of clearer quartz, also has a small rim of calcite on one side. Small isolated cubes of pyrite are seen scattered throughout the quartz. This quartz was used for isotope work.

Fluid Inclusion Sections

* 6121-SP1-A - Inclusions were only seen in the clear rim calcite. Most inclusions appeared to be primary as they very isolated and random in the very crystalline calcite. Best area for inclusions was the area near the boundary between the two different calcites.

* 6121-SP1-B - Similar to SP1-A, but clear calcite cut though the whole sample. Inclusions are seen in calcite that has a mottled look. Most inclusions are primary or pseudosecondary in appearance. The clearest quartz of the sample contains small inclusions that look to be primary.

6121-SP2 - Rock is too cloudy for any fluid inclusion work.

Soldier

Location

The Soldier mine may be found near the boundary lines between sec. 12, T.10 S., R.11 E. and secs. 2 and 11, T.10 S., R.12 E. on the east slope of Soldier Mountain. The workings consist of a rectangular shaft, a tailings pile, and a road that ends near the shaft. The mine and a smaller shaft or pit, down slope from the mine, lie in a dry drainage that may be followed up from the road. The area is in the Bonito stock and the mine was reportedly a silver producer.

Hand Samples

All samples were taken from the remains of the dump. The rock is unusual in that it is jet black with abundant barite.

10021-SD1-A - The sample contains large, rounded masses of crystalline quartz surrounded by much barite, in the form of small blades. Scattered flecks of galena are seen and appear to be the only sulfide present. A quartz crystal was used for isotope work.

10021-SD1-B - Similar to A, but a much smaller piece with less barite.

10021-SD1-C - The sample contains only small pieces of quartz, but also shows a fair amount of pyrite which is not seen in other samples.

10021-SD1-D - Ore sample containing sphalerite and galena in quartz.

Fluid Inclusion Sections

* 10021-SD1-A1 - Cut from an isolated quartz crystal removed from the larger hand sample. Most all of the inclusions are seen near fracture zones and away from the clearest areas of the quartz. The primary or pseudosecondary inclusions are larger than secondaries, more angular in appearance and have a larger bubble.

* 10021-SD1-A2 - Slice of rock with clear quartz. Only minor secondary inclusions were seen, and very few of those.

* 10021-SD1-B - Same as A2, but a few more secondary inclusions were seen.

Spur

Location

The Spur mine is located near the center of sec. 3, T.10 S., R.11 E. The workings of the Spur consist of a shaft, a short adit and a tailings pile. The workings are aligned along a vein in andesite. The Spur vein is similar in composition and texture to the Crow-Renowned O.K. vein, and may be a branch or spur of the latter vein. To the south of the Spur is an adit in the andesite, but no mineralization or alteration is present.

Hand Samples

All samples are taken from the tailings pile at the mine site, as workings were inaccessible.

7191-S1-A - Milky quartz with blebs of galena. Similar in appearance to samples from the Crow and Martha Washington. The quartz was used in the isotope study.

7191-S1-B - Piece of ore from the dump. It contains quartz, galena, sphalerite, pyrite, and barite. The quartz, galena and sphalerite were used in the isotope study.

7191-S1-C - Similar to A, but quartz more massive and much more milky. The quartz used in the isotope study and the gas analysis.

7191-S1-D - Massive, milky quartz with oxidation staining. The quartz was used in the isotope study. The quartz was used in the isotope study.

Fluid Inclusion Sections

* 7191-S1-D - Inclusions are seen in patches of clearer quartz. Most are appear to be primary or pseudosecondary in origin, with a few scattered secondary inclusions present.

Vera Cruz

Location

The Vera Cruz mine is located in sec. 17, T.8 S., R.13 E. on the southwest side of Vera Cruz Mountain, near the junction of U.S. 380 and N.M 37. The mine site was not visited in this study and access to the workings is limited to the surface. The literature reports that the workings consist of a glory hole and two adit, with the uppermost adit used as a haulageway (Griswold, 1959).

Hand Samples

The samples used in this study came from drill core provided by the New Mexico Bureau of Mines from a drilling project carried out by ARMCO in 1980. Core logs of the two holes were looked at and favorable intervals were chosen and visual inspected. Only intervals with abundant quartz and sulfide mineralization were chosen for isotope and fluid inclusion work.

VCD-2 538′ - Piece of brecciated rhyolite that is very vuggy. The vugs are filled with small, clear crystals of quartz and very small cubes of pyrite. The quartz was used in the isotope study.

VCD-2 545′ - Similar to 538′, but no quartz and much larger cubes of pyrite. The quartz and pyrite were used in the isotope study.

VCD-2 703′ - Similar to 538′. Small vugs filled with clear quartz crystals and small cubes of pyrite. The quartz and pyrite were used in the isotope study.

VCD-2 804′ - Core log calls it a grey hornfels. Sample is solid rock with numerous small fractures. Top of one piece is covered with small quartz crystals. The quartz was used in the isotope study.

VCD-2 824′ - A breccia composed of angular fragments of black and grey hornfels suspended in a cement of clear to milky quartz. Abundant pyrite (≤20%) with no other sulfides present. Pyrite is seen crosscutting all of the fragments of hornfels. The quartz and pyrite were used in the isotope study.

Fluid Inclusion Sections

* VCD-2 824′ - Section shows small inclusions with rapidly moving bubbles in only the clearer quartz. Most inclusions appear to be primary as they are isolated from each other by some distance. Very few veils or trains of secondary inclusions, mostly near grain boundaries.

Waterdog

Location

The waterdog prospect covers portions of sec. 36, T.9 S., R.11 E.; secs. 35 and 36, T.9 S., R.12 E.; and secs 1 and 2, T.10 S., R.12 E.. The workings on the prospect consist of numerous shafts and adits in a heavily bleached and silicified portion of the Bonito stock. The more extensive workings of the prospect are in small, localized breccia bodies within the altered area. Tailings from most of the workings show nothing but altered rock with minor flecks of sulfides. Some copper oxide mineralization was found at the back of the Waterdog adit.

Hand Samples

6031-BB1 - Sample was collected from the tailings of an un-named shaft on the ridge between Kraut and George Canyons. Rock around the shaft is highly brecciated and bleached. Tailings consist of altered breccia with euhedral quartz crystals with terminated ends. The crystals are clear to milky with some fracturing. Evidence of remnant sulfides were seen in the tailings. The quartz crystals were used in the isotope study.

6031-BB2 - A piece of ore found on the tailings. Sample contains quartz, sphalerite, galena, chalcopyrite and pyrite. The sulfides appear to have been slightly weathered. The sphalerite was used in the isotope study.

3222-BB1 - The sample consists of individial, small quartz crystals and quartz crystal masses taken from the dump. Several pieces of wall rock with pyrhotite(?) were also collected. Crystals were used in the isotope study and gas analysis.

3222-B1 - A sample of altered stock with a quartz vein running through it. Sample was collected north of the parking area, uphill from the creek. "B" stands for Bonito, but site is in the Waterdog prospect.

Fluid Inclusion Sections

* 6031-BB1 - C-axis section of a large euhedral quartz crystal. The crystal is clear with some fractures. Sample contains many different types of inclusions: large primary inclusions with up to five daughter minerals; large liquid-vapor secondary inclusions; and primary and/or secondary liquid-dominated and vapor-dominated inclusions. The sample shows some evidence for boiling.

6031-BB1-A - A clear, euhedral quartz crystal with only minor fractures. Devoid of inclusion except for large, dark vapor-dominated inclusions (?).

* 6031-BB2 - Quartz is cloudy and very grainy. A few very small inclusions were seen at 80x. Reflected light work shows the presence of gold and tetrahedrite, in addition to the ore minerals listed above.

Appendix B: Isotope Data from Silicate Samples

OXYGEN ISOTOPE DATA FROM SILICATE SAMPLES

Sample number	Date run	Run number	Type of quartz C= crystal V= vein quartz S= silicious rock	Sample size in mg	Ext yield %	D 13 C	D 18 O	Temperature	Temp data F= fluid inc E= estimate	D 18 O H2O	Comments
Samples from the Gold Deposits											
VCD-2 '538	11-09-91	SI-119-2	V, breccia	10.2	109.2	-25.2	12.2	310	F	5.7	Clear qtz cement or indiviual crystals
VCD-2 '538	11-09-91	SI-119-1	V, breccia	9.8	96.4	-25.2	11.9	310	F	5.4	•
VCD-2 '703	11-09-91	SI-119-3	V, breccia	10.8	104.2	-25.2	12.2	310	F	5.7	•
VCD-2 '703	11-09-91	SI-119-4	V, breccia	9.9	118.7	-25.2	12.2	310	F	5.7	•
VCD-2 '904	11-09-91	SI-119-12	V, breccia	10.6	101.8	-25.3	12.1	310	F	5.6	•
VCD-2 '904	11-09-91	SI-119-11	V, breccia	10.7	103.6	-25.3	11.8	310	F	5.3	•
VCD-2 '924	11-09-91	SI-119-6	V, breccia	10.3	138.1	-25.3	9.8	310	F	3.2	•
7240-HR1	03-20-91	SI-96-6	V	10.3	97.5	-25.7	13.5	250	E	4.6	
7240-HR1	12-16-91	SI-126-3	V	10.4	130.4	-25.3	13.3	250	E	4.4	
7240-HR8	01-22-92	SI-140-3	C	10.6	87.1	-25.2	11.0	250	E	2.1	
8170-HR1	03-20-91	SI-98-2	V	9.1	87.5	-25.4	11.2	250	E	2.3	Vein material with sulfides
7260-A1	01-22-92	SI-140-2	V	9.9	48.6	-25.9	9.8	250	E	0.9	•
7260-A1	01-22-92	SI-140-1	V	10.8	113.2	-25.1	9.6	250	E	0.7	•
8160-V1	03-20-91	SI-98-4	V	10.4	114.9	-25.6	7.4	210	E	-3.6	
7180-R1	12-13-91	SI-125-1	C	10.8	99.9	-25.4	8.7	230	F	-1.1	From near mill site
7180-R1	12-13-91	SI-125-2	C	11.0	104.3	-25.4	8.5	230	F	-1.2	•
4122-R1-A	07-20-92	SI-6-1	V	10.7	105.0	-25.3	8.7	230	E	-1.2	
4122-R1-A	07-20-92	SI-6-2	V	11.0	91.7	-25.6	8.8	230	E	-1.1	
4122-R1-B	07-22-92	SI-7-2	V	10.5	106.4	-25.6	7.7	230	E	-2.2	
4122-R1-B	07-22-92	SI-7-1	V	11.1	100.1	-25.5	8.0	230	E	-1.9	
4122-R1-C	07-23-92	SI-8-2	V	10.8	103.3	-25.7	8.2	230	E	-1.7	

OXYGEN ISOTOPE DATA FROM SILICATE SAMPLES

Sample number	Date run	Run number	Type of quartz C= crystal V= vein quartz S= silicious rock	Sample size in mg	Ext yield %	D 13 C	D 18 O	Temperature	Temp data F= fluid inc E= estimate	D 18 O H2O	Comments
4122-R1-C	07-23-92	SI-8-1	V	10.3	106.7	-25.5	8.3	230	E	-1.8	
6061-P1	11-11-91	SI-121-11	V	10.7	110.4	-25.3	4.2	250	F	-4.7	
6061-P1	11-11-91	SI-121-12	V	10.4	94.1	-25.4	3.9	250	F	-5.0	
9251-P1	11-07-91	SI-118-2	V, breccia	9.9	109.9	-25.2	6.8	250	F	-2.1	From dump
9251-P1	11-07-91	SI-118-1	V, breccia	11.1	105.0	-25.2	6.4	250	F	-2.5	"
6061-GW1-A	11-11-91	SI-121-7	S	10.5	102.9	-25.3	13.7	280	E	5.3	Breccia clast
6061-GW1-A	11-11-91	SI-121-8	S	11.0	101.7	-25.3	13.3	280	E	4.8	"
6061-GW1-B	11-11-91	SI-121-10	S	10.8	91.8	-25.4	11.0	280	E	2.8	Breccia clasts in matrix, from dump
6061-GW1-B	11-11-91	SI-121-9	S	10.3	88.8	-25.4	10.7	280	E	2.3	"
6031-BB1	11-07-91	SI-118-4	C	10.3	92.2	-25.2	12.1	480	F	9.5	
6031-BB1	07-16-92	SI-151-3	C	10.3	108.0	-26.0	12.0	480	F	9.6	
6031-BB1-A	11-07-91	SI-118-5	C	10.3	103.8	-25.2	12.5	480	F	9.9	Same as 6031-BB1, but different crystal
6031-BB2	07-21-92	SI-6-1	V	11.2	99.5	-25.5	9.3	240	F	-0.1	From ore sample containing gold, found at site
6031-BB2	07-21-92	SI-6-2	V	10.6	101.0	-25.6	9.5	240	F	0.1	
Samples from the Silver-Lead-Zinc Deposits											
7191-MW1	11-05-91	SI-117-2	V	10.5	104.5	-25.1	7.0	240	F	-2.4	Quartz crystal surrounded by vein quartz
7191-MW1	11-05-91	SI-117-1	V	10.2	103.2	-25.1	6.8	240	F	-2.5	"
7191-MW1-A	12-12-91	SI-124-2	V	10.5	89.1	-25.3	6.2	240	F	-3.2	Same as 7191-MW1
7191-MW1-A	12-12-91	SI-124-1	V	10.6	100.2	-25.4	6.1	240	F	-3.3	"
7191-MW1-B	12-12-91	SI-124-9	V	10.4	94.4	-25.4	4.7	240	E	-4.7	
7191-MW1-C	12-15-91	SI-126-5	V	10.0	112.5	-25.3	5.9	240	E	-3.4	

OXYGEN ISOTOPE DATA FROM SILICATE SAMPLES

Sample number	Date run	Run number	Type of quartz C= crystal V= vein quartz S= silicious rock	Sample size in mg	Ext yield %	D 13 C	D 18 O	Temperature	Temp data F= fluid inc E= estimate	D 18 O H2O	Comments
7191-MW1-C	12-15-91	SI-126-11	V	10.1	97.2	-25.3	5.4	240	E	-4.0	
7191-MW1-C	12-15-91	SI-126-6	V	10.6	104.2	-25.3	5.2	240	E	-4.2	
6031-CR1	11-05-91	SI-117-3	C	10.5	102.9	-25.2	3.4	250	F	-6.6	Quartz crystal from altered vein, in place
6031-CR1	11-05-91	SI-117-4	C	10.3	103.4	-25.0	3.2	250	F	-6.7	"
9251-CR1-A	07-19-92	SI-4-5	V	10.6	102.1	-25.6	5.4	250	F	-3.5	
9251-CR1-A	12-15-91	SI-126-7	V	10.9	96.1	-25.4	3.9	250	F	-6.0	
9251-CR1-B	11-11-91	SI-121-5	V	10.6	94.5	-25.3	5.5	250	F	-3.4	Amorphous quartz with minor sulfides
9251-CR1-B	11-11-91	SI-121-6	V	10.6	103.4	-25.3	3.9	250	F	-6.0	"
6061-RN1-A	11-05-91	SI-117-5	C	10.4	109.2	-25.2	10.7	290	E	3.5	Quartz crystal from altered vein, in place
6061-RN1-A	07-18-92	SI-3-11	C	10.8	123.1	-25.5	10.7	290	E	3.5	"
6061-RN1-B	11-11-91	SI-121-1	V	11.0	92.7	-25.2	3.9	290	E	-3.3	Quartz from altered vein, in place
6061-RN1-B	11-11-91	SI-121-2	V	10.4	107.9	-25.3	3.5	290	E	-3.7	"
6061-RN1-C	11-11-91	SI-121-3	V	10.3	107.9	-25.3	2.7	290	E	-4.5	
6061-RN1-C	11-11-91	SI-121-4	V	10.2	99.2	-25.3	2.2	290	E	-5.1	
6061-RN3	07-23-92	SI-6-6	V	10.4	101.3	-25.6	5.3	290	F	-1.9	
6061-RN3	07-23-92	SI-6-5	V	11.3	88.3	-25.6	5.2	290	F	-2.1	
7191-S1-A	11-05-91	SI-117-7	S	10.1	92.1	-24.8	4.9	300	F	-1.9	Similar to 7191-MW1-B and 9251-CR1-A
7191-S1-A	11-05-91	SI-117-8	S	10.2	116.9	-25.2	4.8	300	F	-2.1	"
7191-S1-B	07-18-92	SI-3-3	V	10.4	101.3	-25.5	8.3	300	F	1.4	Similar to 9251-CR1-B
7191-S1-B	11-10-91	SI-120-6	V	11.1	100.5	-26.3	7.9	300	F	1.0	"
7191-S1-C	07-18-92	SI-3-9	S	10.4	104.0	-25.5	8.1	300	F	1.3	Similar to 7191-S1-A
7191-S1-C	11-10-91	SI-120-1	S	10.8	72.4	-27.6	8.1	300	F	1.2	"

OXYGEN ISOTOPE DATA FROM SILICATE SAMPLES

Sample number	Date run	Run number	Type of quartz C= crystal V= vein quartz S= silicious rock	Sample size in mg	Ext yield %	D 13 C	D 18 O	Temperature	Temp data F= fluid inc E= estimate	D 18 O H2O	Comments
7191-61-D	07-16-92	SI-151-10	S	10.2	97.3	-25.5	4.9	300	F	-2.0	
7191-61-D	11-10-91	SI-120-3	S	11.0	94.7	-25.3	4.8	300	F	-2.0	
3222-MA1-A	07-21-92	SI-6-3	V	10.9	97.4	-25.6	7.4	240	F	-2.0	
3222-MA1-A	07-21-92	SI-6-4	V	10.4	94.4	-25.6	7.8	240	F	-1.6	
3222-MA1-B	07-21-92	SI-6-6	V	11.1	103.0	-25.6	4.3	240	F	-5.1	
3222-MA1-B	07-21-92	SI-6-5	V	10.3	83.5	-25.6	4.1	240	F	-5.3	
7191-AG1	07-16-92	SI-151-9	V	11.0	86.2	-25.4	6.3	270	F	-1.7	
7191-AG1	07-18-92	SI-3-4	V	11.3	105.4	-25.5	6.6	270	F	-1.5	
6091-MB1-A	11-07-91	SI-118-11	V	10.1	92.5	-25.2	5.4	230	F	-4.3	Vein quartz with sulfides
6091-MB1-A	11-10-91	SI-120-11	V	10.2	91.3	-25.5	5.4	230	F	-4.4	"
6091-MB1-C	12-12-91	SI-124-12	V	10.2	104.8	-25.4	5.4	230	F	-4.3	
6091-MB1-C	12-12-91	SI-124-11	V	10.1	101.3	-25.4	5.3	230	F	-4.5	
6091-MB1-D	01-22-92	SI-140-10	S	11.3	83.6	-25.6	5.8	230	F	-3.9	
6091-MB1-E	07-23-92	SI-8-3	S	10.6	97.2	-25.7	5.6	230	F	-4.3	
6091-MB1-E	12-12-91	SI-124-3	S	10.8	81.6	-25.4	6.1	230	F	-3.7	
6121-6P2	12-13-91	SI-125-12	S	10.3	91.2	-25.4	9.7	240	E	0.3	From Silver Plume shaft
6121-6P2	12-13-91	SI-125-11	S	10.5	96.0	-25.4	9.6	240	E	0.2	"

Samples from the Cu-Mo Porphyry Deposit and Related Areas

9251-F1	11-07-91	SI-118-10	S	10.3	104.2	-25.2	6.4	350	E	1.1	Found with crystaline MoS2
9251-F1	11-07-91	SI-118-9	S	10.5	17.9	-25.3	5.8	350	E	0.5	"
9251-JL1	11-04-91	SI-116-7	C, clear	10.5	101.8	-25.2	6.4	220	F	-2.0	Spatially close to drill hole NP-4

OXYGEN ISOTOPE DATA FROM SILICATE SAMPLES

Sample number	Date run	Run number	Type of quartz C= crystal V= vein quartz S= silicious rock	Sample size in mg	Ext yield %	D 13 C	D 18 O	Temperature	Temp data F= fluid inc E= estimate	D 18 O H2O	Comments
9251-JL1	11-04-91	SI-116-8	C, clear	10.8	110.8	-25.1	7.9	220	F	-2.5	•
9251-JL1	11-04-91	SI-116-10	C, cloudy	10.5	101.4	-25.2	7.3	220	F	-3.1	•
9251-JL1	11-04-91	SI-116-9	C, cloudy	10.8	99.0	-26.2	7.0	220	F	-3.4	•
NP-4 '435	07-16-92	SI-3-10	C	10.1	97.4	-25.6	10.2	240	F	0.8	Large quartz crystal from drill core
NP-4 '435	11-04-91	SI-116-6	C	10.5	99.1	-25.2	9.9	240	F	0.6	•
NP-4 '533	11-04-91	SI-116-4	C	11.5	109.3	-25.2	7.1	250	F	-1.8	•
NP-4 '533	07-16-92	SI-151-4	C	10.4	100.6	-25.3	7.6	250	F	-1.3	•
NP-4 '579	11-04-91	SI-116-2	V	10.0	86.0	-25.2	8.8	250	F	-0.1	Drill core
NP-4 '579	11-04-91	SI-116-1	V	10.3	108.2	-25.1	8.6	250	F	-0.3	•
Samples from the Shear Zone Deposits											
4122-RK1-B	07-23-92	SI-6-4	S	11.2	96.7	-25.6	9.0	360	F	4.0	Located inside Bonito stock
4122-RK1-B	07-22-92	SI-7-5	S	10.9	100.7	-25.5	9.1	360	F	4.0	•
10021-SD1	11-04-91	SI-116-11	C	9.6	102.1	-25.1	15.3	240	F	5.9	•
10021-SD1	11-04-91	SI-116-12	C	10.6	104.7	-25.1	15.2	240	F	5.8	•
7161-H1	01-22-92	SI-140-7	V	10.4	90.2	-25.3	10.4	280	F	2.8	•

Fractionation equation used for quartz: 3.34(10*6/T2) - 3.31 Matsuhisa et. al (1979)

Appendix C: Isotope Data from Sulfide Samples

SULFUR ISOTOPE DATA FROM SULFIDES

Sample number	Date run	Run number	Mineral	Sample size In mg	Ext yield %	D 34 S	Temp. Degrees C	D 34 S H2S	Comments
Samples from the Gold Deposits									
VCD-2 '824	03-06-92	SO2-14-10	PYRITE	61.6	91	5.1	310	3.9	
VCD-2 '703	03-06-92	SO2-14-11	PYRITE	75.8	113.7	5.5	310	4.3	
VCD-2 '545	03-06-92	SO2-14-12	PYRITE	64.7	113.4	5.1	310	3.9	
7240-HR3	03-06-92	SO2-14-13	GALENA	90.5	129.2	-8.7	250	-6.4	
6031-BB2	03-06-92	SO2-14-19	SPHALERITE	63.3	104.3	-2.6	480	-2.8	
Samples from the Silver–Lead–Zinc Deposits									
7191-MW1-B	03-06-92	SO2-14-9	GALENA	59.7	131.5	-5.7	240	-3.3	
9251-CR1-A	03-06-92	SO2-15-12	SPHALERITE	50.1	119.1	-2.7	250	-3.1	
9251-CR1-A	03-06-92	SO2-15-13	SPHALERITE	55.3	119	-2.9	250	-3.3	
9251-CR1-D	03-06-92	SO2-15-14	SPHALERITE	66.5	46.4	-2.6	250	-3.2	
9251-CR1-C	03-06-92	SO2-15-4	CHALCOPYRITE	75.4	100.6	-5.8	250	-5.6	
9251-CR1-C	03-06-92	SO2-15-5	CHALCOPYRITE	69.7	104	-5.8	250	-5.6	
9251-CR1-B	03-06-92	SO2-15-11	PYRITE	40.8	66.3	-3.1	250	-4.6	
9251-CR1-B	03-06-92	SO2-15-10	GALENA	50.9	119.4	-5.8	250	-3.5	
7191-S1-B	03-06-92	SO2-14-21	GALENA	89.6	113.2	-5.5	300	-3.6	
7191-S1-B	03-06-92	SO2-15-1	GALENA	97.9	124.7	-5.2	300	-3.3	
7191-S1-B	03-06-92	SO2-15-2	SPHALERITE	67.9	104.3	-2.7	300	-3.0	
7191-S1-B	03-06-92	SO2-15-3	SPHALERITE	66.7	103.8	-2.7	300	-3.0	
7191-AG1-A	03-06-92	SO2-14-20	PYRITE	55.4	91.6	-3.4	270	-4.7	

SULFUR ISOTOPE DATA FROM SULFIDES

Sample number	Date run	Run number	Mineral	Sample size In mg	Ext yield %	D 34 S	Temp. Degrees C	D 34 S H2S	Comments
6091-MB1-G	03-06-92	SO2-15-6	GALENA	82.9	106	-8.6	230	-6.0	
6091-MB1-F	03-06-92	SO2-15-8	SPHALERITE	64.7	123.2	-6.1	230	-6.5	
6091-MB1-F	03-06-92	SO2-15-9	SPHALERITE	72.4	118	-6.0	230	-6.5	
Samples from Cu–Mo Porphyry Deposit and Related Areas									
9251-F1	03-06-92	SO2-14-15	MOLYBDENITE	48.7	117.7	0.2	350	-1.0	From Rialto (Fulmer Adit)
9251-F1	03-06-92	SO2-14-16	MOLYBDENITE	55.7	86.7	-0.1	350	-1.3	•
9251-F1	03-06-92	SO2-14-17	PYRITE	61.7	116.2	-0.4	350	-1.4	•
9251-F1	03-06-92	S02-14-18	PYRITE	65.3	90.6	-0.3	350	-1.4	•
NP-4 '579	03-06-92	SO2-14-4	PYRITE	59.3	93.5	-0.1	250	-1.6	
NP-4 '579	03-06-92	SO2-14-5	PYRITE	62.3	98.4	-0.2	250	-1.6	
NP-4 '579	03-06-92	SO2-14-6	SPHALERITE	65.3	99.7	-7.9	250	-8.3	
NP-4 '579	03-06-92	SO2-14-7	SPHALERITE	68.4	99.4	-8.0	250	-8.3	
NP-4 '435	03-06-92	SO2-14-8	PYRITE	56.2	83.2	-2.0	240	-3.5	
Sample from Shear Zone Deposits									
7181-H1-A	03-06-92	SO2-14-14	PYRITE	55.6	109.9	-5.7	280	-7.0	
Sulfide Standards									
NBS 123	03-06-92	SO2-15-15	SPHALERITE	142.7	116	17.324			Delta 34 S = 17.32
NBS 123	03-06-92	SO2-14-1	SPHALERITE	69.3	116.3	17.479			Delta 34 S = 17.32

SULFUR ISOTOPE DATA FROM SULFIDES

Sample number	Date run	Run number	Mineral	Sample size In mg	Ext yield %	D 34 S	Temp. Degrees C	D 34 S H2S	Comments
CDT	03-06-92	SO2-15-18	TROYLITE	55.8	110.7	-0.315			Delta 34 S = 0.00
GKC-2	03-06-92	SO2-15-19	SPHALERITE	61.8	111.5	0.814			Delta 34 S = 0.45
SYN PbS	03-06-92	SO2-15-20	GALENA	76	115.3	0.922			Delta 34 S = 0.[illegible]

Fractionation equation for:

pyrite = 0.40(10*6/T2) Ohmoto and Rye (1979)

sphalerite = 0.10(10*6/T2) Ohmoto and Rye (1979)

galena = -0.63(10*6/T2) Ohmoto and Rye (1979)

chalcopyrite = -0.05(10*6/T2) Ohmoto and Rye (1979)

molybdenite = 0.45(10*6/T2) Ohmoto and Rye (1979)

Appendix D: Isotope Data From Carbonate Samples

CARBON AND OXYGEN ISOTOPE DATA FROM CARBONATES

Sample number	Date run	Run number	Sample size in mg	D 13 C	D 18 O	Acid correction factor	Corrected D 18 O	Temperature	Corrected D 18 O H2O	Comments
Samples from Gold Deposits										
7250-HR4	03-19-91	CO2-166-2	16.1	-0.1	24.2	10.5	13.9	180	3.2	Vein carbonate
7280-A1	03-19-91	CO2-166-1	15.6	-0.8	23.6	10.5	13.1	180	2.4	•
Samples from Silver--Lead--Zinc Deposits										
3222-MB1-C LATE	04-21-92	CO2-196-7	11.1	-1.2	29.5	10.6	18.9	180	8.3	Late vein carbonate
3222-MB1-C LATE	04-21-92	CO2-196-8	11.9	-1.4	29.3	10.6	18.8	180	8.1	•
6121-SP1	04-21-92	CO2-196-1	13	-1.1	26.6	10.6	16.1	220	7.5	Early vein carbonate
6121-SP1	04-21-92	CO2-196-2	12.7	-1.0	26.6	10.6	16.0	220	7.5	•
6121-SP1	12-16-91	CO2-184-3	15.5	-1.1	26.9	10.3	16.6	220	8.0	Late vein carbonate
6121-SP1	12-16-91	CO2-184-4	15.2	-1.0	26.6	10.3	16.4	220	7.9	•

Fractionation equation used was 1000 ln a = 2.78(10*6/T2) - 2.89

Friedman and O'Neil (1977)

Appendix E: Summary of Fluid Inclusion Data

DATA FROM FLUID INCLUSION MEASURMENTS

Sample Location	Mineral	Type of Inclusion	# of meas	Range in Th	Ave Th degrees C	# of Tm	Range in Salinity	Salinity eq.wt.% NaCl	Remarks
Gold Deposits									
Vera Cruz	Qtz 1	Primary	20	286-383	310	4	7.8-9.4	8	Tm's are approximate
Helen Rae	Qtz 1	Secondary	7	120-227	160	6	3.5-7.6	4	
Rockford	Qtz 1	Primary	21	224-305	230	21	4.8-6.4	6	
Parsons	Qtz 1	Primary	23	236-292	250	12	2.9-5.8	3	
Waterdog	Qtz 1	Primary 1	19	429-538	480	19	40-50	45	Liquid + Vapor + NaCl + Others
		Primary 2	21	371-500	450	21	38-42	40	Liquid + Vapor + NaCl
		Secondary	26	278-374	320	20	5.2-7.4	6	Co-genetic with vapor filled inclusions
Silver-Lead-Zinc Deposits									
Martha Washington	Qtz 1	Primary	18	190-268	240	8	4.6-7.6	6	
Crow	Qtz 1	Primary	23	209-277	250	11	3.4-6.4	3	
Renowned O.K.	Qtz 1	Primary	20	269-344	290	10	3.7-4.8	4	
		Secondary	1	157	157	0			
Spur	Qtz 1	Primary	14	264-311	300	10	2.9-4.5	3	
Maud	Qtz 1	Primary	23	212-280	240	11	2.9-7.0	6	
		Secondary	3	176-193	190	0			
Argentine	Qtz 1	Primary	14	252-416	270	6	5.7-6.4	6	
		Secondary	5	177-230	210	4	6.0-6.2	6	
Mayberry	Sph	Secondary	13	150-218	180	12	11-12.3	11.5	
	Qtz 1	Primary	45	188-307	230	29	2.9-18.0	3	Salinity Highly varible in sample
		Secondary	4	126-160	160	4	3.1-5.7	5	
Silver Plume	Calcite	Primary	14	101-247	220	7	2.4-4.2	2.5	

DATA FROM FLUID INCLUSION MEASURMENTS

Sample Location	Mineral	Type of Inclusion	# of meas	Range in Th	Ave Th degrees C	# of Tm	Range in Salinity	Salinity eq.wt.% NaCl	Remarks
Deposits Related to Porphyry Mineralization									
Jennie Linn	Qtz 1	Primary	13	194-242	200	13	5-6.4	6	
		Secondary	5	210-236	220	5	3-4	3	
Drillhole NP-4									
435 ft.	Qtz 1	Primary	18	212-287	240	10	3.4-7.5	3	
533 ft.	Qtz 1	Primary	16	207-318	255	10	2.6-6.4	5	
Drillhole N-20 164 ft.	Qtz	Primary ?	9	323-460	?	0			Quartz was badly decripitated
Shear Zone Deposits									
Rock No. 1	Qtz 1	Primary	2	354-359	357	2	9.6-10	10	
		Secondary	7	127-205	140	4	3.0-9.2	9	
Soldier	Qtz 1	Primary	10	200-314	240	3	10.1-11	10	
		Secondary	2	175	175	2	10.1-10.4	10	
Hope	Qtz	Primary ?	2	278-280	280	0			
Total									
Twenty-two sites			419	100-538		264	2.4-50		

Appendix F: Fluid Inclusion Measurements by Site

Fluid Inclusion Data by Site

Gold Deposits

Vera Cruz

Type	P	PS	PS	PS	PS	P-PS	P-PS	P	PS	P	P	P	P	P-PS	PS	P	PS	PS	P-PS	P
Th	361	307	289	303	301	310	366	312	286	342	307	312	370	325	309	362	328	345	363	383
Tm	-5.5		-5															-5.3	-8.1	

Helen Rae

Type	S	PS-S	PS-S	PS-S	PS-S	PS	P-PS
Th	152	171	160	162	120	211	227
Tm	-1		-2.6	-2.1	-4	-3.6	-2.9

Rockford	PS-S	PS	PS	PS	PS	P	PS	P	P	PS	P	S	PS	P	P	P	PS	P	P	S	S
Type	230	227	224	236	238	305	226	302	255	230	284	265	273	241	260	256	262	242	246	282	274
Th	-3.9	-3.8	-4	-3.6	-3.8	-3.6	-3.5	-3.7	-3.5	-3.8	-3.3	-3	-3.7	-3.7	-3.6	-3.4	-3.3	-3.3	-3.3	-2.9	-2.9
Tm																					

Parsons

Type	PS	PS-S	P	P	PS-S	P-PS	PS	PS	PS	PS	S	PS	PS	PS-S	P-PS	PS-S	PS	P-PS	P	PS	P	PS	P-PS
Th	269	236	283	267	242	252	252	279	281	262	241	283	254	273	258	282	256	267	265	259	257	279	292
Tm		-1.7		-3.1	-2.2	-2.2	-2			-3.1	-2.4	-3.2		-3.6			-3				-1.9		-2

Waterdog

Type	S, I	S, I	S, I	S, I	S, I	S, I	S, I	S, I	S, I	S, I	S, I	S, I	S, I	S, I	S, I	S, I	S, I	S, I	S, I	S, I	S, I
Th	321	325	327	321	327	300	316	334	347	285	278	285	285	279	327	327	324	335	316	334	324
Tm	-3.6	-3.5	-3.6	-3.6	-3.6			-3.7	-5	-3.2	-3.2	-3.2	-3.2		-4.3	-4.3	-4	-3.9	-4.9	-3.9	-3.9

Type	S, II	S, II	S, II	S, II	S, II
Th	323	342	323	297	295
Tm	-4.7	-4.1			

Type	P, III	P, III	P, III	P, III	P, III	P, III	P, III	P, III	P, III	P, III	P, III	P, III	P, III	P, III	P, III	P, III	P, III	P, III	P, III	P, III
Th	399	388	371	380	428	454	442	423	454	465	413	415	433	413	472	456	500	485	464	447
Dh	317	324	300	298	321	327	327	321	327	322	322	322	320	326	354	345	348	348	300	350

Type	P, IV	P, IV	P, IV	P, IV	P, IV	P, IV	P, IV	P, IV	P, IV	P, IV	P, IV	P, IV	P, IV	P, IV	P, IV	P, IV	P, IV	P, IV	P, IV	P, IV
Th	457	483	477	451	464	443	484	484	482	480	479	479	480	491	429	532	518	538	479	483
Dh	321	385	381	346	346	394	421	424	424	424	424	421	421	373	370	371	379	376	415	427

Ag-Pb-Zn Deposits

Martha Washington

Type	PS	P	PS	PS	P	P-PS	P-PS	P	P	P	P	PS	PS	PS	P	P	P	PS
Th	190	228	252	268	248	249	251	244	243	257	246	216	236	236	248	232	241	238
Tm	-3.9	-2.8			-3.4			-3.8				-3.6	-3.8		-4.8		-3.7	

Crow

Type	PS	P-PS	P-PS	P-PS	P-PS	P	P-PS	PS	PS	P-PS	PS	P	P	P	PS	PS-S	PS	PS	P	P	P-PS	PS
Th	259	242	254	277	259	335	209	237	240	255	267	267	240	241	240	233	248	244	259	253	267	257
Tm	-5.8	-2				-4	-2.1	-2.3	-2.3		-2.7	-2	-1.8	-2		-2.2			-2.2	-2.2		

Renowned O.K.

Type	S	P-PS	P-PS	P-PS	PS	PS	PS	PS	P	P	P	PS	PS	PS-S	PS	PS	PS	PS	PS	PS
Th	157	279	281	286	269	271	291	291	285	344	316	302	337	281	294	318	323	269	234	297
Tm		-2.5		-2.2	-2.7	-2.9	-2.8			-2.5	-2.7				-2.6				-2.0	-2.9

Spur

Type	PS	P-PS	PS	PS	P-PS	P-PS	PS	PS-S	PS-S	P	PS	P	PS	P
Th	301	307	299	302	298	299	298	276	264	309	278	303	311	292
Tm	-2	-1.9	-2.7	-2.6	-2.3	-2	-2	-1.7			-1.7			-2.4

Argentine

Type	P	P	P	P	P	P	P	?	PS	PS	S	P	S	S	PS	S	S	PS	PS
Th	415	416	383	394	299	334	295	288	270	254	230	261	214	229	252	177	191	275	253
Tm						-4	-4.4				-3.5	-3.7	-3		-3.5	-3.8	-3.8	-3.8	-4

Maud

Type	PS	P-PS	P-PS	P	PS	PS	P-PS	PS	P	P-PS	PS	S	PS	PS	PS	PS	PS	PS	PS S	P-PS	P-PS	P-PS	P
Th	217	238	227	252	223	212	261	193	276	256	226	178	213	193	248	237	246	280	222	223	227	234	257
Tm		-4	-4		-4.4	-3.9									-2.3		-2.9		-1.3	-1.7	-2.6		

Type	P	P-PS	P-PS
Th	253	240	247
Tm	-4	-3.9	

Mayberry
Sphalerite

Type	S	S	S	S	S	S	S	S	S	S	S	S	S
Th	210	150	150	172	198	174	170	182	218	186	185	188	188
Tm	-7.8	-7.8	-7.4		-7.4	-8.2	-8.2	-8.2		-8.4	-8.5	-8.5	-7.6

Quartz

Type	PS-S	S	S	P	PS	PS	PS	PS-S	PS	P	PS	PS	P	PS	PS	PS-S	PS	PS-S	PS	PS	PS	PS	PS
Th	160	148	126	287	188	218	227	195	201	228	233	230	235	234	251	188	221	204	261	237	194	214	223
Tm	-3.5	-3.5	-3.5					-3.9			-6.3	-6.3		-3.9	-4		-4				-9	-7.2	-7.2

Type	P	P-PS	PS
Th	230	215	231
Tm	-2.1	-2.2	

Type	P	PS	PS	PS	PS	P	P	PS	PS	PS	PS	PS	PS	PS	PS	P-PS	PS-S	P-PS	P	P-PS	PS	P
Th	237	232	246	160	221	258	240	237	224	207	217	214	288	243	227	279	207	220	307	254	242	244
Tm		-1.6	-1.6	-1.8	-4.5		-1.7	-1.8	-2.6				-5.4				-1.9	-2.1				

Silver Plume
Calcite

Type	P-PS	P	P	P	PS	P-PS	P-PS	P	P	P	P	P	PS	P
Th	103	101	150	186	225	230	212	244	230	222	238	226	194	221
Tm		-1.5	-1.7		-1.7	-1.4	-1.4		-2.5			-1.4	-1.6	

Rialto Stock Deposits

Jenny Linn

Type	P	P	P	P	P	P	P	P	PS	P	P	S	S	PS	S	S	P	P
Th	194	201	208	201	207	207	211	222	223	219	228	229	210	236	235	220	222	242
Tm	-3.5	-3.5	-3.6	3.7	-4	-4	-3.9	-3.7	-3	-3	-3	-1.6	-1.6	-2.4	-2.3	-2.3	-3.6	-3.4

NP-4 435'

Type	S	S	P-PS	P-PS	P-PS	P-PS	PS	PS	PS	PS-S	P-PS	P-PS	PS	PS	PS	PS	PS	PS
Th	235	240	240	253	230	241	239	219	248	252	287	234	247	239	230	212	242	244
Tm	-2.3	-2.1	-2		-3.4					-2.7		-2.3	-2.4		-2.3	-4.7		-3

NP-4 533'

Type	PS	PS	PS	PS-S	PS	?	PS	P	PS	PS	PS	P-PS	PS	PS	P-PS	P-PS	P-PS
Th	273	268	296	206	253	246	257	259	272	251	233	258	207	257	266	378	319
Tm		-3.2	-3.2	-1.5			-3.1	-3.2	-4		-3.2	-3.3	-3				-4

N-20 164'

Type	P	P	P	P	P-PS	P	PS
Th	429	448	323	350	460	243	353
Tm	-12			-22.9			

Shear Zone Deposits

Rock No 1

Type	S	S	S	S	PS-S	S	S	P	P
Th	142	198	150	205	127	144	147	360	354
Tm				-1.8	-5.4	-6	-6	-6.3	-6.6

Soldier

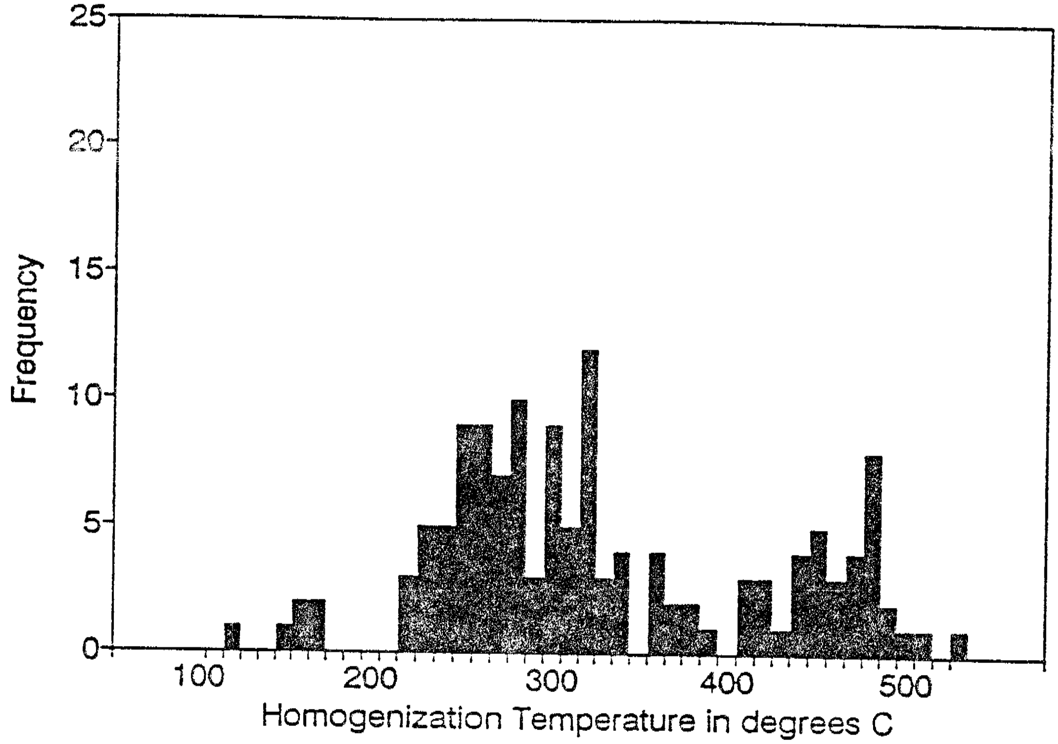
Type	PS	PS	PS	PS	PS	P-PS	P-PS	PS-S	P-PS	PS-S	S	PS
Th	310	314	239	242	200	260	236	261	253	175	175	242
Tm			-6.7		-7.4		-6.9			-6.9	-6.7	

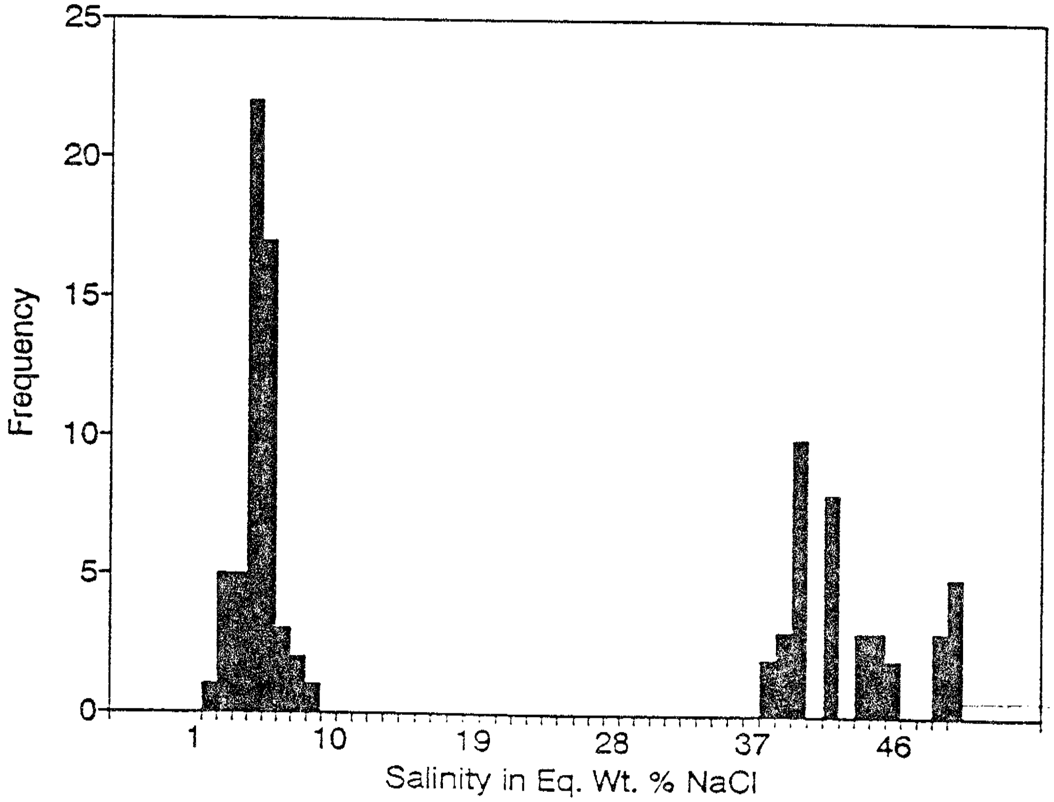
Hope

Type	P-PS	PS
Th	276	280
Tm		

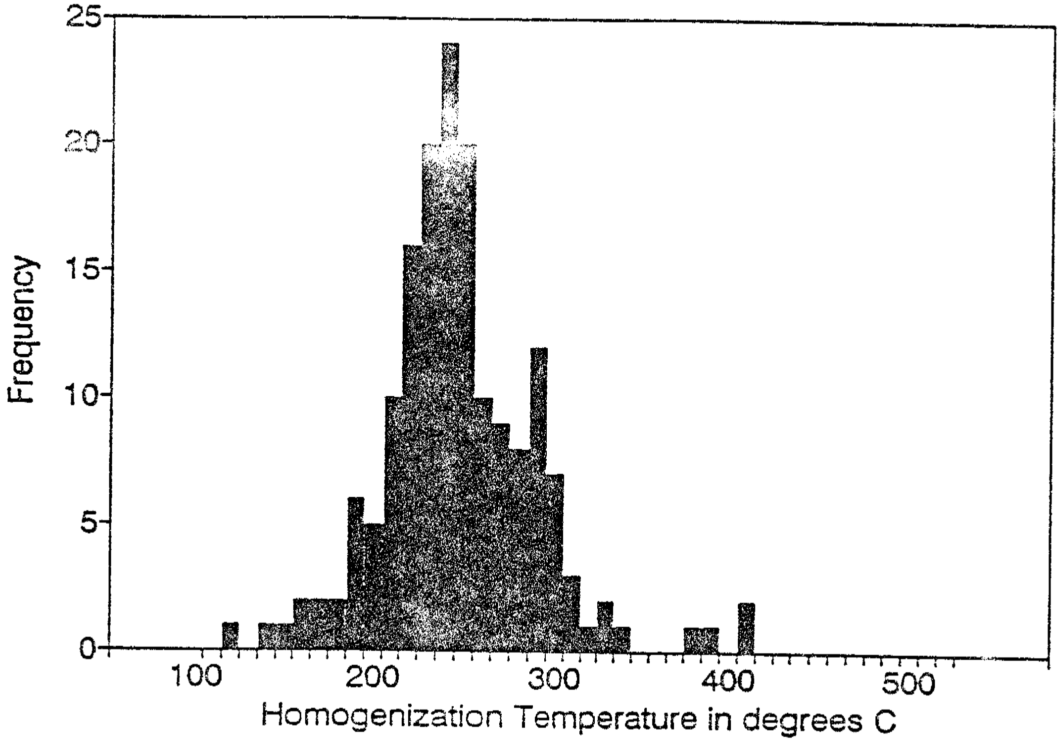
Appendix G: Th and Salinity Histograms by Deposit Type

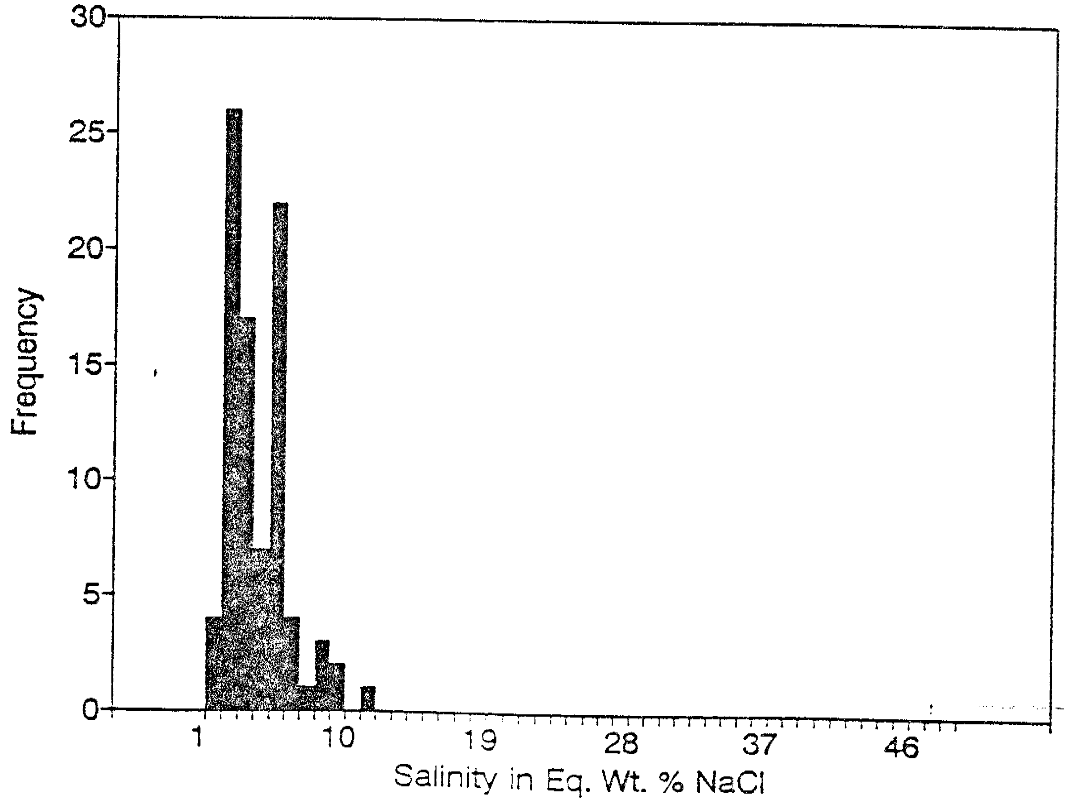
Gold Deposits



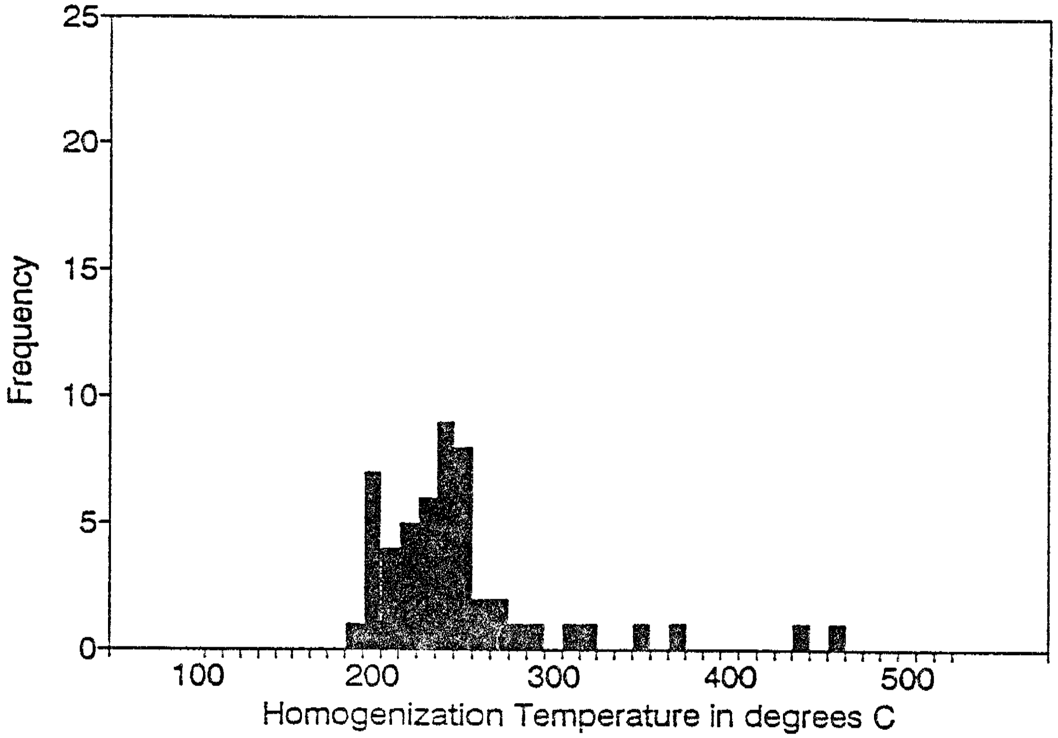


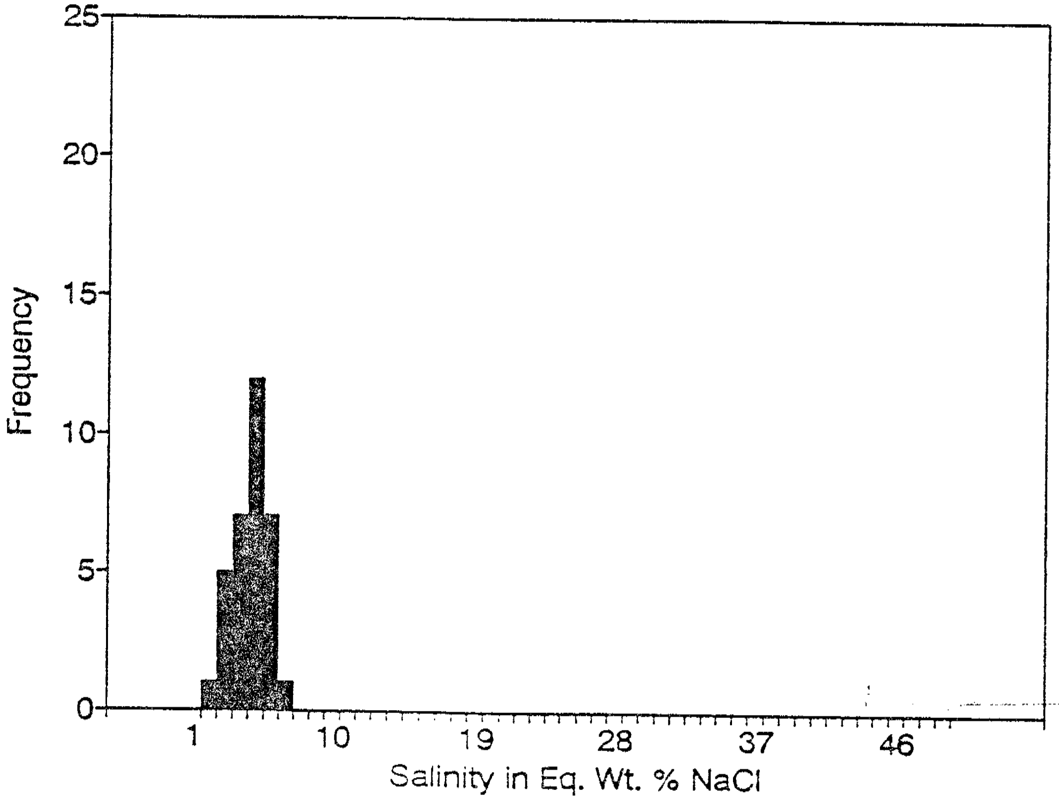
Ag-Pb-Zn Deposits



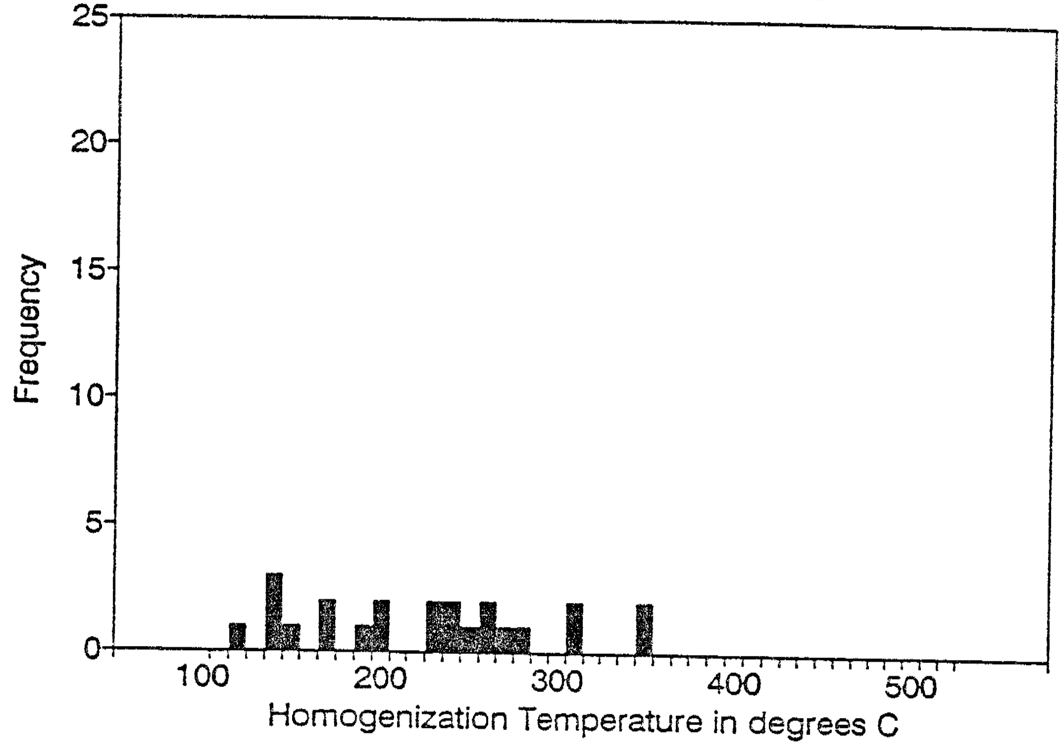


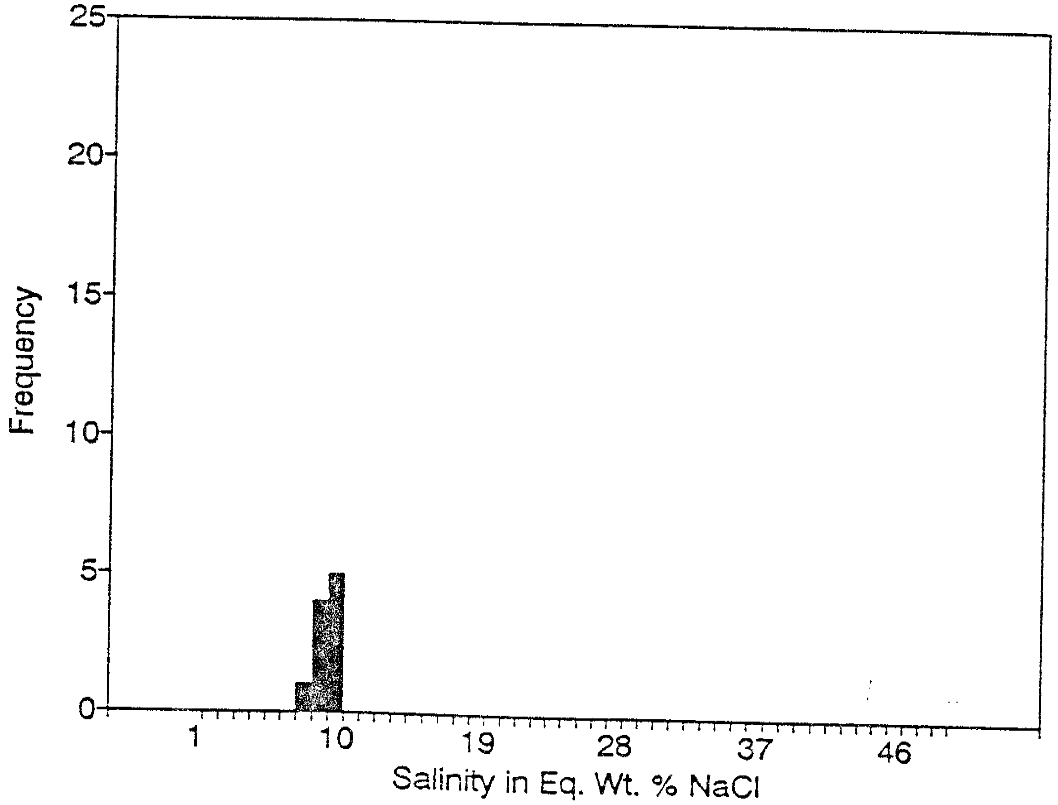
Rialto Stock Deposits





Shear Zone Hosted Deposits





Appendix H: Petrographic Description of Vein Alteration Samples

Samples are listed sequentially going toward the vein. Percent of mineral altered is shown in parentheses, otherwise percentages are visual percent compositions. Opaques are considered to be composed of pyrite and magnetite.

Fresh Andesite Samples

FA-1 (from near the Crow) - Feldspars are not large zoned phenocrysts, but are small subhedral laths that form a felty groundmass. Visible alteration to sericite is present. Sample contains abundant epidote. Non-feldspar groundmass is very dark and full of opaques.

FA-2 (from near the Helen Rae) - Feldspars form large, euhedral lath-shaped phenocrysts in a fine groundmass of feldspar. Feldspar phenocrysts are lightly altered (10-20%). Mafic mineral, mostly hornblend, are variably altered in the sample (0-100%). Groundmass is fresh and un-altered.

Helen Rae Vein

HR-15 (30 feet from the vein) - Feldspar phenocrysts and larger hornblends are lightly altered (15-20%). Groundmass is fresh with an abundance of a green mineral-biotite(?), magnetite, and other opaques.

HR-14 (27 feet from the vein) - Feldspar phenocrysts are a little more altered (30-35%). Alteration of the feldspars is random, with some being altered in the core and some containing altered rims. Mafic minerals are less common but still present. Groundmass is still fresh but contains much more opaques.

HR-13 (24 feet from the vein) - Feldspar phenocrysts are more altered (40-50%). Few, if any, mafic minerals left. Groundmass is altered in spots and fresh in others. Opaques are the same as in HR-14.

HR-12 (21 feet from the vein) - Feldspar phenocrysts are altered (45-55%). Few mafic minerals present. Groundmass is slightly more altered and contains a bit more opaques.

HR-11 (18 feet from the vein) - Feldspar phenocrysts are heavily altered (60-80%). No mafic minerals left. Groundmass consists of 60-70% sericite and opaques. More opaques and Fe oxides/hydroxides(?).

HR-10 (15 feet from the vein) - Feldspar phenocrysts are extremely altered (80-100%). Most phenocrysts are ghosts of sericite. Groundmass is completely altered. Sample contains a bit more opaques and calcite.

HR-9 (12 feet from the vein) - Same as HR-10, but the sample contains chlorite and more calcite.

HR-8 (9 feet from the vein) - Same as HR-9, but a few feldspar phenocrysts survive. Sample contains more chlorite, calcite, and opaques.

HR-7 (6 feet from the vein) - The whole sample is completely altered to sericite. Sample contains less opaques than HR-8, but contains more chlorite. Calcite was not seen.

HR-6 (3 feet from the vein) - Sericite ghost phenocrysts of feldspar in a groundmass of Fe hydroxides, chlorite and opaques. Sample contains more chlorite. No calcite seen.

HR-5 (30 inches from the vein) - Sample not nearly so altered, similar to HR-11. Feldspar phenocrysts altered (70-80%). Groundmass is fresh in spots. Sample contains abundant calcite and opaques.

HR-4 (2 feet from the vein) - Similar to HR-6, sample is completely altered. Sample contains more chlorite but less Fe hydroxides. No calcite seen.

HR-3 (18 inches from the vein) - Completely altered. Sample is composed of fine grained sericite, Fe oxides, opaques and calcite. No ghost phenocrysts are left and chlorite has disappeared.

HR-2 (1 foot from the vein) - Completely altered. Sample is too fine grained to identify most minerals. Lesser amounts of Fe hydroxides and opaques. No calcite is seen.

HR-1 (6 inches from the vein) - Completely altered. Similar to HR-2, but contains 60-80% hemitite and Fe hydroxides. Quartz and calcite are also present.

Crow Vein

CR-8 (13 feet from the vein) - Feldspars are not nice phenocrysts like at the Helen Rae, but rather subhedral blobs. Feldspars are lightly altered (15-20%). Quartz and chlorite are also present. Opaques comprise less than 10% of the sample.

CR-7 (8 feet from the vein) - Feldspars are more altered (25-30%). Sample contains more quartz and opaques, with chlorite remaining constant.

CR-6 (3 feet from the vein) - Feldspars are more altered (50-60%). Samples contains more quartz and opaques. No chlorite was seen.

CR-5 (30 inches from the vein) - Alteration of feldspars the same as CR-6. Sample contains abundant chlorite and slightly more quartz than CR-6.

CR-4 (2 feet from the vein) - Feldspars slightly more altered (60-70%). Sample contains more quartz than CR-5. Chlorite appear to be partially altered to opaques.

CR-3 (18 inches from the vein) - Alteration of feldspars remains constant. Sample contain more quartz than CR-4 and the chlorite is more slightly more altered.

CR-2 (1 foot from the vein) - Feldspars are altered up to 90%. Abundant quartz and opaques. Chlorite is completely altered.

CR-1 (6 inches from the vein) - Similar to CR-2, but contain much more quartz.

This thesis is accepted on behalf of the faculty of the Institute by the following committee:

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Adviser

[illegible] Moran

[illegible] Chavez [illegible]

Dec 15 1992

Date