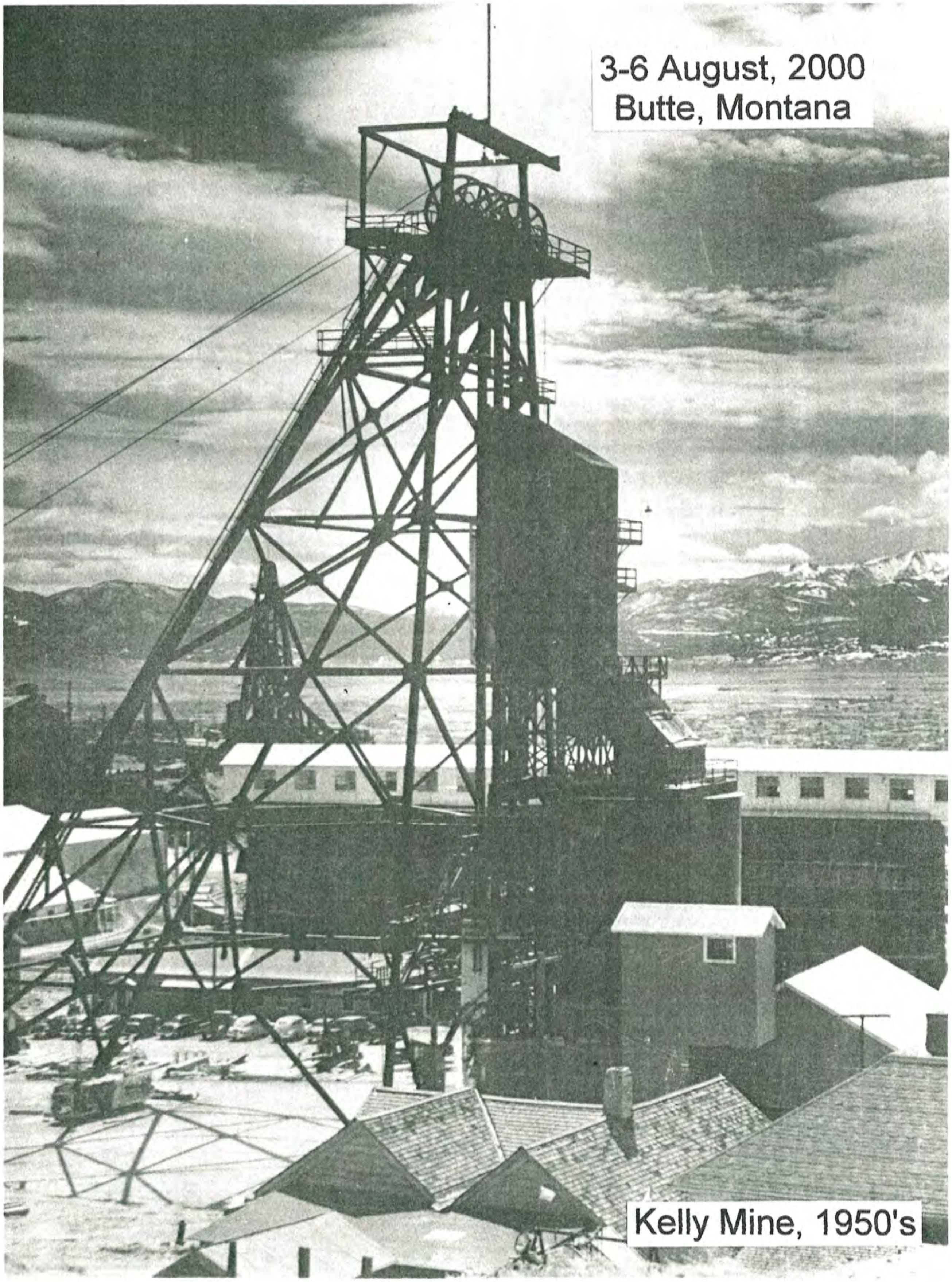
TOBACCO ROOT GEOLOGICAL SOCIETY
25th Annual Field Conference



3-6 August, 2000
Butte, Montana

Kelly Mine, 1950's

GUIDEBOOK
OF THE
TWENTYFIFTH ANNUAL
TOBACCO ROOT GEOLOGICAL SOCIETY
FIELD CONFERENCE

Butte, Montana
3-6 August, 2000

The Tobacco Root Geological Society, Inc.
P.O. Box 2734
Missoula, Montana 59806

Cover Photo of the Kelly Mine
Courtesy of Al Hooper - Butte, Montana

TABLE OF CONTENTS

* Note - Separate printed materials have been prepared by these trip leaders.

TIMING AND DURATION OF THE BUTTE PORPHYRY SYSTEM

MARTIN, Mark W., Dept. Earth, Atmospheric, and Planetary Sciences, MIT, Cambridge MA 02139;
DILLES, John H. Dept. of Geosciences, Oregon State University, Corvallis, OR 97331

Critical to evaluating the timing and duration of mineralization associated with porphyry-type deposits is precisely determining crystallization ages of igneous bodies that define these systems. Historically, K-Ar and Ar-Ar geochronologic methods have been used to date emplacement and mineralization in porphyry systems; however, these methods typically only provide minimum age constraints because they record cooling below ca. 350°C. The U-Pb zircon method, however, provides robust igneous crystallization dates, which provide ages of early, high-temperature events and therefore help to document the entire duration of the porphyry system.

Pre-Main Stage Cu-Mo porphyry deposits and Main-Stage Cu-Zn-Pb-Ag-Mn vein mineralization in the giant Butte base metal hydrothermal system appears to have occurred around 61-64 Ma on the basis of K-Ar and Ar-Ar geochronology (Meyer et al., 1968; Snee et al., 1999). However, our U-Pb analyses suggest that at least some pre-Main Stage mineralization may be at least 10 m.y older.

U-Pb zircon analyses from two samples of the host Butte quartz monzonite yield ages of 76.4 ± 0.3 Ma and 76.2 ± 0.5 Ma. In addition, sphene analyses from one of these samples yield an age of 75.2 Ma. The Modoc quartz porphyry (and breccia) cut the host Butte quartz monzonite and yields a U-Pb zircon age of 75.6 ± 0.3 Ma. Importantly, early high-temperature (~550-600 C) pre-Main Stage Cu-Mo mineralization in this example, appears to be 75.6 Ma or older since the Modoc breccia contains fragments of pre-Main Stage quartz-Mo and "EDM" Cu-bearing veinlets. The Modoc quartz porphyry is lithologically identical to a system or east-west-striking quartz porphyry dikes that are closely tied to pre-Main Stage mineralization in the district. All quartz porphyry dikes, the Modoc breccia, and early Cu-Mo veins are cut by Main-Stage veins formed at lower temperature (250-350 C). Preliminary U-Pb zircon analyses on the quartz porphyry dikes suggest that they are 69-72 Ma. These relationships suggest that locally, igneous activity and mineralization at Butte is as old as 75.6 Ma and tied to the Butte quartz monzonite and emplacement of the Boulder batholith. Furthermore, the U-Pb data from quartz porphyry dikes suggest that igneous activity and mineralization are either diachronous or long in duration. Either scenario could have led to thermal events that caused Ar-loss or elevation of temperature above Ar retention temperatures (280-350 C for micas), thereby explaining observed Ar-Ar systematics at Butte (Snee et al., 1999).

References:

Meyer, C., Shea, E.P., Goddard, C.C., and staff, 1968, Ore deposits at Butte, Montana: in Ridge, J.D., ed., Ore Deposits of the United States 1933-1967 (Graton-Sales vol.): New York, Am. Inst. Mining Metall. Petroleum Engineers, v. 2, p. 1363-1416.

Snee, L., Miggins, D., Geissman, J., Reed, M., Dilles, J., Zhang, L., 1999, Thermal history of the Butte porphyry system, Montana: Geol. Soc., Abstr., National Mtg., v. 31, A380.

Relationship Between Hydrothermal AlterationTypes and Fluid Inclusion Characteristics in Pre-Main Stage Veins, Butte, Montana.

Brian Rusk, Mark Reed, and John Dilles

The gigantic mineral deposits of Butte, MT formed in two separate mineralization events, known as Main Stage and pre-Main Stage. Pre-Main Stage mineralization is recognized as typical porphyry copper-molybdenum mineralization, with high tonnage, low grade chalcopyrite and molybdenite mineralization in narrow quartz-dominated veins, while the later Main Stage mineralization consists of large, through-going veins that formed under cooler and shallower conditions. This study is focused on the pre-Main Stage, porphyry copper-molybdenum mineralizing events

The earliest veins at Butte are chalcopyrite-bearing quartz veins with alteration envelopes containing secondary biotite, K-feldspar, and sericite. These veins are referred to as early dark micaceous (EDM) veins and much of the pre-Main Stage copper is found in chalcopyrite in these veins and disseminated in the alteration envelope. Zonally exterior to these veins, are quartz-magnetite-chalcopyrite veins with alteration envelopes consisting of pale green sericite, K-feldspar, and chlorite (PGS veins). This vein type is another abundant source of pre-Main Stage copper. Cutting both of these vein types are barren quartz and quartz molybdenite veins. These veins consist predominantly of quartz with minor amounts of molybdenite and anhydrite, and a thin K-feldspar alteration envelope. The majority of quartz-moly veins are deeper than the majority of early Cu-bearing veins. They contain little copper, but are the main source of molybdenite in the deposit. Pyrite-quartz veins bordered by gray sericitic alteration (GS) formed in the latest pre-Main Stage mineralization event. Sericitic alteration caused by pyrite-bearing fluids is widespread, and overprints much of the earlier mineralization, obscuring vein-alteration relationships.

Veins and alteration mineralization formed from the action of hydrothermal fluids of varying compositions and at various pressure and temperature conditions. In an effort to determine the pressure and temperature conditions, as well as the composition of the hydrothermal fluid, we are conducting a study of fluid inclusions in the hydrothermal veins and the surrounding wall rocks. From studies of fluid inclusions, we hope to be able to determine pressures and temperatures of mineralization events, compositions of ore bearing fluids, mechanisms for precipitation of ore minerals, and a chronologic and spatial history of hydrothermal fluids as they evolved. We hope to determine whether the mineralizing events could all have been derived from the same initial magmatic fluid, under different pressure temperature conditions, or whether individual pulses of magmatic fluids are responsible for the various types of veins and alteration.

As of yet, we have concentrated on fluid inclusions from two of the dominant mineralization events at Butte. These two types are the barren quartz and quartz molybdenite veins with minor K-feldspar alteration, as well as the later pyrite-quartz veins with sericitic alteration. Our findings are discussed below.

Barren quartz and quartz-molybdenite veins are likely to have formed in one mineralization event because they are closely related in time, space, and mineral content. Both vein types contain at least 95% quartz with minor anhydrite, K-feldspar, and molybdenite. Most quartz-molybdenite veins contain only a few percent molybdenite, and there is a gradation from <1% molybdenite up to approximately 5%. Cross cutting relations show that barren quartz and quartz-molybdenite veins formed during the same interval of time because both cut Cu-bearing veins and are cut by pyrite-quartz veins with GS alteration. Also, barren quartz veins cut quartz-moly veins, and vice-versa. Both vein types are most abundant deep within the deposit. For these reasons, the barren quartz and quartz-molybdenite veins appear to be the result of one hydrothermal event. Fluid inclusions in these veins support such a division as well.

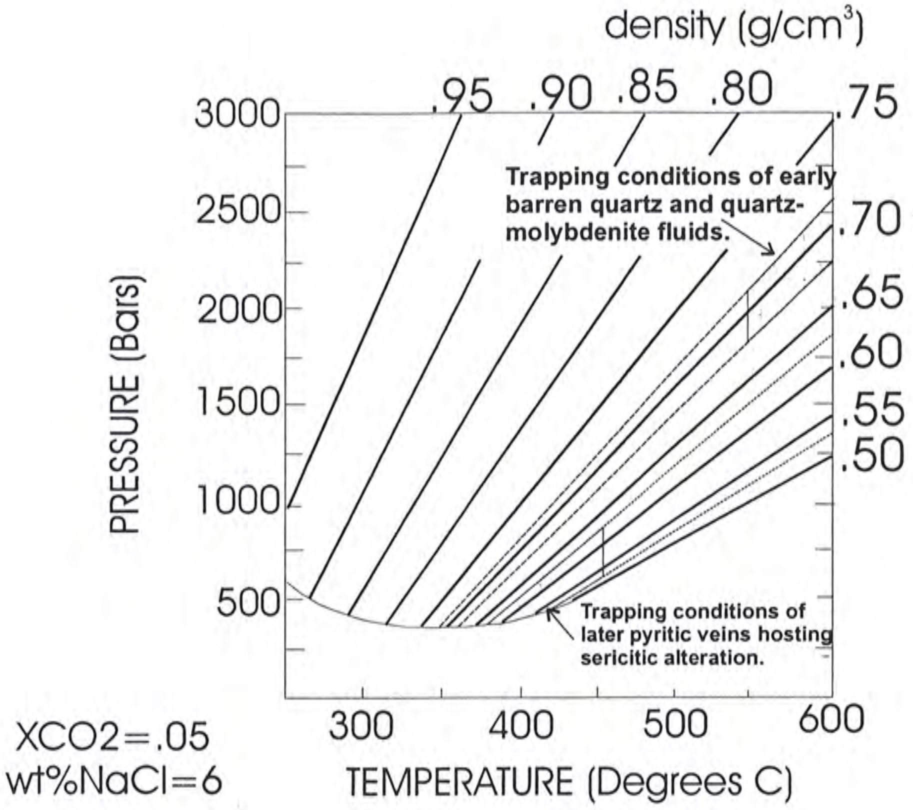
The fluid inclusions in barren quartz veins are indistinguishable from fluid inclusions in quartz-molybdenite veins. At room temperature these inclusions contain two phases; a CO_2 vapor bubble occupies about 40 volume % of the inclusion, while the rest of the inclusion is filled with a saline aqueous fluid. Upon cooling of CO_2-bearing inclusions, a gas hydrate phase forms that contains H_2O and CO_2 in the solid phase. The melting temperatures of these clathrates indicate salinity in the inclusions, matching salinities inferred from ice melting temperatures of non-CO_2-bearing fluid inclusions. In most barren quartz and quartz-molybdenite fluid inclusions, clathrates melt between 6 and 8 degrees C corresponding to a salinity of 4-7 weight % NaCl equivalent. These fluids have ~ 5 mol% CO_2 and a bulk density of 0.7 g/cm^3.

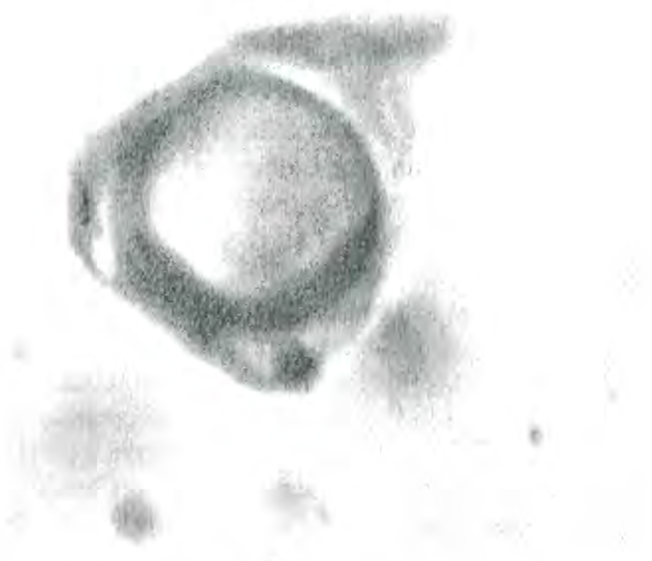
The temperature of homogenization of these inclusions is the temperature at which, upon heating, the two phase inclusion homogenizes to one phase, either liquid or vapor. These inclusions homogenize to the liquid phase at temperatures between 320 and 390 degrees C, with over 70% homogenizing between 340 and 365 degrees C. The pressure at which these inclusions were trapped can be estimated based on an independent estimate of temperature of vein formation. Sulfur isotopes from molybdenite-anhydrite pairs indicates a temperature of trapping between 550 and 600 degrees C (Zhang et al. 1999). Following the 0.7 g/cm^3 isochore (calculated from data of Bowers and Helgeson, 1983) from the homogenization temperature to the estimated formation temperature yields a formation pressure for the barren quartz and quartz-molybdenite veins between 2 and 2.3 kb.

Fluid Inclusions from later pyrite-quartz veins are similar to those in the earlier, deeper barren quartz and quartz-molybdenite veins. Like the earlier veins, they contain ~5 mol % CO_2 in the vapor phase and a saline aqueous liquid. However, the vapor bubble in these inclusions is larger than the vapor bubble in barren quartz and quartz-molybdenite veins, indicating a lower density of CO2. Temperature of melting of clathrates in these inclusions are similar to those in earlier veins indicating a comparable salinity of 4-7 wt % NaCl equiv. The density of these inclusions, however is only 0.55 g/cm^3.

Inclusions in pyrite-quartz veins homogenize to liquid, to vapor, and by critical phenomena at temperatures between 370 and 410 degrees C. Following the 0.55 g/cm^3 isochore (calculated from data of Bowers and Helgeson 1983), and using 450 as an upper limit of formation temperature of the quartz-serecite-pyrite alteration, the pressure of formation of the pyrite veins is between 500 and 900 bars.

Figure 1 shows possible trapping conditions of early barren quartz and quartz-molybdenite fluids, and later pyrite-quartz fluids. Early inclusions trapped in quartz-molybdenite veins were trapped between 550 and 600 degrees C and pressures of around two kilobars. These were probably trapped under lithostatic pressure about 5-6 km beneath the surface. Later, pyrite-quartz fluids were trapped in the same geographic volume , however temperatures were closer to 400-450 degrees C and pressure was likely closer to 600 bars, probably under hydrostatic load. The composition of early barren quartz and quartz-molybdenite fluids and later pyrite-quartz fluids are quite similar. The difference between the two vein types may be due to a change in pressure regime from lithostatic to hydrostatic accompanied by cooling of the hydrothermal fluid. Cooling and depressurization would cause a hydrothermal fluid to become more acidic, and would decrease the solubility of pyrite in the fluid, leading to the precipitation of pyrite and alteration of surrounding rock to quartz, sericite, and pyrite.





Fluid inclusion from a pyrite-quartz vein

Fluid inclusion from a quartz-molybdenite vein

A HISTORY OF HARD ROCK MINING AT BUTTE, MONTANA

Grace Sherwood Winer, (gsw@montana.edu), Department of Earth Sciences, Montana State University
Bozeman, Montana, 59717

The Gold Era

In 1864 the prospectors Budd Parker, P. Allison, and the brothers James and Joseph Esler crossed the mountains from Alder gulch and discovered placer gold deposits on Silver Bow Creek.[10] The richness of the placers attracted so many miners that, in 1866, a mining district was formed and a town-site was located southeast of the volcanic butte for which the mining camp was named.[1]

The placer miners of Butte, as in most other western mining districts, prepared the way for the lode miner. Placer gold can be recovered with the simplest tools: a pick and shovel, a gold pan, a sluice box. The valuable raw gold recovered from the placers needed no refining to be ready for market, and with its low bulk was easily transported.[10]

Despite these advantages, placer mining in Butte was hampered by a shortage of water for sluicing. The miners also lacked the equipment and expertise to mine the exposed metalliferous quartz veins in the area. By 1867 the placer gold had played out and most of the population of Butte, which had reached about 5,000, moved on to other mining camps throughout the west.[1&10]

The Silver Era

In the years following the gold boom, the Butte mining camp languished and its population dwindled to a determined few who still had faith in their mining district. Some assessment work was done on a number of claims and some of the workings were dug to a depth of about 150 feet using windlasses to raise the ore to the surface. But early attempts at smelting the refractory ores failed and the outlook was dismal.[10]

Then, in 1874, William Farlin, one of the placer miners from the gold-boom days, returned to Butte. Farlin had taken ore samples with him and had them assayed in Idaho. He learned that the ores were not only rich in silver, but also contained copper. Farlin had also learned about extracting these metals from such ores. On the last day of 1874, Farlin placed notice of location for the Travona mine. For treatment of the ore near the Travona, he began building a furnace and the Dexter 10-stamp mill which crushed the ore with heavy weights lifted by steam or hydraulic power.[10]

Farlin ran out of money and sought help from William A. Clark, Deerlodge banker and capitalist-entrepeneur.[7] With Clark's help the Dexter mill was completed in 1876 and the profitable treatment of silver ore began in Butte. This success "galvanized the camp into a frenzied activity."[7] Some copper was also mined, but at this time silver was more abundant, more in demand, and easier to process.

William A. Clark soon took over the Travona as Farlin became deeply in debt to Clark and could not meet his payments. And so it was that many of the original claim-holders lost their mines to men of finance.[7] Clark also obtained many other mining properties that he was soon operating at a profit. Clark, described as a severe little Scotsman, was on his way to becoming a "Copper King".

Another future Copper King was Marcus Daly, who arrived in Butte in 1876. Daly was an Irish immigrant and an expert hard-rock miner and mine manager. He was widely recognized as an "expert in his profession, a master at assessing vein structures, at tunneling, timbering, and blasting."[7] Daly knew the names of even the muckers in his mines and was a man much loved by those who worked for him. In Butte he bought and managed the famous Alice silver mine for the Walker brothers, investors from Salt Lake City.

By 1879, nearly every exposed vein in the area was being mined and Butte was the leading hard-rock mining district in the Montana Territory, producing both silver and copper.[7] The Utah and Northern Railroad reached Butte in 1881, providing transportation to ship in heavy smelting equipment and providing access to distant metal markets. Outside capital poured in and by the late 1880's, Butte was America's premier mining center.

Meanwhile, the miners again poured into Butte—this time bringing their families, for lode mining offered more long-term financial stability than placer mining. They came from other mining camps around America and from many other countries—from Ireland, Scotland, China, Latin America, Cornwall, Finland, Italy, Serbia, Wales, Africa, and more, lending an international air to the rough mining camp.[5] They congregated in their own colorful neighborhoods crowded in between the mines and tailing piles with names like "Dublin Gulch, Dog Town, Chicken Flats, Busterville, Butchertown, and Seldom Seen"[7], and they made Butte into one of the greatest hard-rock mining camps in the world. Butte's population grew from 3,000 in 1880,[10] to 22,000 in 1885.[5]

The silver era reached its peak in 1887 when mills were treating 400 tons of ore a day.[10] The crushed ore was treated with salt to form a chloride of the metals and then roasted in huge—some city-block size—open pits or stalls, using logs for fuel. After roasting, the silver was recovered by amalgamation in which mercury was alloyed with the metal to remove it from the ore.

As Butte's prosperity increased, the quality of its air and environment suffered horribly. Around-the-clock unregulated roasting and smelting poured nearly 300 tons of sulfur and arsenic laden smoke into the air every day.[7] During winter time inversions the smoke was so dense that lamps were lit at midday. The acrid smoke killed the vegetation and caused severe, even lethal, health problems for the residents. In 1890 there were only four living trees in the town. Early Butte was described by an Eastern newspaper as "simply and outpost of Hell…" and by the author Gertrude Atherton as looking "like a giant shipwreck".[7] Protesting citizens in the early 1890's finally halted open roasting, but the air quality did not improve much until the early 1900's, when consolidation of the mining companies led to most of the smelting being moved to Anaconda and Great Falls.

In 1882, five years before the highest point of the Silver Era, Marcus Daly made the first major Butte copper discovery while developing the Anaconda silver mine. Daly found a vein of high-grade chalcocite ore at the 300 foot level, the greatest deposit of copper sulfide (Cu_2S) the world had ever seen.[7] (The Anaconda name would be given to what would become the largest copper mining company in the world.) Further exploration revealed a "veritable mountain of copper ore"[5] awaiting the miners beneath the Butte Hill. However, silver mining remained important until the Panic of 1893 dealt a death blow to the already collapsing silver market. As a vital force in the Montana economy, silver was dead.[7]

Copper Era I

The dawn of the age of electricity, availability of rail transport, and the collapse of the silver market combined to usher in Butte's copper era. While other silver mining camps became ghost towns, the growing demand for Butte's vast reserves of copper soared, and smelters and railroads were built to serve the rapidly developing mines.

In 1881, Marcus Daly had purchased the Anaconda mine for $30,000. He then formed a partnership with the San Francisco syndicate of Hearst-Haggin-Tevis, and that was the beginning of the Anaconda Company. A year later Daly discovered the huge copper vein in the Anaconda mine. In 1883, construction began on the company's enormous concentration and smelting plants at Anaconda in the upper Deer Lodge Valley. The site was chosen for its ample supply of water.[7] Improvements, including a 31 mile railroad spur, made the Anaconda works the greatest copper ore reduction facility in the world by the early 1900's, capable of treating 5,000 tons of ore daily.[7]

William A. Clark, whose well established mining operations and partnerships in the Butte mining industry had already made him fabulously wealthy, purchased the Butte Reduction Works to handle the output from his many mines and to provide custom smelting for other operators. Capable of treating 300 tons of ore a day, the Reduction works was a major factor in the Butte economy.

The third Copper-King-to-be, F. Augustus Heinze, arrived in Butte in 1889. A recent graduate of Columbia School of Mines, Heinze was young, handsome, debonair—and shrewd. Heinze learned all he could about the complex geology of the Butte Hill. In 1893, Heinze and his brothers formed the Montana Ore Purchasing Company, and the next year opened a sophisticated smelter in Meaderville near Butte. Heinze became known for his vast knowledge of the local geology and his ability to locate rich ore veins.[7]

The Butte mining industry had far reaching effects on the rest of Montana and beyond. The Mining operations drew in timber and coal from around the state, with the Anaconda Copper Company smelter alone using 400 tons of coal a day at the turn of the century. Tens of thousands of board feet of lumber were also used daily for construction, fuel, and timbering in the mine shafts, stopes, and drifts. In Missoula seven sawmills ran double shifts as mine operators and logging companies ravaged the forests, cutting on private and federal land, often bypassing or ignoring federal conservation laws in order to supply the insatiable timber appetite of the mining industry. Besides the effects of Butte's demand for natural resources, state and even national politics were influenced by the corrupt power struggles of Butte's Copper Kings.[7]

Butte was a town of limitless opportunity. With the miners came investors and entrepreneurs who would fight for the wealth of the mines in the "war of the Copper Kings," a national scandal. The three main copper barons were William A. Clark, Marcus Daly, and F. Augustus Heinze, often unscrupulous businessmen who bought off judges, newspapers, seats in government, and literally fought for the very ore in underground battles of looting and dynamite. The Butte Miner and the Anaconda Standard, rival tabloids, ran these headline stories the day after the 1889 municipal elections.

Th Butte Miner story:

> By coercion, intimidation, and bribery, the returns show that the Dalycratic ticket has managed to force itself on Silver Bow County … The freedom of the ballot and honesty in elections has become a farce in light of the methods used by the Dalycratic leaders.

The Anaconda Standard story:

> In spite of the wholesale buying of votes, repeating and fraudulent balloting as indulged in by the unscrupulous opposition … the entire democratic ticket won …

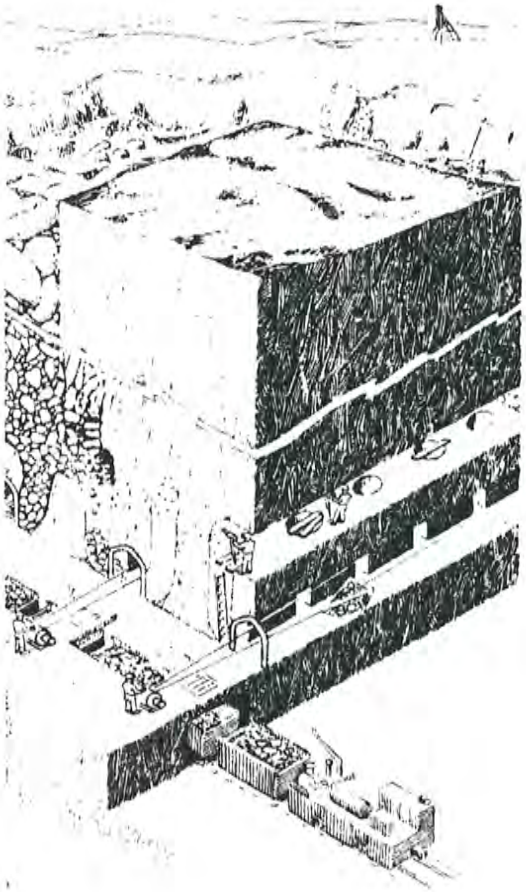
> That the lying and thieving tactics of the Clark forces availed them little is proven by the results of yesterday's balloting.

As one curbside editorialist observed, "The hell of it is, the two papers were both damn near telling the truth, if they only knew it."[5]

The rivalries for control of government and the mines continued until the war of the Copper King ended in 1906 with the consolidation of the Butte mining industry under the control of the mighty Anaconda Company.[7]

Copper Era II

Until 1942, the copper miners of Butte had used basic drilling and blasting methods to retrieve the ore. Then, with mining costs rising, block caving was introduced as a more efficient and profitable method of removing the copper ore. In this new technique, huge blocks of ore, 150-200 feet on a side, were undercut leaving only supporting pillars. The pillars were then blasted away, causing the ore blocks to cave downward, breaking up the ore. Mine shafts were enlarged and hoist were upgraded, until some were capable of lifting 15,000 tons of ore from the 2000 foot level each day. Between 1944 and 1962, 300,700 tons of copper ore were retrieved by block caving.[8]



BLOCK CAVING[9]

Block caving technique in underground mining showing the block on the left undercut and caved in; broken ore is drawn off through the bell-shaped draw points.

Copper Era III

Between 1952 and 1954, feasibility studies on open pit mining were conducted. It was shown that this method would be profitable for mining even larger amounts of low-grade copper ore that the block caving method. The Berkeley Pit operation began in March of 1955 with the stripping of overburden, and in July ore production began. By 1956, 12,500 tons of ore were mined from the Berkeley Pit each day, and the ore was transported to Anaconda by rail for metallurgical treatment. Production increased steadily and by 1973, three shifts of workers were moving 248,000 tons of rock per day. The ore-to-waste rock ration was low, about 20 percent, and that was very low grade ore, averaging only 0.75 percent copper. The Berkeley Pit was mined until 1983, by which time it was more than a mile wide and over a third of a mile deep. In 28 years, 1.4 billion tons of rock had been removed from the great pit.[8]

In 1876, the once mighty Anaconda Company, because of losses in foreign investments and declining metal prices, was sold to the Atlantic Richfield Company (ARCO). By 1983, ARCO had shut down all of its mining and smelting operations in Montana. A century after Marcus Daly's great copper discovery in the Anaconda mine, ARCO "pulled the plug on the Berkeley Pit" ... and "the nerve center of the Montana economy slowly filled with toxic waste water."[4]

Today, in 1993, only one company, Montana Resources, continues to mine in Butte. They mine the Continental Pit, one mile east of the Berkeley Pit, for very low grad (0.3 percent) copper ore, molybdenum, and traces of precious metals. Mining goes on 24 hours a day with the blasted, fractured ore being removed by 15-foot electric shovels and hauled in 170-ton diesel-electric trucks to the Weed Concentrator on the south rim of the Berkeley Pit.[11] From there the concentrate, now 24-30 percent copper, is shipped to smelters in El Paso, Texas, and Hayden, Arizona. The molybdenum is primarily used as a hardener in steel manufacturing, and is also used as a lubricant and as an oil additive.[3]

A great reserve of ore still remains beneath the Butte Hill—enough that, when prices and demand for its ores increase, Butte may once again boom as "the richest hill on Earth".

Total Butte Metal Production 1880-1991 [2&8]
(all mining methods and ore types)

METAL	PRODUCTION
Copper	20,428,831,775 lbs*
Zinc	4,909,202,540 lbs.
Manganese	3,702,787,341 lbs.
Lead	854,797,405 lbs.
Silver	706,019,918 oz
Gold	2,922,446 oz**
Cadmium	4,306,156 lbs.
Bismuth	4,042,663 lbs.
Sulfuric acid	9,456,105 dry short tons
Selenium	316,855 lbs.
Tellurium	237,256 lbs.
Molybdenum	52,344,889 lbs.

*This much copper would pave Interstate 90 from Butte to Bozeman, 88 miles (141 kilometers), with a six-inch layer of copper—and that includes all the shoulders. Adding the other metals produced would extend this imaginary metallic highway another 50 miles (80 km), nearly to Big Timber.[6]

**Estimated due to incomplete records.

Addendum

August 27, 2000. Since the above article was written Montana Resources continued to mine the Continental Pit until this summer. It is now temporarily closed due to a tremendous increase in electricity rates. Negotiations are underway to find a new electricity provider so mining operations can resume. This information is from the Montana Bureau of Mines and Geology.

Works cited

1. Brothers, Beverly J. Historical Butte: The Richest Hill on Earth. Butte, MT. Artcraft Printers, 1977.
2. Burns, George. Chief Geologist, Montana Resources. Telephone interview, March1992.
3. Crenshaw, Bill. Mining Engineer, Montana Resources. Telephone interview, August, 21, 1992.
4. Fritz, H.W.
5. "The Origins of Twenty-First-Century Montana." Montana: The Magazine of Western History, Helena, MT: Montana Historical Society, Winter 1992.
6. Glick, Dennis. Life and Death in the Butte Mines. Butte, MT: Butte Historical Society, n. d.
7. Lewis, Sharon E. Butte Under the Hill: A Brief Introduction to Mining and Geology. Information Pamphlet 1: Butte, MT: Montana Bureau of Mines and Geology, 1989.
8. Malone, Michael P. Miller, Richard N. "Production History of the Butte District and Geological Function, Past and Present." Guidebook for the Butte Field Meeting of Economic Geologists. Butte, MT: n.p., 1973.
9. Parker, Sybil P. McGraw-Hill Dictionary of Scientific and Technical Terms. 4th ed. New York: McGraw-Hill, 1989.
10. Rickard, T.A., A History of American Mining. New York: McGraw-Hill, 1932. Reprinted by Johnson Reprint Corp., NY, n.d.
11. Shovers, Brian, Mark Fiege, Dale Martin, and Fred, Quivik. Butte and Anaconda Revisited: 1991. Butte, MT: Special Publication of the Montana Bureau of Mines and Geology, 1991.

Structural Revelations Along the Lewis and Clark Line: A Progress Report

Jeff Lonn - Montana Bureau of Mines and Geology, 1300 W. Park St., Butte, MT 59701

New mapping along the western end of the Lewis and Clark Line (LCL) between Lookout Pass and Superior, MT, shows complex but revealing map patterns. A long episode of late Cretaceous and Paleocene compression produced a belt of west-northwest-striking structures that include reverse faults, overturned folds that verge both southwest and northeast, and shear foliation. Individual structures are often doubly plunging, but can usually be followed for long distances (>25 km) along strike. Cenozoic extension produced normal and right-lateral strike-slip faults that parallel the compressive structures or cut them at acute angles.

Regionally, the zone of strike-slip faults coincides with the west-northwest-trending belt of intense compressive deformation represented by the closely spaced reverse faults, the tight folds, and the shear foliation. The Osburn and Boyd Mountain faults experienced normal as well as strike-slip movement, and some segments are interpreted to be reactivated high-angle reverse faults.

Recognition of the Camel's Hump Structure (see Figure 1) has been particularly important to deciphering the structural history. This sinuous west-northwest-striking structure has features reminiscent of a triangle zone with two parallel, upwardly-convergent, reverse faults. It has a winding strike length of at least 50 km. Parallel, straight, strike-slip faults have displaced segments of the Camel's Hump Structure in a right-lateral sense. Displacement ranges from 2 to 6 km on individual faults--the Osburn, Butler Gulch, and Thompson Pass Faults. With early Tertiary (pre-extension) geometry restored, the Savenac Syncline, Keystone Syncline, and Pardee Anticline can all be seen to be part of the Camel's Hump Structure.

Structures of the LCL plunge gently southeast from Superior, exposing progressively higher structural and stratigraphic levels. Reverse faults flatten and folds open, as illustrated by changes along the strike of the Dry Creek-Campground Fault. Future mapping planned for this area, together with downplunge projection techniques, should allow development of a deep cross-section and a better understanding of this portion of the LCL.

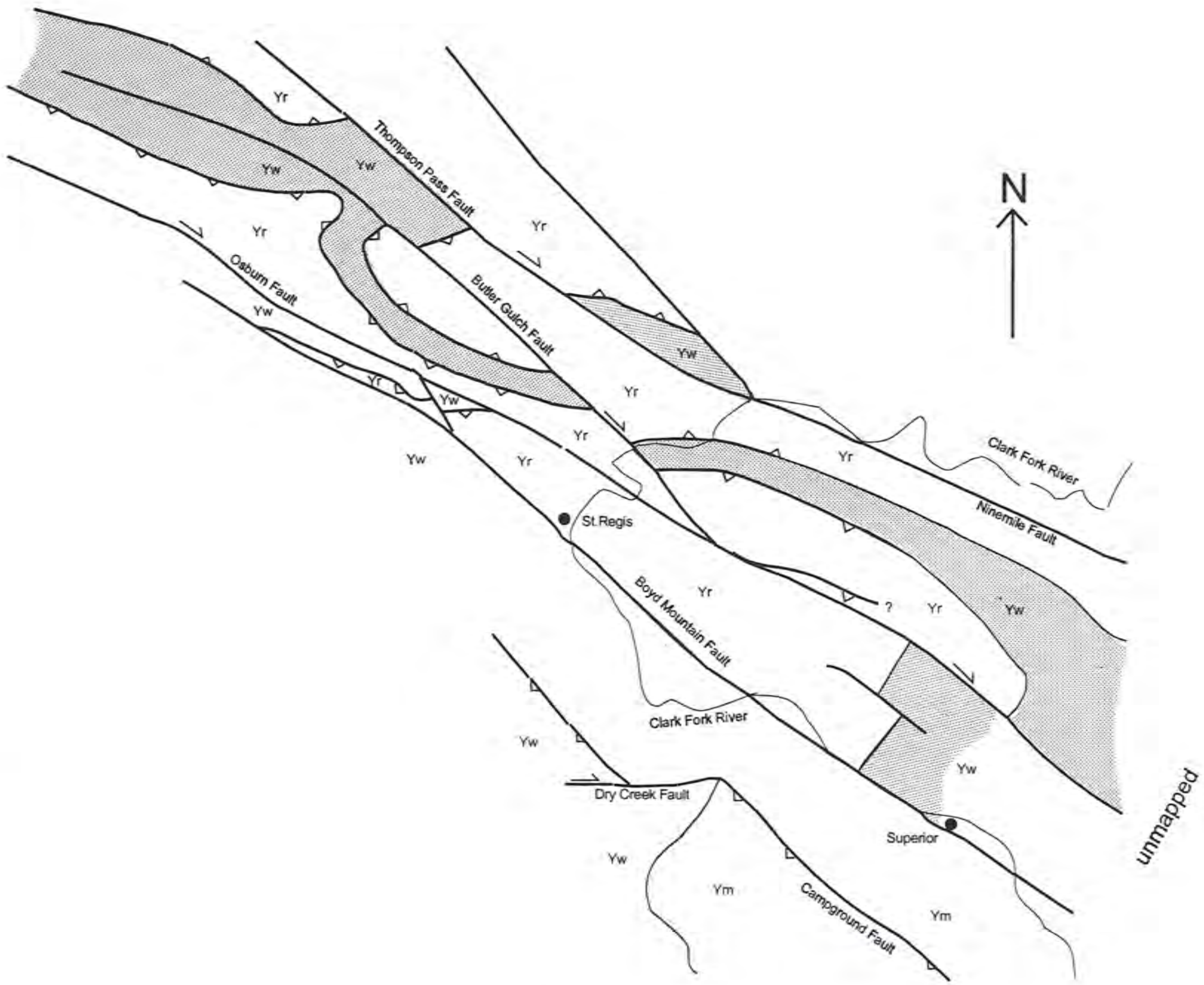


Figure 1. Simplified map of the Lewis and Clark Line near St. Regis, Montana. Displaced segments of the Camel's Hump Structure are marked by shaded Wallace Fm. Its southeastern end is a syncline caught between two overturned anticlines that face one another. Teeth on upthrown sides of reverse faults. Yr - Ravalli Group; Yw - Wallace Fm; Ym - Missoula Group. Scale 1:250,000.

HOMESTEAD KIMBERLITE: NEW DISCOVERY IN CENTRAL MONTANA

Peter C. Ellsworth
Consulting Geologist • 265 Benton Ave. • Missoula, MT 59801 • (406)721-9626 • maddog@bigsky.net

INTRODUCTION

Recent diamond exploration in central Montana led to the discovery of the first diamond-bearing Montana kimberlite. The Homestead Kimberlite is the only kimberlite found within the state in more than 20 years.

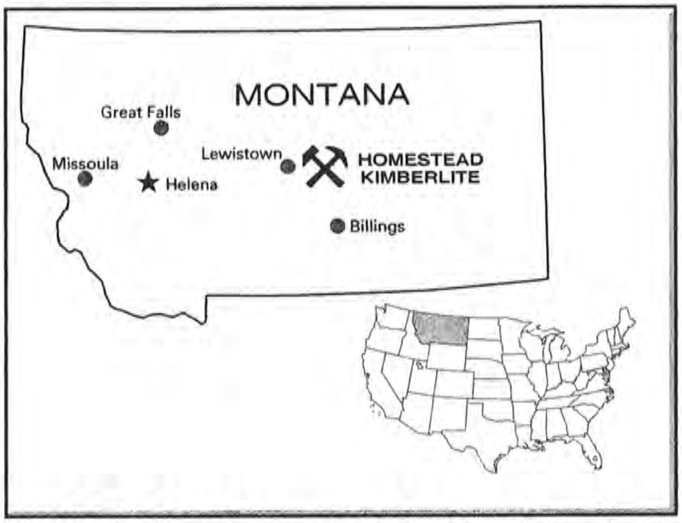


Figure 1. Location map of the Homestead Kimberlite.

The Homestead Kimberlite is located 40 miles east of Lewistown within the Grassrange diatreme field (Fig.1). Petrographic and microprobe studies confirm its kimberlite classification, and identified diamond indicator minerals typical of diamondiferous kimberlites elsewhere. Its discovery, central to the Wyoming Craton, elevates Montana's potential to host economic diamond deposits.

DIAMOND POTENTIAL OF MONTANA

Montana has experienced occasional diamond exploration throughout the years, and is considered high priority (Hausel, 1998). Alluvial diamonds have been found throughout the state. Of particular note is the Lewis and Clark diamond, found near Craig by a woman taking a walk in 1990. The 14 carat stone sold for $80,000 (Missoulian, 1990).

The region is underlain by the thick "cool" crust and upper mantle of the Wyoming Craton, a stable portion of the North American continent. Developed kimberlite diamond deposits are located along the southern margin of the Wyoming Craton in the State Line District of Colorado and Wyoming, and to the north in Canada. Figure 2 shows the extension of the Wyoming Craton and locations of surrounding in situ diamond discoveries.

Figure 2. Active diamond mining and exploration projects in western North America.

The first significant North

American diamond deposits were discovered at Lac de Gras in the Northwest Territories in 1993, and led to the opening of the Ekati mine in 1998, which is expected to produce $7 billion worth of diamonds. Another project of similar size, the Diavik mine, is planned nearby.

REGIONAL GEOLOGY

Figure 3. Detailed map of the Wyoming Craton. Modified after Hausel (1998).

Montana is centered over the core of the Wyoming Craton, composed of Archean metamorphic and granitic basement rocks. The Wyoming Craton was crystallized at 2.6-3.2 Ga (Mitchell and Bergman, 1991) and affected by a regional metamorphic event dating to 1.7 Ga (Eggler et al., 1988). Much of the central and northern Rocky Mountains were underlain by the thick, cool lithospheric mantle keel of the Wyoming Craton at the end of Archean, and was at least 175 km thick (Eggler and Furlong, 1991). Cretaceous to Eocene tectonomagmatism eroded the lithosphere eastward, however, heat flow data, seismologic evidence and isotopic data indicate that mantle keel roots remain beneath central Montana and southeast Wyoming. Eggler and Furlong (1998) propose that the mantle-crust lithosphere beneath central Montana remains at least 140 km thick at present. Garnet peridotite xenoliths from at least three central Montana Tertiary pipes equilibrate at depths up to 180 km, within the diamond stability field (Irving, 1999).

Mafic alkalic diatreme fields are located at Missouri River Breaks, Porcupine Dome and Grassrange. All three fields yield diamond indicator minerals within kimberlitic diatremes. Montana also hosts lamproite intrusions at Bearmouth, Highwood Mountains and Smoky Butte, mafic alkalic intrusions in the Sweetgrass Hills, the Central Montana Alkalic Province and Cretaceous shonkinites in the Adel Mountains volcanics. Locations of all known kimberlites, lamproites and diamond bearing pipes of the Wyoming Craton are illustrated in figure 3.

Figure 4 summarizes the tectonic geology of Montana. The western portion of the state is dominated by the Proterozoic Belt Supergroup, a thick sequence of meta-sedimentary rocks that partially overlie Archean basements rocks. Much of the Belt Supergroup is overlain by Paleozoic and Mesozoic sedimentary rocks, and is thrust eastward over Paleozoic rocks along the Montana Disturbed Belt and the Sapphire allochthon of the Cordillera thrust belt. The Helena Salient forms an embayment of Belt rocks in central Montana.

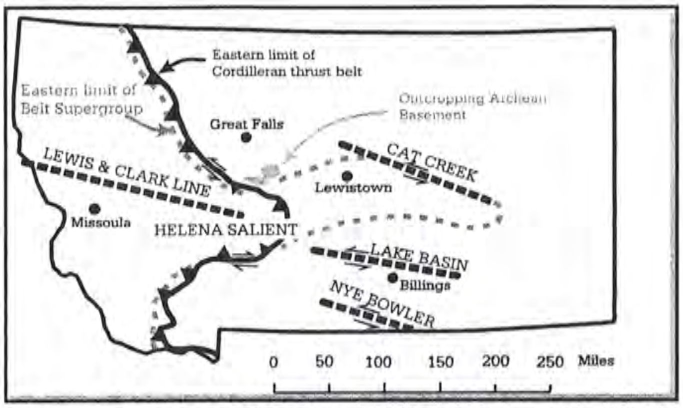


Figure 4. Tectonic map of Montana. Modified after Woodward et al. (1997).

The Lewis and Clark Line is a major continental scale tear fault that forms a deep crustal feature extending from Coeur d' Alene to Billings. The Bearmouth Lamproite intrusion is controlled by faulting along the Lewis and Clark line (Ellsworth, 1996).

Archean basement rocks outcrop within southwest Montana mountain range cores, and as far east as the Little Belt mountains (Fig. 4). Central and eastern Montana is underlain by a platform, with gently dipping Paleozoic and Mesozoic sedimentary rocks that overlie the Archean basement. Several eroded remnants of Tertiary back-arc volcanoes form isolated mountain ranges in the central portion of the state. The Cat Creek lineament produces a wrench fault system exhibited by northeast trending en echelon normal faults enveloped with a northwest trending zone, and the Cat Creek anticline to the north (Porter and Wilde, 1999). The Grassrange diatremes are emplaced within the Cat Creek fault zone, and are aligned along the northeast trending extensional wrench faults.

DISTRICT GEOLOGY

The Grassrange diatreme field extends 26 miles from east to west, and 17 miles from north to south, and includes approximately 19 pipes and 15 dikes that are known. The intrusions are composed of carbonate altered lamprophyre, carbonate vent breccia, tuff, lamprophyre, alnöite, monchiquite, aillikite, lamproite(?) and kimberlite. The Grassrange diatreme field is previously described by Bowen (1915), Reeves (1927), Ross (1926), Johnson and Smith (1964), Marvin et al. (1980), Hearn (1989), Scambos (1991), Mitchell and Bergman (1991), Doden and Gold (1993) and Hausel (1998). There are some reports of diamond exploration in Grassrange. However, no advanced exploration efforts have been made, based on information gathered.

The majority of the Grassrange intrusions are hosted within extremely friable Cretaceous shale, while more resistant Cretaceous sandstone underlies portions of the southwestern area. The Telegraph Creek Fm., Belle Fourche Shale, Mowry Shale, Thermopolis Formation and Fall River Sandstone host the diatremes, and form a series of northwest trending anticlines, domes and synclines. Northeast trending normal faults offset stratigraphy within the southeastern area, and the Cat Creek anticline forms a series of petroleum-bearing domes to the north (Porter and Wilde, 1999).

The diatremes form topographic highs, or "buttes", due to carbonate alteration or

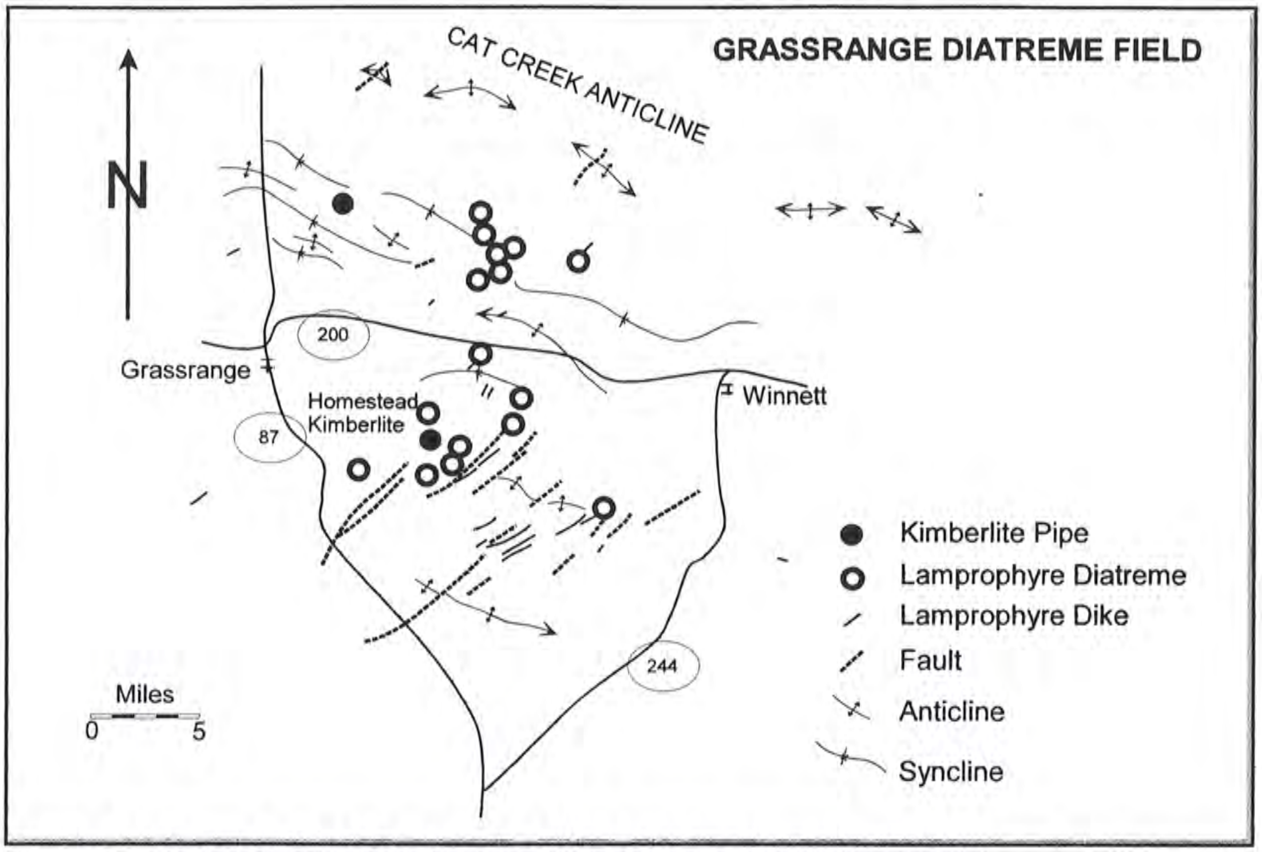


Figure 5. Generalized geologic map of the Grassrange diatreme field.

associated carbonate vent breccias, which are more resistant to erosion than surrounding shale. Diatreme pipes are typically associated with northeast trending narrow dikes with lengths exceeding one mile. Orange, carbonate rich vent breccias, tuffs and altered porphyries are associated with all diatremes examined thus far. This type of carbonate alteration has also been observed at South African kimberlites (Hearn, 1989) and the diamondiferous Sloan kimberlite pipe in Colorado (personal observation, 1999). Carbonate-rich dikes are also very common at Grassrange, and resemble similar dikes at the Premier Mine, South Africa (Gaspar and Wyllie, 1984). Lamprophyre and kimberlite intrusions appear to post date the emplacement of carbonate vent breccias and carbonate alteration events in at least three of the pipes.

HOMESTEAD KIMBERLITE

The Homestead Kimberlite, discovered in 1999, forms low-lying hills located about one and a half miles west of the well known Elk Creek Butte "lamproite" described by Mitchell and Bergman (1991). The kimberlite diatreme complex extends at least 1500 feet in length, and up to 300 feet in width. Vent breccia hosting abundant Paleozoic, Mesozoic and basement clasts form the hill tops. Late stage kimberlite intrusions, are aligned northeasterly, and crop out discretely between and around the vent breccias. Large peridotite mantle xenoliths occur as float on and as inclusions within the kimberlite. The well-rounded mantle xenoliths range up to 25 inches across, and are classified as lherzolite, harzburgite, dunite and websterite. These mantle xenoliths are composed of olivine, phlogopite, Cr-rich diopside, pyrope garnet, orthopyroxene, serpentine and chromite.

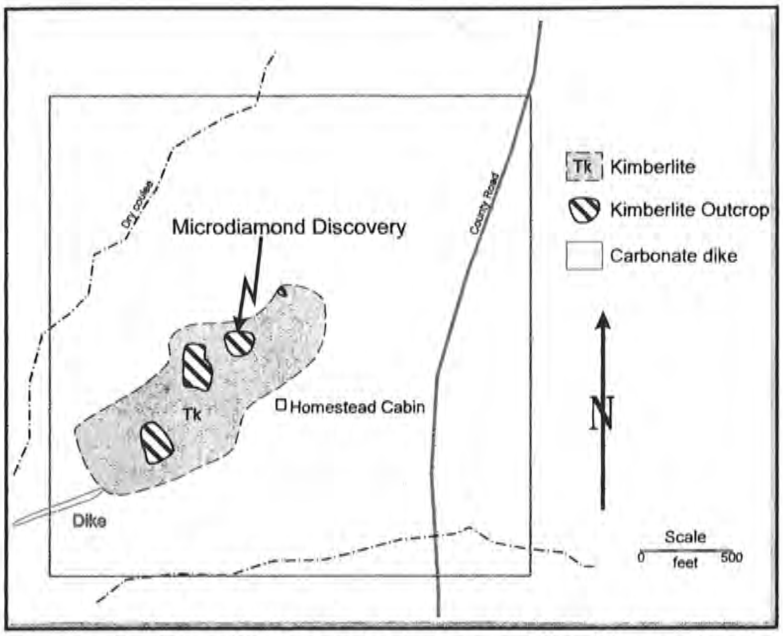


Figure 6. Simplified geologic map of the Homestead Kimberlite.

The kimberlite matrix is composed of xenocrystic olivine, orthopyroxene, phlogopite, monticellite, serpentine, chlorite, Mg-rich chromite (rimmed by Ti-magnetite) perovskite, pectolite, calcite, apatite and pyrite. Abundant fresh xenocrystic and xenolithic debris from disaggregated mantle xenoliths were observed in all samples(Irving, 1999). The kimberlite outcrops poorly, with the majority exposed as deeply weathered, green, kimberlitic soil. Trenching outlines a maximum true width measuring 290 feet of kimberlite, which includes large blocks of country rocks and a 70 foot wide zone of poorly consolidated volcaniclastic kimberlite tuff.

Quantitative microprobe geochemical analyses of pyropes within mantle xenoliths collected from outcrop yield compositions ranging from G9 to G10, as shown on the figure 6 plot (Irving, 2000). The same polished pyrope crystals were analyzed for nickel geothermometer. Results show that the Homestead pyropes plot within the diamond window assuming a geotherm of 40 mW/m^2 for the Wyoming Craton (Irving, 2000, personal communication).

To date, one microdiamond has been recovered from the mantle xenolith-rich portion of the kimberlite (Fig.6). The stone was recovered by caustic fusion of one 98.8 lb. sample, producing one white, clear fragment measuring 0.14 mm by 0.16 mm by 0.32 mm.

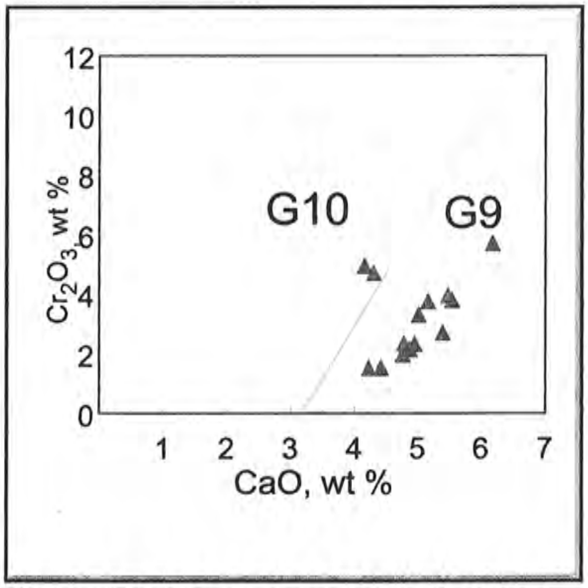


Figure 7. Cr_2O_3 vs. CaO plot of pyrope garnets collected from outcropping Homestead Kimberlite mantle xenoliths.

CONCLUSIONS

The discovery of the Homestead Kimberlite pipe in the Grassrange diatreme field, centered in the Wyoming Craton sheds new light on the potential for Montana to host economic diamond bearing pipes. The microdiamond and diamond indicator mineral discovery verifies that the central Montana mantle lies within the diamond stability field, and potential exists for the discovery of additional diamondiferous kimberlites.

REFERENCES

Bowen, C.F., 1915, Possibilities of oil in the Porcupine Dome, Rosebud County, Montana: USGS Bull. 621, Cont. to Econ. Geol., Part 2, p. 61-70.

Doden, A.G. and Gold, D.P., 1993, Diatreme-dike associations of central Montana: *in* Energy and Mineral Resources of Central Montana, Montana Geol. Soc., Field Conf. Guidebook, p. 215-226.

Doden, A.G., 1996, Ultramafic lamprophyres from Porcupine Dome, east-central Montana, and their potential for diamond (abstract): 32nd Annual Forum on the Geology of Industrial Minerals, Laramie, Wyoming, Abstracts with Program, p. 14-16.

Eggler, D.H. and Furlong, K.P., 1991, Petrochemical and geophysical evidence for old mantle lithosphere beneath Montana: *in* Baker, D.W. and Berg, R.B., eds., Guidebook of the central Montana alkalic province-Geology, ore deposits and origins: Mont. Bur. of Mines and Geology Spec. Pub. 100, p. 87-91.

Eggler, D.H., Meen, J.K., Welt, F., Dudas, F.O., Furlong, K.P., McCallum, M.E. and Carlson, R.W., 1988, Tectonomagmatism of the Wyoming Province: Colorado School of Mines Quarterly, P. 25-40.

Ellsworth, P.C., 1996, Submittal summary for the Bearmouth lamproite diamond prospect: Consultants Report, Missoula, Montana, July 27, 7 p.

Gaspar, J.C. and Wyllie, P.J., 1984, The alleged kimberlite-carbonatite relationship: Evidence from ilmenite and spinel from Premier and Wesselton Mines and the Benfontein Sill, South Africa: Cont. Min. Pet., v. 85, p. 133-140.

Hausel, W.D., 1998, Diamonds and mantle source rocks in the Wyoming Craton with a discussion of other U.S. occurrences: Wyoming State Geological Survey Report of Investigations No. 53, p. 41-46.

Hearn, B.C., 1989, Alkalic ultramafic magmas in north-central Montana, USA: Genetic relations of alnöite, kimberlite and carbonatite, *in* Kimberlites and Related Rocks, Volume 1, ed. J. Ross et al., Geol. Soc. Australia Spec. Pub. 14, p. 109-11.

Irving, A.J., 1999, Mineralogic characterization of igneous rocks from the Grassrange area, central Montana, Part 3: In-house Consultants Report, 4 p.

Irving, A.J. 2000, Mineralogic characterization of mantle xenoliths from the Homestead Hills kimberlite prospect, Central Montana: in-house Consultants Report, 17 p.

Johnson, W.D. and Smith, H.R., 1964, Geology of the Winnett-Mosby area, Petroleum, Garfield, Rosebud, and Fergus Counties, Montana: USGS Bull. 1149, p. 1-91.

Marvin, R.F., Hearn, B.C., Mehnert, H.H., Naeser, C.W., Zartman, R.E., and Lindsey, D.A., 1980, Late Cretaceous-Paleocene igneous activity in north-central Montana: Isochron West, v.29, p. 5-25.

Missoulian, 1990, Diamond find raises hopes in Craig: November 19, 1990 issue.

Mitchell, R.H., 1995, Kimberlites, Orangeites, and Related Rocks: Plenum, New York, 386 p.

Mitchell, R.H. and Bergman, S.C., 1991, Petrology of Lamproites: Plenum Press, New York, 447 p.

Porter, K.W. and Wilde, E.M, 1999, Geologic map of the Musselshell 30'x60' Quadrangle, central Montana: Mont. Bur. of Mines and Geology Open File Report MBMG 386, 13 p., 2 plates.

Porter, K.W. and Wilde, E.M, 1999, Geologic map of the Winnett 30'x60' Quadrangle, central Montana: Mont. Bur. of Mines and Geology Open File Report MBMG 307, 15 p., 2 plates.

Reeves, F., 1927, Geology of the Cat Creek and Devils Basin oil fields and adjacent areas in Montana: USGS Bull. 786-B, p. 39-95.

Ross, C.S., 1926, Nephelite-Hauynite alnöite from Winnett, Montana: Am. J. Sci., v. 11, p. 218-227.

Scambos, T.A., 1991, Isotopic and trace element characteristics of the central Montana alkalic province kimberlite-alnöite suite: *in* Baker, D.W. and Berg, R.B., eds., Guidebook of the Central Montana Alkalic Province: Geology, Ore Deposits, and Origin: Mont. Bur. Of Mines and Geol. Spec. Pub. 100, 16th Annual Field Conference Tobacco Root Geol. Soc., Great Falls, Montana, p. 93-109.

Woodward, L.A,, Kleinkopf, M.D. and DuChene, H.R., 1997, Tectonic evolution and geophysics of central Montana: Northwest Geology, v. 27, p. 51-77.

FIELD TRIP 2 - RECLAMATION ACTIVITIES IN THE BUTTE AREA SUPERFUND SITE

John Metesh, Butte Montana - Trip Leader

Stop 1 (Rose and Shamrock, north of Walkerville):
Overview of the "headwaters" of the Columbia River basin and Yankee Doodle tailings pond.

Stop 2 (Alice Dump):
Example of recent reclamation and overview of the Summit (Butte) valley.

Stop 3 (Granite Mountain memorial):
un-reclaimed / active area - waste-rock dumps, leach pads, tailings pond

Stop 4 (Berkeley Pit):
Berkeley Pit and active mine area

Stop 5 (Metro Storm Drain):
ground-water discharge, wetlands, and tailings

Stop 6 (Lower Area One Operable Unit):
Colorado tailings / Silver Bow Creek removal/reclamation activities

Stop 7 (Silver Bow Creek downstream of Butte - as time permits)
Stream side tailings reclamation/removal

Water Level and Water Quality of the Flooding Underground Mines and Berkeley Pit, Butte, Montana

John Metesh , Ted Duaime and James Madison
Montana Bureau of Mines and Geology

Butte, Montana stands at the headwaters of the Clark Fork River and has been a center of extensive underground mining since the 1870's. Open-pit mining began in 1955 and continues today. As part of the underground mining activities, ground-water levels had to be continually lowered as mining went deeper. When underground mining finally ended, the workings included more than 42 miles of vertical shafts and 2,700 miles of other passageways. As early as 1901, ground water encountered in Anaconda Copper Mining Company properties was drained to a common mine level (2,800 level) for pumping to the surface. Water drainage was through interconnected stopes, drifts, and diamond-drill drainage holes that were used to transport water to the central pump stations. By the 1910's as many as 28 mines were dewatered this way. The pumped mine water contained sufficient quantities of dissolved copper sulfate that it was directed to precipitating plants for copper recovery.

The Berkeley Pit, an open-pit copper mine, was also dewatered through the underground pumping system. The Atlantic Richfield Company bought the Anaconda Company in 1977 and continued to operate the pumping system until April 1982, when the decision was made to suspend mining in the Berkeley Pit. (Underground mining had been stopped in 1975.) In its 27-year life span, about 1-billion tons of material were mined creating a pit with final dimensions of about 1.5 miles long, 1 mile wide and 1,700-feet deep. The pump station, on the 3900 level of the Kelley Mine (3600 feet below ground surface), was shut down and ground-water levels began to rise immediately. By the end of 1982 water levels had risen more than 1,300 feet, and more than 3,000 feet by the end of 1999. In 1984, the water level in the underground workings reached the bottom of the Berkeley Pit. Between 1984 and 1996, about 2,000 gallons per minute of surface water and 2,000 gallons per minute of ground water continuously flowed into the pit. In 1996, the surface-water flow was diverted around the pit. Currently, the pit lake is about 715 feet deep and contains about 30 billion gallons of water. The chemistry of water in the Berkeley pit is controlled by complex interactions between in-pit processes and influent ground water and surface water.

After 18 years of flooding, the Butte underground mines are far from equilibrium with respect to water levels and water chemistry. The water in the underground workings of the East Camp has evolved from an oxidizing, strongly acidic, metal-laden solution to one that is reduced, near neutral, and relatively low in dissolved metals. Although the precise data are not available, it is likely that the chemistry of the bedrock water prior to mining was of good quality. If flooding to historic levels were possible, pre-mining water quality might be re-established. Because flooding will be limited to several hundred feet below historic levels, a significant portion of the ore body will remain exposed to air and ground-water circulation. As such, without detailed geochemical modeling, the final chemistry of the underground mine waters is not readily determinate.

The water levels in the West Camp (Travona, Emma, and Ophir mines) are currently controlled by pumping; however, it has been necessary to increase the rate of pumping as the system responds to the rising levels of the East Camp. The chemistry of the water in the West Camp has been relatively stable through most of the period of record.

The water quality of the Outer Camp (Orphan Boy, Orphan Girl, and Marget Ann mines) probably represents future conditions for the East Camp. These mines have been flooded for some 45 years and, with a few exceptions, concentrations are stable. The pHs of the waters are near neutral and the concentrations of dissolved constituents are generally below drinking-water limits. The period of record is too short, however, to evaluate climatic changes. The annual precipitation for water years 1995 through 1998 was nearly double the long-term average. Ground-water levels in the Butte area outside the influence of mine flooding have risen. The same is true for the Orphan Boy and Marget Ann mines. Any resulting change in water chemistry has yet to be manifested.

A maximum elevation that water levels will be allowed to reach in the underground workings and Berkeley Pit has been established by EPA and the Montana Department of Environmental Quality in order to maintain the Berkeley Pit as a "Terminal Pit". Flooding of open-pit mines is on-going at a number of abandoned mines worldwide. The water in individual pits ranges from highly acidic and containing high concentrations of heavy metals, to moderately alkaline with little or no water-quality contamination. The Butte mines and Berkeley Pit are unique with respect to other flooding open pits due to the large historic underground mine operations interconnected with the Berkeley Pit.

The Butte underground mines and the Berkeley Pit are a part of a Federal Superfund Site. A long-term monitoring program was put in place to ensure that the Berkeley Pit remains a sink, or terminal pit, for bedrock water entering and filling the historic mine workings. This closed system would preclude mine-water discharge to nearby aquifers and surface waters. Both water levels and water quality are monitored. Water levels are monitored monthly in 73 wells and 12 mine shafts and water-quality samples are collected semi-annually at selected locations.

The Montana Bureau of Mines and Geology has recently released reports on the water-level and water-quality history of the flooding mines and Berkeley Pit:

Duaime, T.E., Metesh, J.J., Keschen, M.K., and Dunstan, C.B., 1998, The Flooding of Butte's Underground Mines and Berkeley Pit: 15 Years of Water-Level Monitoring (1982-1998), Montana Bureau of Mines and Geology Open-file report: MBMG-376, August 1998, 116 p.

Metesh, J.J. and Duaime, T.E., 2000, The Flooding of Butte's Underground Mines and the Berkeley Pit - 18 Years of Water-Quality Monitoring (1982-1999), Montana Bureau of Mines and Geology Open-file Report: MBMG-409, July, 2000, 79 p.

Duaime, T.E., and Metesh, J.J., 2000, The Flooding of Butte's Underground Mines and Berkeley Pit, Butte Mine Flooding Operable Unit: Annual Water-level Update (1998-1999), Montana Bureau of Mines and Geology Open-file report: MBMG-410, July, 2000, 90 p.

ABSTRACT

HISTORY OF MINING AND TECHNOLOGY ON THE BUTTE HILL

A Walking Tour of Mines and Mine Yards Featuring Discussions of Historic Mine Operations, Recent Cleanup Activities, and Possibilities for Preservation of Landscapes and Artifacts

John Koerth, Montana Department of Environmental Quality
Mark Reavis, Butte Historic Preservation Officer
Bill Weatherly, Geologist

The historic and mining landscape of Butte today is directly linked to the area's geology. Human interaction with the mineral resources underlying Butte has created a unique assemblage of mining related historic industrial sites that due to their chemical and physical nature have attracted attention from various federal and state agencies pursuing strategies geared at removing or mitigating health and safety hazards. Concerns about the impacts of mine reclamation on historic resources and the lack of coordination between agencies has led to concerted efforts to identify and protect significant historic mining sites and features. In 1990 the Montana Department of State Lands developed the Butte Historic Properties Management Plan as part of an effort aimed at determining the historical significance of a mining feature and its importance to the mining landscape at large. A focus of the management plan was identification of the various elements that make up mining systems that create a historic mining landscape so that strategies could be developed for treating contaminated or dangerous historic mining sites without compromising historic integrity.

The attached historical background information is excerpted from the Butte Historic Properties Management Plan and is reproduced by permission of the Montana Department of Environmental Quality.

WALKING TOUR AFTERNOON AUGUST 5, 2000

Start tour at Anselmo Mine Yard – Lunch at the Anselmo

Anselmo was closed as a producing mine after the 1959 strike and used afterward as one of the locations where slime-tailings were pumped to the underground for use as stope backfill material. All the mine buildings present when this was an operating mine are still present including the timber framing plant. The Anselmo has been developed for interpretive purposes and houses railroad cars and engines that formerly operated on the Butte Hill.

Butte Anaconda Pacific tracks along compressor line to Steward Mine Yard:

This section of BA&P track has been utilized in the recent past as part of a Butte Hill railroad tour that operated out of the World Museum of Mining. Concerns about responsibility for removing contaminated rail bed material have surfaced and the railroad tour is not operating at this time. EPA has proposed to remove track and cap rail bed and develop the line as a walking tail.

Steward Mine Yard

The main hoist and chippy hoist at the Steward are the only intact compressed air powered hoists remaining on the Butte Hill. Steward Mine has seen recent activity and is proposed as the site for the Butte "Story Tellers" project.

Shuttle Vehicle to Upper Part of Butte Hill

Walking tour will continue with views of the Berkley and Continental Pits and a tour of Pilot Butte Mine Yard along the "mine wilderness trail". The trail offers one of the best chances for wildlife viewing in Butte. Conclude tour at Granite Mountain Memorial.

Brief Annotated Bibliography of General Butte History Source Materials

Calvert, Jerry W. The Gibraltar, Socialism and Labor in Butte, Montana 1895-1920. Helena, Montana Historical Society Press, 1988. A detailed account of the political and labor history of Butte during the time of its greatest productivity and social unrest with an emphasis on ethnicity, mining and socialism.

Connolly, C.P. The Devil Learns to Vote. New York, Covivi Friede, 1938. Political history of Montana from Virginia City in 1863 to the culmination of the ACM consolidation of the mines in 1920. Anti-AMC.

Federal Writers Project, Copper Camp. New York, Hastings House, 1943. An anecdotal and not entirely reliable history of Butte.

Freeman, Harry C. A Brief History of Butte. Chicago, Henry O. Shepard Co. 1900. Includes photographs of mines and material about mining in Butte and includes a description of the people and places of the Mining City.

Harrington, Daniel. Lessons from the Granite Mountain Shaft Fire, Butte. Department of Interior, Bureau of Mines Bulletin 188. Washington, GPO 1922. Analysis of Granite Mountain – Speculator mine disaster, includes a list of individuals who assisted in fire control and rescue operations.

Malone, Michael P. The Battle for Butte: Mining and Politics on the Northern Frontier, 1864-1906. Seattle, University of Washington Press, 1981. A history of mining, politics and economics in Butte, from the initial discovery of mining properties by Daly and Clark to the ultimate consolidation of the Butte hill by the Anaconda Copper Company.

Marcosson, Isaac F. Anaconda. New York; Dodd Mead & Co., 1957. A corporate history of the Anaconda Copper Company, includes corporate holding outside Butte.

McNelis, Sarah. Copper King At War. Missoula, University of Montana Press, 1968. Narrative of F. Augustus Heinze's conflict with the Amalgamated Copper Mining Company.

Montana Department of State Lands, Abandoned Mine Reclamation Bureau. Butte Historic Properties Management Plan. GCM Services, Butte, MT, 1990. Historical context and management plan for Butte mining properties affected by abandoned mine land reclamation program activities. Includes a 27 page annotated bibliography of primary and secondary sources relating to Butte.

Sales, Reno H. Underground Warfare at Butte. Caldwell, ID; The Caxton Printers, Ltd, 1964. An ACM mining engineer, Sales was involved in the conflict between the Amalgamated and Heinze over interpretations of apex law.

Weed, Walter. Geologic Atlas of the United States – Butte Special Folio. USGS, Washington DC; GPO 1897. Topographic base map and geologic atlas of the Butte Special District including economic geology featuring description of the lodes.

Weed, Walter. Geology and Ore Deposits of the Butte District, Montana. USGS Survey Paper No. 74. Washington, DC; GPO 1912. Describes in detail the mineral and geological composition of the Butte hill. Also list the quality of ore in each individual mine in Butte.

Historic Properties Management Plan for the Butte Mining District, 1990: Department of State Lands - Abandoned Mine Reclamation Bureau. Written by GCM Services, Butte Montana; chapter reprinted by permission of the Montana Department of Environmental Quality.

HISTORICAL BACKGROUND

Early Placer Mining

Gold mining in the vicinity of Butte drew directly upon the experience of earlier western gold rushes, especially the California gold rush of 1848-49. With the decline of the California placers, many of California's miners struck out for the gold-bearing streams of neighboring Nevada, Colorado, British Columbia and Idaho, during the period from 1857 to 1861. Placer mining in the Clearwater, Salmon and Boise tributaries of the Snake River proved more fruitful than either the Nevada or the Colorado gold fields. From Idaho, the placer miners ventured east into Montana (still part of the Idaho Territory in 1862), bringing with them placering techniques refined in the gulches and streambeds of the Sierra Nevada (Malone 1981; Paul 1963).

Placer mining in Montana can be divided into two categories: river mining (associated with apparatus such as rockers, long toms and sluice boxes) and deep gravel mining (associated with hydraulicking and dredging). The rocker was basically a wooden box--open on one end and mounted on rockers--with cleats or "riffles" nailed to the bottom of the trough designed to capture the heavy gold when river dirt and water are agitated. Two men could process up to five cubic yards of dirt a day through a rocker, using a relatively small volume of water. The long tom was a relatively small wooden trough (up to 12 feet long) with riffles designed to effectively process up to four yards of composed dirt or six yards of loose dirt, using relatively small volumes of moving water. The sluice box was the most common method employed in working shallow, alluvial deposits. Built in 12-foot sections to lengths of 100 feet, miners using a sluice box could wash as much as 75 yards of gravel a day. Early Montana sawmills cut boards in 12-foot lengths to meet the needs of placer miners. Hydraulicking, a technique using water under pressure to remove gravels from stream banks and terraces, represented a much more capital-intensive system than the river mining systems for extracting gold but had the advantage of exposing large volumes of gravel for treatment (Paul 1963; Cushman 1973; Young 1970).

Montana's early gold strikes at Bannack and Alder Gulch, during the early years of the American Civil War, brought the first placer miners into the Summit Valley. During the early spring of 1864, Bud Parker, William Allison and Pete McMahon located placers along a creek they named Silver Bow. Later that spring, Allison returned (after re-supplying in Virginia City) with G.O. Humphreys to locate placer claims along Baboon Gulch, although actual gold mining did not occur until later that summer. By fall, a cluster of cabins appeared in the vicinity of Town Gulch, the future site of Butte City. Meanwhile, placer mining commenced to the west of Butte in German Gulch, along Silver Bow Creek at Rocker and Silver Bow City, and later at French Gulch and south of Butte in the Highland Mountains. The Summit Valley gold boom actually peaked during the next couple years with as many as 5,000 miners sorting the local stream gravels (Malone 1981).

The winter of 1864-65 saw prospectors organizing the Summit Valley mining districts while staking claims along Missoula, Buffalo, Town and Parrot Gulches. The low-grade gold, which occurred in fine particles, paid only $11 to $14 an ounce (pure gold was valued at $20 per ounce). The miner's returns for labor expended were decreased by the need to haul the paydirt down from the gulches to Silver Bow Creek for washing. By 1867, several ditches had been dug to bring water to the workings but only $1.5 million in gold was recovered in more than three years of placering, a rather lackluster performance when measured against the $30 million in gold recovered at Alder Gulch (Virginia City) in three years. Even though total production was small, Butte placer miners boasted daily wages of $7. The Montana gold rush reached its apex in 1866 with the Montana Territory ranking second only to California in overall production. During this time, the population of Silver Bow surpassed Butte City by 500 inhabitants, but the demise of local placer mining was already evident by 1869. The Summit Valley diggings lacked both the water, which was accentuated by a drought, and the surface gold necessary to garner the attention given to Alder Gulch. The 1870 census sounded the death knell for Butte's future as a gold camp with 241 inhabitants remaining, half of whom were Chinese re-working the discarded gravels (Weed 1912; Malone 1981; Paul 1963).

Early Quartz Mining

Even before the eclipse of Summit Valley placer mining, a small group of prospectors sought out the mother lode, just as miners had done earlier in the foothills of the Sierra Nevada in California and later in the Nevada Comstock. Late in 1864, William L. Farlin staked the Asteroid claim (later known as the Travona) in search of free milling gold, but like most others who followed, Farlin discovered lodes containing gold combined with minerals of silver, copper, zinc and manganese, which were difficult to separate. During the next three years, miners located dozens of lode claims, including the Rainbow Lode in present day Walkerville. In October 1864, a claim was filed on the Parrot Lode by Joseph Ramsdell, Billy Parks, Dennis Leary and Charles Porter, an area that would ultimately include some of Butte's earliest copper mines. The successful exploitation of rich silver claims within the Nevada Comstock Lode during the 1860s prompted a variety of experiments in Butte to process the silver veins outcropping on the Butte hill (Malone 1981).

The complex nature of the Butte outcrops did not deter a small cadre of early Butte quartz miners from attempting to overcome their lack of technical expertise and shortage of capital for needed mill and smelter construction. In 1866, Ramsdell and his partners built a crude blast furnace near Quartz and Main streets, but the design proved inadequate. They rebuilt the furnace in 1868 in Town Gulch, just below the Parrot Mine, and shipped four tons of copper matte to Fort Benton, where it was loaded on a steamer bound for St. Louis and from there shipped by train, on America's first transcontinental railroad, to Newark, New Jersey for smelting. Even though some of the ore they processed assayed at 50 percent copper, their primitive smelter proved inadequate for the task, producing a matte too expensive to ship east for processing. The inadequacy of their blast furnace, combined with the high cost of transportation due to the absence of rail connections, proved the undoing of these pioneer Butte quartz miners. However, Butte's legendary copper ledges did not go unnoticed. In 1865, miners uncovered a six-to seven-foot wide vein of copper ore adjacent to the Parrot mine. Miners squatting along Town Gulch remained optimistic about the camp's future, but these hopes quickly dimmed as Butte remained isolated from milling and smelting techniques being refined on the Nevada Comstock during the 1860s. William Farlin continued to experiment with roasting the silver ores of his Asteroid claim without success, and Charles Hendrie and Harvey Bay erected a mill in 1868 for processing gold-silver ore, which failed to capture the sought-after gold. Other unsuccessful experiments included the use of a Spanish ore crusher known as an arrastra. By 1870, the newborn camp of Butte City appeared to be headed for obscurity and the dead end met by many western gold camps that lacked the technology, capital and transportation necessary to process silver and copper ores (Weed 1912; Anderson 1985; Smith 1953; Malone 1981).

During the first half of the 1870s, Butte's pioneer quartz miners, men like Billy Parks, Joseph Ramsdell, Rolla Butcher and Bill Farlin, struggled to make good on their discoveries, even in the face of the depression of 1873 and the refractory ores. Working behind the scenes, frontier capitalists Andrew J. Davis and William A. Clark began to make their move, buying up claims and mines and investing in milling equipment. The year 1872, in retrospect, marked a significant turn of events for the struggling mining camp of Butte with the purchase of the Lexington Mine by Davis and the creation of the First National Bank of Deer Lodge by Clark. While unwavering persistence failed to bring prosperity to the camp pioneers, that same personal quality created enormous wealth for Davis, Clark and a mine engineer and entrepreneur named Marcus Daly (Malone 1981).

The Emergence of Significant Silver Mining in Butte

The exploitation of silver ores at Butte must be seen initially from the broader perspective of silver mining in the West because the technologies for mining and smelting Butte silver ores were developed and perfected in Nevada and Colorado. The origins of western silver mining can be traced to the discovery and development of the Comstock Lode at Virginia City, Nevada after the American Civil War. Until 1877, the Comstock remained the largest producer of silver in the nation. The Comstock's success can be attributed to several significant advances in mining techniques and ore processing, including the invention of "square set" timbering by Philip Deidesheimer in 1860 and the "Washoe Pan Amalgamation Process", developed by Almarin Paul to separate base metals (lead, copper and zinc) from silver ores. These two innovations allowed the silver frontier to spread east to Eureka, Nevada and to Colorado. During the late 1870s and early 1880s, Eureka, Nevada and Leadville, Colorado shifted western silver production out of the Comstock and into the hinterlands, and Montana's silver discoveries were not far behind. The success of these silver camps probably was influenced as much by national politics as by the spread of new mining and ore processing technologies. Congress responded to pressures from "silverites," a group of farmers, silver miners and laborers, for an increased government purchase of silver for coinage by passing the Bland-Allison Act in 1878, permitting government purchase of $2 million to 4 million worth of silver monthly for coinage. A new demand for silver would encourage miners and entrepreneurs in Montana to develop rich silver deposits, creating a frenzy of mining activity and a rapid increase in territorial population (Paul 1963; Chadwick 1982).

Initial silver mining in Montana coincided with the Comstock rush with a mine and smelter developed by Helena entrepreneur Samuel Hauser at Argenta in 1866. The following year, Hauser and his out-of-state associates, the St. Louis & Montana Mining Company, moved into the Flint Creek Range to work the Hope Mine. They brought in Philip Deidesheimer to supervise construction of a 10-stamp pan amalgamation mill at the future site of Philipsburg, named for the Comstock mine engineer. In the early 1870s, William Farlin assayed some ore from his 1864 Asteroid claim and, finding it rich in silver and copper, relocated 13 claims in the last day of 1874, giving birth to a new era of mineral development in Butte. The next year, Farlin began construction of the 10-stamp Dexter mill with a loan from the bank of William A. Clark (Chadwick 1982).

In February of 1875, Farlin arranged for delivery of a mill, manufactured in the East, to be shipped from Corrine, Utah by wagon. By June of that year, the Dexter Mill, measuring 54 by 108 feet, had a contract to reduce 50 tons of ore from the Banker lode. The ore was dry-crushed, roasted in Bruckner cylinders and amalgamated in revolving iron pans to which mercury and salt were added. After being strained through canvas to remove the free mercury, the amalgam was placed in a cylindrical retort, distilling off residual mercury and leaving a residue of "silver sponge," which was then reheated to be cast into silver bars for shipping. The Dexter mill treated the silver ore using the processes of chloridization, roasting and amalgamation, constituting the first successful treatment of silver ores in the district. This initial effort at reducing the complex Butte sulphide ore was not without its problems, however. The cost of freighting salt from Salt Lake City by wagon amounted to $120 per ton, driving down the potential for profit. In fact, by October 1877, Clark's bank declared Farlin in arrears and auctioned the property to the highest bidder, which happened to be Clark's brother and business partner, Joseph. The $25 to $30 per ton levied for milling was sufficient to promote the rapid development of a milling industry in Butte, which in turn prompted a rapid increase in construction. Between October and November of 1875, 48 new houses and six new businesses were erected in Butte and a settlement of 30 buildings sprouted up around the Dexter Mill, transforming the Butte hill from a camp of tents and crude cabins into a settlement with a future (Butte Miner June 1 and 3, 1876; Raymond 1877; Smith 1953).

The year 1876 represented a pivotal year in the development of Butte's silver mining and milling. John Howe moved his silver mill from nearby Brown's Gulch to a location south of Silver Bow Creek, where it became known as the Centennial Mill. That same year, Young & Roudebush erected a mill for processing silver ore at the Burlington mine west of Butte, and Andrew J. Davis reopened the Hendrie Mill to process the ore extracted from the Lexington mine. Early in 1876, Rolla Butcher, locater of the Alice claim, shipped some silver ore to the Walker brothers in Salt Lake City for processing. The Walker brothers responded in August by sending a young immigrant mine engineer named Marcus Daly to investigate this rich silver claim. Daly bought the claim and others along the Rainbow Lode, north of Butte, and sent for Robert Walker and geologist John E. Clayton, who choose a shaft location for the Alice Mine. By 1877, a shaft had been sunk to 200 feet and a 20-stamp mill from Ophir Canyon, Utah, was erected on the site to treat free-milled ores. During the next three years, the Walkers added 60 stamps, two White-Howell roasters (the first of their kind in the territory) and the "dry crushing" system for treating sulphide ores. By 1876, these mining and milling activities had begun to reshape the local landscape. That same year the Butte townsite was platted and miners' cabins appeared in clusters around mines and mills and some wood frame business establishments appeared on the brow of the Butte hill near Town Gulch. The events of 1876-1877 created an avalanche of milling activity in the new silver district as well as the adoption of several new ore processing techniques (Smith 1953; Malone 1981; Weed 1912).

Butte's earliest silver mill operators learned from the experiences of their counterparts in Virginia City and Austin, Nevada, by adapting the Washoe Amalgamation Process and later the Reese River Process to meet their ore-processing needs. Both the Alice and Dexter mills adopted the Reese River Process, a dry-crushing process first tried in a 20-stamp mill near Austin, Nevada in 1863 as an alternative to the wet-crushing Washoe Process. The Washoe Process had been devised in 1860 by Almarin Paul on the Comstock Lode as a means of significantly reducing both labor costs and the amount of wood fuel necessary while, at the same time, doubling production. Actually, the concept of crushing the silver ore wet had its origins in Mexico in 1557, but Paul improved these earlier techniques by combining the grinding and amalgamating into a single step within a large pan. The Washoe Process proved effective in treating free-milling ores where base metals were not present and was used for a time at the Lexington mill in Butte. The refractory Butte ores, containing large amounts of zinc, copper and manganese, ultimately required an alternative to the Washoe Process, which used the Reese River process combined with lixiviation (the treatment of crushed ore by percolating certain elements through the ore to extract silver chlorides) (Oberbillig 1967).

The original Reese River process involved the dry crushing of the ore, the roasting of the ore with salt in reverberatory furnaces and the amalgamation of the silver with mercury in Freiburg barrels or modified Wheeler pans. This process persisted until 1870, when a furnace designed by Carl A. Stetefeldt in 1867 came to dominate the industry because of its high production potential and lower labor costs. The Stetefeldt furnace, first erected in Reno in 1869, roasted the ore as it was dropped with salt from a hopper at the top of the furnace into a roasting shaft 20 to 30 feet high. This new furnace achieved up to 90 percent chloridization of the silver, using half the salt, one-third less fuel, 60 percent less labor and with cheaper construction costs than the reverberatory furnace. Although Butte's early silver mills used less efficient roasting furnaces, the Bluebird mill, constructed in 1884, adapted not only the Stetefeldt furnace but also the more efficient lixiviation process. After five years of operation, the Bluebird mill installed the machinery necessary to use the E.H. Russell process of lixiviation, a technique pioneered by Russell in Silver Reef, Utah in 1884. The Bluebird installed two Stetefeldt furnaces and one Howell furnace, increasing its ability to process "base" ores up to a capacity of 150 tons per day. In 1858, Von Patera introduced the concept of lixiviation of silver ore using a sodium hyposulphite solution for leaching the ore in. It was first used in a California mill by Guido Kuestel in 1874. Russell's modification of the Von Patera concept involved mixing sodium hyposulphite with copper sulphate, providing a more effective and faster extraction of the silver from ore using less energy and small capital costs for construction. It also used chemicals costing one-tenth the cost of mercury and retrieved a much higher percentage of silver from the ore. The process did, however, require more skilled and conscientious mill workers. The Russell process allowed the owners of the Bluebird to reprocess tailings at a profit ,and the owners of the Bi-Metallic Mining Company in Philipsburg also took advantage of this technique for processing tailings by building a plant in 1894 - one year after the great silver crash. While great distances separated Butte from the innovative centers of silver metallurgy,the new techniques were published and readily adapted by mill owners in the Butte district (Oberbillig 1967; Stetefeldt 1895).

In 1881, A. J. Davis sold the Lexington mine and mill to a French company, which immediately began work on the addition of 60 stamps. That same year, W. A. Clark constructed the 40-stamp Moulton Mill, providing additional ore-processing capacity to the growing Butte silver district. These significant events were overshadowed at the end of 1881 with the arrival of the Utah & Northern Railroad, a branch of the Union Pacific, which provided economical shipping of concentrate and the delivery of mining and milling machinery and supplies. The importance of this event cannot be understood without allusion to previously existing transportation systems. Prior to the arrival of the Utah & Northern, the receipt of supplies and shipment of ore relied on wagons and on steamboats travelling the Missouri River between Fort Benton, Montana and St. Louis, both of which were slow, expensive and unpredictable. Montana's rapid rise in national silver production must be attributed, in part, to rail transportation. By 1883, Montana ranked second in silver production to Colorado, due in part to the location of the silver ore in shallow deposits, the arrival of the railroad, an enormous infusion of outside capital and the evolution of milling and smelting techniques. The following year, F. Van Zandt opened the Bluebird Mine and Mill in the western part of the Butte district and,within three years, the Bluebird became the largest silver mill in the district, operating 90 stamps. The year 1887 was also significant as Butte's period of greatest silver production with 345 stamps operating and Montana's silver production topping Colorado's, with $15.5 million in silver (Smith 1953; Chadwick 1982).

This outburst of activity during the 1880s completely transformed the landscape of crudely-built cabins and wood-framed, false fronts into a town identified by its substantial brick architecture. A major fire engulfed the business district in 1879, ushering in a new era of brick building and the incorporation of the town of Butte. While the 1880 census tallied a population of 3400, Butte's revitalized mining industry increased that number to 14,000 by the mid-1880s and brought changes to the local landscape, including an increasing number of wooden headframes and mine/mill buildings, electric lights in the business district and a street railway connecting far flung mines and mills from Meaderville to Walkerville to south Butte. Although Silver Bow County (the Butte district) led the state in overall silver production, the Granite Mountain and Bi-Metallic mines at Philipsburg were regarded as the world's greatest single silver mining operation. Rich silver deposits were also being worked at Elkhorn, the Alta mine at Wickes, the Hecla at Glendale, at Rimini, Castle, and Neihart. With every mining boom, a bust is sure to follow and at both Butte and Philipsburg an omen of the oncoming collapse occurred in 1891 when miners began encountering the end of the high-grade shallow ore deposits below the 900-foot level. The end of high-grade silver ore deposits, coupled with unprecedented silver reserves, a halt to silver exports to Great Britain and India, and the repeal of the Sherman Silver Purchase Act in 1893 brought the silver mining boom in Montana to an abrupt end. During the summer of 1893, the Alice and the Moulton shut down. However, the Nettie and the Lexington continued to produce silver even after 1896, primarily as a by-product of copper milling and smelting. The Butte district did not succumb to the depression affecting the other great Montana silver camps because of the diversity of its ore body. Below the silver lay copper and zinc, base metals with increasing value with the widespread use of electricity in the home and industry during the 1890s (Martin & Shovers 1986; Malone 1981; Myers 1984; Chadwick 1982).

The Development of a World-Class Copper Mining District

The opening of the Dexter mill in 1876 and the subsequent boom in silver mining and milling drew attention away from a very important discovery that same year. One hundred and fifty feet below the surface, on the Parrot Lode, Butte mining pioneer Billy Parks encountered a four-foot wide vein of copper after years of exploration. Even though Parks was soon shipping a ton of copper ore a day to Baltimore for smelting, the attention of miners and entrepreneurs was riveted on the Alice, the Moulton, and the Lexington. However, the development of the Parrot Lode was not lost on W. A. Clark, who purchased the Parrot No. 1 mine for only $10,000 in 1876. In the early 1870s, William A. Clark, Deer Lodge banker and freighter initiated his interest in Butte mining with the purchase of the Original, Colusa, Mountain Chief and Gambetta claims. By 1874, Clark began to develop these claims and shipped the copper ore by wagon to Corrine, Utah. From Utah the ore went by train to the Boston & Colorado Smelting Company in Black Hawk, Colorado, owned by western mining giant Nathaniel Hill. On Clark's request, the Colorado smelter sent Henry Williams north to investigate Butte's smelting potential and, by 1879, the Colorado & Montana Smelting Company was erected in Butte, encouraging rapid expansion of Butte copper mining. In 1880, the Lewisohn brothers of New York sent Charles Meader, a veteran Utah copper man, to Butte to investigate its copper potential. By 1879, convinced of Butte's copper potential, Meader purchased the East and West Colusa claims, formed the Montana Copper Company, and built a smelter east of Butte. The importance of building smelters capable of treating the complex Butte sulphide ore cannot be overestimated. The cost of shipping and processing the rich copper and silver ores to Baltimore, Maryland or Swansea, Wales, literally eliminated all profits, discouraging large-scale copper mining. The opening of the Clark smelter in 1879 launched a promising economic future for Butte (Raymond 1877; Smith 1953; Malone 1981; Weed 1912).

The 1880s represented a pivotal decade in Butte mining history. During the decade Butte grew into a world-class copper producing center. Both of the major players involved in transforming Butte into a major American copper district,W. A. Clark and Marcus Daly, were active in the silver mines period. In 1880, after selling his share of the profitable Alice silver mine, Marcus Daly purchased the Anaconda claim, located by Civil War veteran Michael Hickey in 1876. In acquiring this relatively undeveloped, but extremely rich, copper prospect, Daly sought the attention of investors in San Francisco who, in turn, generated interest within New York and Boston mineral investment circles. Daly turned to San Francisco capitalists George Hearst, James Ben Ali Haggin and Lloyd Tevis, in order to garner the capital to develop the Anaconda mine. Daly eventually convinced the San Francisco syndicate of the value of the property and work was begun in sinking the Anaconda shaft. Initial excavation uncovered rich deposits of silver ore, which were sent to the Dexter mill for processing. An even richer vein of copper sulphide--varying from 12 to 45 percent copper-- was encountered at the 300-foot level, prompting Daly to cancel orders for a new silver mill. The discovery of the rich copper deposit called for a shifting of priorities and Daly immediately responded by approaching his San Francisco backers with a grand scheme, including construction of a major copper concentrator and smelter. Although initially skeptical, Daly convinced Hearst, Haggin and Tevis that a major investment in copper mining and smelting would eventually pay big dividends. With access to capital, Daly proceeded to purchase the St. Lawrence and Neversweat claims, adjacent to his Anaconda, and to locate an appropriate smelter site, 26 miles west of Butte along Warm Springs Creek. By 1884, under the direct supervision of William McCaskell, Daly oversaw the construction of the nation's largest concentrator and a 450-tons-per-day smelter near Daly's new town of Anaconda. That same year, a branch of the Utah & Northern began hauling ore between the Butte mines and the Anaconda smelter. With an investment of over $4 million of his backers' money, Daly launched a dynamic new era in Butte mining history. By the mid-1880s, Butte's daily production of mines and mills topped 1900 tons of ore. Over 2500 men were employed and Butte was established as one of the nation's premiere metal mining districts, soon surpassing Leadville and the Comstock (Malone 1981; Weed 1912).

Beginning in 1887 and continuing into the twentieth century, the Butte district surpassed the mines of Michigan's Keweenaw Peninsula in annual copper production by producing over 78 million pounds of copper. Literally dozens of mines appeared on the Butte hill during the late 1880s and early 1890s, including the properties of several prominent operators outside the Anaconda syndicate. The Walker brothers continued to operate large silver mines in Walkerville, along with a French Syndicate operating the Lexington. The Parrot Silver and Copper Company held 19 claims, and Clark continued to operate numerous mines and two of Butte's most productive smelters, the Colorado Smelter and the Butte Reduction Works. The eastern part of the Butte district was dominated by companies financed by eastern investors such as the Butte and Boston and the Boston and Montana (which, by 1890, became the third most productive copper producer in the nation). During the early 1890s, F. Augustus Heinze broke upon the Butte scene, gathering up a number of mining claims and built a smelter in Meaderville under the corporate aegis of the Montana Ore Purchasing Company. Until the creation of Amalgamated Copper in 1899 and consolidation of the Anaconda Syndicate, a handful of successful independent mining companies continued to operate on the Butte hill with a visible impact on the local landscape (Malone 1981).

Within three decades, Butte had grown from a marginal placer camp into a city with a vital mining industry of over 80 underground mines and a dozen major mills and smelters (see Figure 2). The growth of industrial activity had transformed a town of modest wood frame storefronts and houses surrounding the major Butte shafts into a northern Rocky Mountain metropolis with growing regional influence. By the mid-1890s, Butte was served by three transcontinental railroads, creating a major rail hub at the base of the Butte hill and an extensive brick warehouse district just north of the Northern Pacific depot. By 1896, branch lines of Daly's Butte, Anaconda & Pacific Railway, the Montana Central (Great Northern), and the Montana Union (Union Pacific) crisscrossed the Butte hill, connecting the various mine yards and smelters. During the 1890s, secondary commercial districts grew outside the central business district, to the north in Walkerville, to the east in Meaderville and East Butte, and to the south along the main rail lines and depots, in each case serving workers and their families in the vicinity of the workplace. Butte's first major building boom occurred during this period, bringing with it dignified examples of commercial/civic architecture such as the Hennessy Building, the Butte City Hall, and Silver Bow County Courthouse. Although the first steel headframe did not appear on the Butte hill until 1898, the skyline was dotted with the smokestacks of numerous steam-powered hoisting plants and wood frame shaft houses. The larger smokestacks were associated with Butte's six major smelters. These smelters, located primarily on the south and east edges of Butte, emitted clouds of sulphurous fumes that, at times, required street lights to be lit during the day and effectively destroyed all local grass and trees. The Butte hillside, dotted with waste rock and tailings dumps, remained barren for decades as a result of the deleterious smelter fumes. Unlike most Western hard rock districts, where one or two deep mines and their associated concentrators prevailed, Butte had literally dozens of active mines separated from the milling and smelting operations. Over time, the underground mines shared connections for water removal and ventilation and a grid of powerlines linked independent mines to hydro-electric plants on the Madison, Big Hole and Missouri rivers. By the mid-1890s, miners clustered around the mine yards and smelters in privately owned small wood frame houses in Centerville, Walkerville, Meaderville and McQueen. Butte's appearance just prior to the Amalgamated's consolidation of mining properties on the Butte hill did not differ markedly from other western hard rock mining towns, but the year 1899 and the events that followed would signify a distinct departure from the previous 35 years (Martin and Shovers 1986).

Butte Smelting Industry

Where Butte silver mining imported technologies from Nevada and Colorado, Butte's copper industry, after its earliest phase, led the nation in smelting innovations. The story of the first phase of copper mining mirrored that of the Butte silver industry that preceded it, in that early quartz miners immediately found refractory ores indifferent to free-milling and smelting. Technologies imported from Nevada allowed entrepreneurs to exploit Butte's rich silver deposits, whereas the processing of Butte copper ore initially relied on techniques pioneered in Colorado. Early attempts at separating the red metal from associated sulphide minerals and base metals proved inadequate. As early as 1866, Butte pioneers Dennis Leary, Joe Ramsdell, Charles Porter and Billy Parks built a crude blast furnace with a blacksmith's bellows to process copper ore from the Parrot lodes. Undaunted by their initial failure, Leary, Ramsdell and Newkirk moved the furnace east to the Gold Hill claim in Town Gulch, adapted a fan to the blast furnace and produced approximately four tons of copper matte. For most of the next decade, attempts at extracting copper ceased while Butte's early miners focused on extracting and processing silver ore. In 1876, Giles Olin built a custom plant along Silver Bow Creek in the vicinity of the future Butte Reduction Works for concentrating copper. The Olin concentrator consisted of a 12-horsepower engine, a boiler, a crusher and two hand jigs and was capable of processing two tons of ore a day. The concentrates were sacked for shipment to Baltimore for smelting. During this same time, W. A. Clark was shipping copper ore from his Butte mines by wagon to Corrine, Utah, to make a rail connection to the smelter in Black Hawk, Colorado. Clark convinced the Boston & Colorado Smelting Company to send a representative to Butte to investigate the potential for transferring Colorado smelting technologies to Butte. At the end of 1879, Nathaniel Hill, a pioneer of Colorado, joined with Clark to create the Colorado & Montana Smelting Company and to build the Dexter mill and a 24-ton reduction works south of Silver Bow Creek. The concentrator and smelter produced a 60 percent copper matte and 700 ounces of silver per ton of ore using a Blake crusher, two Cornish rolls, assorted jigs and vibrating tables, two long-hearth reverberatory roasting furnaces and two reverb matting furnaces capable of producing one ton of matte from six to twelve tons of ore, depending on the grade of ore. Lacking converters, Clark still had to ship the copper matte to Black Hawk for additional processing. The success of the Clark and Hill smelter, in addition to increased development of local copper mines, planted the seed for a major smelting industry in Butte (Smith 1953).

Only one year after the formation of the Colorado & Montana Smelting Company, two of Butte's major reduction plants, the Montana Copper Company and the Parrot Silver and Copper Company, were started. The Montana Copper Company, financed by New York interests and managed by Charles Meader, reduced copper by heap roasting lump ore to drive off the sulphur followed by matting in reverberatory furnaces. The basic reduction process remained similar throughout the Butte district, beginning with an initial separation of the ore into first class (not less than seven percent copper) and second class (all ore less than seven percent copper). The higher grade ore was simply roasted to drive off the sulphur and then smelted, while the lower grade had to be concentrated prior to smelting, using a wide array of jigs, vibrating tables and Frue vanners to remove the lighter waste from the minerals. Crushing preceded concentrating, breaking up the sulphide ore and allowing for the removal of the 45 to 70 percent silica (waste) through gravity separation. The practice of heap or stall roasting lump ore (relatively pure sulphide ore) continued until 1896, causing enormous problems with air pollution from sulphur fumes. The Parrot, owned jointly by eastern capitalists Migron and Farrel and Holter and Hauser of Helena, erected a smelter north of Silver Bow Creek and east of the Great Northern depot in 1881. Initially, the plant used a series of reverberatory furnaces for roasting and producing copper matte. The Parrot made history in 1884 by becoming the first American smelter to adapt the Bessemer process to copper, producing a blister copper (higher percentage copper) from copper matte, using a process devised by Frenchman Pierre Manhes in 1880. The Parrot's daily production of 25,000 lbs. of blister copper ranked it second only to a Michigan smelter (Smith 1953).

Between 1881 and 1910, nine ore processing plants operated in Butte. Among the early pioneers was Charles Meader who left the Montana Copper Company in 1881 to build his own smelter, the Bell, located near present day Harrison Avenue north of Bell Creek. During its first year of operation, the Bell became the first smelter in Butte to successfully produce copper matte with a blast furnace and to operate a concentrator capable of processing 70 tons of ore daily. While the Bell's operations remained short-lived, other new smelters persisted into the twentieth century. Butte ore processors also included the Butte Reduction Works, the Colusa (Montana Copper Company and Boston & Montana), the Butte & Boston, and the Montana Ore Purchasing Company, all located south and east of the city. In 1885, the Butte & Boston Company began operations and quickly acquired the Silver Bow Mill, located in East Butte along Silver Bow Creek. The Butte & Boston was absorbed by the Boston & Montana in 1895 and continued to operate until 1905, when it was bought by the Anaconda Copper Mining Company (ACM). The Boston & Montana smelter (above Clark's Colusa) and Clark's Colusa were located adjacent to one another and both started operating in the early 1880s. The installation of a mechanical O'Harra roasting furnace in 1884 gave Clark's Colusa the prestige of having the first furnace of its type in Butte. The O'Harra furnace, redesigned as the Brown-Allen-O'Harra in 1887, had enormous advantages over earlier roasting techniques, such as heap or stall or hand-rabbled reverberatories. Mechanical rabbling reduced time and labor costs and its horizontal design meant it could be more easily connected to the reverberatories and converters, hence making use of the heat generated in the reverboratories. The success of this design immediately attracted the attention of the Butte & Boston smelter operators, who installed eight of the redesigned O'Harra's. The Butte & Boston eventually merged with the Boston & Montana but, in 1891, the Boston & Montana built a state-of-the-art smelter and refinery in Great Falls, Montana, signaling the ultimate demise of the Butte smelting industry in the early twentieth century. Foreshadowing of the smelter industry's demise occurred in 1884 with the completion of Daly's mammoth concentrator and smelter in Anaconda and with the addition of the Lower Works in 1889, raising daily production capacity to 4000 tons, far surpassing the combined capacity of all the Butte smelters (Smith 1953).

Until 1906, Butte mining companies had virtually ignored the zinc found in increasing quantities in the Butte copper ore. That year, the Butte and Superior Mining Company was organized to develop the Black Rock mine, and in 1912, the company constructed a mill to process the zinc ore being removed from the Black Rock. That mill, designed by James Hyde, became the first American company to successfully use the flotation process of concentration on a large scale. That same year, W. A. Clark began building the Timber Butte Mill to process zinc ore from his Elm Orlu mine, replacing capacity lost at the Butte Reduction Works by a fire in 1911. Although both of these events represented steps forward in the production of zinc, their significance was overshadowed by the construction of an electrolytic zinc plant, capable of producing high-grade zinc, at both Anaconda and Great Falls (Smith 1953).

Another major reduction works, which persisted long into the twentieth century, was the Colusa Parrot, known as the Butte Reduction Works after its purchase by W. A. Clark in 1887. Initially, the copper ore was roasted in heaps, and later stalls, and was then smelted in a blast furnace. In 1886, a 100-foot long hearth-hand reverberatory furnace was constructed; in 1889, Clark increased the furnace capacity and efficiency by adding a top hopper feed system. During the period from 1887 to 1900, the size of reverberatory furnaces throughout the district increased from 20 feet to 100 feet in length, increasing smelting capacity and efficiency by creating a better separation of slag and copper matte. The length of reverberatory furnaces at the new Washoe Reduction Works in Anaconda continued to increase during the first decade of the twentieth century, significantly reducing labor costs and increasing the volume of copper matte produced. In 1891, under pressure from the local citizenry, the company erected a 112-foot smokestack in an attempt to direct the sulphurous fumes emanating from the plant's stall furnaces into the air above the valley. In 1910, the Butte Reduction Works was sold to the Anaconda Copper Mining Company but a major fire destroyed most of the facility in 1911. ACM rebuilt the plant but did not operate the smelter, although it did lease the zinc concentrator to W. A. Clark. Between 1928 and 1940, the Domestic Manganese & Development Co., a subsidiary of ACM, rebuilt the facility to produce manganese nodules, constituting the last smelting works to operate in Butte. In 1893, an enterprising graduate of the Columbia School of Mines from a wealthy Connecticut family, F. Augustus Heinze, opened the Montana Ore Purchasing Company smelter in Meaderville. The next year, F. Augustus Heinze replaced existing O'Harra roasters with multi-hearth Herreshoff roasters and, by 1902, his smelter used two horizontal and eight upright converters. Heinze did not build his national recognition on his engineering prowess but, rather, on unabashed nerve for challenging Amalgamated Copper, a dominant player in the Butte "war of the copper kings." The Montana Ore Purchasing Company continued to process ore until 1902, when a major fire destroyed much of the facility. After years of courtroom battles, Heinze finally succumbed and sold all of his properties to Amalgamated in 1906, only after waging both legal and underground warfare against Montana's most powerful corporation. The Pittsmont (the East Butte Mining Co. after 1909) operated between 1902 and 1930 and represented the only local smelter owned and operated by business interests independent of the ACM Company after 1910. The construction of the Washoe Works in Anaconda in 1902, the acquisition of the Boston & Montana smelter at Great Falls and the consolidation of smelting companies by Daly's corporate heirs during the first decade of the twentieth century, effectively brought an end to the smelting industry in Butte. For a summary of the Butte milling and smelting industry see Appendix D (Smith 1953; Malone 1981; Martin, Quivik & Shovers 1989; Weed 1912; Historical Research Associates, Butte Report, 1983; Laist 1945).

The demise of Butte's once prosperous smelting industry can be attributed to a number of factors, the most prominent of which was the construction of the world's largest non-ferrous reduction works by Amalgamated Copper Company (Anaconda Copper Mining Company after 1910). The erection of Butte's major copper smelters during the first half of the 1880s caused serious environmental problems. The emission of sulphur fumes from heap and stall roasting destroyed local vegetation and created severe respiratory problems for Butte citizens. In 1891, citizens petitioned the local government to force the smelters to stop open roasting. Although they were temporarily deterred, local smelters did not stop heap roasting until 1896. A significant factor in the shift from Butte to Anaconda and Great Falls for ore reducing facilities actually has more to do with water than with air quality. Although Butte possessed a rich natural endowment of minerals, it lacked water -- a basic ingredient needed for milling and smelting copper. Reliable volumes of water were found in both Anaconda and Great Falls and, beginning in 1884, a major reduction works was erected along Warm Springs Creek by Marcus Daly. In 1891, smelter operators tapped into the inexpensive hydro-electricity being produced along the Upper Missouri River at Great Falls. At the same time, copper miners in Butte began to encounter lower grade copper deposits (less than 12 percent) and a sulphide ore containing great quantities of zinc and manganese minerals, requiring ever greater quantities of water and energy for concentrating the ore. As concentrators and smelters grew in size to meet increased volumes of lower-grade ore mined at Butte, steam-powered engines initially fired with wood and later with charcoal and coke, became more costly to operate, creating an enormous demand for electricity being produced at a series of dams on the Missouri, Madison and Big Hole Rivers. By the mid-1890s reduction plants at both Great Falls and Anaconda introduced electrolytic copper and later zinc refining, eliminating much of the costly transportation to eastern refineries, thus allowing the Anaconda Copper Mining Company (ACM) and the Boston & Montana Company to devote more of their profits to plant expansion outside of Butte. By 1910, ACM had purchased the Boston & Montana Company, along with the majority of Butte's most productive mines, and had erected the world's largest and most efficient smelter in Anaconda, putting an end to the Butte smelting era. Smelting forever altered the Butte landscape. Even though all of the reduction works have been dismantled, the byproduct of removing vast quantities of waste from the valuable minerals can still be seen in the vicinity of the Colorado and Montana Smelter and the Butte Reduction Works (Malone 1981; MacMillan 1984; Smith 1953).

Consolidation of Mining on the Butte Hill

On April 27, 1899, the Amalgamated Copper Company incorporated, consolidating the properties of Daly's Anaconda Company and other smaller Butte mining companies with assets provided by H. H. Rogers of the Standard Oil trust. Prior to this date, a number of different companies and financial interests divided the rich spoils of the Butte hill. W. A. Clark had controlled the Moulton Mining and Reduction Works, the Colusa Smelter, and the Colorado Smelting and Mining Company, as well as other valuable mining properties, including the Original, the Steward, and the Gagnon. New York and Boston investors controlled the Boston and Montana, and the Boston and Boston Mining Companies. The Montana Copper Company, owned by Charles Meader and the Lewisohn Brothers, operated the Leonard, the Colusa, the Mountain View, and the Badger State mines. F. Augustus Heinze created the Montana Ore Purchasing Company and operated the Rarus, as well as other successful properties. In addition to the acquisition of dozens of Butte mines, Amalgamated also acquired the Anaconda Company's portfolio of very important assets, which included thousands of acres of virgin timber in western Montana, electric-power companies, a foundry in Anaconda, an ore-hauling and passenger railway between Butte and Anaconda, coal mines in Montana and Wyoming, as well as extensive water rights. Combining these assets with its domination of Montana's smelting industry, Amalgamated created the nation's first fully integrated copper company, controlling all aspects of the extractive process from mine to refinery (Malone 1981).

The creation of Amalgamated in 1899 initiated a period of corporate warfare in Butte, waged both in the mine workings below ground and in the courtrooms and newspapers on the surface. The bitter struggle between Heinze and Amalgamated resulted in the shutdown of all of Montana's Amalgamated operations in 1903, paralyzing the state's entire economy. However, Heinze finally succumbed in 1906, selling all of his mining interests to Amalgamated for $12 million. A twenty-year feud between W. A. Clark and Marcus Daly ended in 1910 with Amalgamated (known as Anaconda Copper Mining Company after 1910) acquiring Clark's most significant holdings. The ACM did not actually acquire all of Clark's Butte holdings until 1928 when the Clark-Montana Realty Company was purchased. ACM acquisitions continued with the purchase of the Butte & Superior Mining Company in 1940. By 1950, ACM controlled all mining operations on the Butte hill, with the exception of small individual operations and some properties of the North Butte Mining Company. Amalgamated's initial victory over Heinze and Clark for control over the Butte hill and ACM's ultimate domination of Butte mining would have a long-lasting impact on the Butte mining landscape (Malone 1981; Weed 1912; Anderson 1984).

> With its mines and rail connections, by the late 1910s Butte supported a population of nearly one hundred thousand. In the early twentieth century, Butte had more than twice the population of any other city in the five states of the northern Rocky Mountains and Great Plains. The city's thriving commercial district, several dozen churches, public and parochial school systems, and theaters offering shows and stars of national prominence helped make Butte a metropolitan center without close rival. It was the largest city in the region bounded by Spokane, three hundred miles to the west; Salt Lake city, four hundred miles to the south; and Minneapolis-St. Paul, almost one thousand miles to the east . . .(Martin and Shovers 1986:8).

In 1910, the Butte District produced over 284 million pounds of copper, making it the largest producer of copper in North America and second only to South Africa in world production of metals. That same year, Butte miners uncovered over 10 million ounces of silver and 37,000 ounces of gold, derived primarily as a by-product of copper smelting and refining. Butte was aptly known as "the richest hill on earth." A decade later, moving out from the center of the district, ACM developed a series of rich zinc and manganese mines, only after devising processes for concentrating, smelting and refining these metals. The effective extraction of zinc from the complex Butte ore was related in part to the extraordinary demand for the metal for use in shell casings during World War I. With increased steel production during the 1920s, ACM began producing ferro-manganese nodules in Butte in 1928. During the 1940s, facilities for processing manganese were moved to the Washoe Works in Anaconda (Weed 1912; Martin & Shovers 1986; Laist 1945).

Advantages of Consolidation

Between 1910 and 1927, ACM successfully consolidated all of the major Butte mines, with the exceptions of the North Butte Mining Company properties (i.e., the Speculator and the Granite Mountain), the Butte and Superior mines, and the East Butte Copper Company operations. ACM linked together its 22 Butte shafts through a series of underground and above ground connections. Tunnels and drifts tied together the workings of mines at either end of the three-mile wide district, allowing for more efficient hoisting, ventilation and pumping. By 1927, ore was hoisted through a dozen shafts with the most efficient hoisting engines and tallest headframes. Some hoisting shafts became air shafts while connections between mines increased the efficiency of the mechanical ventilation system installed by ACM after 1914. ACM connected all of its mines on the Butte hill to a centralized drainage system (Daly 1929).

ACM centralized individual systems with the construction of the High Ore Pumping Plant in 1902. At a cost of $350,268, ACM constructed three pumping stations on a single drain level. These large pumps were quintuplex, vertical plunger types. Centrifugal pumps could not be used because of the acidic mine water. The corrosive nature of this water dictated the use of bronze, lead or wood-lined pumps, drainlines and pipelines. The Company protected hoist ropes, cages, skips, mine cars, drills, and all air and water lines to prevent deterioration from acid water. By 1923, all of ACM's main shafts were connected on the 2800-foot level so as to channel the mine water to the pumping stations located at that level. These electric pumps operated day and night to remove water from the Butte mines and to lift it to a precipitation plant on the surface (Piper 1987; Young 1978; ACM Company Records 1902-1906; Daly 1929).

Precipitation of Minerals

Water from the upper levels of the Butte mines contained copper. Commercial values in the water first appeared after the waste rock that filled the stopes and drifts was exposed to the air and then came into contact with the water, making the copper salts soluble. The profitability of this acidic mine water was first apparent after a fire at the St. Lawrence mine and its subsequent flooding in November of 1889. The mine water (which was 0.75% copper) was pumped out through a Mr. Miller's yard which contained piles of scrap iron and old tin cans. The copper salts readily precipitated out onto the metal. William Ledford acquired a lease on the St. Lawrence water a year later and proceeded to build a 40-ft wooden flume filled with scrap iron to trap the copper precipitate. Ledford then sold the rich precipitate to the Colorado and Parrot smelters (Febles 1914).

When Ledford's lease expired, ACM pumped mine water from the High Ore Pumping Plant to a precipitation plant of its own. This plant operated until 1901 when it was enlarged to handle precipitate from all the Company mines. This new plant received water pumped from the 300-foot level of the St. Lawrence and Anaconda mines, where it was gravity-fed down through a tunnel and into precipitation flumes at a velocity of 1200 gallons a minute. From there it fell into settling tanks and was then removed to drying vats. This plant, the largest of its type in the United States, produced 2.2 million pounds of pure copper annually. There were two other small plants operating on the hill at the same time (Lakes 1900).

Even while ACM dominated production and processing of ore on the Butte hill after 1910, there are isolated examples of independent experiments with mineral processing. In 1912, Patrick Clark of the Bullwhacker Company built a 50-ton copper leaching plant in the eastern part of the district, just below the East Ridge in the vicinity of the Columbia Gardens, to process low-grade oxide ore. This early experiment with copper leaching and electrolytic recovery of the copper in solution predated work on a similar process developed at the ACM's Washoe Works in Anaconda and successfully recovered over 50,000 pounds of fine copper. These early efforts at hydrometallurgy proved technically successful but were not cost-effective and, financial problems forced closure of the plant in 1914. Prior to its closure, the company had planned to extract large quantities of ore using an open-pit mining method, more than 40 years in advance of Butte's actual first open-pit mine. At the same time, the Butte & Duluth Company opened an even larger capacity leaching plant adjacent to the Bullwhacker, which boasted a monthly production of 120,000 pounds of electrolytic copper and 30,000 pounds cement copper. Unfortunately, like the Bullwhacker, production costs exceeded market prices for copper by 1915. The technique of leaching low-grade porphyry copper ore actually had its origins in Morenci, Arizona before the turn-of-the-century. During the first decade of the twentieth century, major efforts were made in Utah and Arizona to exploit low-grade (less than 3 percent) ore bodies with widely disseminated copper oxide minerals using block-caving and open-pit mining methods and substituting leaching and precipitating for more traditional methods of concentration, such as oil flotation. In 1913, ACM experimented with leaching dried and roasted slimes in a dilute sulphuric acid solution and precipitating copper sulphides onto iron sponge. Widespread use of the leaching technique came to the fore in the Butte district with the development of the Berkeley Pit after 1955. Montana Resources, Inc., the operator of Butte's current open-pit operation, combines dump leaching of sub-milling grade ore with the concentration technique of flotation (Smith 1985; Parsons 1957).

Electrification of the Butte Hill

ACM's phenomenal rise to prominence as a world-class copper producer would not have occurred without the company's access to large quantities of inexpensive hydroelectric power ($35 a horsepower per year, compared to $125 per horsepower per year for steam power). The mining operations in Butte and the smelting and refining that occurred in Anaconda and Great Falls profited greatly from John D. Ryan's business ventures in electrical power generation. Ryan served as the president of ACM from 1909 to 1933 and on the Board of Directors of Montana Power. With the consolidation of independent power companies under the Montana Power Company, Ryan linked together eleven power plants and constructed over 1300 miles of high voltage transmission lines. Ryan used hydro-electric facilities at Madison River Plants 1 and 2, Canyon Ferry Dam, Hauser Lake Dam, the Rainbow Falls Plant and the Black Eagle Plant to meet the 24,000 kilowatt needs of the Butte mines and the 20,000 kilowatts of power necessary to operate ACM smelters at Anaconda and Great Falls. Montana Power constructed a total of 46 substations across the state to regulate the electricity produced at company dams. This power was distributed to more than 40 Montana cities for lighting, public transit and industrial use. The enormous demand for electrical energy created by the mining and smelting industries made power available for other aspects of the Montana economy, such as irrigation for agriculture, coal mines and flour mills. Hydroelectric power generation, designed to power Butte mining and smelting operations, prompted the early industrialization and modernization of parts of rural Montana as well (Hebgen 1914).

By 1910, ACM decided to put electricity to work to power its ore-hauling shortline between Butte and Anaconda. In 1911, the Butte, Anaconda and Pacific (B.A. & P.) purchased the equipment necessary to transform its system of steam power to one powered by electricity. The 2400-volt direct current system manufactured by General Electric eliminated much of the costly maintenance of steam locomotives while, at the same time, providing faster more efficient service. The B.A. & P. high-voltage system was unique among American electric railroads and it soon established a record of remarkable freight-hauling prowess, carrying some 13,700 tons of ore daily and more than five million tons a year. By 1914, the B.A. & P. system included over 36 miles of mainline tracks and spurs, serving over a dozen mines on the Butte hill and the smelter at Anaconda (Fiege 1987; Hebgen 1914).

Spurs of the B.A. & P. mainline tied all the ACM mines on the Butte hill to company smelting facilities in Anaconda and to the various consolidated shops on the hill. Between 1880 and 1910 ,each mine had its own machine shop, blacksmith shop, carpentry shop and wire rope repair shop. After 1910, ACM consolidated a number of these functions in single locations around the hill. Dull drill steels from ACM mines were sharpened and wire rope was repaired at the Diamond shop. With the opening of the Kelley shaft in the late 1940s, ACM concentrated all company blacksmithing and machine repair at a shop adjacent to the Kelley. ACM also maintained small blacksmith and carpenter shops at each mine to handle immediate needs well into the twentieth century. The B.A. & P. constituted a lifeline for the ACM mines, daily hauling ore and supplies across the hill to company mines (Piper 1987).

On the surface, ACM connected its far-flung mining properties through an intricate web of powerlines, pipelines, roads and railroad tracks. Electrical power for hoisting, pumping, ventilating, lighting and tramming was distributed to the various ACM mines through a 100,000 volt substation located on the Butte hill just below the High Ore compressor plant. ACM produced compressed air to operate hoisting engines and rock drills at three separate locations on the hill -- at the Leonard, the Bell, and the largest at the High Ore -- replacing smaller compressors originally sited at individual mines. The central compressor plant at the High Ore contained six 1200-horsepower synchronous electric motors. Twelve-inch steel pipes carried the compressed air to steel receiving tanks located at each mine where compressed air was stored for use in the event of a breakdown at the central plant. A single mine hoist could operate for one hour on stored air. The tanks also helped regulate the air flow with demand. ACM constructed a 100-ft. steel water tank with a capacity of 500,000 gallons just below the High Ore plant to maintain a constant pressure of 90 pounds/square inch throughout the system. By 1922, the High Ore compressor plant served 22 ACM mines, requiring a coordinated hoisting schedule to avoid demand overloads within the district-wide system (Hebgen 1914; Gillie; Nordberg 1914).

The adoption of a centralized compressor system and the introduction of the steel headframe in Butte combined to make hoisting more efficient and mining more productive overall. Beginning in 1898 with the construction of Butte's first uncovered steel headframe at the Diamond mine and with the installation of Butte's earliest first-motion duplex hoist (powered by compressed air) in 1906, separate technologies combined to make possible ever deeper mines capable of hoisting ever larger amounts of ore daily. Other advantages to the steel headframe included its portability, aptly demonstrated by ACM with its movement of major headframes from one company mine to another over the years and its invulnerability to fire (Stevens 1906).

The direct use of electric motors for raising ore represented a quantum jump in ore hoisting technology. In 1914 the North Butte Mining Company became the first Butte company to install an electric hoist at the Granite Mountain mine. The Wellman-Seaver-Morgan direct-connected, 550-volt D.C. motor/generator electric hoist installed at the Granite Mountain was reputed to be one of the fastest in the United States, capable of lifting 200 tons of ore per hour from a depth of 4000 ft. Electric hoisting offered numerous advantages over compressed air, such as greater efficiency, speed, safety while being easier to operate and simpler to maintain. However, an inventory of hoisting operations in Butte mines indicated that of the 33 main shafts, 17 still operated compressed air hoists, 10 operated steam and only six operated electric. ACM remained reluctant to abandon its considerable investment in its elaborate compressed air system. In fact, ACM did not convert its three largest mines, the Badger State, the Belmont and the Mountain Con, to electric hoisting until 1927 (Hooper 1984).

The availability of electricity from hydroelectric facilities around the state had a dramatic effect on ventilation and tramming in Butte mines. Prior to 1918, all mines on the Butte hill relied solely on natural convection for cooling the deep drifts and raises. The consolidation of individual mining properties by ACM prompted a district-wide ventilation scheme using large, reversible electric fans and miles of flexible canvas tubing, which considerably improved underground working conditions. With consolidation under a single company, crosscuts between neighboring mines were also opened, facilitating the flow of air for improved ventilation. Electricity also helped replace ACM's vast stable of mules, used for tramming ore from the stopes to the shaft, with electric locomotives. By 1923, ACM retired all but two of its mules and relied on a battalion of 200 four-ton locomotives (Daly 1926, 1929; Gillie 1914).

The creation of Amalgamated Copper Company in 1899 made the enormous capital assets of eastern investors available to Marcus Daly to broaden his portfolio of mining and smelting operations and forever altered the Butte mining and architectural landscape. The "Apex" litigation that pitted Amalgamated against Heinze after 1899 eventually lead to a concentration of mines and mills in the hands of a single corporation with extraordinary resources, which assured the Butte district's survival and growth over the long term. Amalgamated had the financial resources to weather the storms of "boom and bust" in the world copper markets, as well as to invest in the latest mining and ore-processing technologies. Amalgamated (and later ACM) survived the self-imposed shutdown of 1903, and national depression in 1907 and the 1920s and 1930s. After 1900, the Butte landscape began to reflect ACM's domination of the local mining industry. The steel headframe rapidly replaced the wooden shafthouse on the Butte hill; electric transmission lines crisscrossed the hill; ore trains of the B.A. & P. worked their way across the hill between ACM mines; mining claims were consolidated as ACM abandoned certain non-productive shafts and increased the depth and surface facilities of other mines; mills and smelters (and the associated smoke) disappeared over much of the Butte hill. The financial stability of a large, integrated copper mining company encouraged the growth of the central business district, dominated by a new crop of steel and brick buildings three to seven stories high, as well as, a number of large brick apartment buildings. With the outbreak of war in Europe came a guaranteed demand for copper and zinc, boosting the Butte mining work force to over 10,000 men and assuring the need for additional housing. A major building boom occurred in Butte between 1910 and 1920, dominated by a new generation of both transient hotels and single-family houses. Substantial building occurred on the flats, south of Butte's mining activity, in an area served by the local streetcar lines. During this era of unprecedented copper production, Butte took on the appearance of a bustling industrial city operating round-the-clock. However, after 1920 and the crash of copper prices, the domination of a single corporation afflicted the city quite differently. For the next 35 years, time remained frozen in Butte; new building stopped abruptly, due to periodic downturns in copper prices and the domination of a single industry (Malone 1981; Martin and Shovers 1986; Calvert 1988).

The Miner and the Industrial Landscape

The exploitation of Butte's rich silver and copper deposits relied on an industrial work force. The dangers inherent in underground mining were well known to Butte's early miners, most of whom were veterans of the quartz mines of California, Nevada, Michigan, Ireland and Cornwall. Butte miners did not waste any time organizing. After walking off the job to maintain the $3.50 daily wage for all workers, miners at the Alice and Lexington mines officially organized the Butte Workingmen's Union in June, 1878, beginning an era during which Butte became known as the "Gibraltar of Unionism." Since they believed that all workers shared in the dangers of the underground the organizers of Butte's first union fought to maintain the same wage for all miners regardless of their task. In 1885, the name was changed to the Butte Miners' Union, but leadership remained in the hands of veterans of the Comstock, the site of earlier hard rock mining unionism. In 1886, Butte miners joined with other workers to form the Silver Bow Trades and Labor Assembly, which represented 34 different unions and nearly all of the town's 6,000 workers. The success of the Butte Miners' Union attracted experienced miners from around the West and, in 1893, Butte organizers attempted to spread their influence and power by creating the Western Federation of Miners. In May, miners from Ouray, Colorado; Burke, Idaho; Lead City, South Dakota; and Eureka, Utah, gathered in Butte, representing more than a dozen unions and thousands of workers. As long as ownership of the Butte mines stayed in the hands of numerous private entrepreneurs and small companies relations between workers and management remained civil, negotiations over wages and conditions proceeded with few strikes and without the violence that occurred in Cripple Creek and the Coeur d' Alene district. This early period of tranquility would come to end with the consolidation of Butte mining properties by Amalgamated after 1900 (Martin & Shovers 1986; Malone 1981; Jensen 1950).

The first two decades of the twentieth century represented a turbulent time for the miners who made up the membership of Butte Local No. 1 of the Western Federation of Miners. A number of factors combined to make life above and below ground more financially uncertain and dangerous for Butte's miners. The domination by Amalgamated, and later by ACM, brought an end to the honeymoon between labor and management. Strikes proliferated and ACM responded by hiring strikebreakers and using their economic muscle to manipulate local, state and federal forces to put down insurrections. Between 1914 and 1920, federal troops occupied Butte on six different occasions. Internal politics also had a negative impact on the Butte miners' union -- first in 1905 when a disgruntled faction left the union to form the Industrial Workers of the World (IWW), and again in June, 1914, when factionalism within the union led to the dynamiting of the union hall. The rapid increase in production that came with consolidation meant an extraordinary demand for underground miners, which was met by ACM by hiring thousands of inexperienced immigrants from Finland, Serbia and Italy. At the same time, new mining technologies increased dangers to the miners working in deeper shafts with inadequate ventilation while filling the air with silica dust from mechanical drills. In 1883, only seven miners died in underground accidents in Butte. In comparison, in the years from 1916 to 1920, 410 miners died in the mines. Respiratory disease killed 675 Butte miners between 1907 and 1913. A federal study of Butte conducted during this period indicated that the tuberculin death rate in Butte was twice the national average; this was attributed to the silica dust encountered by the miner underground coupled with his often squalid living environment above ground. Single miners crowded into poorly-ventilated and unsanitary rooming houses in Centerville and Dublin Gulch during these years, further aggravating the health hazards already experienced by Butte miners (Malone & Roeder 1976; Jensen 1950; Shovers 1987).

By the end of 1914, the miners' union was in disarray and split into two factions: the Butte Miners' Union and the Butte Mine Workers' Union, neither of which ACM recognized. The miners' unions remained powerless until the Speculator mine fire of June 8, 1917, which killed 164 men and remains the worst hard rock mining disaster in American history. The miners responded immediately with a wildcat strike against the Elm Orlu and with the creation of the Metal Mine Workers' Union (MMWU), which gathered support and fostered a walkout by more than 15,000 workers by the end of June. However, the union did not last more than a few months; continuing internal dissension and company hostility caused its demise. The last gasp of the MMWU occurred following the murder of IWW activist, Frank Little on August 1, 1917. Little's martyrdom evoked immediate outrage from organized labor but did not provide the glue necessary to hold together the splintered factions of Butte miners. Most of the strikers had returned to work by September, disabling organized labor in Butte until a revival in the 1930s (Malone & Roeder 1976).

Although ACM, with help from local and state officials, had virtually eradicated a very powerful union of industrial workers by 1920, the miners left their imprint on the city landscape. The working-class neighborhoods of Centerville, Dublin Gulch, Finntown, East Butte, South Butte, McQueen and Meaderville, with their many thousands of modest, hip-roofed, wood-frame houses, remained, as did the churches, neighborhood groceries, fraternal halls, saloons and brothels that the miners patronized. While the mine supervisors and merchants maintained their enclave on the west side, Butte remained the workers' town with its all-night eateries and gambling establishments, many with a distinctive Irish imprint. However, ACM's domination over its workers persisted over time with the development of the Berkeley Pit in 1955 and the eventual displacement of the residents of Meaderville, McQueen and East Butte. Remnants of union activity

Figure 10. Quartz Street circa 1900 looking into the heart of the mining district at the Parrot, Anaconda and seven stacks of the Neversweat mine. (Photo World Museum of Mining)

Figure 13. Park Street in 1989 looking east toward the Berkeley Pit. Photo documents the impact of the Berkeley Pit on the Butte landscape.

have become more difficult to find with the destruction of the miners' union hall in 1914 and with the recent transformation of the subsequent union hall into an office complex. The headframe for the Granite Mountain mine, site of the Speculator mine fire, can still be seen. Most of the working-class saloons have disappeared, along with Chinatown and the adjacent "cribs" and parlor houses of the Red Light district. Probably the most striking reminder of Butte's industrial heritage is the row upon row of miners' tombstones in the city's five cemeteries (Martin & Shovers 1986).

The Growth of ACM and Its Impact on the Butte Hill

Corporate Expansion

Only 16 years after Marcus Daly's death in 1900, ACM had grown into a multi-national corporation with a portfolio of subsidiaries in mining, mineral processing and fabrication. John Ryan, the architect of this expansion, made the following acquisitions during his first eight years at the helm of ACM: a lead-copper smelter at Toole, Utah; a lead refinery in East Chicago; a large copper mine in Cananea, Mexico; and the Potrerillos copper mine in Chile. Ryan did not stop with these non-ferrous ore production and processing additions. In 1922, ACM purchased American Brass Company, the nation's largest brass fabricator and a major consumer of copper and zinc. That same year, ACM sought and acquired an additional source of copper ore with the purchase of the rich Chuquicamata mine in Chile. But these two decades of extraordinary corporate expansion ultimately did not overcome the advantages in output and cost achieved by ACM's competitors, Phelps Dodge and Kennecott. At the same time, ACM corporate expansion accrued an enormous debt burden for the company, indirectly affecting the Butte operations. During this period of ACM expansion abroad in ore production and into fabrication at home, the company continued to employ methods of deep-shaft mining in Butte. Butte's supremacy over world copper production gave way to producers in Utah and Arizona, employing the new mining techniques of block-caving and open-pit extraction (Navin 1978).

Block-Caving: The Kelley Greater Butte Project

With John Ryan's death in 1933, ACM came under the direction of Butte native, Cornelius Kelley, beginning an era in which Butte shifted its focus of corporate activities to operations in South America. Between 1916 and 1940, ACM expanded zinc production at the Badger and the Anselmo and manganese mining at the Emma. During the same time, improvements were made in hoisting efficiency and ventilation, but Butte's overall output remained stagnant and labor costs remained high with the major underground mines reaching a depth of 4000 feet. At this depth, Butte miners encountered an increasingly lower grade ore, leading to the abandonment of some of Butte's older shafts and the pursuit of more efficient mining techniques. In 1947, ACM initiated the Kelley Greater Butte Project, a major block-caving operation directed from a new concrete-lined shaft in Dublin Gulch, to be known as the Kelley shaft. Block-caving constituted a non-selective underground mining technique developed for low-grade copper ores in mines at Miami and at Inspiration, Arizona, during the early part of the twentieth century (1914-15). The Kelley block-caving operation followed traditional methods, dividing the ore body into 80 by 120-foot blocks that were undercut from below until caving began, crushing the ore into fragments removable by controlled drawing. The ore was hoisted through the No. 1 shaft with its 178-foot headframe moved to the site from the Leonard mine. A second headframe, measuring 160 feet tall and brought to the site from the Tramway mine, was erected to bring men and materials to the surface. The No. 1 shaft was constructed by raising upward from the 3000-foot level, reached by connections from the nearby shafts of the Steward and Mountain Consolidated mines, two of Butte's oldest working copper mines. During the latter years of underground operations at Butte ,the Mountain Con and Steward were both worked through the Kelley shaft. As the Kelley block-caving proceeded east into the heart of the district, old workings and mine yards were abandoned by ACM, preparing the way for development of the Berkeley Pit. One of the most visible results of the Kelley block-caving project on the landscape was the related creation of Butte's first company housing in McGloin Heights. ACM built a sizeable number of small, single-family ranch houses for professional staff brought in to oversee the project. This housing development was unique to Butte's past, since, throughout its history, Butte grew independent of a company plan or investment in residential or commercial buildings. Upon completion in 1952, the Kelley became the most productive hoisting shaft in America, capable of bringing ten times more ore to the surface than either the Badger or the Mountain Con, previously Butte's most productive hoisting operations. While daily production levels eventually reached 15,000 tons, the poor grade of ore required an even more radical departure from traditional Butte mining methods (Navin 1978; Corbett 1984).

The Opening and Operation of the Berkeley Pit

The Berkeley Pit, started in July 1955, represented the most dramatic change in mining methods seen in Butte during the district's 80-year history, although it was a change that had come to the American southwest some 40 years earlier. A very visible result of the development of the Berkeley Pit was the dismantling of more than a dozen Butte mine yards, including the Anaconda, the St. Lawrence, the Neversweat, the Rarus, the Leonard and the Berkeley, as well as the loss of the residential communities of Meaderville, McQueen and East Butte. The Berkeley Pit rapidly became recognized as the largest truck-operated pit mine in the nation. Behemoth ore trucks, ranging in size from 25-to 150-ton capacity, lumbered out of the pit en route to the nearby Weed Concentrator, designed to crush and concentrate low-grade copper ore more efficiently than its older counterpart in Anaconda. This new mining technique also produced a sub-milling grade ore in which copper could be removed using a process called dump leaching, further extending the life of the Berkeley

Pit. As the Berkeley Pit expanded over the years, the Anaconda Company continued to buy more land surrounding the pit, removing houses in the vicinity after acquiring title to the land. Beginning in the 1970s, a group calling itself Butte Forward, Inc. investigated the possibility of selling all property on the Butte hill to the Anaconda Company to allow westward development of the Berkeley Pit. The local government rejected the idea of relocating the city to an area southwest of the Butte hill in 1976. While open-pit mining in the Berkeley Pit dominated Anaconda activities in Butte through the 1960s, the company explored the potential for zinc mining at the Missoula and Ryan shafts on the west edge of the district and at the Badger on the east side. Even though Anaconda abandoned its block-caving operation in the Kelley in 1961 because the adverse effect it had on the pit operation, the company continued to mine copper in the deep levels of the Mountain Con and the Steward which they hoisted through the Kelley shaft, sunk to the 4800-foot level in 1961 to accommodate this activity. In 1974, Anaconda halted almost all underground mining, placing all hope for the future in pit mining (Corbett 1984).

Financial Problems and the Demise of ACM

The origins of Anaconda's ultimate demise in 1983, signalled by the closure of all mining operations in Butte, had its roots in corporate folly during the 1960s. Actually, Anaconda had remained a step behind its competitors in Utah and Arizona from the 1920s forward. With the company's acquisition of mines in South America after 1930, there developed a growing dependence on the company's mines and smelters in Chile. By the 1970s, 85 percent of Anaconda's profits were derived from mines in Chile, when a popular move towards nationalization threatened American assets. In the early 1970s the government of Salvadore Allende expropriated all foreign mining operations, including Anaconda's mines. These circumstances created an enormous financial crisis for Anaconda, ending with the sale of all corporate assets to the Atlantic Richfield Company (ARCO) in 1977. Under ARCO's direction, work continued in the Berkeley Pit. Exploratory work was also continued in the Kelley but was then abruptly halted in 1979. In 1980, ARCO suspended all smelting activities in Anaconda and Great Falls, which was followed closely by a closure of the Berkeley Pit in 1982.

Over its 27-year life, the Berkeley Pit yielded over 400 million tons of copper ore and grew to a dimension of approximately one mile wide by one mile long, an incredible chasm in an area that once housed thousands of Butte miners and their families. The Berkeley Pit, producing 50,000 tons of ore per day at the end, could not on its own overcome shrinking world markets and foreign competition with their rich ore reserves and labor at one-tenth the cost of American labor. On June 30, 1983 ARCO suspended all mining in Butte (Navin 1978;Corbett 1984).

Epilogue

The demise of the century-old enterprise of hard-rock mining in Butte was part of a world-wide trend in which the leading North American metal producers have succumbed to challenges from Third World producers. Until the 1970s, American corporations (Kennecott, ASARCO, Phelps Dodge, AMAX and ACM) dominated the world production of copper, but political, technological and geologic circumstances reversed the American position. Chile is typical of foreign producers with its largely untapped, rich ore reserves, the absence of environmental regulations, latest recovery techniques, cheap labor, and access to open markets in the industrialized world. The results have been catastrophic to an American industry besieged by costly environmental compliance and the depletion of high-grade ore reserves. Between 1981 and 1984, the number of working American metal miners decreased from 109,000 to 44,800 and corporate losses topped $3 billion. Since 1984, the price of copper has risen almost 90 cents a pound which, along with a streamlined work force and wage cuts, has led to a resumption of copper mining in Butte. In 1986, Washington Construction of Missoula, Montana reconstituted the Anaconda Company under the name of Montana Resources, Inc. (MRI) and reopened the East Continental Pit for copper and molybdenum production. In 1989, MRI and its 300 workers produced over $100 million in copper/moly ore. In 1987, an Australian investor purchased a number of the historic Butte underground mines from Montana Resources under the corporate name New Butte Mining, promising to re-explore the Butte underground for silver and lead. New Butte Mining has reopened the Lexington Tunnel between the Syndicate Pit and the Lexington shaft, as well as opening a new adit on the Chief Joseph claim, west of the Badger shaft. In August 1989, New Butte Mining obtained a state mining permit and is currently extracting approximately 500 tons of ore daily (Business Week 1984; Shovers 1988).

Although mining re-emerged as part of the Butte economy in 1987, it will never again approach the dominant position it held between 1880 and 1980. At the same time, the imprint left on the local landscape by mining remains quite visible. The most striking features of Butte's contemporary landscape reflect two specific eras of mining activity: the underground era of 1890 to 1920 and the modern open-pit era from 1955 to 1983. The earlier period is represented by the tall steel headframes that still dot the hillside, by the impressive commercial architecture of the business district and by the working-class neighborhoods surrounding the underground mines. This area is recognized as a National Historic Landmark District covering approximately one and one-half by two and one-half miles and containing over 4,000 historic buildings. The most obvious features of the latter era are the Berkeley Pit and the currently operating East Continental Pit. The wildly fluctuating price of copper on the world market has as much to do with the current configuration of the landscape as do changing mining and ore processing technologies and the shape and content of the ore body. The world economy and the plummeting price of copper during the 1920s halted Butte's World War I building boom. During the 1920s, the automobile prompted a dispersion of population off the hill onto the flats. This exodus became more pronounced during the 1950s with the development of the Berkeley Pit and, by the 1970s, a significant new commercial district and new neighborhoods took root along the interstate highway at the base of the Butte hill (Martin and Shovers 1986).

The Butte District, Montana - New Field Data and Reassessment of Post-Mineral Structural Tilting, Field Trip Guide
August 5, 2000

Houston, Robert A., Dept. of Geosciences, Oregon State Univ., Corvallis, OR 97331, FeS22H2O@aol.com

- From Montana Street travel 1.93 miles west on I-90 interchange, stay in the right-hand lane. After crossing over Whiskey Gulch, carefully pull off the road onto the right-hand shoulder.

Stop 1: Sheet aplite sill exposed in the northern road cut of Interstate 15/90, just west of Whiskey Gulch.

Northeast striking, moderate northwest dipping sheeted aplite sills exhibit multiple injections of aplite / granoaplite phases, parallel to contact margins. This road cut is in the hanging wall of the moderately west-dipping Milwaukee fault that shows approximately 500 meters down-to-the-west displacement (Meyer, 1968).

In the northwestern part of the district, primary bedding planes (055-35NW) in the basal sedimentary unit, now tilted moderately northwestward, are concordant with attitudes of eutaxitic textures in the overlying lower welded ash-flow tuff and 11 sheeted aplite sills (086-34NW) in the immediately underlying Butte Quartz Monzonite. This observation supports northwest tilting occurred post-emplacement of the lower welded ash-flow tuff unit. Since sheeted aplite sills were emplaced horizontally, attitudes of sheeted aplite sills throughout the district directly describe the extent of tilting in the Butte Quartz Monzonite.

Stereonet plots of 407 aplite dikes and sills, grouped into twelve structural domains, reveal that aplites are gently tilted 9 to 14 degrees northward throughout the district (Figure 1). Two exceptions are the central and the northwestern regions of the district. The mean orientations of 49 sheeted aplite sills from the central part of the district, excluding the area around the Berkeley Pit for lack of access, exhibit a gentle 14 degrees eastward tilt and lie in the hanging wall of the west dipping Continental Fault (ca. 1500-m displacement). Accommodation along a synthetic fault, west of the Continental fault, could account for this eastward rotation. The northeast striking, moderate northwest dipping Rarus fault may be such a fault. Sheeted aplites sills in the northwest part of the district dip moderately northwestward. These exposures are closely associated with moderately east dipping, north-northeast-striking normal faults in the western part of the district.

By restoring the district prior to regional 5 to 15 degrees northward rotation, steeply south-dipping pre-Main Stage biotite crackle veinlets, quartz porphyry dikes, Main Stage veins, pre-Main Stage / Main Stage mineralization and alteration patterns and east west striking 58.5 Ma (Martin et al., 1999) rhyodacite dike would become consistent with vertical emplacement models.

- Continue west on I-90 to Rocker, Montana. From the Rocker exit of I-90, turn north, then east, after 0.19 miles, follow the road northward for 4.75 miles and turn east at the junction with Hail Columbia Gulch road, travel 0.64 miles and park.

Stop 2: The contact between moderately northwest tilted ash-flow welded tuff and the overlying quartz latite lava.

At this location, exposures of north-northeast striking, moderately west-dipping welded ash-flow tuff lie along the ridge, north of the road. Abundant collapsed pumice lapilli (fiamme), locally devitrified to clay minerals, produces a vesculated appearance. Vertical changes in accidental and cognate materials suggest fluctuations in the collapsing eruption column during emplacement of the lower welded ash-flow unit. Locally, zones of chloritized accidentals occur in the upper sections of this unit. Down section, a northeast trending normal fault, down drops the quartz latite lava unit against the lower ash-flow tuff unit. Up section towards the west, the quartz latite lava unit overlies the lower ash-flow welded tuff. Locally, quartz latite lava overlies a basal autobrecciated zone of quartz latite lava fragments. This brown to purplish red quartz latite lava, locally, exhibits platy joint sets parallel to well developed planar flow layering, marked by aligned plagioclase phenocrysts.

In the northwestern part of the district, attitudes of eutaxitic textures in the welded ash-flow tuff, now tilted moderately northwestward, are concordant with tilted primary bedding planes (055-35NW) in the underlying basal sedimentary unit and attitudes of platy joint sets, parallel to well developed planar flow layering in the quartz latite lava unit. This observation suggests that northwest tilting was post-emplacement of the quartz latite lava unit.

- Re-trace your route back (south) to the junction with Oro Fino Gulch road and turn east. Follow the road, keeping left, to the junction on the north side of the Alice (reclaimed) tailings dump, turn north and stay right up to the top of the hill. Down in the next gulch, turn west onto a dirt road and drive 2 miles.

Stop 3: Gently west to southwestward tilted Lower Welded Ash-Flow Tuff.

Stop 3 investigates an isolated hill of gently west-southwest-dipping, north-northwest-striking welded ash-flow tuff. In the saddle on the eastern side of the hill, poor exposures of deeply weathered Butte Quartz Monzonite (grus) and intensely weathered boulders of Butte Quartz Monzonite and aplite, mark the depositional contact between the Eocene volcanics and the underlying Cretaceous plutonic units. The southeast-dipping, northeast trending rotational normal fault traces along the break in slope on the western side of the hill (Plate I).

The rotational axis of the northeast trending normal faults is proximally located to the southwest of stop 3. This region represents lessor amounts of displacement and block rotation, than regions further northeastward along the fault. Locally, the basal contact of the welded ash-flow tuff is offset 138 meters southeast side down and is tilted 10-15 degrees west southwestward (Figure 2, C-C'). Northeast trending rotational normal faults form prominent hog back ridges, typical in extensional stress regions. These ridges can be viewed to the north from the top of the hill.

- Retrace the route back to the junction on the north side of the reclaimed Alice tailings dump and turn east. The road will loop southward, turn north, and follow the road north 3.97 miles and park where the road turns northeastward. Walk the private road, up the hill to complete the field trip.

Stop 4: Moderately tilted welded ash-flow tuff overlies basal surge deposits.

Moderately northwest dipping, northeast striking welded ash-flow tuff overlies a variable colored, partially fluvially reworked basal surge deposit. This region represents greater amounts of displacement and block rotation than observed at Stop 3.

The northern extension of the northeast trending southeast-dipping rotational normal fault, visited at Stop 3, displaces the welded ash-flow tuff 645 meters, down to the east, and moderately rotates the fault block northwestward, placing Butte Quartz Monzonite in fault contact with the welded ash-flow tuff. From east to west, each of the four occurring faults blocks progressively exhibit greater amounts of block rotation. The total local offset across all three of the northeast trending faults is 835 meters (Figure 2, B-B').

Northwest tilting is closely associated with northeast trending, moderately southeast-dipping rotational normal faults in the northwest part of the district. Stops 3 and 4, describe differing amounts of offset and tilting, at different locations along northeast trending rotational normal faults and illustrate the character of tilting in the northwest part of the district. These rotational normal faults show decreasing displacement and diminishing amounts of northwest tilting southwestward along the fault. Additionally, from east to west, each individual fault block has successively experienced greater amounts of block rotation.

- Completion of the field trip.

References:

Meyer, C., Shea, I.P., Goddard, C.C., and staff, 1968, Ore deposits at Butte, Montana: in Ridge, J.D., ed., Ore Deposits of the United States 1933-1967 (Graton-Sales vol.): New York, Am. Inst. Mining Metall. Petroleum Engineers, v. 2, p. 1363-1416.

Martin, M., Dilles, J., and Proffett, J., 1999, U-PB Geochronologic constraints for the Butte porphyry system. Geol. Soc. America abstracts with Programs, p. A-380.

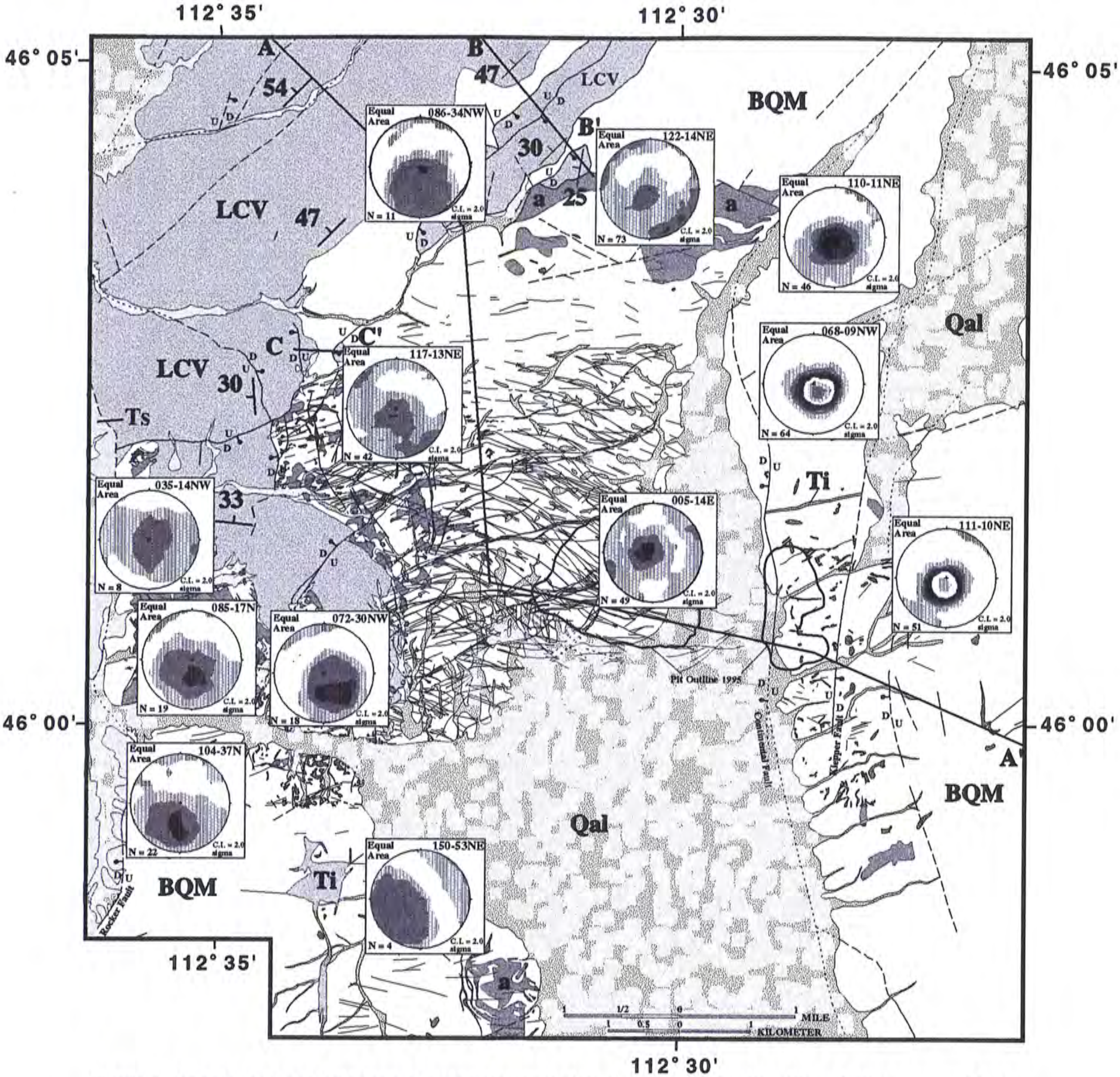


Figure 1, Generalized geologic map showing stereonet plots of 407 sheeted aplite sills and dikes grouped into twelve structural domains occurring in the Butte district. Contours drawn at 2 sigma.

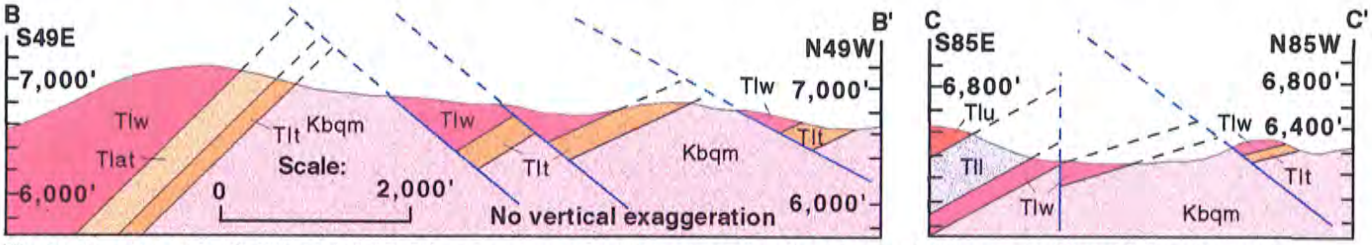


Figure 2, Stops 3 (C-C') and 4 (B-B'), describe differing amounts of offset and tilting, at different locations along northeast trending, moderately southeast-dipping rotational normal faults and illustrate the character of tilting in the northwest part of the district. These rotational normal faults show decreasing displacement and diminishing amounts of northwest tilting southwestward along the fault. Additionally, from east to west, each individual fault block has successively experienced greater amounts of block rotation. Cross sectional lines and explanation shown in Figure 1 and on Plate 1.

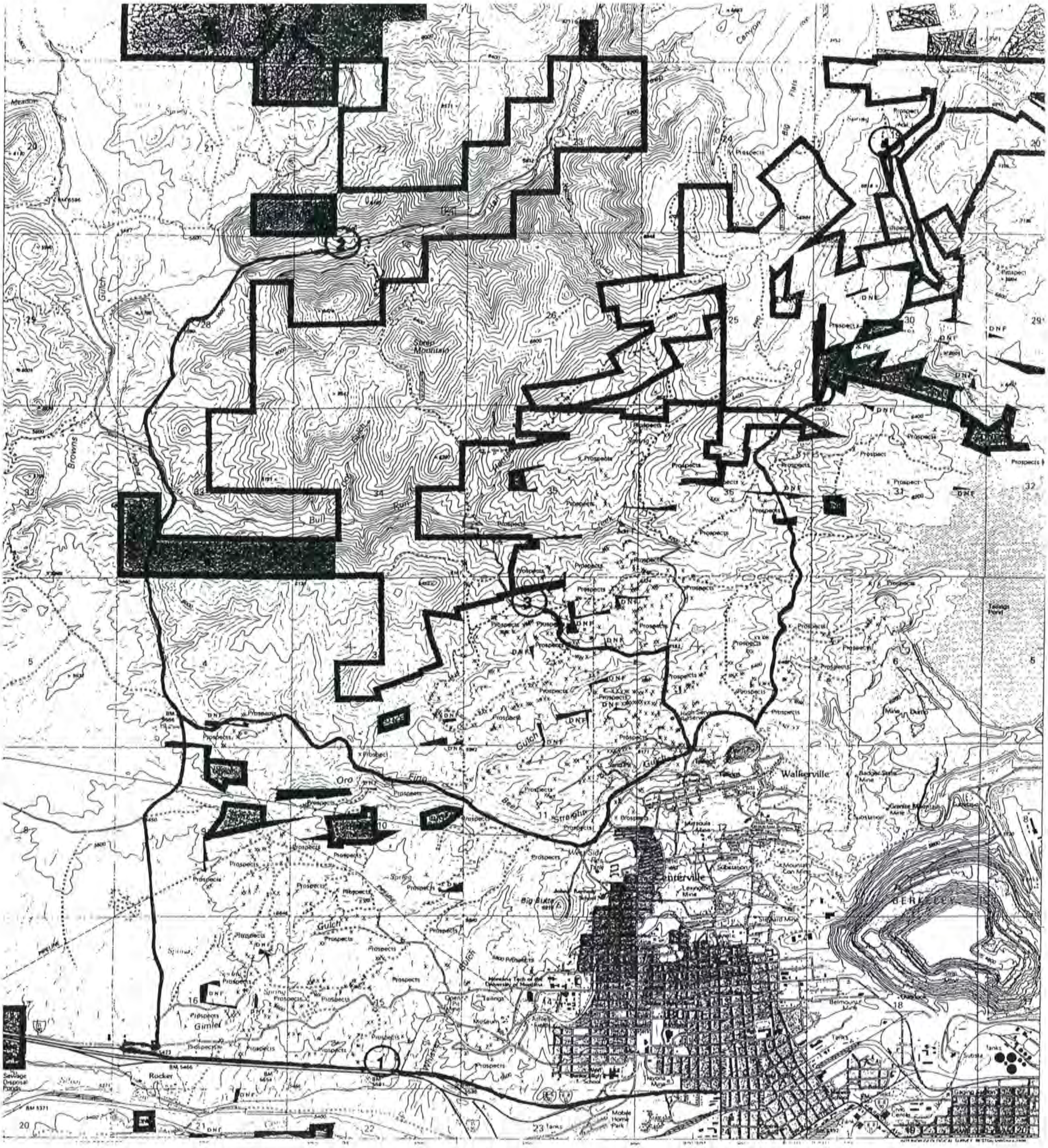


Figure 3, Road map and field trip stop locations.

An Intact Cupola Revealed by Alpine Glaciation at the Historic Hecla Mines Area, Beaverhead County, Montana

Tom Gignoux

Take Melrose exit from **I-15**. **Mile 0.0**

0.3 Town of Melrose. Go straight across RR tracks and follow road around to left.

0.5 Big Hole River

2.0 Go straight on Trapper Cr. Road at Cherry Cr. road intersection

3.1 Bear left at fishing access intersection

5.4 Beginning of town of Glendale witnessed by old cellar holes for next half mile. Glendale/Hecla graveyard on hill on left.

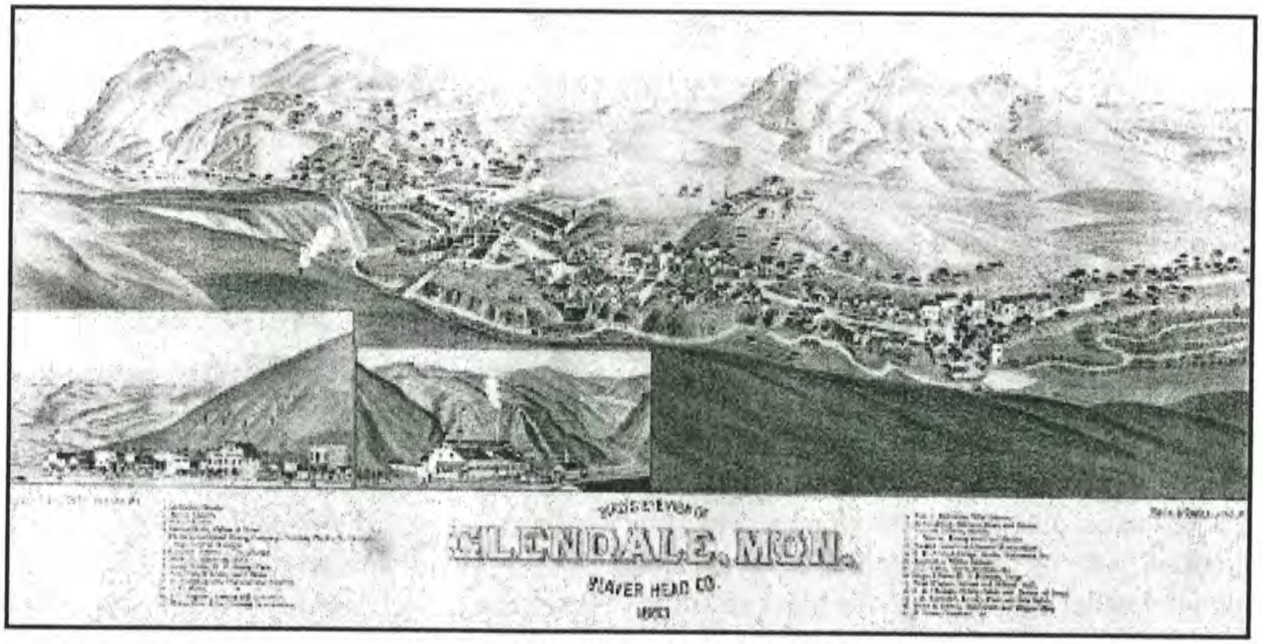


Fig. 1. Glendale, Montana 1883

5.8 Hecla Consolidated mining company smelter stack

5.9 Bear left at intersection and follow Trapper Cr. on Forest Service Road 188

9.0 Cattle guard. Road climbs steep pitch up terminal moraine of the Trapper Creek Glacier. Time to vindicate payments on vanity 4WD.

13.0 Watering trough for horse and oxen traveling to and from mines. Cabin sites along road in this area indicate a developed way point.

Ore was taken from mines to Melrose on 10-ton ox carts. From Melrose ore was carried by stage to Salt Lake City to a San Francisco train. From San Francisco, it was loaded on clipper ships bound for smelters in Wales.

13.4 Greenwood Concentrator site on right. The concentrator was built in the 1880's and concentrated 350,000 tons of high grade silver, lead, and zinc ore. It was a five story wooden building with many large windows. In the road are the remains of the original corduroy road.

14.7 Mill building. Erected in 1970.

15.2 Stay right at intersection.

15.3 Gate, usually locked.

15.4 Cleve Mine Portal. Compare the strike and dip of the Jefferson formation dolomites at the portal with the Mississippian Madison formation limestones on the ridge line above. The portal is on the steep limb of one of a series of folds which characterize the bedrock in the lower part of the basin. Between the portal and the ridge above are two thrust faults which separate the folded dolomites from the only slightly deformed limestones and quartzite.

15.5 **Stop 1**. Franklin mine Area. This is a good point to get a sense of the structure in the area which is dominated by the Hecla dome.

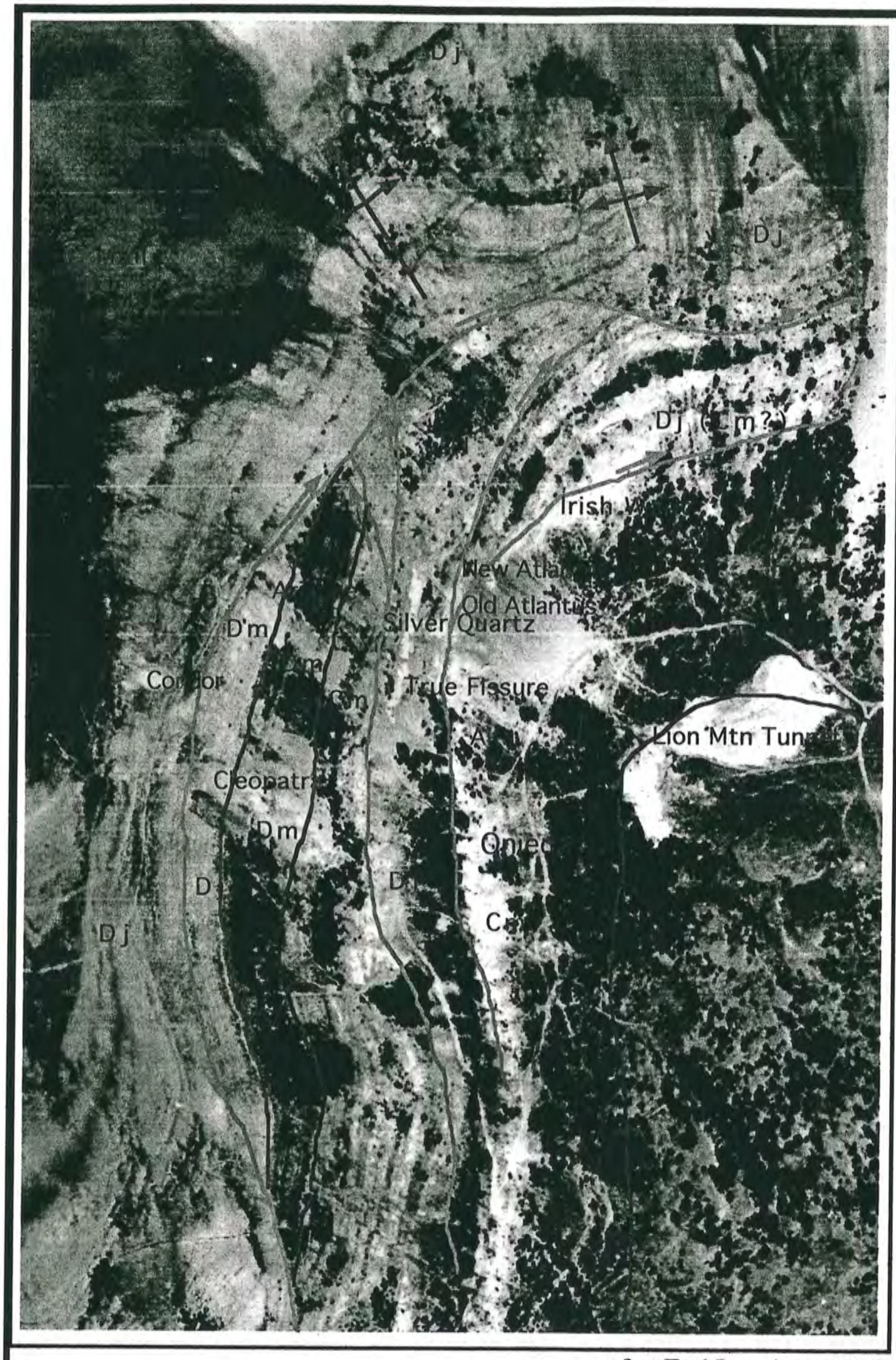
The dome has its core in the low timbered hill to the SW. Here the oldest rocks in the district, the possibly Precambrian Black Lion formation and Wolsey (Silver Hill) siliciclastic sediments are exposed. They are severely altered by contact metamorphism.

Above and to the right of this hill looms the face of Lion Mtn. This cirque head wall exposes a thousand feet of marbleized dolomite. As you travel up to Stop 2, try to trace the imbricate thrust faults which form a duplex structure. The thrusts are indicated by slight discordances in bedding and by the alignment of mine workings. Hasmark formation carbonates make up the bottom half of the mountain. The upper half are Devonian Jefferson formation dolomites leading up to the black cap of the Mississippian Lodge pole formation. At Stop 2 there will be a discussion of these faults.

To the south is the aptly named Granite Mtn. (10,663 ft.). It is the northern exposure of the Pioneer Batholith.

The Franklin Mine was most recently mined by the Lively family in the post WWII era. Ag-Pb-Zn manto replacement deposits were mined in shallow, generally flat-laying deposits about fifty feet beneath the surface.

Return to vehicles. Avid walkers may want to follow Spring Creek through the Lion City town site to Stop 2 which is 0.7 miles distant.



East Face of Lion Mountain   Annotated Areophotograph
Hecla Mines Area, Beaverhead County,   Montana

after Earl Lovejoy, 1976

Figure 2.

15.6 Bear left at intersection and drive into the Lion City town site.

15.7 Old general store on left.

15.8 Turn right at intersection and go up hill. On left is the remains of a stamp mill moved here from the town of Elkhorn, near Helena, in 1912. Danger! Stay away from this mill.

16.2 **Stop 2**. Turn left on road in meadow below mine dump. Park . Watch out for nails and other tire hazards. Walk to area near the remaining cabins of Upper Lion City.

You are on the NE flank near the center of the Hecla dome, a complex NW-trending anticline. To the west is the face of Lion Mountain; to the north the flank of Sheriff Mountain and to the NE the flank of Cleve Mtn. The timbered peak in the near distance to the east is Morrison Mountain. Each of these mountains illustrates a major feature of the local geologic structure.

Morrison Mountain is a klippe with Proterozoic Belt sediments thrust over Cretaceous Colorado Formation sediments. Zen maps the thrust as the Wise River Thrust, the lower of two low angle regional thrust faults in the East Pioneer range. The upper thrust, the Pattengail, has been eroded from the area.

Clockwise to the south from Morrison Mountain is the flank of Granite Peak leading along a lateral moraine to its summit. The contact of Mississippian Madison formation limestones can be seen on the flank to the ESE.

Visible on the Head wall of Lion Mtn. to the west are numerous mine dumps marking the trends of the thrust faults. The mines exploited oxidized Ag-Pb-Zn replacement deposits which formed at the intersections of thrust faults and favorable beds (**Fig 2**.). Three primary mines occur in a step-like pattern starting with the Cleopatra mine visible on the skyline and working down the face offsetting to the right with each step.

Sheriff Mountain joins Lion Mountain on its north. A syncline is visible at its peak. It is part of a series of recumbent folds which extend to the east. This style of folding, much different than the thrust faults on Lion Mountain, extends to the Cleve Mine and to the south, beneath the basin. Between Sheriff Mountain and Lion Mountain is the Gary Lively Fault, a normal fault with several hundred feet drop on the NE side. It is one of three parallel normal faults mapped in the district. Current exploration is evaluating their role in localizing mineralization.

Stop 3. 1/4 mile. (Easy walk on road). Take the jeep trail that leads south towards Granite Peak at the base of the Lion Mountain tunnel dump. It crosses the apex of the anticline near the edge of the trees. Bedrock here is the Wolsey formation (Silver Hill) in a transitional phase from predominately siliciclastic rocks and predominately carbonate rocks. A conglomerate with pebble size clasts is visible on the upper side of the road several hundred feet after the road enters the trees . The conglomerate is the Black Lion, a new formation proposed by E-An Zen with a restricted outcrop area in the east Pioneer Mountains.

Stop 4. (Moderately strenuous Hike with a five hundred foot elevation change. An alternate is to drive back to lower Lion City and to hike horizontally east along an abandoned water ditch above the old mill) Leave the road here and walk down the ridge to the SE. The Black Lion Formation is repeated by a thrust fault with minor displacement. Lower on the ridge the intensity of the contact metamorphism increases. In the lowest outcrops, on the steep slopes above the swamp, siliciclastic rocks are altered to a sericitic shist and the argillic carbonates are altered to skarn. Near the old mill are outcrops of rock which appear to be partially melted. Steep dipping carbonate rocks predominate on the north side of the ridge, siliciclastic on the south.

Pseudomorphs in the shist may have originally been garnet or staurolite but are now andalusite, biotite, quartz, tourmaline clorite, and magnetite. Zen reports that in thin section, a red amorphous mineral, metakaolinite, is visible. These minerals indicate a second thermal event, caused by a second, more hydrous pluton. (Zen, 1988)

Discussion

The deep seated, regional Wise River thrust carried Precambrian Belt quartzite east to the surface and deposited them on Colorado shales. Red quartzite clasts, similar to the quartzite in the klippe, occur locally in a conglomerate on top of the Colorado shales. They are thought to be part of the Beaverhead conglomerate and indicate surface exposure of the quartzite and the near surface environment of the thrusting in the district.

Intrusion occurred after thrusting. Marolitic cavities and estimations on the thickness of the sedimentary rocks indicate shallow emplacement depths. Zen calculates normal sedimentary depths of 2 Km with an additional 2 Km added by thrust faulting (Zen, 1988).'

Relationship of Mineral Deposits to intrusion, thrusting and folding.

At least some thrusting preceded folding as the mineralization in the Cleve mine appears to be controlled by a thrust fault incorporated into the Cleve anticline. Intrusion followed thrusting and folding since vertical beds in the core of the anticline are altered to skarn. A granitic sill south of the district occurs in a thrust near the Forest Queen mine, and a lack of alignment in metamorphic minerals indicates intrusion occurred during a period without compression.

Thrusting and folding preceded mineralization since the thrust faults control mineralization in Lion Mountain and the mineralization in the Cleve mine is centered in an anticline. However, some movement did occur along the thrusts on Lion Mountain after mineralization since the ore is brecciated.

Mineralization occurred after or along with normal faulting as there is an association of mineral deposits and normal faults. There was stoping at the only place where a normal fault was intersected in underground workings in the Cleve mine, and there is jasperoid alteration with gold near the fault in the same area.

Intrusion occurred either during or after normal faulting as there is no offset in marbleization on the Gary Lively fault near the base of Lion Mountain.

Mineralization is related to intrusion from a number of lines of evidence. Intrusive rock drilled beneath the district is anomalously high in lead and zinc. Potassic pegmatites grade upward into molybdenum, tungsten, and gold bearing skarn. Mineralization in the Keokirk mine occurs on the contact of the Keokirk Quartz Diorite and there is a spatial distribution between the mines in the district and the magnetic anomaly believed to reflect the intrusive. Zoning in mineralization, alteration and chemistry also indicate an intrusive centered system.

Character of Mineral Deposits

The mineral deposits were primarily high grade pipes and mantos averaging a kilometer in length. Shipping records show about 18% each of lead, zinc, and iron and one percent copper . The deposits also contained 30 ounces per ton silver, and 0.03 ounces per ton gold. The district produced about 350,000 tons of ore, almost entirely in the nineteenth century.

Exploration

The Hecla area was chosen for an exploration target for several reasons. Extensive unexplored areas of excellent host rock exist beneath a shallow glacial ground moraine which discouraged nineteenth century exploration. Continuing advances in geologic perception, geophysical techniques and drilling technology combine to increase the odds in the favor of the explorationist. Furthermore, the extensive carbonate bedrock and concentrated nature of the deposits have allowed the extraction of large quantities of metals from the district with no surface water degradation and little surface disturbance - even with pre-environmental mining methods.

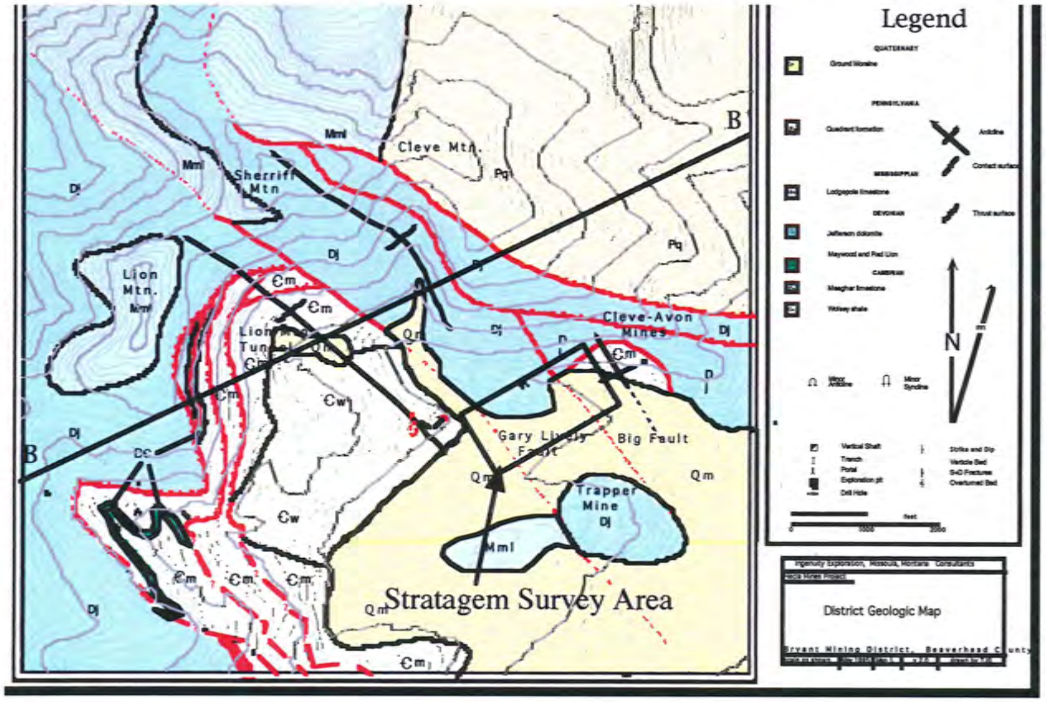


Fig. 3. Geologic Map of the Hecla Mines Area

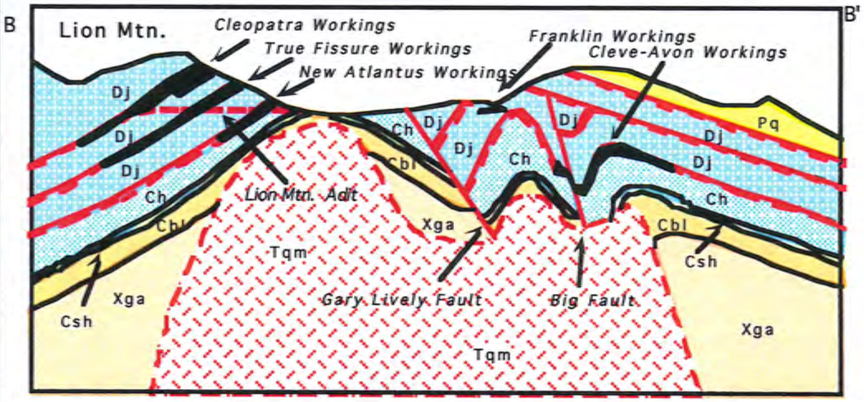


Fig. 4. Cross Section B-B'

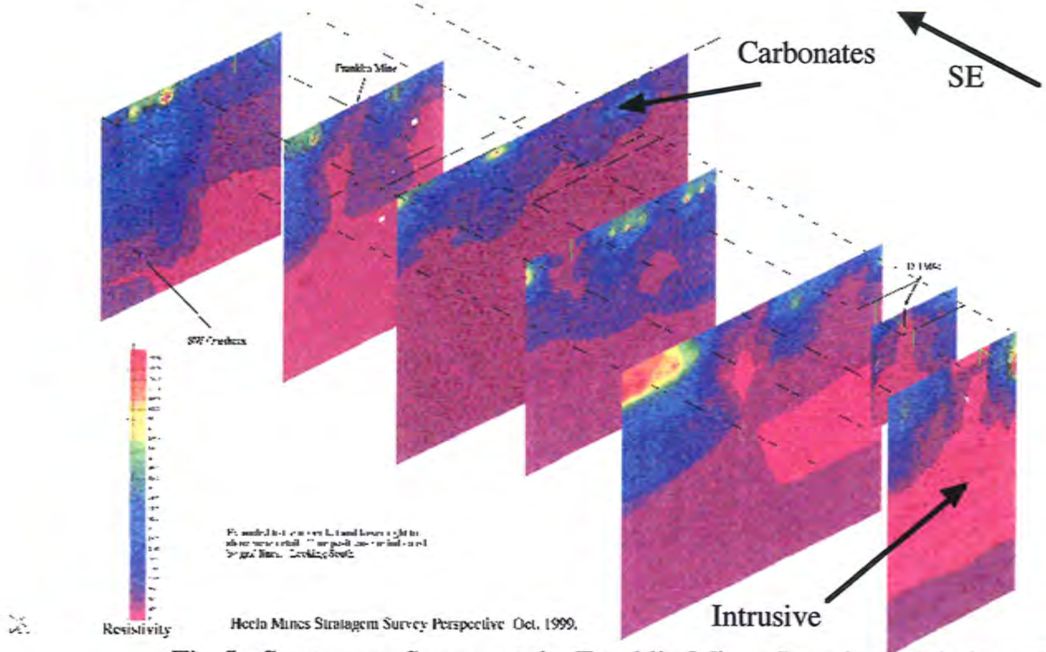
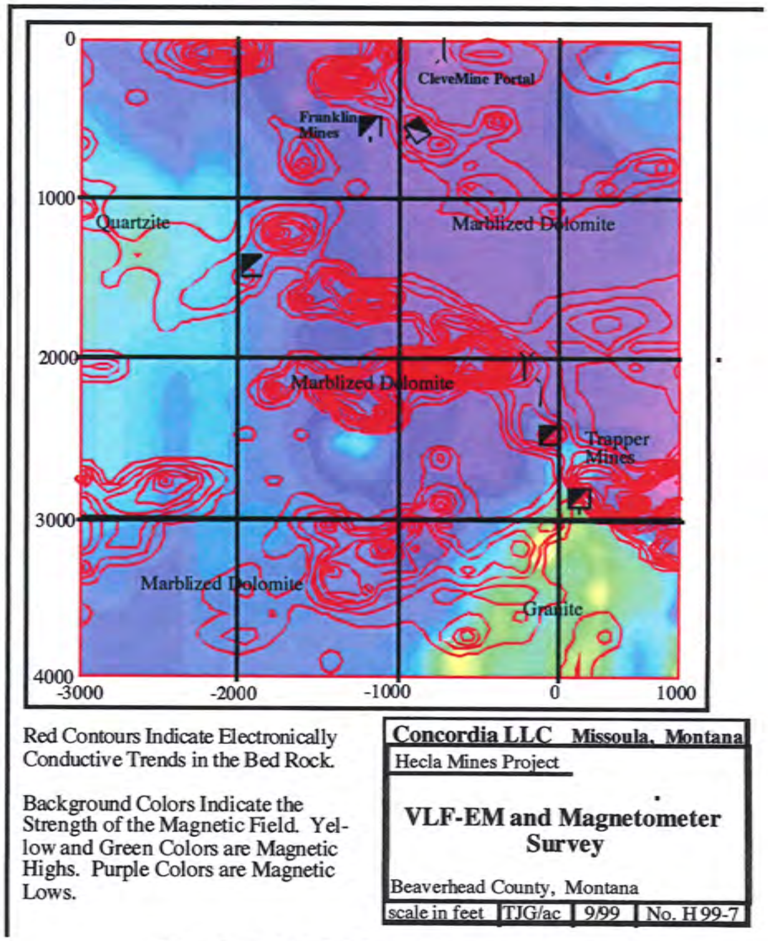


Fig 5. Strategem Survey at the Franklin Mine. Longitudial Axis to the SE Red areas more conductive, probably intrusive. Blue areas less conductive, Probably Carbonates



Red Contours Indicate Electronically Conductive Trends in the Bed Rock.

Background Colors Indicate the Strength of the Magnetic Field. Yellow and Green Colors are Magnetic Highs. Purple Colors are Magnetic Lows.

Fig. 6. VLF-EM and Magnetometer Survey Franklin Mine Area

Porphyry Copper-Molybdenum Mineralization Below Butte, MT: A Field Trip to the Core Shed

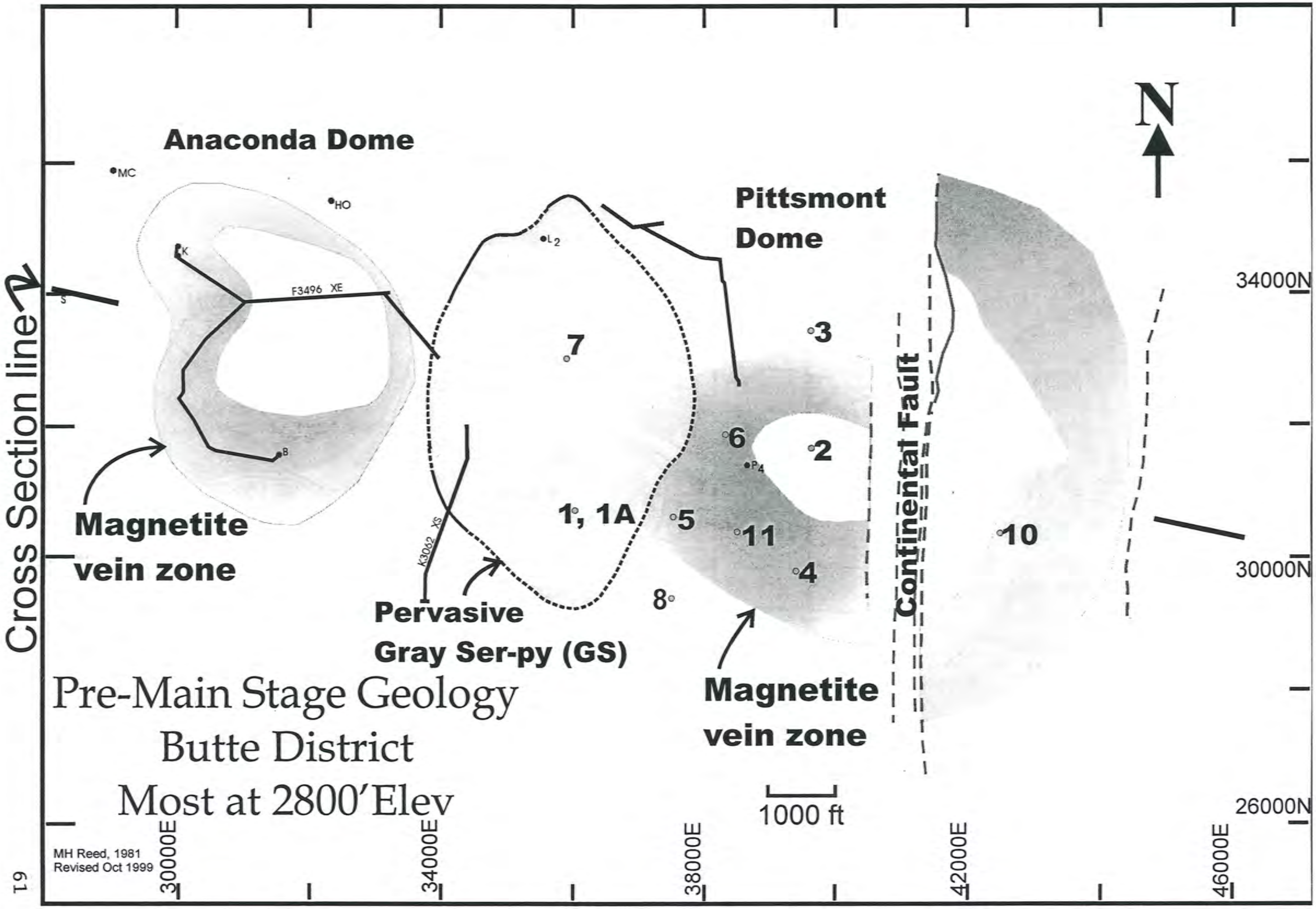
Brian Rusk, Mark Reed, and John Dilles

Butte Pre-Main Stage (porphyry copper-molybdenum) mineralization occurs in two separate internally zoned domes of hydrothermal alteration. The domes are clearly delineated by a zone of magnetite-bearing veins and by molybdenite grade contours *(see map).* These two domes of mineralization are separated by a bulbous body of pervasive quartz-sericite-pyrite alteration that extends to depths of greater than 2 Km. Exploration drill holes were drilled in the eastern Cu-Mo dome, known as the Pittsmont dome, and in the central QSP zone in the late seventies and early eighties. We will examine core from several of these eleven drill holes to show the predominant vein assemblages and their characteristic alteration selvages, and to show the spatial and chronologic relationships among the vein types. The relationships will be observed in core from holes 1A, 2, 5, and 10.

The deepest and earliest Pre-Main Stage copper mineralization occurs in veins consisting of quartz, pyrite and chalcopyrite with alteration envelopes of secondary biotite, K-feldspar, and sericite (EDM veins). Copper is present in chalcopyrite both in the veins and replacing biotite and plagioclase in the alteration envelope. Zonally exterior to the EDM vein zone, early copper mineralization occurs in quartz-magnetite-chalcopyrite veins with alteration envelopes containing pale green sericite, K-feldspar, chlorite, and calcite (PGS veins). Some such veins yield very high bulk Cu grades of more than 1% Cu for tens of feet. The majority of these veins will be seen in the central part of the Pittsmont dome in holes 2 and 5.

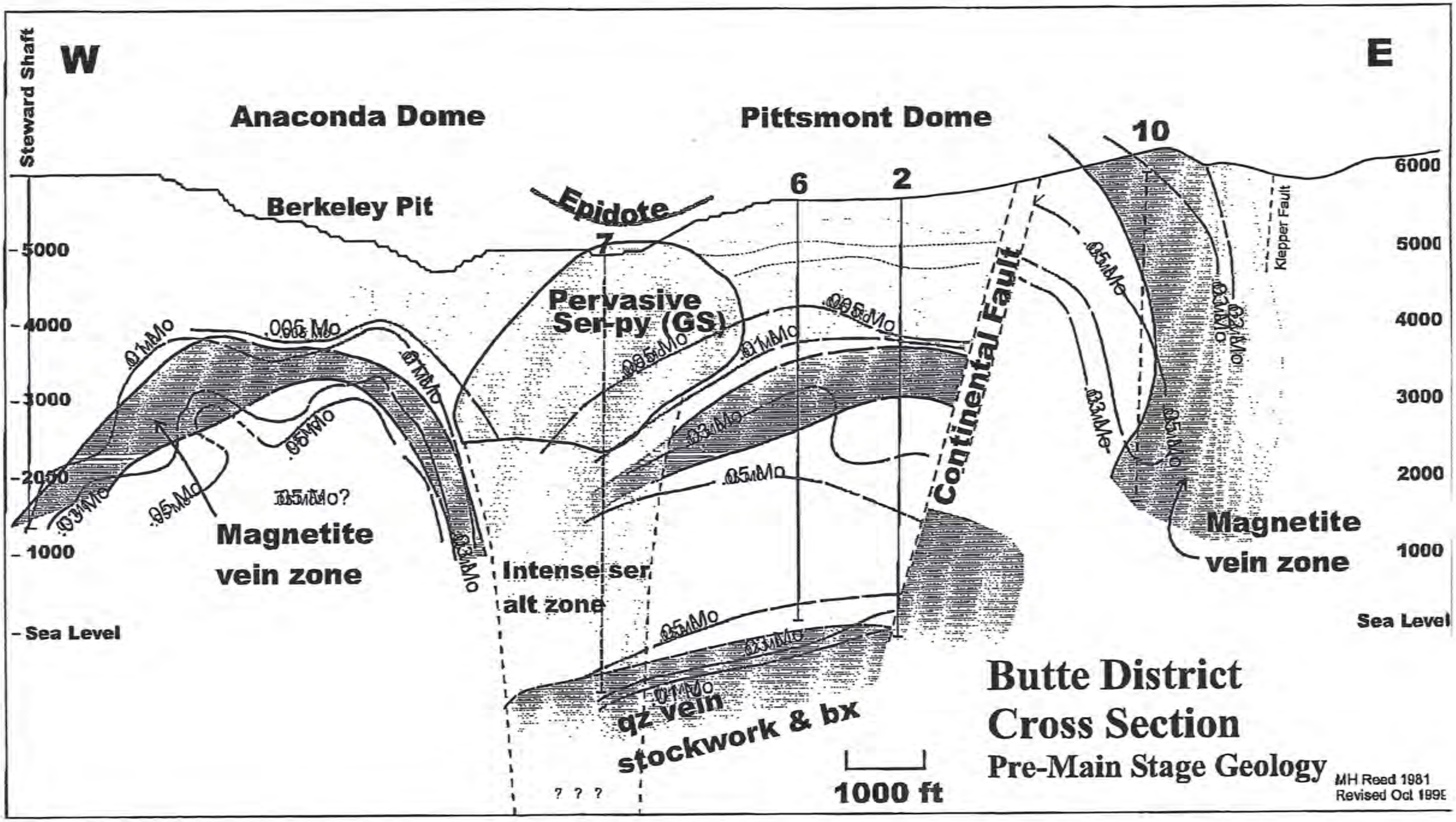
Quartz-molybdenite mineralization in the form of quartz-molybdenite veins cuts both EDM and PGS mineralization, and occurs deeper within the mineralized domes. Beneath the zone of highest molybdenum grades is a zone of intense barren quartz veining Barren quartz and quartz-molybdenite veins are abundant in deep drill hole 10, which is collared east of the Continental fault in the upthrown block. There is an estimated 4000 feet of displacement along this fault, and rocks from deep in this drill hole are the deepest recovered from Butte. Because this drill hole is on the eastern periphery of the Pittsmont dome, rock from this drill hole lacks sericitic alteration and is little touched by the Main Stage alteration that overprints much of the rest of the deposit. Since the rock in this drill hole lacks much hydrothermal overprinting from later fluids, it offers an excellent opportunity to study early mineralization. Studies of sulfur isotopes and of fluid inclusions in barren quartz and quartz-molybdenite veins from this hole indicate that the veins formed at around 2 Kbars pressure and 550-600 degrees C.

Late pyrite-quartz veins have alteration envelopes that consist of quartz, sericite, and pyrite and are termed "gray sericite" (GS). In the central bulb-like zone that lies between the two Cu-Mo domes, pyrite-quartz vein densities are high, and the Butte quartz monzonite and quartz porphyry dikes have been pervasively altered to quartz, sericite, and pyrite. Deep drill hole 1A penetrates over 7500 feet into the roots of this QSP zone, and in the deepest part of the hole, barren quartz veins are abundant. The quartz veins are older than the QSP alteration and formed under similar conditions as the barren quartz and quartz molybdenite veins from drill hole 10. Fluid inclusions in the pyritic veins that cut these barren quartz veins indicate conditions of formation between 400 and 450 degrees and pressure between 500 and 900 bars from a fluid of similar composition to barren quartz and quartz-molybdenite fluids.



Pre-Main Stage Geology
Butte District
Most at 2800'Elev

MH Reed, 1981
Revised Oct 1999


W
E
Steward Shaft
Anaconda Dome
Pittsmont Dome
Berkeley Pit
Epidote
7
6
2
10
Pervasive Ser-py (GS)
Continental Fault
Klepper Fault
Magnetite vein zone
Magnetite vein zone
Intense ser alt zone
qz vein stockwork & bx
.005 Mo
.01 Mo
.03 Mo
.05 Mo
.05 Mo?
? ? ?
5000
4000
3000
2000
1000
Sea Level
6000
5000
4000
3000
2000
1000
Sea Level
1000 ft
Butte District
Cross Section
Pre-Main Stage Geology
MH Reed 1981
Revised Oct 1995

The Continental Orebody - Montana Resources
Butte, Montana

S. Czehura - Manager Engineering and Geology, MR
G. Zeihen - Former Senior Geologist

Geologic Setting

Butte, Montana is located in the southern portion of a body of rock called the Boulder Batholith. The batholith is an intrusive rock that is exposed with a surface area of some 2,000 square miles. As the batholith melted its way up into the earth's crust, blobs of different ages (called plutons) formed, as if you froze a lava lamp. Richly mineralized zones are typically associated with multi-phased intrusive rocks and the city of Butte sits in a very mineral rich zone within the Butte Quartz Monzonite, the dominant phase comprising the Boulder Batholith. This is a granular rock made up of greenish-gray plagioclase feldspar, pinkish orthoclase feldspar (k-spar) along with light gray quartz grains and black, shiny biotite and accessory laths of black, hornblende. Within the area of the mine complex it is exposed, interlaced, with gray quartz veinlets containing shiny, metallic sulfides of iron (pyrite) and copper (chalcopyrite). This type of mineralization is very common at Butte.

Mineralization

As the magma cooled into rock, some 78 million years ago, it formed cracks that were, subsequently, filled with quartz and sulfides forming veins and veinlets between 63 and 56 million years ago. In some areas, especially as seen cropping out on the hills above the city, these cracks were very large, and formed the veins which were mined underground in the early days. Deeper in the system, the veins were smaller, and throughout the area, different veins formed at different times.

The earliest veins are called EDM (Early Dark Micaceous) veins. They are generally only about 0.1 to 0.2 inches wide and are enclosed in an envelope of green biotite (dark greenish-brown to black mica), 0.2 to 1.0 inches per side. These are very abundant, carry chalcopyrite ($CuFeS2$), and are the main copper ore source in the Continental pit. A later set of veins and veinlets consist of quartz, molybdenite, rare k-spar, and have no alteration envelope. These are also abundant and are the other important ore vein type in the Continental pit (Zeihen, 1999, MR unpublished pit mapping). Here, vein swarms tend north 50-60 degrees east, dipping steeply, mostly to the south.

The bigger "Main Stage" veins are also present in the Continental pit, but are not a major source of ore. These are the types of veins that were mined in the early underground mines and, later, in the Berkeley pit. They are characterized by massive ribbons of quartz, pyrite, and copper sulfides including: chalcocite, bornite, enargite, and tennanite in the area of the Berkeley pit with pyrite, sphalerite and galena (iron, zinc, and lead minerals, respectively) occurring as the dominate sulfides higher in the system and in surrounding areas. In the Continental pit, these veins are typically, narrow, less than 2 inches in width; but locally, they can be found up to several feet at flexures in the vein swarms. Usually, these are found following the trend of early banded, molybdenum veins and veinlets that have been rebroken along planes of molybdenum mineralization.

Early Pervasive Alteration

Within the area of the mine complex all hornblende laths, typical of the unaltered host rock, have been altered to a mossy, fine grained, biotite and peripheral to the mining district this is the most outward expression of the early, massive porphyry copper style mineralization (Brimhall and Roberts, 1973, personal communication Butte Field Meeting), subsequently, exposed by open pit mining in the Continental pit. Locally, vein alteration envelopes, both EDM and sericitic-argillic Main Stage envelopes, overprint this pervasive biotitization of the host rock.

Continental Pit

The geometry of the Continental orebody appears domical in shape surrounded by leached capping in a series of low hills, bounded on the west by the Continental Fault and on the east by the Klepper Fault. These north-south trending, major, basin and range faults dip steeply to the west and offset the Continental orebody. Displacement along the Continental fault is drill indicated by an offset in molybdenum mineralization that was found to be as much as 3,500 feet.

Sulfides immediately below 160 to 200 feet of mottled brown leached capping are weakly enriched by surface weathering. Here, pyrite and chalcopyrite grains occurring in interlacing veinlet swarms and as disseminations in the Butte Quartz Monzonite are coated with secondary chalcocite along with copper sulfate and a variety of green copper oxides that characterize the mixed oxide-sulfide zone for a depth of some 100 to 200 feet (Burns, 1986-1996, MR unpublished east-west cross sections). Oxide molybdenum occurs as mottled coating on weathered quartz molybdenum slicks and veinlets near aplite dikes and sills. Below the mixed zone, sulfide veinlet swarms and disseminations extend to drill indicated depths over 1,500 feet. Locally, alluvial overburden is found up to a depth of 100 feet in small valleys that dissect the topography.

Simply, once the sulfide and mixed zones are fully exposed, almost all the gray material is in the ore and subore category. In the upper levels of the final pushback, designated "C" pushback, the orebody is bounded by an assay cutoff and does not extend east to the Klepper Fault. Here, sulfide waste is exposed along the ultimate highwall cut.

West of the Continental Fault weathering of copper mineralization along with the supergene enrichment of the pyritic alteration halo associated with deeper copper-molybdenum mineralization has resulted in a tabular orebody in the "Central Zone" conforming to the paleotopography between the Continental pit and the Berekely pit. This ore zone is exposed in the west highwall of the Continental pit overlain by some 100 to 300 feet of leached capping followed by 200 to 600 feet of alluvium (north to south, respectively). The supergene enrichment blanket, characterized by secondary chalcocite replacing pyrite, will eventually sustain production as the Continental pit expands westward toward the Berkeley pit.

As of January 1, 2000 ore reserves for the mine complex totaled some 433.5 million tons averaging 0.34 percent copper and 0.028 percent molybdenum. Reserves are reported at a 0.23 percent copper equivalent cutoff.