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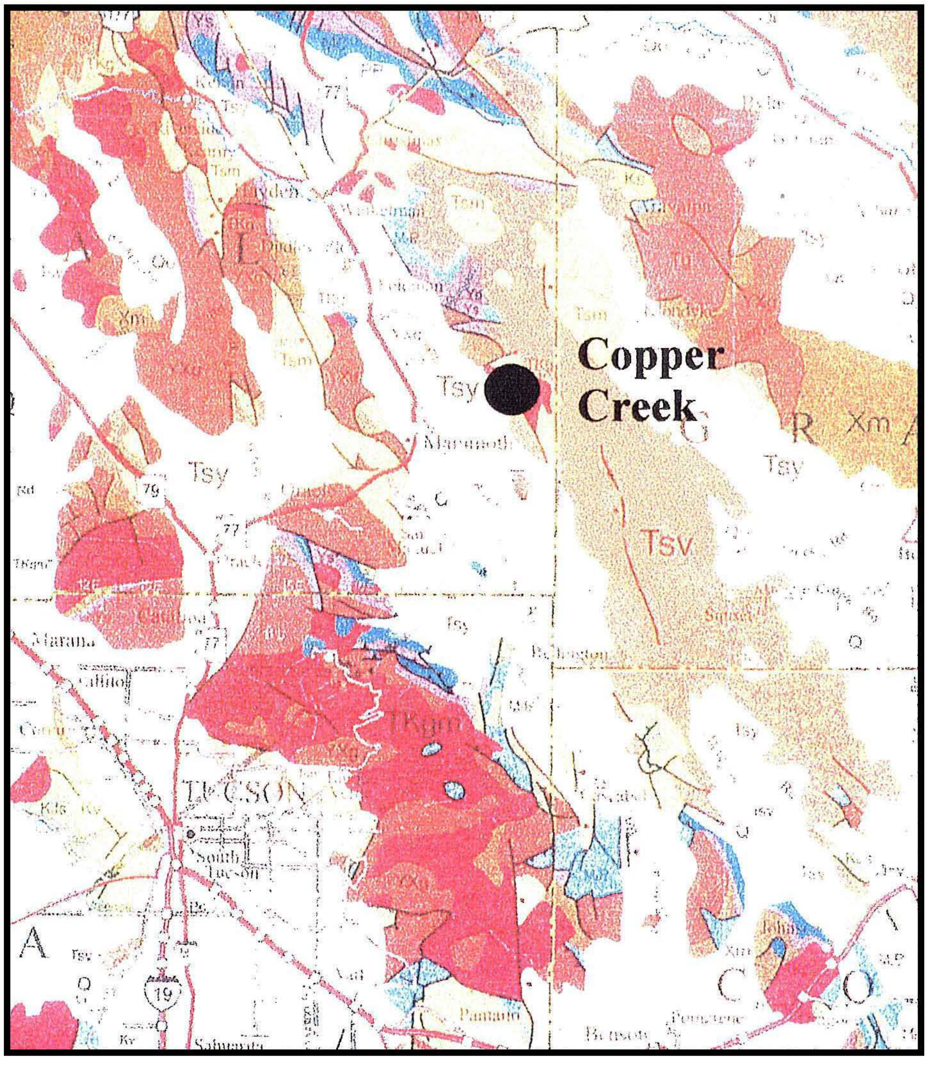
Geologic field guide tothe Copper Creek district

Arizona Geological Society February 2001 Field Trip

Leader: Tim Marsh, AMT (USA) Inc.



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Geologic field guide to the Copper Creek district

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Introduction

The AMT's Copper Creek project is located 50 miles northeast of Tucson Arizona, 12 miles east of BHP's San Manuel-Kalamazoo mine/mill/smelter complex, and 25 miles southeast of ASARCO's Hayden smelter. Mean elevation is 1200 m (4000 ft.).

The Bunker Hill (Copper Creek) district has a long history of copper and molybdenum production from high grade (>2% Cu) breccia pipes and distal veins with first activity dating to 1863 (Kuhn, 1951). Later exploration and mining activities in the district were undertaken between 1903-1917 by Copper Creek Mining Company, Copper State Mining Company, Calumet and Arizona Company, and several others, followed by Arizona Molybdenum between 1933 and 1938 (Sibley, 1909, Martin, 1910, Higgins, 1911, Weed, 1913, Hafer, 1914, Kuhn, 1951, Simons, 1964). Beginning in the late 1950's, exploration for porphyry copper deposits was conducted by Bear Creek, Magma, Newmont, Phelps Dodge, Siskon Mining, Occidental Minerals, and Humble Oil-Exxon Minerals. During the 1970's, Ranchers Exploration recovered cement copper from the Old Reliable breccia pipe, and a large tonnage porphyry-type copper deposit was identified on the property by Newmont and Humble Oil (Ullmer, 1978; Guthrie and Moore, 1978; Creasey et al., 1981).

AMT entered the district in 1995 when it signed an agreement with Magma Copper to earn a 50% interest in the Newmont/Magma ground by completing a drilling program and producing a positive feasibility study on the extraction of high grade breccia resources at Copper Creek. In 1996 AMT entered into an agreement with Phelps Dodge on a contiguous block of patented land with the goal of earning in to a position on that ground. In 1997, following completion of the Magma earn-in, AMT acquired Magma Copper's (then BHP Copper's) remaining interest in the district through a buyout. AMT's current mineral land position covers nearly 5500 acres of patented and unpatented mining claims, state mineral leases, and private land, representing the first consolidation of the historically productive areas of the district under a single operator. AMT has also entered into purchase option agreements on the surrounding Ryland and Mercer ranches, totalling over 30,000 acres of fee land and state and federal grazing rights.

Planned Production

Mineral resources identified in the Copper Creek district approach 3 billion pounds of copper, one-eigth of which is found in shallow, high-grade (≈1.5% Cu) breccia pipes and the rest of which is in deeper hybrid (≈0.8% Cu) large-tonnage deposits. AMT's production plans call for early underground exploitation of high-grade breccia-hosted ore, followed by underground mining of large-tonnage disseminated copper ore.

AMT has received an Aquifer Protection Permit from the Arizona Department of Water Resources to drive a 9200' long, 18'x 16' rubber tire/conveyor decline from the Ryland Ranch to the area of ore production. Current plans call for 5000 tons/day ore production, conveying to surface, 3-stage crushing, heavy media pre-concentration, fine grinding, and copper and molybdenum flotation. Copper concentrate will be trucked off site to a nearby operating smelter. Production costs for copper are projected to be in the low 40 cent/lb range, including credits for molybdenum, rhenium, gold, and silver. General Motors has signed a contract with AMT to take 40 million pounds of copper per year from Copper Creek beginning in June of 2002. AMT is currently pursuing funding to achieve this end.

Proven and probable reserves of 9.9 million tons grading 1.42% Cu, 0.031% Mo, 0.005 opt Au and 0.18 opt Ag are present in the Childs-Aldwinkle, Mammoth Breccia, and Old Reliable breccia deposits. AMT expects to add to this reserve 4.4 million tons of currently drill-indicated resources grading 1.59% Cu equivalent in the Lower Mammoth zone following completion of five infill drillholes. Additional breccia resources exist in the Marsha, American Eagle, Copper Prince, Copper Giant, and Globe-Gloryhole deposits. Large-tonnage "hybrid" porphyry copper resources (ca. 125 million tons grading 0.75% Cu) are present in the American Eagle and Lower Mammoth zones.

Exploration targets are numerous and potential is high throughout AMT's land package for the discovery of breccia deposits of similar size, grade, and tonnage to those of AMT's Childs-Aldwinkle, Mammoth, and Old Reliable deposits, and for deeper, large-tonnage (100s of millions of tons) "hybrid" porphyry deposits.

Host Rocks

The principal host rocks for ore-bearing breccia pipes in the Copper Creek district are the 66 million-year-old, 3 kilometer by 5 kilometer Copper Creek Granodiorite and slightly older hornfelsed Gloryhole andesitic-dacitic clastic volcanic rocks (McCandless, 1994; Shafiqullah et al., 1980; Guthrie and Moore, 1978; Keith, 1977; Creasey and Kistler, 1962), though a few breccias are hosted by late Precambrian Dripping Springs Quartzite and Mescal Limestone (Fig. 1). Several textural varieties of porphyry dating between 65 and 58 million years having granodioritic to quartz monzonitic compositions intrude the host rocks (Fig. 2) (McCandless, 1994; Shafiqullah et al., 1980; Guthrie and Moore, 1978; Keith, 1977; Creasey and Kistler, 1962). These porphyries include, from oldest to youngest, Diorite Porphyry, Pink Porphyry, Copper Giant Porphyry, Quartz-eye Porphyry, Gray Porphyry, and Dark Porphyry (see Fig. 3 for key age relationships). The Gray Porphyry, a hornblende-biotite-plagioclase porphyry having an aplitic quartz/K-feldspar groundmass, is most closely related to economic copper mineralization, though all of the porphyries and even the Copper Creek Granodiorite carry at least a few hundred parts per million of copper.

Structure

Copper Creek lies at the intersection of an ENE trend of Laramide porphyry centers that includes the Lakeshore, Owl Head, San Manuel/Kalamazoo, Safford, and Morenci porphyry copper deposits and a NNW trend of porphyry centers that includes Christmas and Miami-Inspiration. Strong, regionally extensive ENE-striking fracture sets cut Glory Hole volcanic rocks, Copper Creek Granodiorite, and the early Diorite Porphyry and Pink Porphyry plugs, but are weakly developed or absent in the younger porphyries. These fracture sets, which show evidence of very limited left-lateral, strike-slip offset, control regionally-extensive quartz-pyrite/sericite veins, but not volumetrically significant copper ore.

Geology

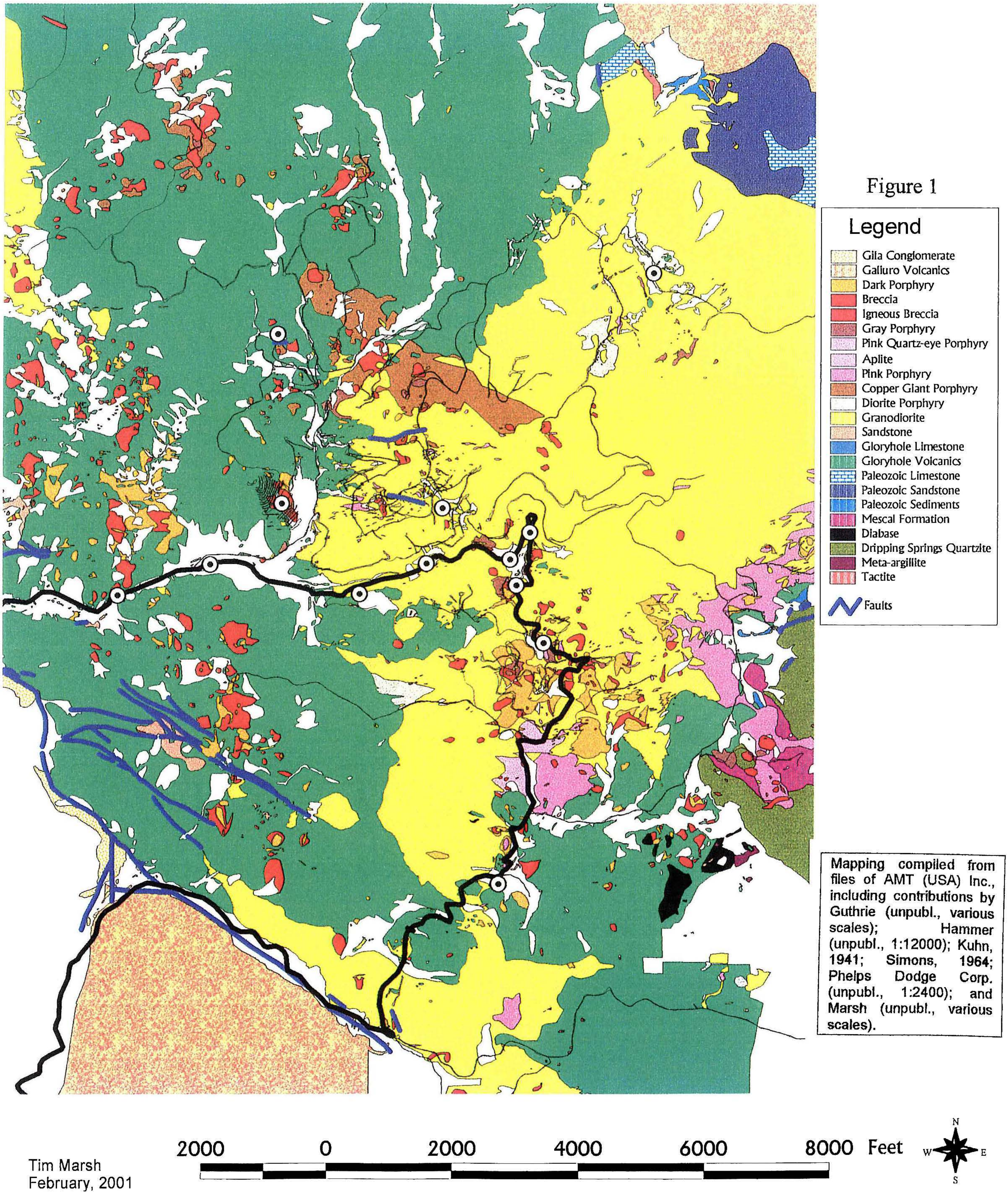

Figure 1

Mapping compiled from files of AMT (USA) Inc., including contributions by Guthrie (unpubl., various scales); Hammer (unpubl., 1:12000); Kuhn, 1941; Simons, 1964; Phelps Dodge Corp. (unpubl., 1:2400); and Marsh (unpubl., various scales).

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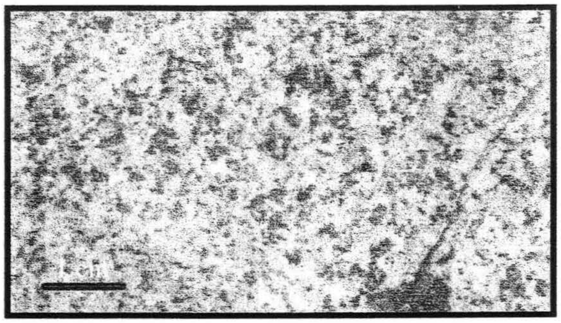


Figure 2a. Copper Creek Granodiorite, showing medium-grained, hypidiomorphic-granular texture. Hornblende grains are variably altered to shreddy biotite, and plagioclase is rimmed by secondary orthoclase. Biotite is anhedral.

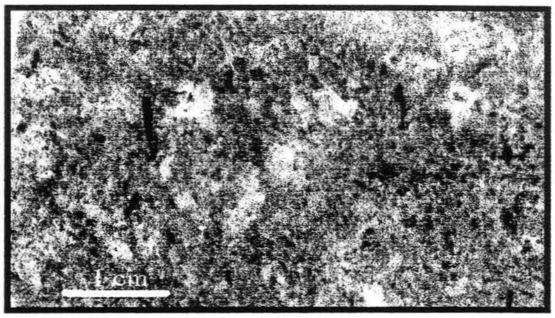


Figure 2b. Diorite Porphyry, showing medium-grained, porphyritic texture. Phenocrysts consist of plagioclase, hornblende, and biotite. Groundmass consists of the same phases, with minor aplitic K-feldspar and quartz.

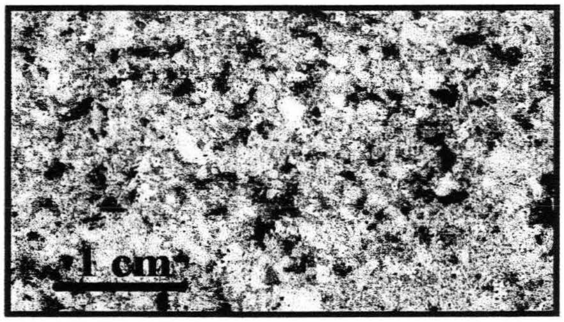


Figure 2c. Pink Porphyry, showing medium-grained, groundmass-rich porphyritic texture. Phenocrysts consist of euhedral biotite and plagioclase. Groundmass is aplitic K-feldspar and quartz.

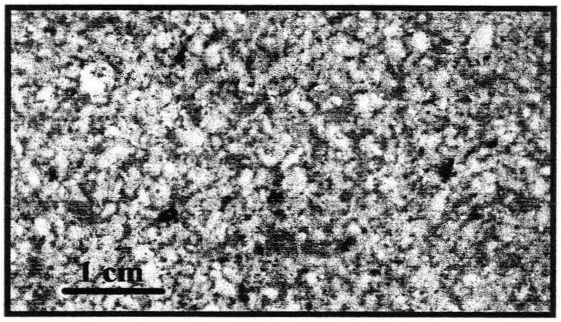


Figure 2d. Copper Giant Porphyry, showing medium-grained, crowded porphyritic texture. Phenocrysts consist of euhedral hornblende, biotite, and plagioclase. Groundmass is aplitic K-feldspar and quartz.

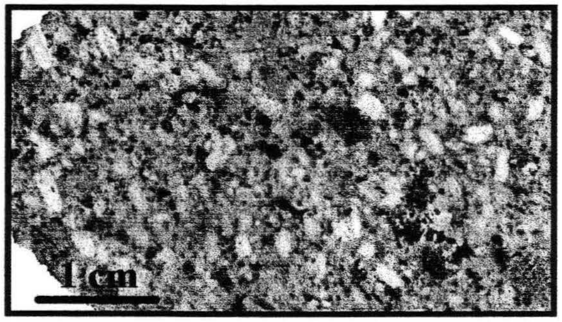


Figure 2e. Quartz-Eye Porphyry, showing medium-grained, porphyritic texture. Phenocrysts consist of euhedral hornblende, biotite, quartz, and crowded plagioclase. Groundmass is aplitic K-feldspar and quartz.

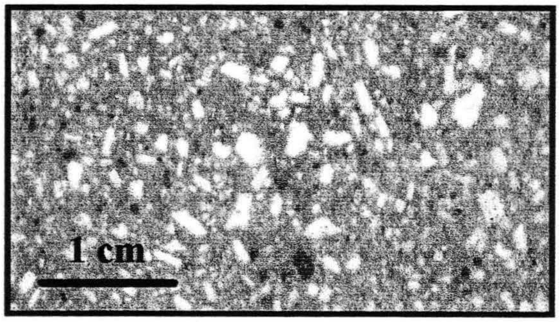


Figure 2f. Gray Porphyry, showing medium-grained, porphyritic texture. Phenocrysts consist of euhedral hornblende, biotite, and tightly crowded plagioclase. Groundmass is aplitic K-feldspar and quartz.

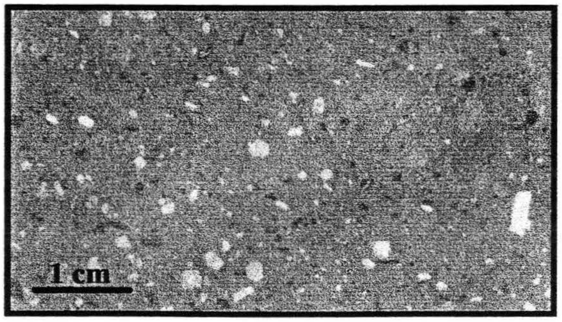


Figure 2g. Dark Porphyry, showing fine-grained, groundmass-dominated porphyritic texture. Phenocrysts consist of euhedral hornblende, biotite, plagioclase, and rare quartz. Groundmass is felted trachytic plagioclase and biotite.

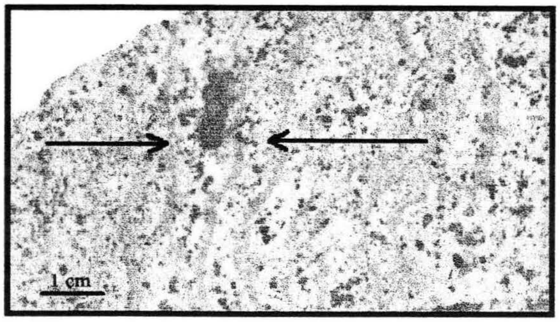


Figure 2h. Symmetric uni-directional solidification texture (UST) in Pink Porphyry, showing alternate quartz and porphyry bands that converge on a central miarolytic cavity. Arrows indicate termination direction of quartz crystals.

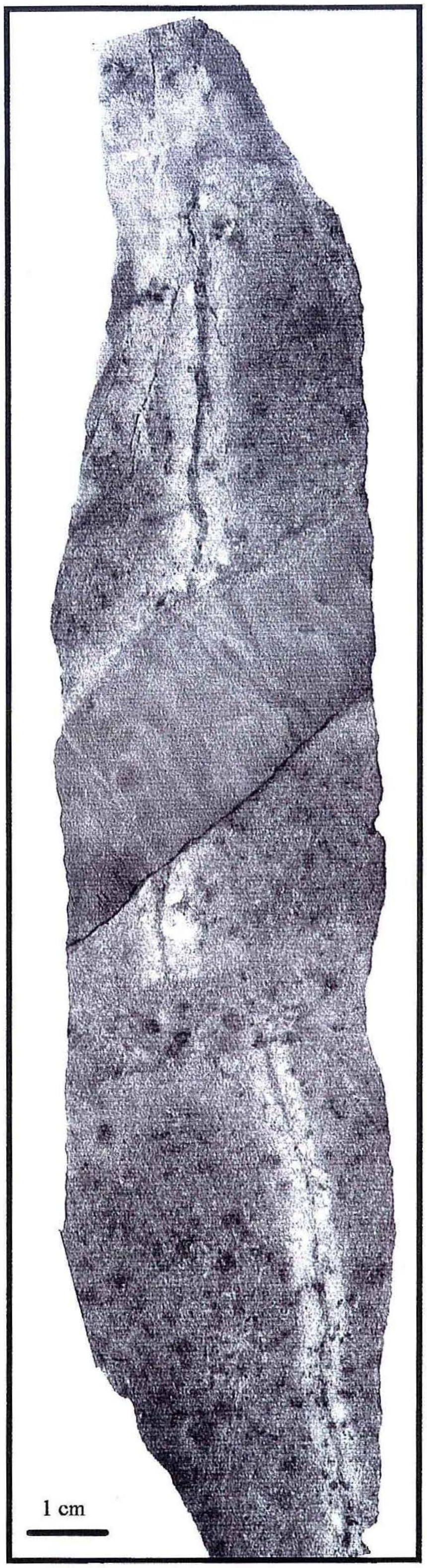


Figure 3c. Core sample from near-vertical hole LM-2, 149' below the old mill foundation showing coarse-grained quartz filling moderately- to shallowly-dipping open spaces, cutting and variably offsetting a thin vertical quartz-pyrite veinlet having a distinct bleached sericitic envelope. The older quartz-pyrite veinlet resembles the steep, sheeted, easterly-striking quartz-limonite veinlets seen in the rock cut at the base of the old mill.

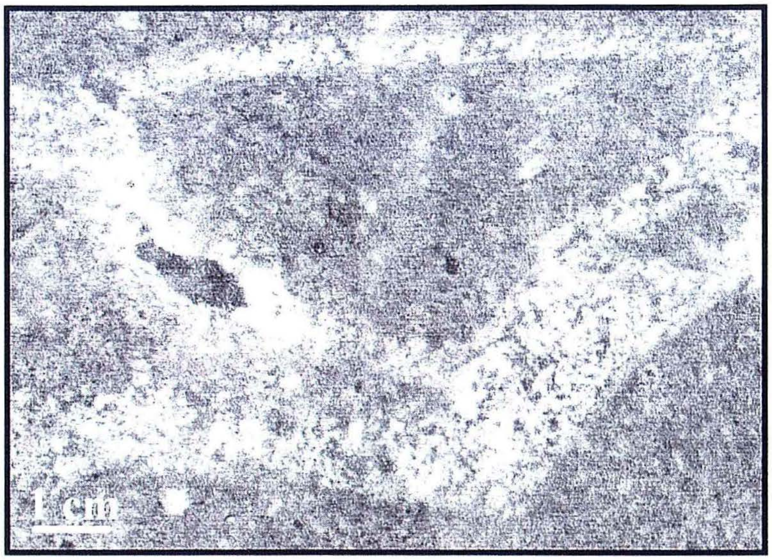


Figure 3a. Dikelet of Pink Porphyry cuts Diorite Porphyry. Miarolytic cavity is filled with pitchy limonite, malachite, and relict chalcopyrite.

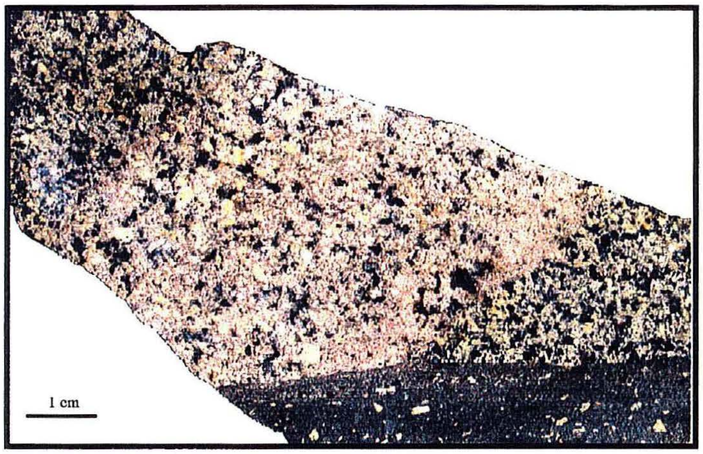


Figure 3b. Hand sample showing equigranular Copper Creek Granodiorite cut by Pink Porphyry, both cut by Dark Porphyry.

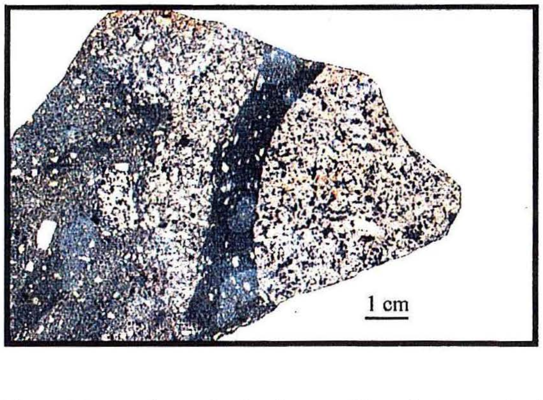


Figure 3d. Hand sample showing xenoliths of Copper Creek Granodiorite (right) and Gray Porphyry (center) engulfed by phenocryst-poor Dark Porphyry (left and center).

A strong N50W fault zone hosting strong quartz-sericite-tourmaline alteration cuts Glory Hole volcanic rocks along the southwest edge of the district but apparently predates emplacement of the Copper Creek Granodiorite, which locally intrudes it (Guthrie, 1994). The distribution of Laramide porphyry plugs, breccia pipes, and other mineralized features in the district is cryptically controlled along at least three parallel belts trending N30W across the district. Measurements of the orientation of 2622 mineralized veinlets spread across the district show that less than 1% have a strike of N30W ±5° (randomly-oriented fractures would yield about 3% in this direction). This demonstrates clearly that the N30W mineralized trend did not originate due to syn-mineral tensile stresses in the host rocks. Rather, it reflects the structural control of the pre-Laramide basement, imprinted upon the overlying Laramide igneous rocks. Post-mineral faulting is largely restricted to areas adjacent to the range front fault system and has had little effect on the distribution of ore, which is situated well east of the range front.

Breccia Pipes

More than 500 breccia pipes ranging in width from 1 to 250 meters, and extending to depths of as much as 1000 meters beneath the present surface, cut the main host rocks and early porphyry stocks and dikes. Several of the best-mineralized breccia pipes are completely blind, i.e. they do not crop out. Where the density of drillhole penetrations is adequate, breccia pipes are seen to root down into small Gray Porphyry and Dark Porphyry plugs and sills. A transitional volume of porphyry-matrix igneous breccia commonly separates the overlying open-space breccia from pure porphyry. The youngest Laramide porphyry dikes and sills (Dark Porphyry) intrude the breccia pipes.

Breccia pipes at Copper Creek consist of vertically-extensive, porous columns of clast-supported breccia comprising angular to subangular clasts of locally-derived fragments (Fig. 4). Exotic fragments (those derived from rock types not observed in the immediate walls of the breccias) are not found in these breccias, and those breccias which are polymictic show multiple wallrock types at the current level of exposure. Monomictic breccias on the footwall side of shallowly-dipping lithologic contacts limit downward transport of breccia clasts to less than 50 meters. Evidence of multiple generations of brecciation superimposed upon the same volume of rock is quite uncommon, though injections of slurried, hydrothermally-altered rock flour and broken gangue and ore minerals are present as post-ore-stage components of several of the breccias. But in general, breccia clasts in any particular pipe appear to have been generated during a common, single fracturing event.

Breccia clasts having a rounded appearance are often found to be angular clasts surrounded by alteration selvedges that blend closely in appearance to adjacent altered breccia matrix. Very few rounded clasts are found whose origin might be ascribable to transportational abrasion rather than common hydrothermal corrosion. Slabby clast shape and a weak, preferential subhorizontal clast orientation is observed in most of the breccia pipes found in competent wallrocks, whereas clasts are more equant and randomly oriented where wallrocks are strongly fractured. The peripheral contacts of most breccia pipes show conspicuous sheeted concentric fracturing extending a meter or two beyond breccia into the wallrocks. This volume of intense sheeted fracturing may consist of dozens of individual fractures spaced from decimeters down to millimeters apart.

Stereographic statistical evaluation of 1000 breccia-clast and veinlet orientations from within the Mammoth Breccia shows two weak modal orientations; one nearly horizontal (14° west-dipping) and one nearly vertical (84° SSE-dipping)(Fig. 5). These two orientations represent the flat, slabby wallrock

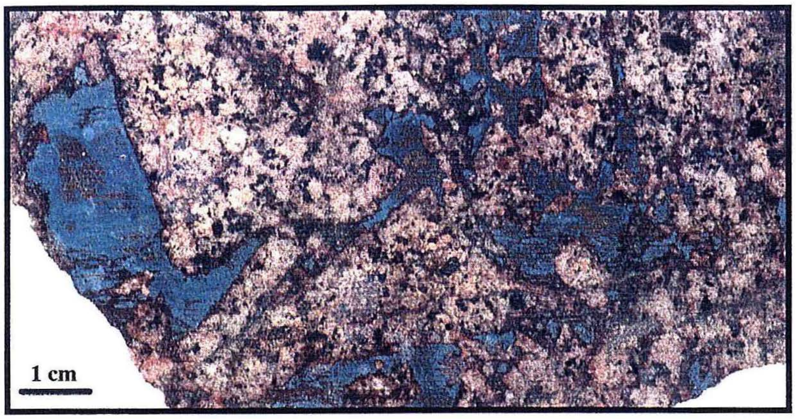


Figure 4a. Childs-Aldwinkle breccia, showing coarse-grained chalcopyrite-molybdenite replaced by bornite-chalcocite-magnetite. Angular granodiorite clasts are altered to K-feldspar.

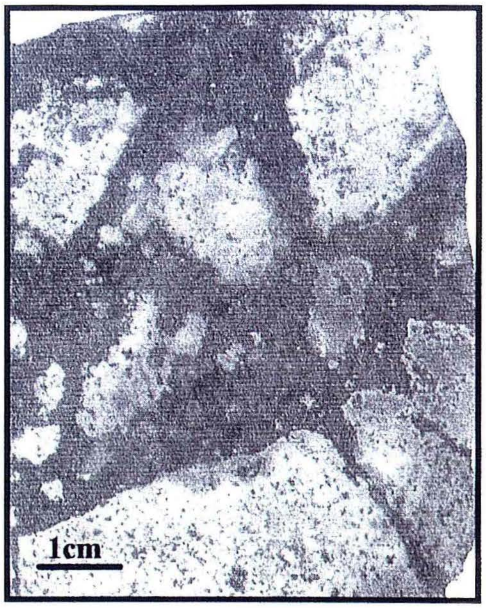


Figure 4b. Magnetite-matrix breccia, with angular K-feldspar-altered clasts.

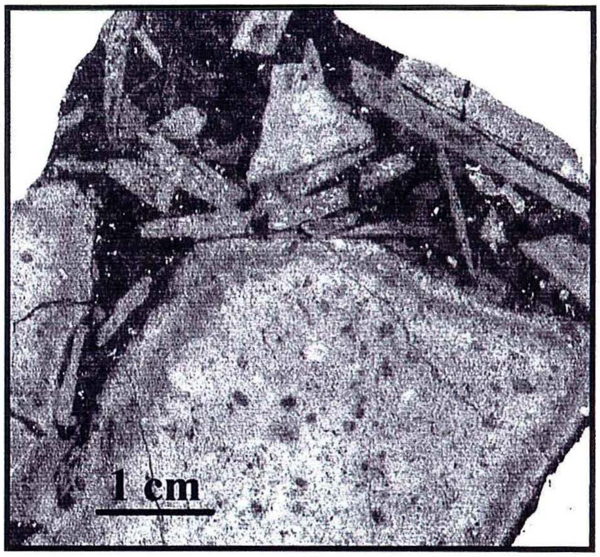


Figure 4c. Specularite-matrix breccia, with angular sericitized Pink Porphyry clasts.

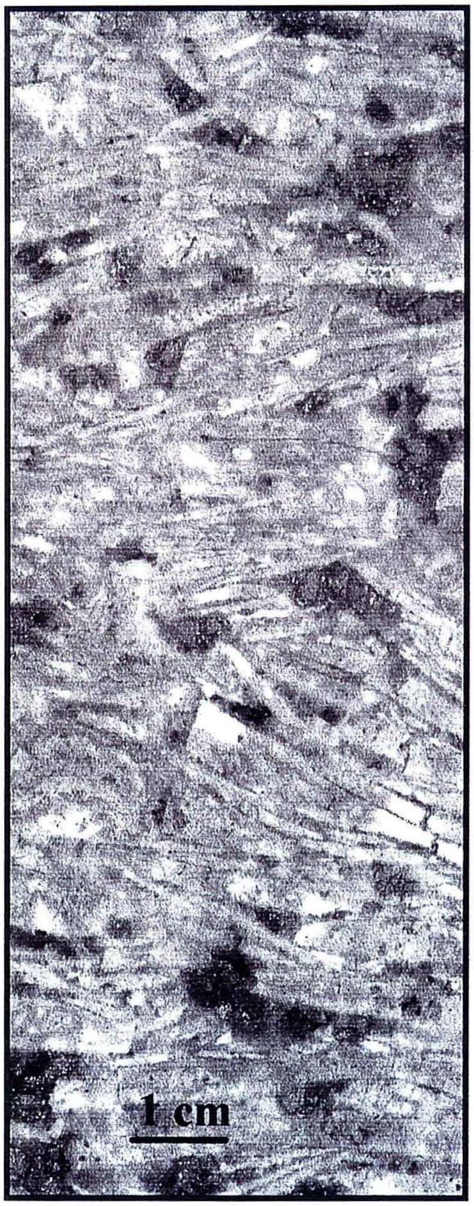


Figure 4d. Pyrite-matrix shingle breccia, with platy sericitized clasts of Glory Hole volcanic rocks, from the Globe-Glory Hole breccia complex.

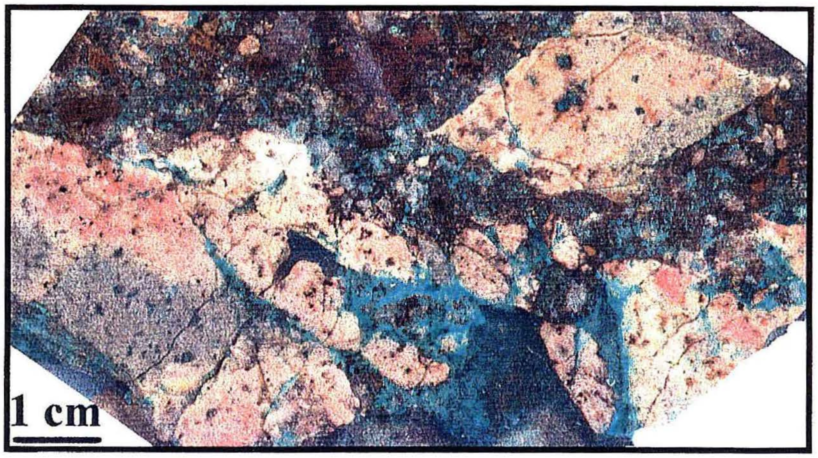


Figure 4e. Childs-Aldwinkle breccia, showing effects of surficial oxidation on coarse-grained chalcopyrite-molybdenite matrix. Angular clasts are K-feldspar-altered Pink Porphyry. Malachite, azurite, pseudomalachite, brochantite, lindgrenite, and ferrimolybdite are oxide minerals found in the weathered portions of these ore-bearing breccias.

Mammoth Breccia
Vein Orientations

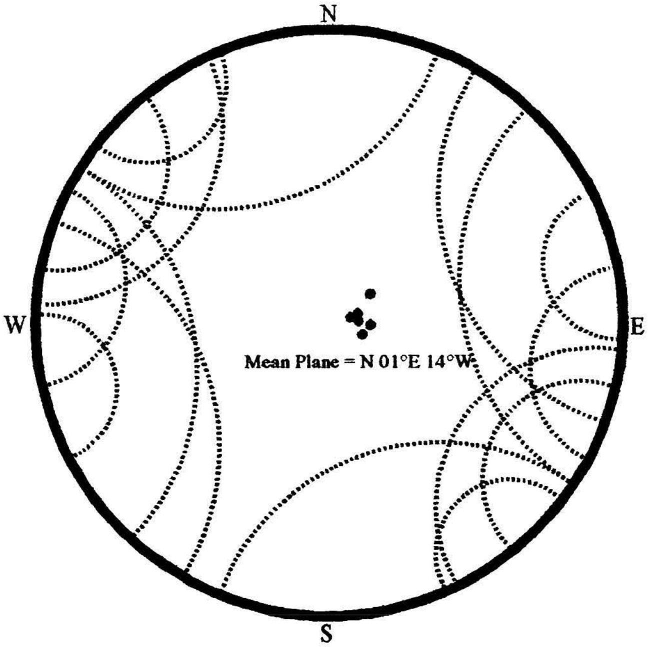
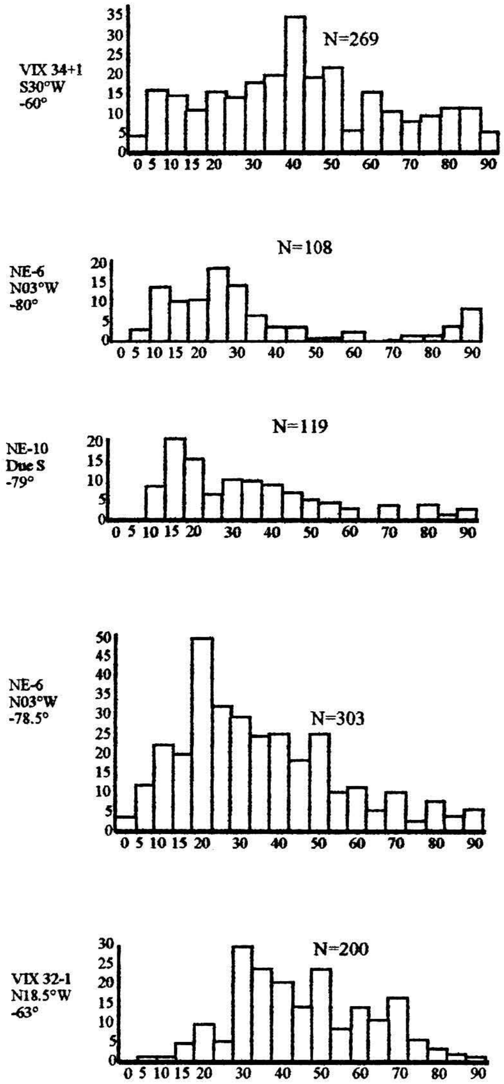
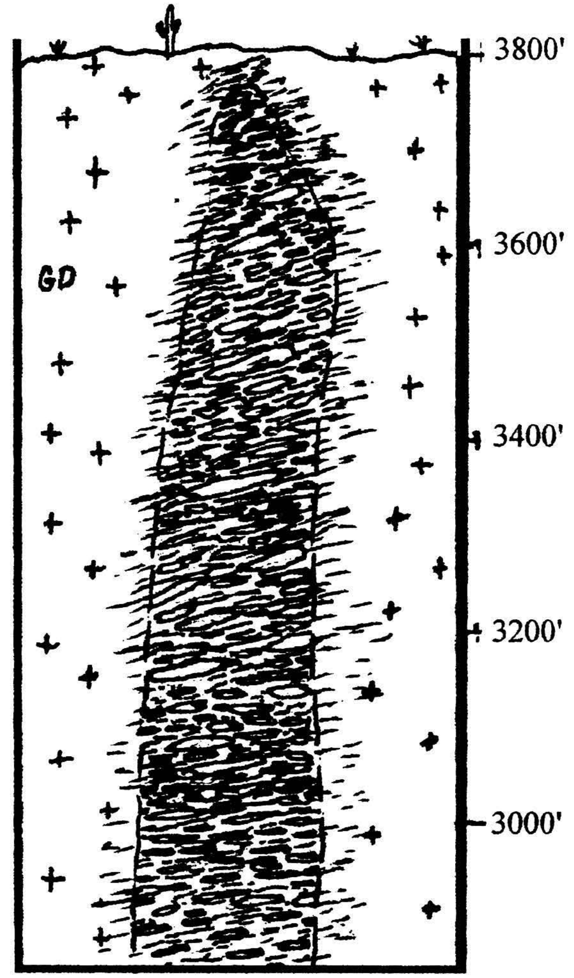


Figure 5. Histograms showing the orientation of 1000 "vein walls" in drill core from the Mammoth deposit. The lack of a strong mode in these histograms argues against fault-controlled dilation or fracture set intersections as important controls in the formation of this deposit. Instead, the nearly random distribution of "vein wall" orientations is what one might expect in irregular open space fillings surrounding randomly-oriented angular clasts in a breccia pipe. Stereographic solution from four distinctly-oriented drillholes shows that a weak mode present in each histogram corresponds to a subhorizontal (15° west dipping) fabric. Contrast this orientation with the steep easterly-striking sheeted veins observed in the rock cut at the base of the old mill. I interpret this weak mode to represent weak preferred orientation of subhorizontal slabby clasts in breccia, a feature observed in almost every breccia cropping out in the Copper Creek district. Joints and thin veinlets having this same orientation are visible on the surface, 105' vertically above the apex of the blind Mammoth deposit.



Interpretive Section



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clasts exfoliated from the spanning roof of the breccia pipe (subhorizontal set), and the steeply-dipping, pre-existing, district-scale, easterly fracture zones (vertical set).

Breccia matrix may consist of hydrothermally-altered rock flour, hydrothermal mineral fillings, 0-20 volume percent open spaces, and in some cases, Gray or Dark porphyries. The distribution of high-grade ore zones within the breccias is characterized by gobby massive chalcopyrite, bornite, or chalcocite in central open spaces scattered between low-grade slabs of wallrock clasts or in sheeted veins forming a thin shell around the perimeters and apices of the pipes.

Integration of all observations of the Copper Creek breccia pipes suggest that these features formed during implosive wallrock collapse initiated by porphyry withdrawal. The sheeted ring structures, slabby, angular clasts, and preferred subhorizontal orientations observed internal to the breccia pipes are probably the product of a single mechanism (gravity-induced collapse) that is triggered when local tensile stresses surrounding the apex of a withdrawing porphyry intrusion induce explosive spallation of wallrock into the resulting cavity (analogous to rock bursts in deep mines). Upward propagation of the breccia column was modulated by the volume of magma withdrawal and the swell of brecciated wallrock into the resulting void. Lateral propagation of the breccia is largely controlled by the lateral dimensions of the causative porphyry intrusion (generally circular to elliptical in plan view) and the distribution of pre-existing fractures in the local wallrocks. Continued withdrawal of porphyry caused downward propagation of concentric fractures to the ultimate depth of porphyry solidification, providing vertically-continuous conduits for the upward transportation of ore-forming hydrothermal fluids distilled from porphyry cupolas. Saline magmatic aqueous fluids that exsolved from cupolas of the porphyry stocks invaded the breccia columns and precipitated coarse-grained clots of ore and gangue minerals in open spaces.

Breccia Mineralogy and Alteration

Primary ore minerals found in high-grade breccia include bornite, chalcopyrite, molybdenite, chalcocite, tennantite, and scheelite in the central part of the district (American Eagle, Childs-Aldwinkle, Mammoth Breccia, Old Reliable, Copper Prince, Copper Giant, and Globe mines) supplemented by galena, sphalerite, and silver-rich sulfosalts in base-metal-rich distal deposits (Blue Bird and Bunker Hill mines, Kuhn, 1951). Primary gangue minerals include quartz, pegmatitic biotite and orthoclase, tourmaline, apatite, magnetite, specularite, anhydrite, siderite, ankerite, rhodochrosite, dolomite, calcite, and zeolites. Secondary ore minerals, including chalcocite, malachite, native copper, azurite, cuprite, tenorite, and chrysocolla, are variably developed in the breccia pipes, with strongest supergene enrichment present in the topographically highest-outcropping breccias. A chalcocite enrichment blanket within the Old Reliable breccia pipe exists at an elevation similar to the hydrologic baseline of the adjacent Saloon Gulch, and forms the principal part of the Old Reliable breccia orebody (Denton, 1947).

Wallrock alteration varies from early orthoclase-biotite (with bornite-chalcopyrite) to late sericite-chlorite-carbonate-clay (with chalcopyrite-pyrite). Intensity of alteration can be very high in the interior of the breccia pipes, but often falls off to nil less than one meter into the unbrecciated wallrocks. Significant volumes of propylitically-, silicically-, or advanced argillically-altered rocks are lacking in the district.

In the Mammoth Breccia, ore is represented by two distinct mineralogical styles, probably representing two distinct thermal regimes: a high temperature “magmatic” hydrothermal regime where bn-cp-mo mineralization was accompanied by anhydrite gangue and orthoclase alteration, and a medium-temperature mesothermal regime where cp-py mineralization accompanied by quartz and calcite gangue and sericite-illite alteration gave way with decreasing temperature to gal-sph-tn. These two thermal regimes were spatially separated by a 400 meter vertical breccia interval lacking ore, and characterized by pyrite mineralization and sericitic alteration accompanied by ankerite-dolomite gangue.

The "magmatic" ore is localized within and as much as 60 meters away from southeasterly-dipping dikes of gray porphyry. Mineralization is most intense above the hangingwall contact of these dikes. Finely disseminated bornite, chalcopyrite, and molybdenite in Gray Porphyry, sometimes containing what seem to be anhydrite phenocrysts accompanied by very fresh plagioclase phenocrysts, lead to the conclusion that this porphyry played the central role in introducing the ore metals to this breccia system.

In the Mammoth Breccia, the mesothermal ore formed a thick shell within the outermost skin of the upright, cylindrical breccia pipe at an average distance of 400 meters vertically above the magmatic ore. The intervening core of the breccia pipe is strongly mineralized with pyrite and is strongly altered to sericite-ankerite, but generally lacks economic concentrations of copper. Focussed upwelling of hot ore-fluids through the core of the pipe followed by cooling and fluid mixing locallized at the outer breccia contacts produced the hemispherical ore shell.

Ore deposition in the Mammoth Breccia was apparently interupted by a late collapse event which resulted in the upward propagation of the roof of the breccia pipe by about 150 meters. Continued ore deposition under a retrograde thermal regime resulted in a second, upper shell of high grade copper ore. Partial disruption of the earlier, lower ore shell is evinced by leached calcite gangue, brecciated and rounded clasts of massive chalcopyrite, and breccia open spaces injected with a slurry of sericite and broken quartz crystals. The upper ore shell is characterized by higher concentrations of galena-sphalerite, scheelite, and calcite, and generally less complete alteration of the cores of breccia clasts, with relict primary magnetite, plagioclase, and biotite commonly preserved. Alteration in the lower ore shell was more complete, and relict primary magnetite in the cores of breccia clasts is considerably rarer than in the upper ore shell.

The Big Picture

An explanation is required for both the vast number of breccia pipes and their distribution in three N30W-trending belts at Copper Creek. Application of Occam's razor reduces the myriad possibilities to just a few. Perhaps the simplest answer is that the three breccia belts reflect the distribution of three hidden porphyry parent stocks emplaced into N30W-trending structures in the pre-Laramide basement. Hundreds of porphyry plugs sprouting upward from the roof of the parent stocks through the overlying competent Copper Creek Granodiorite, and still hydraulically (magmatically) connected to the parent stocks, may have undergone simultaneous withdrawal, initiating collapse brecciation at dozens, even hundreds, of loci simultaneously above each porphyry finger. The suggested simultaneous withdrawal may have been triggered by seismicity which dilated the parent magma chambers. Long duration of such tectonically-linked parent magma chambers might have provided for repeat collapse events each time the magma chambers were further dilated.

Alternatively, the breccia fields may mark a short period late in the consolidation of the porphyry parent stocks when accumulated exsolved magmatic volatiles had pooled into cupolas at the upper tips of porphyry plugs to the extent that the condensing magmatic vapor, rather than viscous porphyry magma, was the only substance supporting the weight of the overlying column of host rock. The ensuing gravitational collapse may even have reloaded the yet-molten porphyry plugs beneath, triggering final minor intrusive activity of phenocryst-poor, Dark Porphyry up into the breccia columns themselves. A competent roof trap rock, like the freshly congealed Copper Creek Granodiorite, and a regional stress regime that was not actively dilating magmatic conduits while magmatic volatiles were accumulating, would be needed for magmatic vapor to pool into dimensions large enough to trigger mechanical failure of the overlying rock mass.

In either of the above cases, upward breccia propagation through a competent sill-like mass of Copper Creek Granodiorite may have halted at a depth where the unsupported rock span could stand the weight of the overlying rock, and a blind breccia pipe would be preserved with all of its contained treasures. Upward breccia propagation through fractured, weak rock like the Gloryhole volcanic rocks may have proceeded to depths were open fractures would permit the dispersal of magmatic volatiles (including ore metals) contained in the breccia column out into the surrounding wallrocks, perhaps even up to the surface where it would be lost.

While the breccias and related porphyries extend across an area more than 4 kilometers by 3 kilometers, no hypothetical parental porphyry stock or stocks having similar dimensions is known in the shallow subsurface (0-4000'). Multiple lines of evidence highlight the projection to surface of what is probably a deep causative copper porphyry stock centrally located in the Copper Creek district. The mineralogy and trace element geochemistry of the breccia pipes and veinlets serve as the best records of the ore-forming capacity of the fluids which streamed out of at least one of the hypothetical parental porphyry stocks and upward into porous breccia columns and fractured granodiorite. A 3-kilometer by 2-kilometer zone of magnetite-specularite (Fig. 6) and hydrothermal K-feldspar (Fig. 7) in breccia and veins, ringed by a broad belt of tourmaline (Fig. 8), is coincident with strong Cu-Mo-U-W geochemistry (Fig. 9) and a deep magnetic low (Fig. 10), ringed by Sb-Pb-Ag-As-Bi geochemistry (Fig. 11). Elevated gamma-ray counts extending outward from this same central zone reflect K-metasomatism, low-level U-enrichment in apatite related to Cu ore, and low-level Th-enrichment in Pink Porphyry (Fig. 12). Linear vegetation anomalies observed in ortho-rectified aerial photographs reflect the distribution of water-bearing fractures (Fig. 13) which may once have conducted ore fluids from the central to the distal portions of this zoned hydrothermal system. These complementary sets of geological, mineralogical, geochemical, and geophysical elements, taken together, can represent little else than the leakage of a major porphyry copper system caught largely beneath a sill-like slab of Copper Creek Granodiorite.

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Magnetite-Specularite Distribution

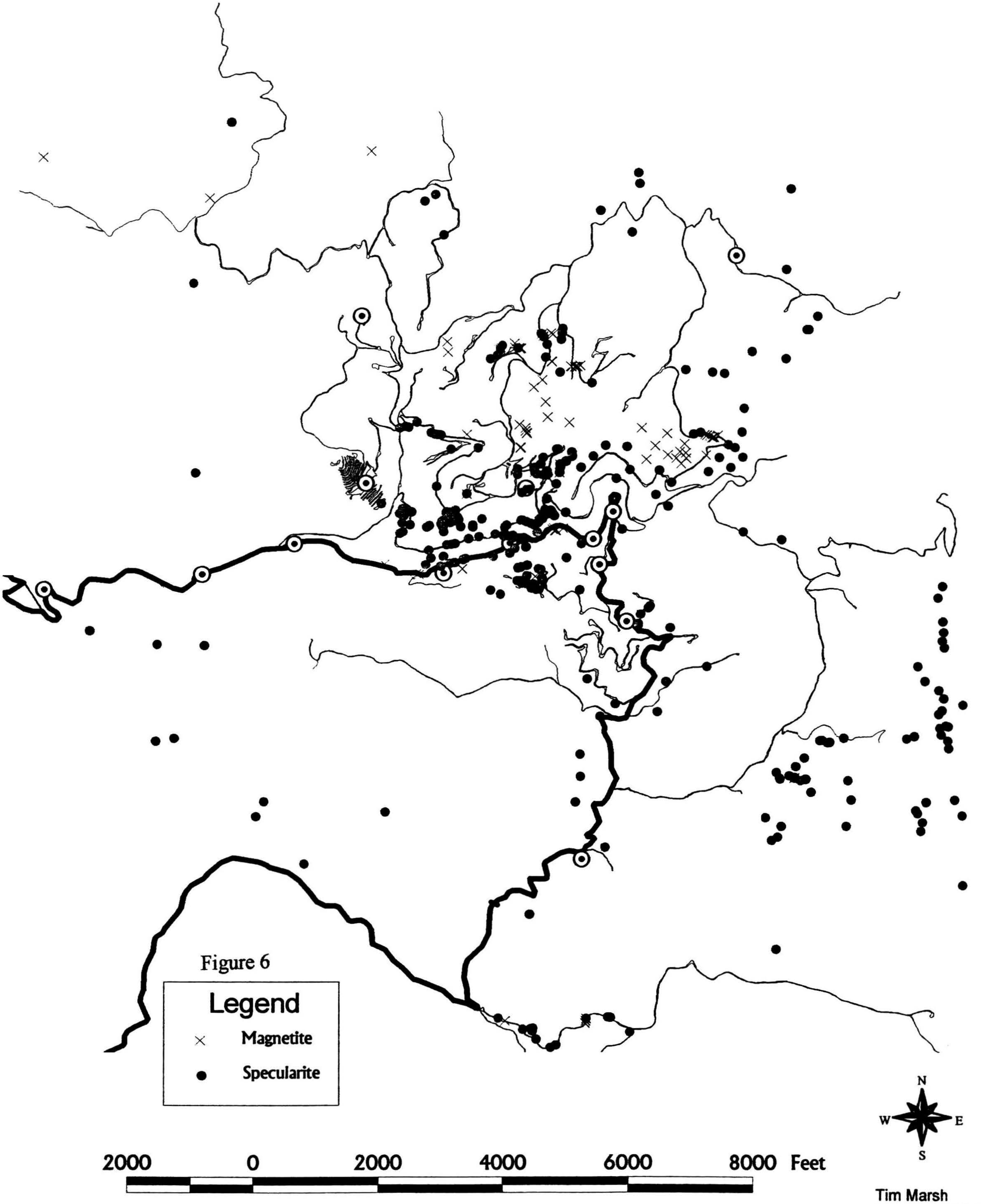

Figure 6

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Hydrothermal K-spar Distribution

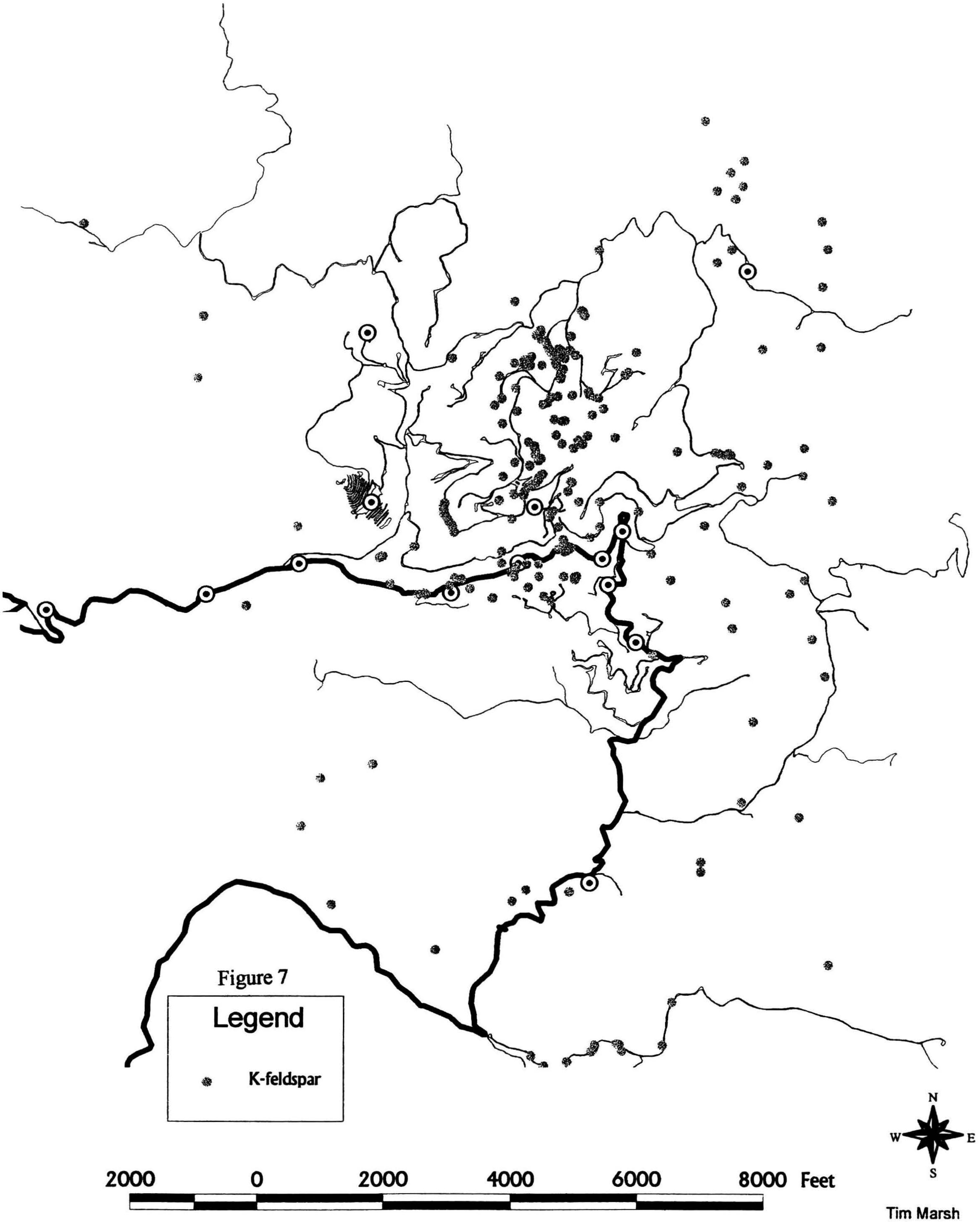

Figure 7

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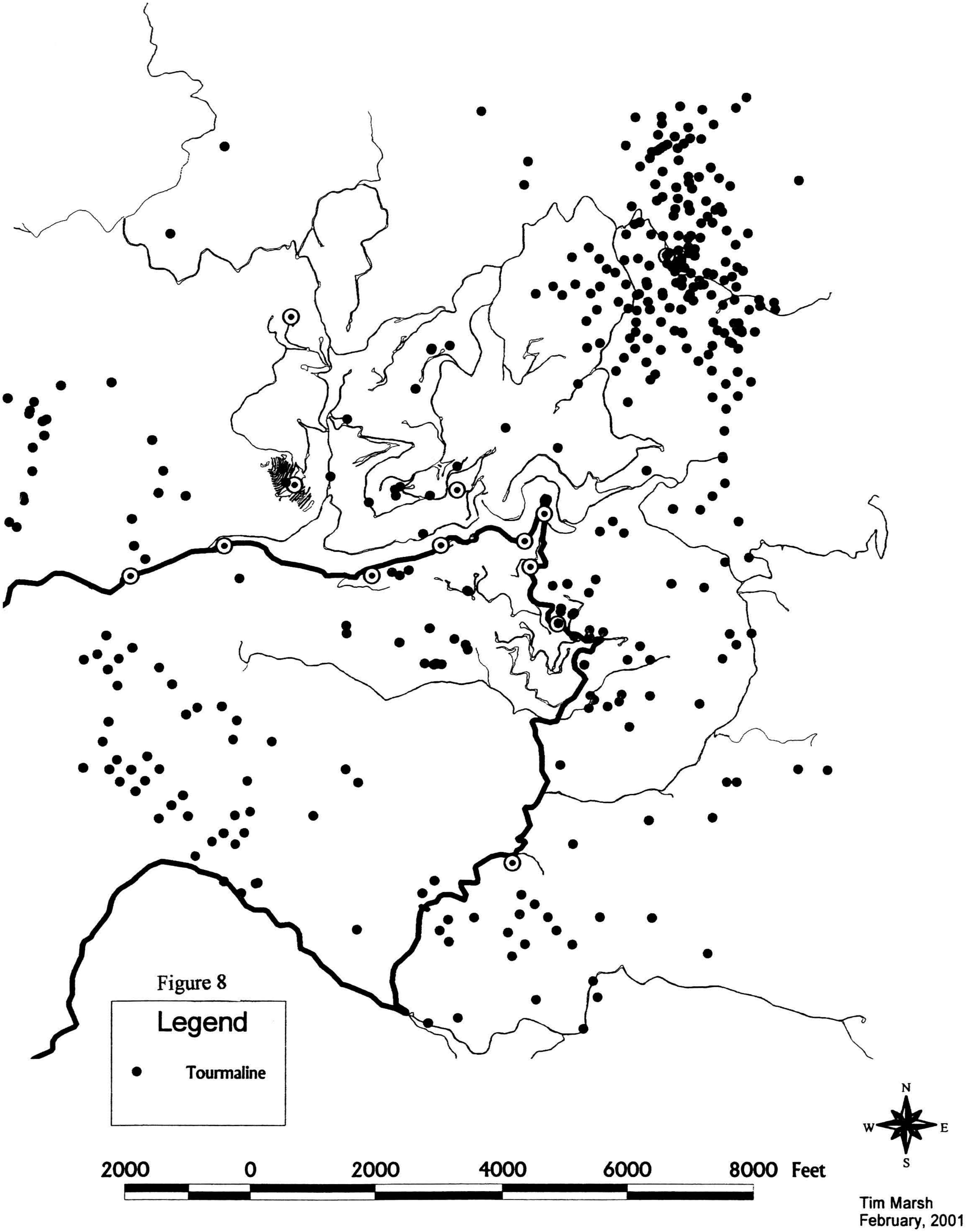
Tourmaline Distribution



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Q-Mode Factor Cu-Mo-U-W

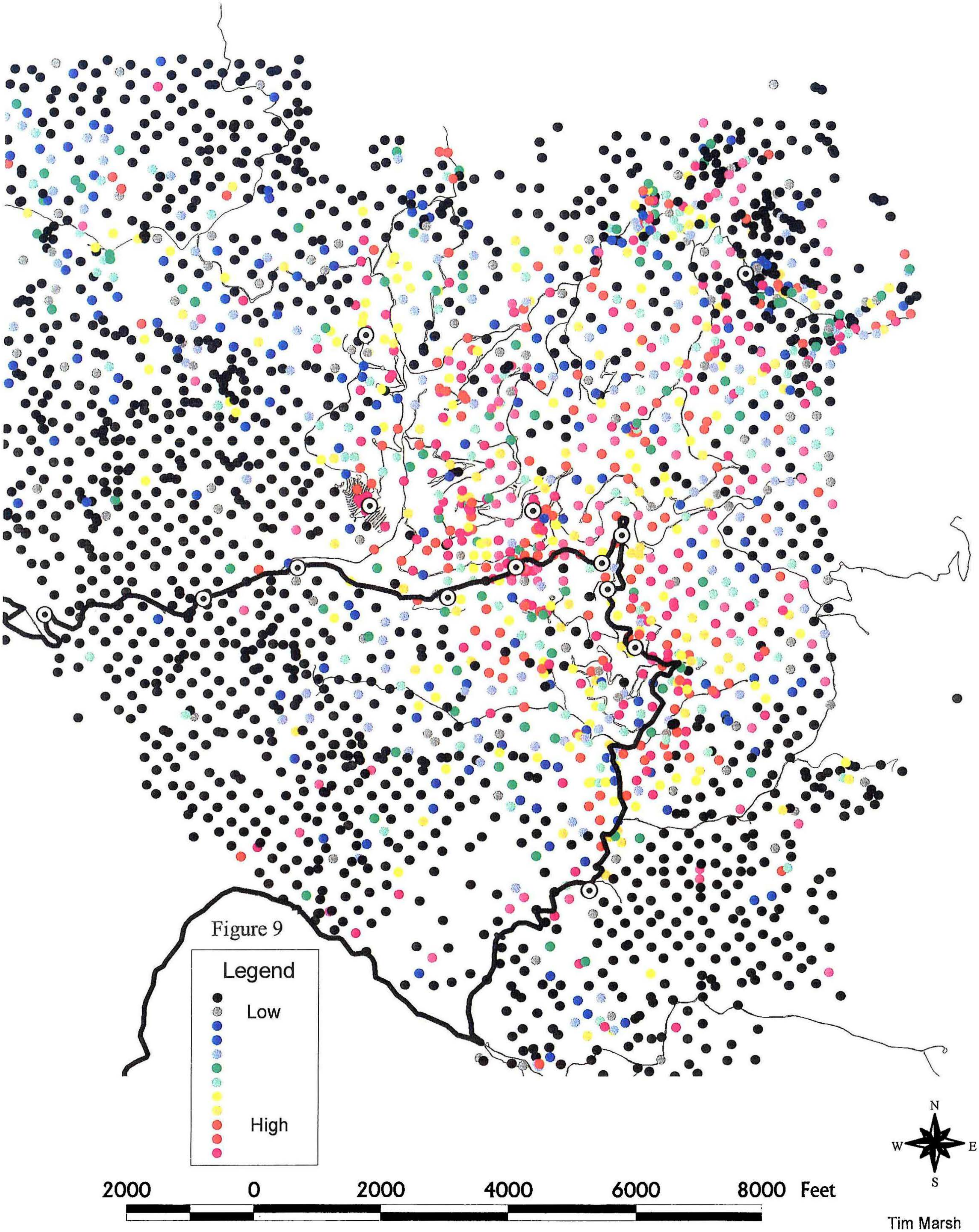

Figure 9

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Ground Magnetics

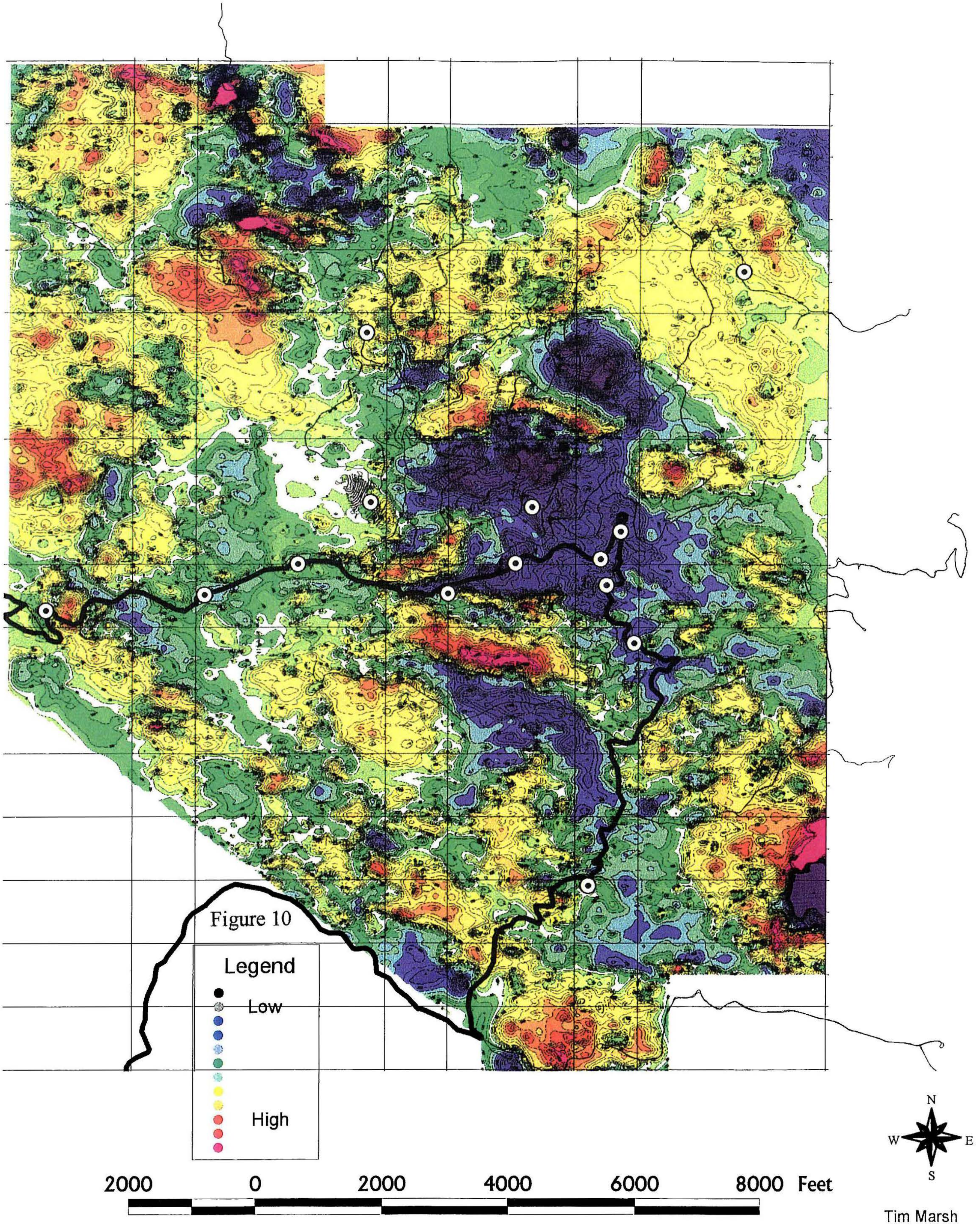

Figure 10

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Q-Mode Factor Sb-Pb-Ag-As-Bi

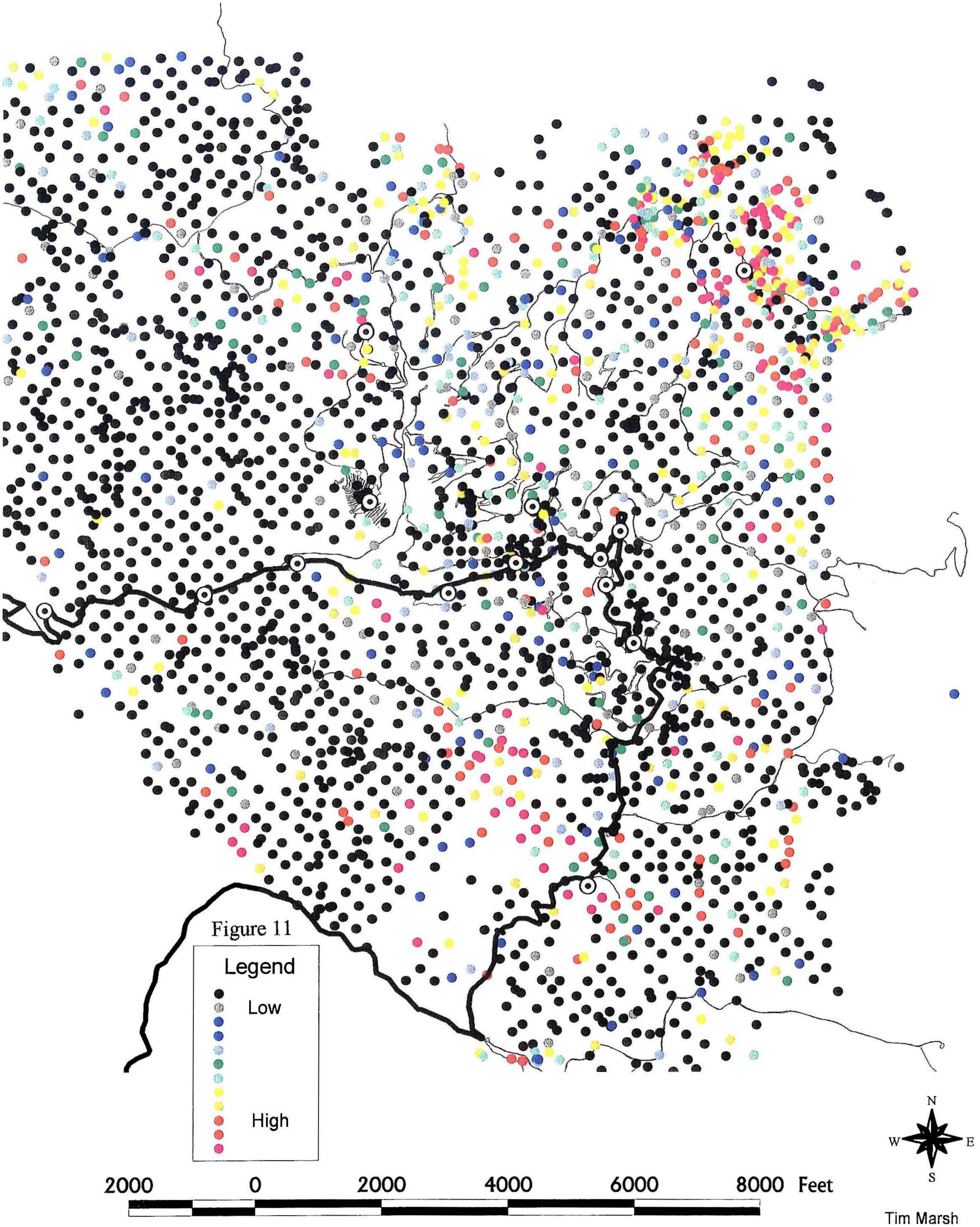

Figure 11

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Total Gamma

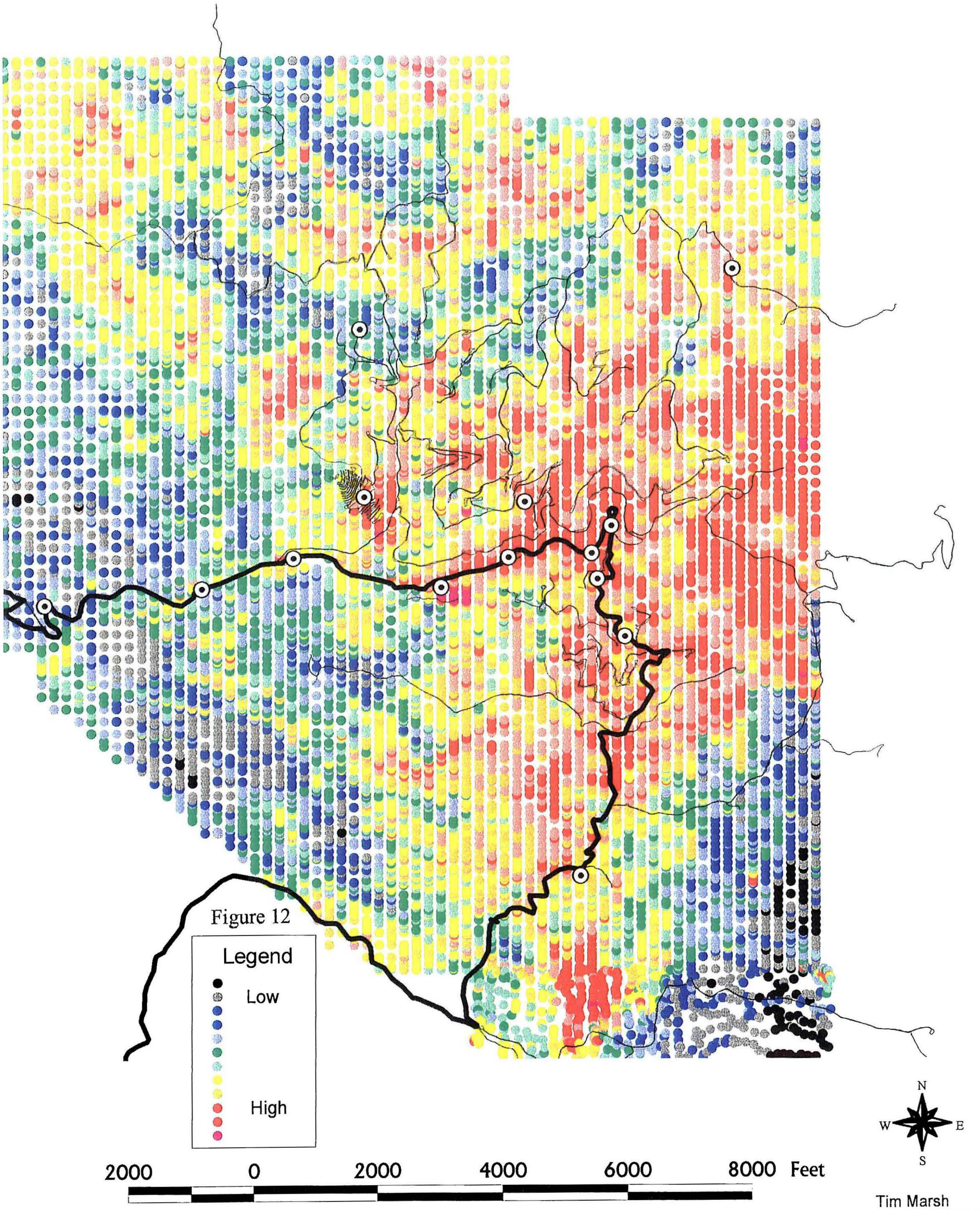

Figure 12

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Orthophoto Linears

Figure 13

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February, 2001

Copper Creek Road Log

Total Round Trip Mileage = 25.0
Please drive carefully!

Miles	Site (*Stop)	Description (map on back cover)
0.0	1	Set odometer at the intersection of Copper Creek Road and River Road.
0.0-1.0		Pliocene lacustrine sedimentary rocks of the Quiburis Formation. This formation hosts gypsum mined by National Gypsum at the Feldman Quarry 10 miles to the north, and diatomaceous earth mined by Canner Oil at the White Cliffs Mine 8 miles to the south.
0.9	2	East-striking strike-slip fault zone cutting youngest beds, including volcanic ash, of the Quiburis Formation. The trace of the fault zone disappears westward beneath modern sediments of the San Pedro River and eastward beneath post-Pliocene pediment gravel. The westward projection of the fault zone would pass quite nearly through the summit of Signal Peak, the highest point in the Black Hills. A local compressional slip component has resulted in minor reverse faults that strongly disrupt the lacustrine sedimentary rocks. Maximum apparent offset is about 6 feet.
1.0		Climb onto pediment surface developed on Pliocene lacustrine sedimentary rocks. During late Quiburis time, Copper Creek constructed a large delta westward into the lake, producing the peculiar high ground one mile to the south of the road.
1.0-3.3	3	Post-Quiburis pediment. The break in slope along the eastern highstand of the paleo-lake may mark a NNW-trending fault, subparallel with the axis of the San Pedro graben.
3.3-6.9		Climb up pre-Quiburis alluvial fan derived from the Copper Creek area. Whereas most of the fragments are mid-Miocene Galiuro volcanic rocks, older Laramide clasts become increasingly abundant in the younger deposits as more of the Galiuro volcanics were stripped off. Modern sediments in Copper Creek are dominated by Laramide and older clasts. In 1972, Cyprus drilled 8 holes across these thick deposits to test aeromagnetic lows found during a USGS survey.
6.9	*4	Gila-type conglomerate at this stop consists mainly of clasts derived from the Galiuro volcanics, but also includes clasts of granodiorite and tourmaline breccia. This demonstrates that paleo-Copper Creek had by this time stripped off a portion of the mid-Miocene Galiuro volcanic rocks, exposing Laramide and older rocks. The view eastward shows the Copper Creek district, with Laramide Gloryhole volcanic rocks, Copper Creek Granodiorite, porphyry stocks, and breccia pipes exposed in a wide erosional window beneath post-mineral (26 Ma), gently-dipping Galiuro volcanic rocks. Many of the knobby iron-oxide-stained outcrops in the distance are breccia pipes.
6.9-8.2	5	Ryland Ranch, former home of rancher, schoolmarm, and author of Woman in Levis, "Sister" Ryland. She homesteaded originally on the west side of the San Pedro, but took this ranch in exchange when Magma needed her homestead for tailing ponds. The Ryland Ranch had formerly been the Hendrickson Ranch,

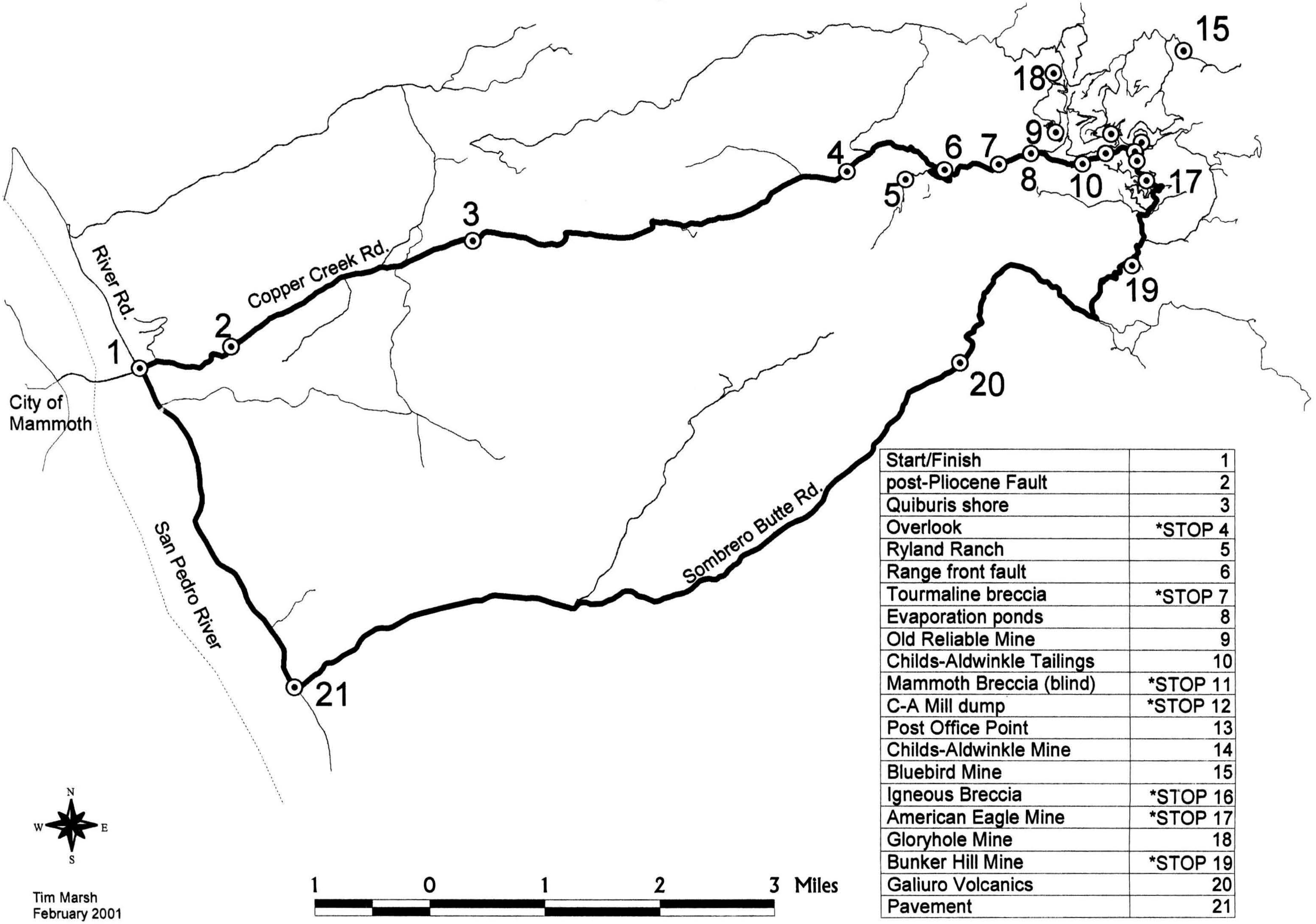
Miles	Site (*Stop)	Description (map on back cover)
		home of the mine manager for Arizona Molybdenum Corporation at Copper Creek and his son, who retired from Magma Copper as Mill Superintendent. AMT plans to construct a 5000 tpd plant site here, and collar a 9200'-long 18'x16' rubber-tire/conveyor decline further to the east to extract high grade sulfide breccia ore from underground mining operations in the heart of the Copper Creek district. Water can be produced from the Gila conglomerate at 1000 gpm for mill usage. Tailing and coarse mill reject will be slurried back underground for stope backfill, eliminating the need for tailing disposal. A portion of the coarse mill reject will be sold as high-quality construction aggregate.
8.2-8.3		Beneath the easternmost Gila-type conglomerate exposures, a clastic wedge consisting solely of angular, unsorted fragments of Laramide volcanic rocks marks the fault scarp debris slope that accumulated within a few hundred feet of the then-active local range-front fault. This evidence demonstrates that accumulated slip on the fault had exceeded the entire thickness of the mid-Miocene Galiuro volcanic rocks before the first local Gila-type conglomerates were preserved.
8.3	6	Cross the NNW-trending range front fault. Gouge in the fault zone is nearly 20 feet wide, and partially exposed in the bottom of the western ravine. Normal slip on the fault is close to 3000', calculated between the summit of Sombrero Butte at 5700' and the top of Galiuro volcanics in a Bear Creek hole drilled in 1955 west of the fault in Section 19, T. 8S. R. 18 E. which entered Galiuro volcanics at an elevation of 2946' and allowing for some erosion off of the top of Sombrero Butte. The dark rocks east of the fault are Laramide biotite-magnetite-Kspar hornfelsed clastic andesitic to dacitic Gloryhole volcanic rocks. Weathered surfaces highlight the fragmental nature of the rocks. They consist mostly of block-and-ash-flow deposits, though some lava flows, welded ash flows, and at least one base-surge deposit (J. O. Guthrie, pers. comm.) are also found. Where it has been possible to determine the attitude of bedded deposits in the Gloryhole, dips are in the range of 10-20° and generally easterly. Judging by the similar elevations of the highest Laramide granodiorite exposures in the district and the lowest exposures of mid-Miocene Galiuro volcanic rocks, erosion following the termination of Laramide igneous activity had almost certainly unroofed the Copper Creek Granodiorite and some of the breccia pipes from their cover of older Laramide volcanic rocks (Gloryhole volcanic rocks) before the district was once again interred beneath Galiuro volcanic rocks at about 26 Ma.
8.9	*7	Tourmaline Breccia. This stop illustrates the close spatial association between porphyry plugs and breccia, and the angular nature of breccia clasts. Tourmaline is common in the matrix of this breccia and in a steep E-striking, jarosite-stained pyrite-sericite structure cutting the breccia that forms the main face of this roadcut. Other breccias may be seen well-exposed in the bottom of the creek. This breccia is poorly mineralized with Cu, Mo, Au, and Ag, but shows anomalous Co-Ni-Se indicative of its original pyritic composition. This breccia is in the heart of the pyritic halo forming the western side of the Copper

Miles	Site (*Stop)	Description (map on back cover)
		Creek porphyry system.
9.2	8	Evaporation Ponds. These ponds, constructed in 1986 on the site of Ranchers Exploration former Old Reliable scrap-iron copper cementation plant, permit controlled evaporation of 1 gpm copper-rich, low pH effluent from the Old Reliable breccia.
9.5	9	Old Reliable Mine (view). Copper States Metals produced 700,000 lbs Cu from high grade breccia-hosted ore from three underground levels between 1903 and 1918 and transported ore to a mill up Copper Creek via steam-driven narrow gauge railway (Denton, 1947). Later, Siskon Mining controlled the Old Reliable and large tracts of the surrounding district when in 1966 Newmont exercised a purchase option on Siskon's claims, subject to Siskon's 15-year right to mine the Old Reliable and subject to Siskon's liability for mining-related damages (internal Magma Copper report). In 1968, Oxymin acquired the right to mine the Old Reliable, which was subsequently sold to Ranchers Exploration, who proceeded to develop the deposit. In 1972, Ranchers and Dupont blasted the breccia pipe using 2-kilotons of ANFO (*big boom*), terraced the rubble pile, and installed a wobbler sprinkler system to distribute sulfuric acid across the surface. The grouted floor of the lowest underground workings served to collect pregnant solution, which was then directed into a siphon which carried it beneath Copper Creek to the scrap-iron copper cementation plant at the site of the current evaporation ponds. Between 1972 and 1980, non-continuous operation of this property produced 11 million pounds of copper, about 20% of the pre-blast in-situ reserve. Drilling by AMT has shown that Ranchers recovered copper oxides located on fracture surfaces, but recovered little of the supergene chalcocite. AMT plans to recover the balance by underground mining. Expiration of the 15-year mining right left Newmont holding the bag (temporarily) when EPA issued a Violation Order in 1986 for acid drainage into Saloon Gulch. Costs borne by Magma (Newmont's successor) for construction of a catchment system and the present evaporation ponds were largely recovered via settlement against Hecla Mining (Siskon's successor) in 1989. AMT plans to eliminate the need for the collection system by mining out 3.8 million tons of ore averaging 0.8 % Cu, the source of the acid drainage.
9.6	10	Childs-Aldwinkle Tailing (view). This tailing pond was fed by a 1000' slurry pipeline originating at the millsite further up the canyon. Environmentalists in the 1930's forced Arizona Molybdenum to stop discharging tailing into Copper Creek and construct this impoundment. Please drive carefully to the next stop!
9.9	*11	Mammoth Breccia (blind). Just 105' below this former mill site is the apex of a vertically-plunging 2600'-high breccia pipe measuring 600' by 300' in plan view. High grade chalcopyrite ore in the upper 600 feet of the breccia constitutes 6.2 million tons of minable ore reserves grading 1.37% Cu, while high grade chalcopyrite-bornite-molybdenite in the lower 500 feet constitute at least 4.4 million tons of resources grading 1.59% Cu equivalent. South-southeast-plunging Gray Porphyry dikes form the floor of the breccia pipe. The strongest surficial evidence for this blind pipe is shallowly-dipping (15°W)

Miles	Site (*Stop)	Description (map on back cover)
		veinlets carrying pitchy limonite and anomalous Ag-Au-Bi-Pb-Sb-W-Zn that cut and offset the steep sheeted E-W quartz-pyrite veinlets showing prominent zoned sericitic envelopes. Weak Pb-Zn-W-apatite mineralization in the upper few feet of the breccia support the geochemical link with the surface. Stereonet analysis of 1000 clast-margins in drill core show a subtle preferred orientation of 15°W, supporting a link with the surficial veinlets. These veinlets apparently reflect incipient mechanical failure (collapse) of the wallrocks above the upward propagating breccia pipe.
10.2	*12	CA Mill Dump. This is a "low grade" dump from an earlier mill which processed ore from the Old Reliable and Childs-Aldwinkle mines, and which was fed via a narrow gauge railway. Coarse grained molybdenite, chalcopyrite, and bornite associated with orthoclase-biotite-apatite overprinted by sericite-calcite from the Childs-Aldwinkle mine can be found here. The bornite carries several ppm Au, several tens of ppm Ag, and the molydenite carries about 1000 ppm rhenium.
10.4	13	Post Office Point. Former social and governmental center of the thriving community of Copper Creek (pop. 200), this foundation supported the general store and U.S. Post Office. Stone foundations for tent-houses are scattered across the slopes on the north side of the creek. The narrow gauge railway leading back to the Old Reliable Mine ran through the rock cut to the south and on to the head of the mill, a few hundred feet south of here. A sharp magnetic anomaly in recent sediments filling the reservoir just upstream of the old dam may mark the resting place of the steam locomotive!
10.4-10.6	14	Childs-Aldwinkle Mine. The view to the northwest shows two prominent gloryholes which produced 7.3 million pounds of copper, 4.2 million pounds of molybdenum (6.9 M lb MoS_2), 27,000 oz Ag, and 723 oz Au from 358,000 tons of ore (Simons, 1964). An internal winze extends 850' below the haulage adit at creek level. The two mined breccia pipes converge at depth with a third, blind, unmined high grade pipe which apexes 80' below surface in the saddle to the north of the gloryholes. AMT has reserves of 2.9 million tons at 1.79% Cu equivalent in the unmined parts of this breccia system. This mine marks the central Cu-Mo-(Au) zone of the Copper Creek porphyry system.
10.6	15	Bluebird Mine. View northeastward of the first mine in the Copper Creek district. Early high grade Ag ore was packed on mules eastward over the Galiuros, loaded onto wagons, hauled to the Sea of Cortez, then sailed around world to the smelter at Swansea, Wales, rather exhausted (Simons, 1964). Between 1863-1940 this mine produced 119,000 oz. Ag, 4,000,000 lbs Pb, and 200,000 lbs Cu (Simons, 1964). This mine marks the northeastern side of the distal Ag-Pb-Zn zone of the Copper Creek porphyry system.
10.6	*16	Igneous breccia. This site displays the transitional volume where open-space breccia gives way downward to igneous-matrix breccia, and finally to porphyry. Granodiorite and Gray Porphyry can be found as clasts in this Dark Porphyry intrusion. Clast margins are altered to orthoclase, and magnetite, biotite, tourmaline, and chalcopyrite (or pitchy limonite) can be found in miarolytic cavities and other open-space fillings. Rotated clasts containing quartz-pyrite

Miles	Site (*Stop)	Description (map on back cover)
		veins with prominent sericitic envelopes help reveal the history of igneous and hydrothermal activity at this site.
10.9	*17	American Eagle breccia. The mine in this breccia pipe produced high grade chalcopyrite-tourmaline ore between 1905-1915. This breccia exposure illustrates subtle preferred orientation of angular breccia clasts, annular sheeted fractures, and the close spatial association between breccia and porphyry. Follow the ring fracture around the pipe, and inspect the oxide copper minerals. Gray Porphyry, Dark Porphyry, and Pink Porphyry may all be found in this area.
10.9	18	Glory Hole Mine. This view far to the northwest reveals the Glory Hole breccia and mine dumps (1907-1909) on patented ground that AMT joint-ventures with Phelps Dodge. The adjacent Copper Prince Mine (behind a ridge) in 1937 produced 1,200,000 pounds of Cu from high grade chalcopyrite breccia ore (Simons, 1964).
12.0	*19	Bunker Hill Mine. This mine produced 200,000 lbs of Cu and 15,000 oz. Ag. Galena-tennantite may be found in the dump. This mine marks the southern edge of the distal Ag-Pb-Zn zone of the Copper Creek porphyry system.
14.8	*20	Galiuro volcanic rocks. The exposures on the west-facing slope of Sombrero Butte reveal gently-dipping 26 Ma rhyolitic ash tuffs, vitrophyre, yellow lithic-pumice tuff, and basal olivine-bearing andesite flows, flow breccias, and agglomerates. Intense zeolitic alteration has affected some of the uppermost tuffaceous units. The range-front fault runs below the base of the butte and accomodates about 3000' of normal offset. A 2553'-thick section of Galiuro volcanic rocks, including a rhyolite flow-dome complex, beneath 845' of Gila conglomerate, was cut in Cyprus drillhole CCP-1, 2 miles west of here.
25.0	21	Return to point of beginning, intersection of Copper Creek Rd. and River Rd.

Copper Creek, AZ
Field Trip Guide



Start/Finish	1
post-Pliocene Fault	2
Quiburis shore	3
Overlook	*STOP 4
Ryland Ranch	5
Range front fault	6
Tourmaline breccia	*STOP 7
Evaporation ponds	8
Old Reliable Mine	9
Childs-Aldwinkle Tailings	10
Mammoth Breccia (blind)	*STOP 11
C-A Mill dump	*STOP 12
Post Office Point	13
Childs-Aldwinkle Mine	14
Bluebird Mine	15
Igneous Breccia	*STOP 16
American Eagle Mine	*STOP 17
Gloryhole Mine	18
Bunker Hill Mine	*STOP 19
Galiuro Volcanics	20
Pavement	21

Tim Marsh
February 2001