EPITHERMAL DEPOSITS

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INTRODUCTION

It has become increasingly clear in recent years that the majority of epithermal ore deposits hosted by volcanic rocks or volcano plutons were formed by geothemal systems similar to active modern day systems. White (1955) discussed five thermal spring systems which he thought were closely related to epithermal mercury and precious metal deposits. These hot spring systems had all been drilled to depths great enough to provide some three-dimensional data. In the early 1950's only a few active geothermal systems had been drilled out, and their relation to hydrothermal ore deposits had not yet been recognized. White (1981) gives a good review of the current state of knowledge and understanding of the relationships between geothermal systems and hydrothermal ore deposits.

Our understanding of the active geothermal systems and the fossil geothemal systems has developed along several interdependent lines: (1) detailed geologic and mineralogic studies of ore deposits, (2) laboratory studies of fluid inclusions and isotopic composition of ore and gangue minerals, (3) detailed geologic and geochemical studies of active geothermal systems, and (4) studies of natural systems which show close connections to ore deposits.

Epithemal mineralization in the western United States appears to be related to magmatism associated with both compressional and extensional tectonics. The magmatic character changed in response to the major change in the tectonic regime (Christiansen and Lipman, 1972). The compressional tectonics can be related to convergence (subduction) while the extension tectonics are attributed to: (1) convergence related intra arc extension, (2) convergence relation back arc extension related to cessation of plate convergence, and (3) the initiation of a transform plate boundary (Eaton, 1979).

PLATE TECTONICS

According to the concepts of plate tectonics, the earth's lithosphere has broken into several plates (Fig. 1). There are a total of seven (7)

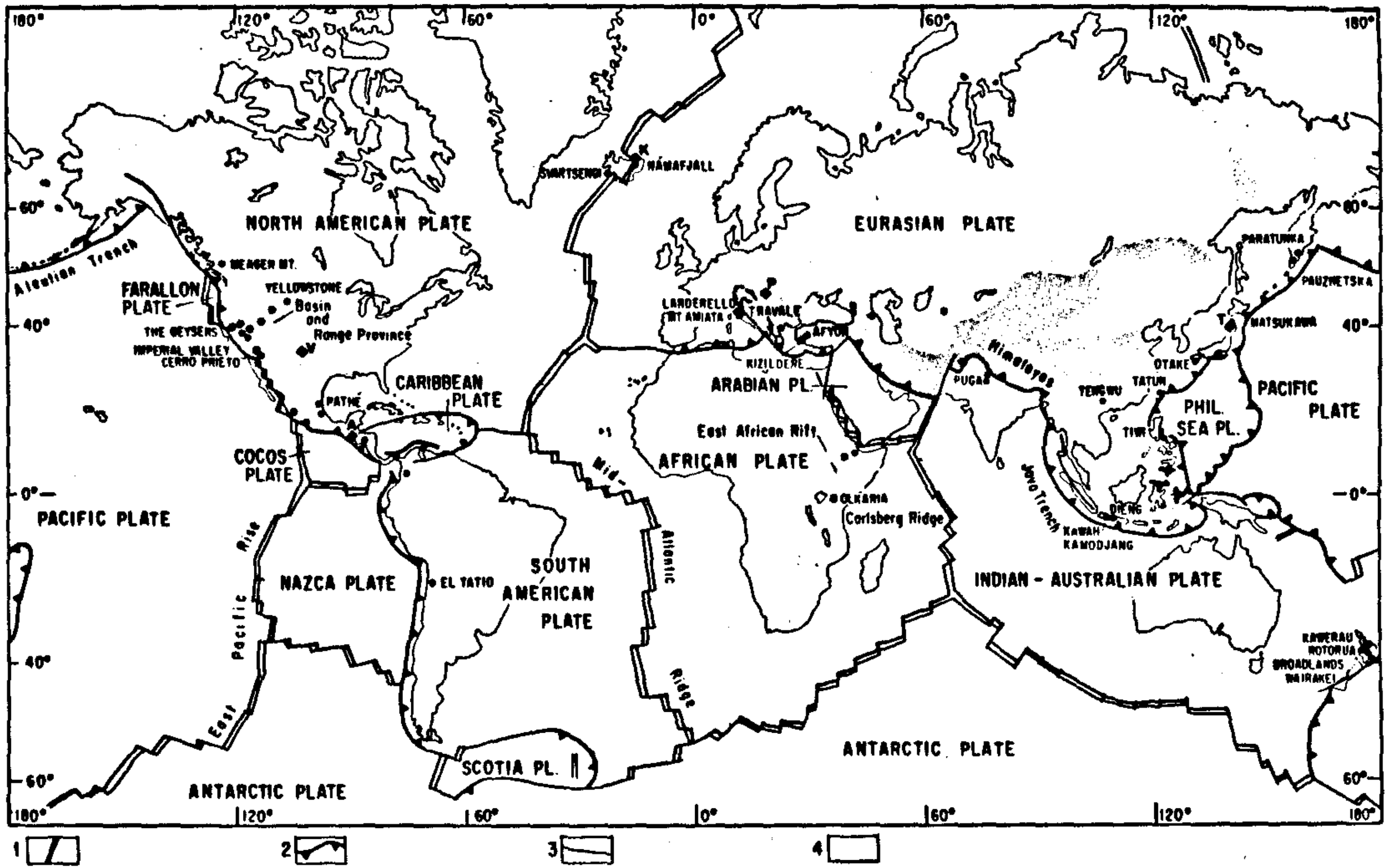


Figure 1. Lithospheric plate boundaries provide the framework for the global distribution of major geothermal systems. Plate boundary types: Spreading ridge (1), subduction/trench (2), transform fault (3). Shaded areas (4): Plate interior undergoing active extensional, compressional or strike-slip faulting. Base map and plate boundaries after Hamilton (1976) and Panza and Mueller (1979), goethermal systems (dots) after Muffler (1976a, 1976b). Systems discussed in detail in this volume: A (Ahuachapán/El Salvador), K (Krafla/Iceland), P (Pannonian basin/Hungary), T (Takinoue/Japan), V (Valles Caldera, Jemez Mts/U.S.A.)

large plates and several small plates which slide upon the asthenosphere relative to one another. The motion at plate boundaries may be divergent, convergent or transform. Magmatic activity and geothermal activity appear to be confined to the first two types.

Spreading Ridges

The oceanic ridges (Fig. 1) are spreading centers associated with divergent plate boundaries. As the plates spread apart, upwelling basaltic magmas from the mantle fill the gaps and form new oceanic crust (Fig. 2). The age of the rocks increases away from the ridge axis and the heat flow decreases away from the spreading center. The geothermal areas of Iceland are related to the mid-Atlantic ridge spreading center. The geothermal systems of the Imperial Valley of California and Mexico are located on the extension of the East Pacific Rise beneath the North American Plate (Fig. 1).

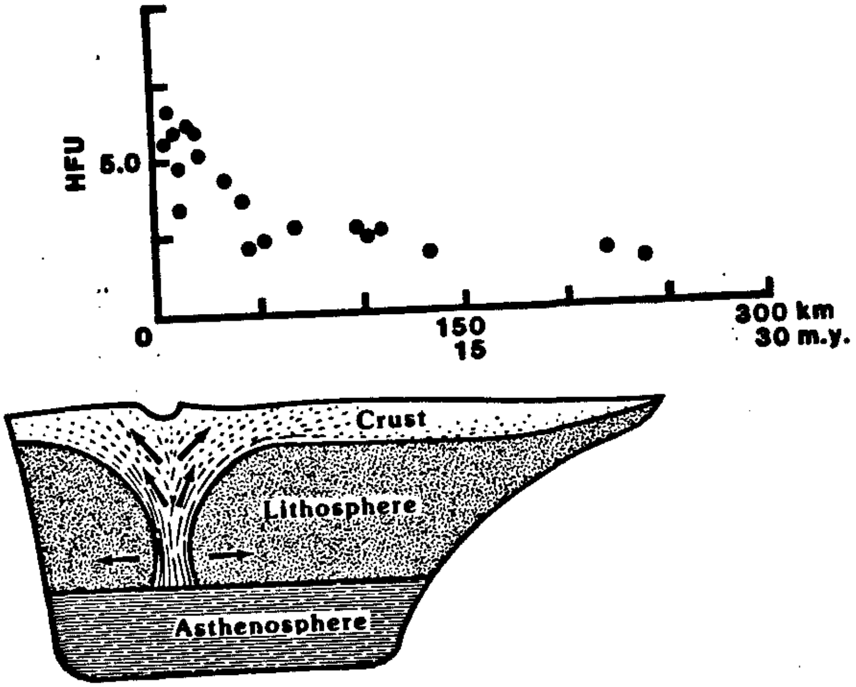


Figure 2. Schematic diagram of a spreading ridge, heat flow and age of volcanic rocks (after Palmason, 1973 and Rybach, 1981).

Submarine hydrothermal systems have been called upon to explain the formation of the massive sulfide deposits in Cyprus. Confirmation that submarine hydrothermal systems do form massive sulfides came with the observation of "black smokers" on the East Pacific Rise (Francheteau et al 1979 and Hekinian et al 1980) and more recently on the Juan de Fuca Ridge.

Subduction Zones

A subduction zone occurs at convergent plate boundaries (Fig. 1) in response to the lateral movement produced at the spreading ridges. Usually the overriding plate is continental; however, in some cases the convergence can be between two oceanic plates such as the small Philippine Sea Plate and the large Pacific Plate. The subducted plate pulls down the isotherms to form a heatflow low in the Trench area (Fig. 3). The magma generation by partial melting above the subducted slabs gives rise to a volcanic belt or arc parallel to the subduction zone. Geothermal areas related to active subduction zones include Karwah Ramodjang, Indonesia; El Tatio, Chile, and Meager Creek, B.C. Canada. Epithermal deposits are associated with Mesozoic to Quaternary subduction related volcanics.

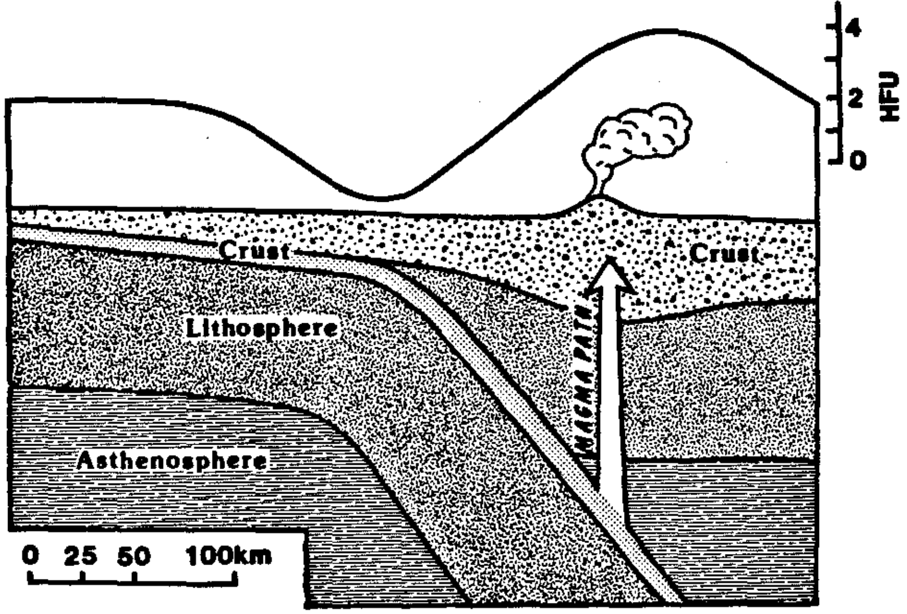


Figure 3. Schematic diagram of a subduction zone, associated volcanic arc, and heat flow profile.

Intraplate Rifting

The bulk of the Earth's magmatic and geothermal activity occurs along plate margins (Fig. 1); however, volcanism has repeatedly occurred within both continental and oceanic plates. The magma source for such volcanism is thought to be deep below the lithosphere. The lithospheric plate moves past the source, a mantle plume (Fig. 4), while the mantle plume remains in a fixed position (Morgan, 1972).

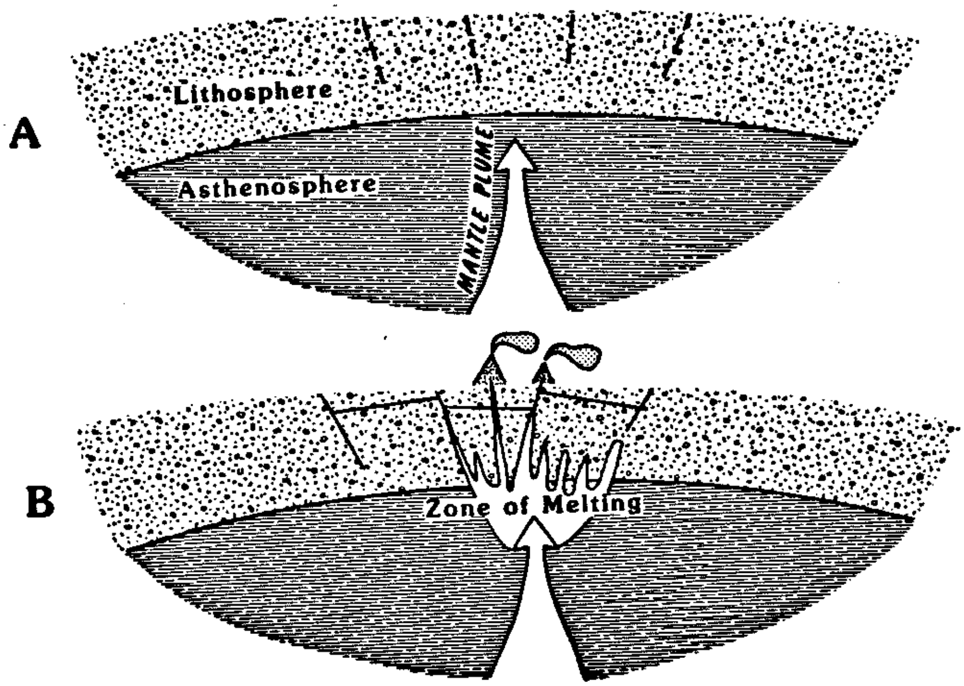
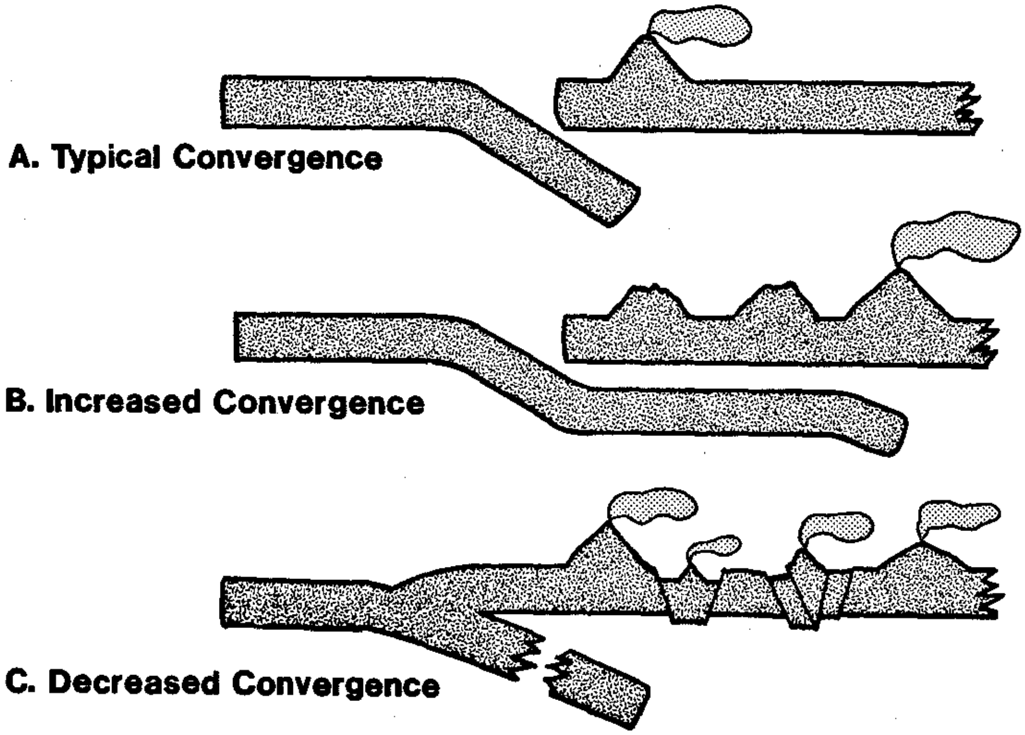


Figure 4. Schematic diagram of intraplate mantle plume in the early stage (A) and late stage (B).

The thermal perturbations within the mantle which give rise to mantle plumes may orignate from chemical streaming, convective upwelling or shear melting at the lithosphere-asthenophere boundary. The lithosphere reacts by thermal expansion, doming, thinning, fractures (rifting) and finally with volcanism. The Hawaiian Islands represents intraplate volcanism on an oceanic plate and Yellowstone has been interpreted to be intraplate volcanism on a continental plate.

Intraplate extension and volcanism can also be explained by the plate tectonic model. Typical plate convergence (Fig. 3) results a steeply dipping subduction plate and associated volcanic arc. If the rate of plate convergence increases, Lipman (1980) proposes that the dip of the subduction slab flattens (Fig. 5) and that the magmatism advances inboard from the trench giving rise to alkalic-calcalalic ash-flows. When the rate of convergence decreases to normal or ceases entirely, the dip of the subduction slab steepens resulting in back arc extension and associated bimodal basalt-rhyolite volcanism. Beowawe, Desert Peak, Dixie Valley and Roosevelt are examples of geothermal systems developed in areas of intraplate extension.



A. Typical Convergence

B. Increased Convergence

C. Decreased Convergence

Figure 5. Schematic diagram showing typical convergence (A), flattening of the dip due to increase convergence (B) and back arc extension as dip increases due to decreased convergence (C).

EPITHERMAL DEPOSITS

Epithermal mineral desposits, as defined by Lindgren (1933), are mineral deposits associated with volcanic rocks, formed within 1,000 meters of the premineral erosional surface and were deposited in a restricted vertical range of 400 meters or less. The deposits were formed from low salinity fluids at temperatuares in the range of 50-200^{0}C. The majority of epithermal deposits are of precious metals and are characterized by the presence of As, Sb, Hg, Tl, Se and Te.

Based upon the mode of occurrence the epithermal precious metal deposits can be divided into three types: (1.) Veins: e.g. Oatman, Bodie, Goldfield; (2.) Rock Masses: e.g. Carlin, Cortez, Round Mountain; and (3.) Surface exhalites: e.g. Borealis, Steamboat Springs. While each type has characteristics of its own, all probably formed in the same geothermal environment. One feature which is ubiquitous is the fine grained silica gangue. In the latter two types, the precious metals are, for the most part, fine-grained and disseminated in much the same way as the sulfides in a porphyry copper deposit.

A great many of the epithermal mineral deposits occur volcanic or volcaniclastic rocks; however, the host rocks may include a variety of sedimentary rocks or metamorphic rocks as well. One feature common to all deposits is the presence of a major structure which acts as a channelway for the introduction of fluids.

Vein Deposits

Vein or "bonanza" type deposits occur within fractures and usually have sharp contacts with the wallrock. The most common vein filling material is microcrystalline or chalcedonic quartz often accompanied by adularia. Other vein minerals include calcite, dolomite, rhodocrosite, barite, fluorite and small quantities of sulfides. Pervassive wallrock alteration spreads outward from the veins. Silicified veins give way to quartz + sericite (Fig. 6) which then changes gradually into a peripheral chlorite + carbonate (propylite) zone. The propylitic alteration may extend up to 0.5 km from the vein. The alteration is usually much more widespread in the hanging wall than in the footwall. The nature and extent of the prophylitic alteration is a function of the wallrock composition: rhyolitic host rocks yield low albite whereas andesites gives rise to abundant albite. The carbonate occurs in microveinlets and also as disseminated blebs.

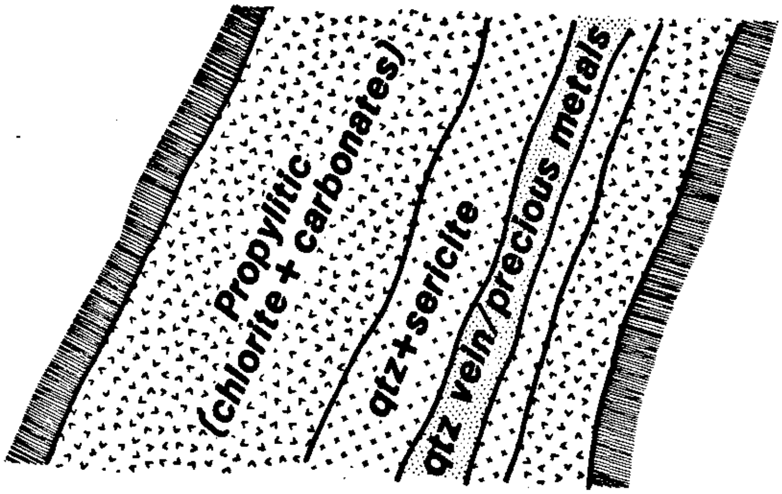


Figure 6. Schematic cross section of typical epithermal vein showing wall rock alteration.

Bodie District - The Bodie Mining District is located near the eastern margin of the Bodie Hills in Mono County, California (Fig. 7) about 16 km east of the Sierra Nevada scarp. The Bodie Hills are a volcanic massif which developed from many local vents. The Bodie Hills volcanic complex

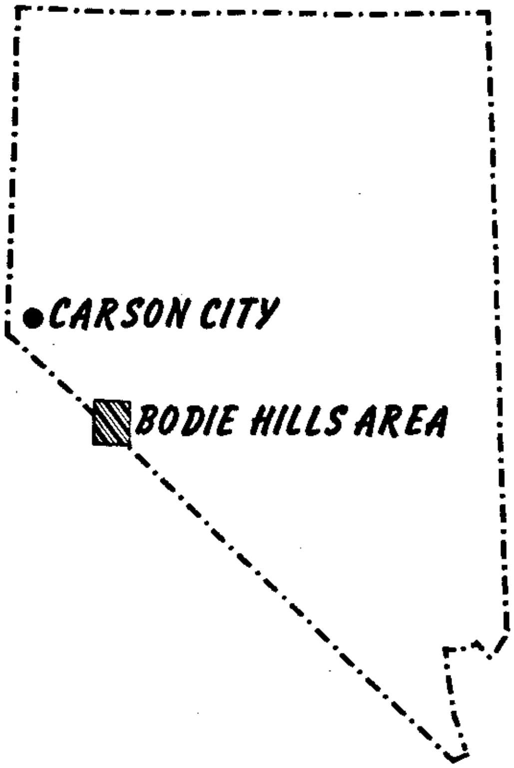
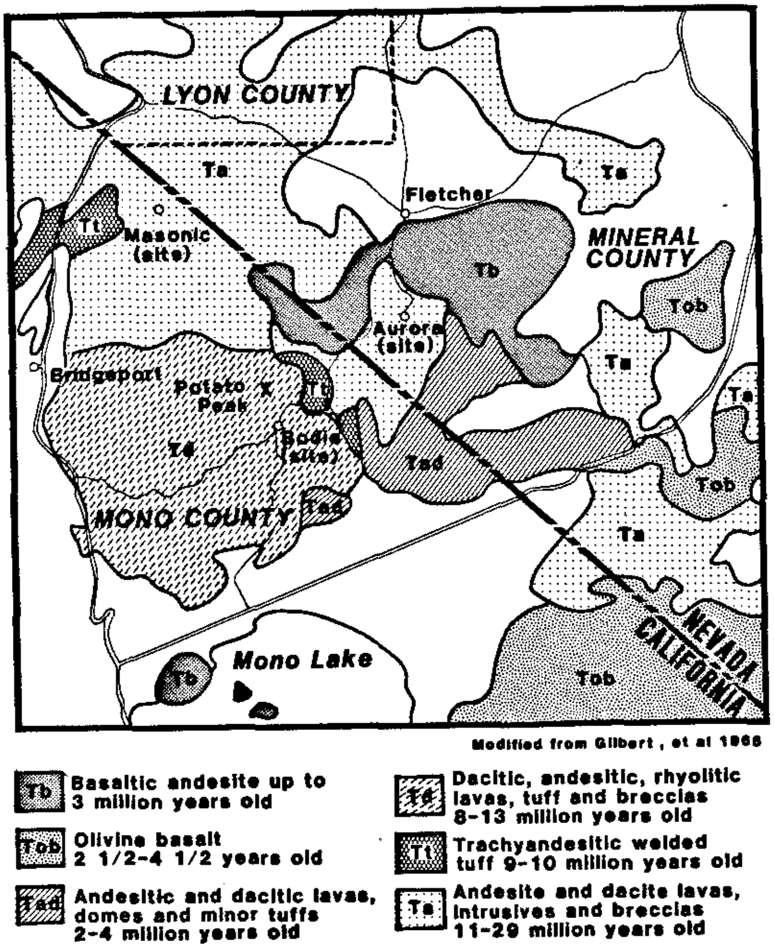


Figure 7. Index map of Bodie Hills area, California and Nevada.

and surrounding area constitute a major volcanic province which has been subdivided (Kleinhampl et al. 1975) on the basis of lithology and age (Fig. 8). The area is underlain by two groups of Tertiary and Quaternary volcanic rocks. The oldest rocks are calc-alkaline (Oligocene and Miocene) and the younger suite (Pliocene and Pleistocene) is alkalic-calcic. The oldest division is chiefly andesite and dacite with minor rhyolite (Fig. 8) and is the most widespread unit in the area. In the Aurora Mining District, the rocks have been dated in the 13.5-15.4 m.y. range. In the southeastern corner of the map area and the northwestern part the rock ages fall into the 22-29 m.y. range. Unit 2 consists of Trachyandesite welded ash-flow tuff which occurs in small outcrops on the flanks of Bodie Hills. Unit 3 comprises the main volcanic complex in the Bodie Hills and consists of dacitic, andesitic and rhyolitic lavas, tuffs and breccias. The mineralization is confined to the rocks of Unit 3.



Modified from Gilbert, et al 1968

Figure 8. Generalized geologic map of Bodie Hills area, California.

The major veins and fractures in the Bodie District strike north to northeast. The productive quartz veins vary in thickness from 1 to 90 feet; however, most veins are only a few feet high. Quartz and adularia are the most abundant vein minerals. The ore minerals are native gold and silver with some argentite, pyrite, and sphalerite.

Wall rock alteration at Bodie has not been studied in detail. O'Neil et al (1973) reported on the chemical and isotopic effects of the K-silicate alteration in the Bodie Bluff area. Chesterman et al (Silberman, 1983) discuss both a vertical and lateral zonation of the alteration. The rocks in the northern part of the district are stongly silicified. Silberman (1982) suggested the silicified zone represents a very shallow, near surface level within the system. In the Bodie area below the near surface silicified zone the wall rocks show strong K-silicate alteration including adularia, sericite, and quartz. In the southern part of the district the alteration is argillic mostly kaolinite but with some montmorillonite. Outside the main area of mineralization at Bodie, the vocanic rocks are strongly propylitized.

The hydrothermal alteration and mineralization represents the final phase of activity associated with the Bodie Hills volcanic field. Radiometric dating of the alteration and mineralization (Silberman, 1983) suggests the activity lasted about 1.5 m.y.

Goldfield District - The Goldfield Mining District (Fig. 9) is located in the Goldfield Hills of western Nevada. The Goldfield Hills are underlain by a sequence of Oligocene and Miocene volcanic rocks which rest upon a pre-Tertiary basement of Ordovician sediments and Jurassic granites. The older Oligocene volcanic rodks (Fig. 10) are silicic flows and ash-flow tuffs erupted from a caldera outlined by the ring fractures and alteration. The pre-Tertiary rocks are exposed as inliers at Columbia Mountain and Vindicator Mountain. Jurassic granitic rocks are the main pre-Tertiary rocks exposed in the area. Small remnants of siliceous shales and argillites were mapped by Albers and Stewart (1972) as Palametto Formation of Ordovician age.

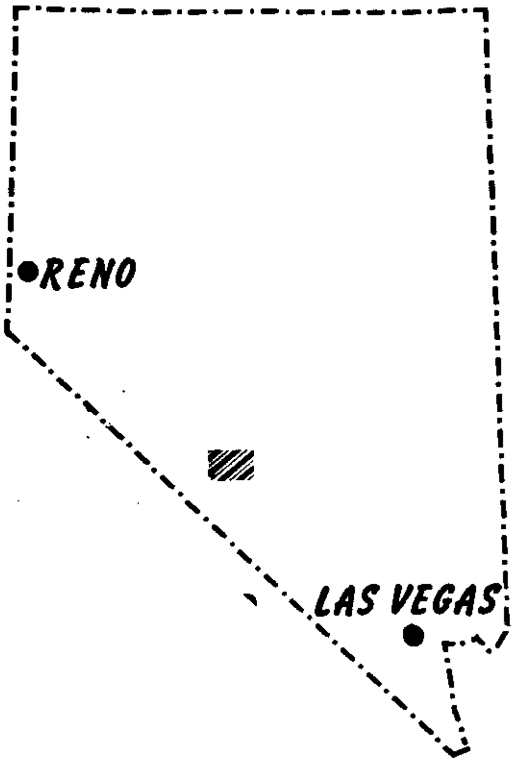


Figure 9. Index map Goldfield Mining District, Nevada.

The Tertiary volcanic complex consists of Oligocene rocks at the base resting uncomformably upon the pre-Tertiary rocks in the vicinity of Columbia Mountain, Vindicator Mountain, and Banner Mountain (Fig. 10). The silicious volcanics include rhyolitic ash-flow tuffs, flow breccias and flows overlain by quartz latite tuffs and flows. The most extensive Tertiary volcanic rocks are Lower Miocene calc-alkalic rocks (Fig. 10). The most widespread map unit is the Milltown Andisite (TMA) which rests unconformably upon the Oligocene volcanics. The Milltown volcanics consist of ash-flow tuff and flows of trachyandesite and rhyodacite with minor amounts of basalt and quartz latite. In the southern part of the district, the Milltown andisite is overlain by the Chispa andisite (Fig. 10) while in the northereastern part of the area the rhyolite of Wildhorse Spring rests upon the Milltown. Post mineralized volcanic rocks and interbedded sediments lap onto the older rocks on all sides of the Goldfield Hills. The volcanic material was evidently derived from vents outside the area; however, the intercolated sediments contain hydrothermally altered detritus derived from within the district. The erosion of the Goldfield mineralization began about 15 m.y. ago.

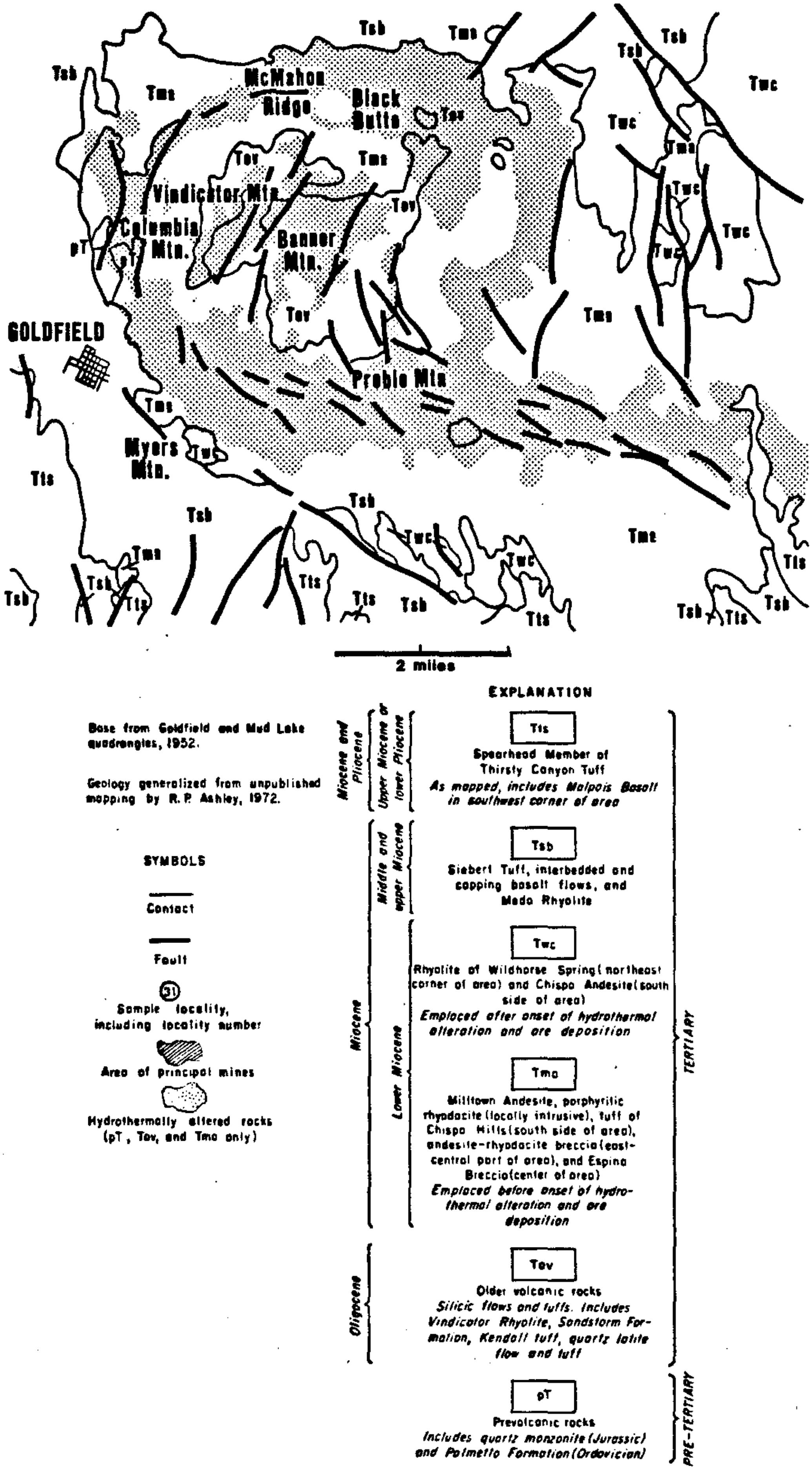


Figure 10. Geologic and alteration map of Goldfield District, Nevada, after Ashley and Silberman, 1976.

Mineralization in the Goldfield District occurs in silicified "ledges" according to Ransome (1909). The silicified ledges form prominent outcrops throughout the hydrothermally altered area (Fig. 10) at Goldfield.

The silicified "ledges" are replacement bodies of very fine-grained quartz which formed along faults, fractures, and permeable beds. Alunite is an important epithermal mineral in the silicified rocks where it occurs as veins cutting the silicified ledges and as replacement of feldspar phenocrysts and pumice fragments. Kaolinite, pyrophyllite, and diaspore are also common within the silicified "ledges". Ore mineralization consists of native gold, pyrite, telluride, and sulfosalt minerals. Athough relict textures are preserved within the silicified zones the only relict minerals are quartz phenocrysts.

Outward from the silicified ledges the wall rocks exhibit decreasing silica replacement of the groundmass and fewer silica filled fractures. Alunite occurs as veins and texturally controlled replacements of feldspar phenocrysts and pumice fragments. Ashley and Silberman (1976) report coarse-grained aggregates of alunite and jarosite in some brecciated siliceous zones on Preble Mountain. Here the alunitic silicified rocks extend to depths of 600 meters below the surface.

Quartz-sericite alteration is present in the Goldfield District; however, it does not form a mappable unit. The quartz-sericite grades into quartz-kaolinite and quartz-montmorillonite which has been mapped as a general argillic alteration zone. Outside the argillized zone the rocks are propylitized. Harvey and Vitaliano (1964) ascribe the propylitization to the same hydrothermal event as the quartz-alunite and argillic alteration.

DISSEMINATED DEPOSITS

Disseminated precious metal deposits have been found in the wall rocks adjacent to some veins e.g. Carlin, Jarbridge, Cortez. The mineralization commonly occurs in sedimentary rocks but has also been found in metasediments and volcanic hosts as well. In all known deposits the mineralization appears to be confined to a specific unit within the stratigraphic section (i.e. to be stratabound) extending outward from steeply dipping faults. Stock rock deposits such as Round Mountain and the Comstock are intermediate between vein deposits and disseminated deposits.

Cortez District - The Cortez District is located near the south end of the Cortez Range in north central Nevada (Fig. 11). The area is about 65 miles southwest of Elko and about 55 miles south of the Carlin gold mine. Mining in the district started in 1863 for vein and manto deposits of silver-lead-zinc-copper-gold. The U.S. Geological Survey reported a gold geochemical anomaly in the area in 1966 which was later explored and mined by a joint venture group headed by AMEX, the American exploration arm of Placer Development Ltd.

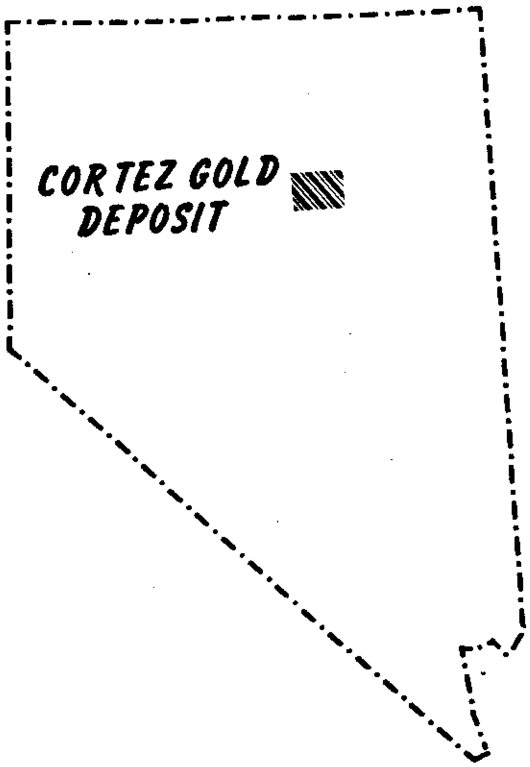


Figure 11. Index map Cortez Gold Deposit, Nevada.

The Cortez gold deposit is in the altered Roberts Mountains limestone of Silurian age exposed in a window (Cortez Window) of the Roberts Mountain thrust. The geologic mapping in the area was done by Gilluly and Masursky (1965) and their map is shown in Figure 12.

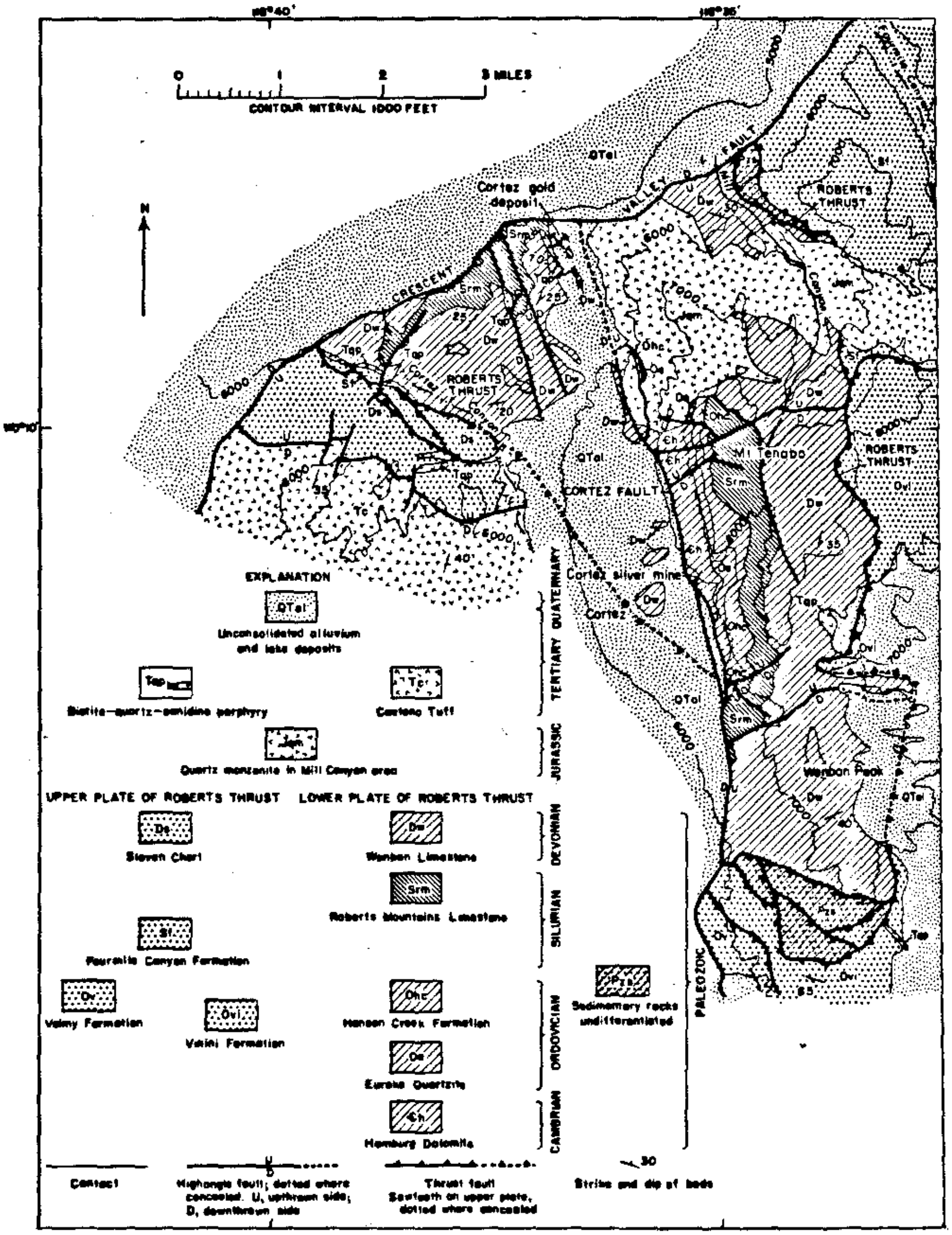


Figure 12. Generalized geologic map of the Cortez district, modified from Gilluly and Masursky, 1965.

The lower plate carbonate rocks and the Roberts Mountains limestone in particular, are favorable hosts of low-grade (no-see-um) gold deposits in north central Nevada (Wells et al, 1969). The Roberts Mountains limestone is a laminated silty, dark gray to black graphitic limestone about 1000 feet thick. Euhedral pyrite cubes occur through the unit. Some organic carbon is present and graded bedding and cross-bedding are common in the silty layers. The Wenban limestone is a massive to thin bedded argillaceous bioclastic gray limestone.

Gilluly and Masursky (1965) recognized four periods of igneous activity in the Cortez District. The oldest was the Late Jurassic quartz monzonite stock in the Mill Canyon area (Fig. 12). Low grade contact metamorphism occurred around the intrusive. The next episode was the deposition of the caetono welded ash-flow tuff and intrusion of small masses of biotite-quartz-sanidine prophyry at about 33-35 m.y. Pliocene basaltic andesite flows and rhyolite plugs are found to the east and northeast.

The Cortez gold deposit is located where altered Roberts Mountains limestone is faulted, folded, and brecciated along the margin of a biotite-quartz-sanidine porphyry intrusive (Fig. 13). The deposit cuts across bedding along the intrusive front, but is confined to certain altered beds away from the intrusive.

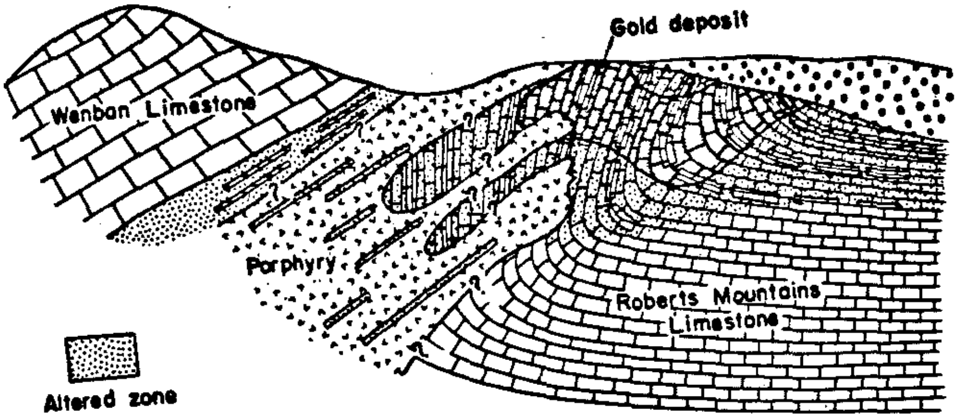


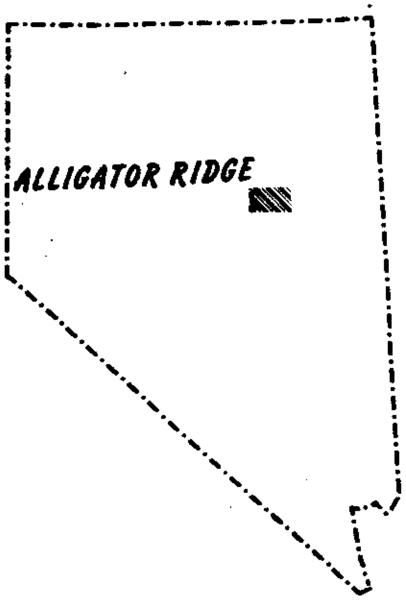
Figure 13. Idealized cross section (W-E) showing gold deposit and alteration zone, after Wells, et al., 1969.

The Roberts Mountains Formation has been leached and bleached by hydrothermal solutions. The solutions were introduced after the emplacement of the biotite-quartz sanidine porphyry. The alteration is most intense in the highly fractured rocks. The hydrothermal fluids changed the pyrite to iron oxide. The contact between the fresh unaltered gray to gray-black rock and the light gray bleached rock and the reddish-gray altered rock is sharp. In the weakly bleached rocks the effects of alteration are a reduction in the organic carbon content and the carbonate content with a concomittant increase in porosity. The porosity increase facilitates the movement of fluids. The fluid circulation resulted in deposition of late chalcedonic silica or jasperoid which produces semi-brittle rocks varying from light-gray to red-gray.

The gold occurs as (1) particles between silt grains; (2) as scattered grains in silica veinlets; and (3) as individual grains in hematite-goethite pseudomorphs after pyrite according to Wells, et al (1969). The gold particles range from 0.5 microns to as much as 100 microns. Post-ore coarse-grained calcite is a common fracture filling.

Alligator Ridge - The Alligator Ridge gold deposit is located 70 miles northwest of Ely, Nevada (Fig. 14). The deposit was discovered in 1976 by a lone prospector working under a grubstake contract for Amselco Minerals, Inc. (Stanford, 1984). Production from the deposit began in the fall of 1980.

Figure 14. Location map for the Alligator Ridge gold deposit, Nevada.



The Alligator Ridge deposit is disseminated micron sized gold hosted by Paleozoic sedimentary rocks. The main area of mineralization occurs in the Pilot shale of Devonian-Mississippian age. The Pilot shale in the Alligator Ridge area (Fig. 15) consists of thin bedded calcareous siltstones and claystones approximately 460 feet thick.

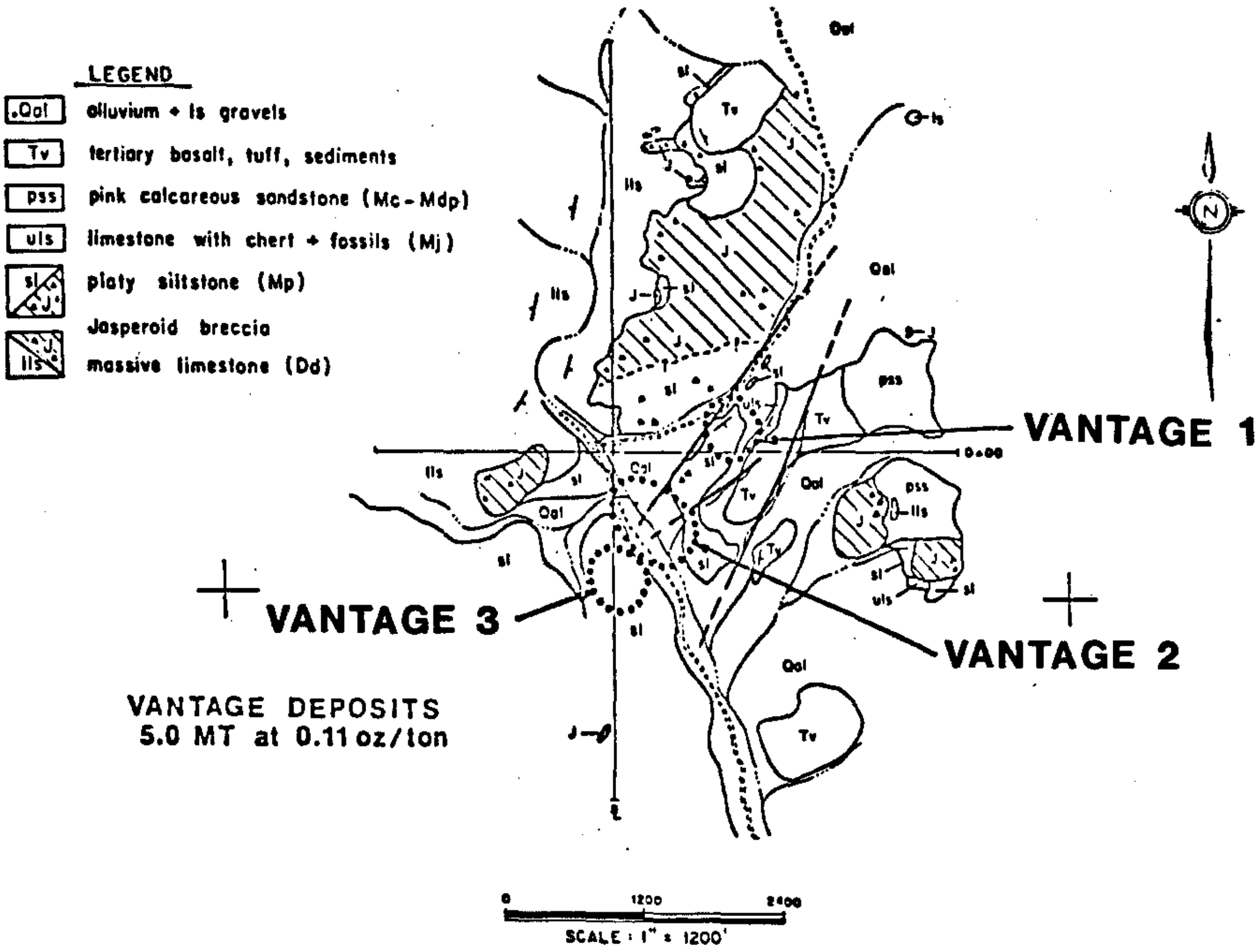


Figure 15. Geologic map of the Alligator Ridge area, Nevada.

The Paleozoic rocks in the Alligator Ridge area have been folded into a series of anticlines and synclines which trend north-south and plunge to the south. The folds have been cut by high angle faults with a northwest trend. The youngest deformation is along northeast trending high angle faults.

The mineralization occurs in both carbonaceous and oxidized rocks. The hydrothermal alteration resulted in carbonate removal, silica deposition and oxidation of sulfide minerals. The rocks have been altered vertically and laterally. The vertical fluid movement appears to have been controlled by fractures and an impermeable claystone cap. The cap may account for the lateral fluid flow along bedding planes. Much of the carbonaceous material observed in the more calcareous rocks at Alligator Ridge is thought to have been introduced by the hydrothermal fluids. Late stage calcite fracture filings cut across bedding, alteration, and ore.

SURFACE EXHALITES

Hot springs and fumeroles provide an excellent place to study epithermal processes because gold is found in presently active systems as well as in older extinct systems. The exhalative material (Beane, 1982) is siliceous sinter, with or without calite, and minor amounts of metastibnite and pyrite (Fig. 16). Below the silica cap is solfataric and argillic alteration which changes with depth into propylitic alteration. The resulting alteration sequence forms a concave upward zoning pattern with the silica cap in the center.

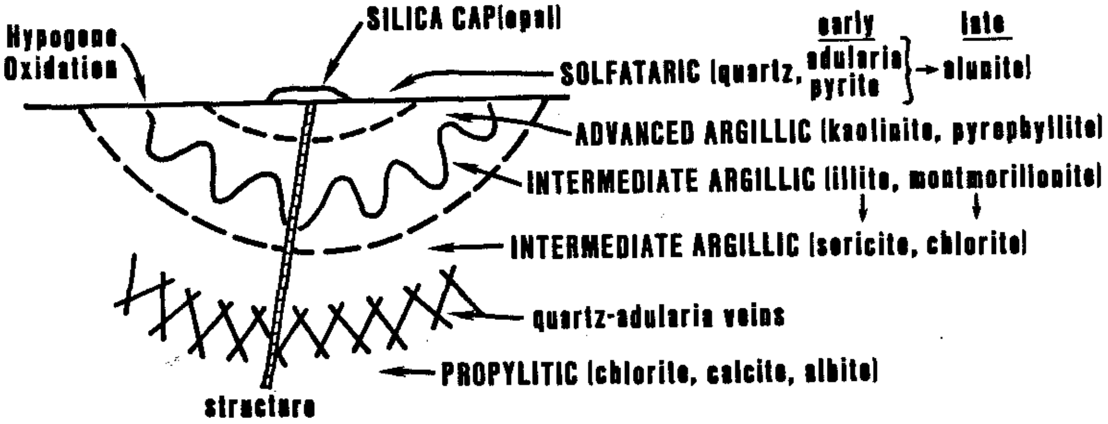


Figure 16. Schematic cross-section of a typical hot spring-epithermal system and alteration tuning.

Steamboat Springs, Nevada - The hot spring system at Steamboat Springs, Nevada is regarded by White (1981) as a modern-day equivalent of geothermal systems which formed the epithermal precious metals deposits of the Great Basin. The siliceous sinter deposits, chemical sediments in the spring vents and veins intersected in the U.S. Geological survey drill holes all contain concentrations of Au, Ag, Hg, Sb, As, B and Tl. The hydrothermal activity in the area (Fig. 17) formed siliceous sinter deposits prior to the eruption of the basaltic andisite flows about 2.53 m.y. ago. At Sinter Hill the U.S. Geological Survey drill hole

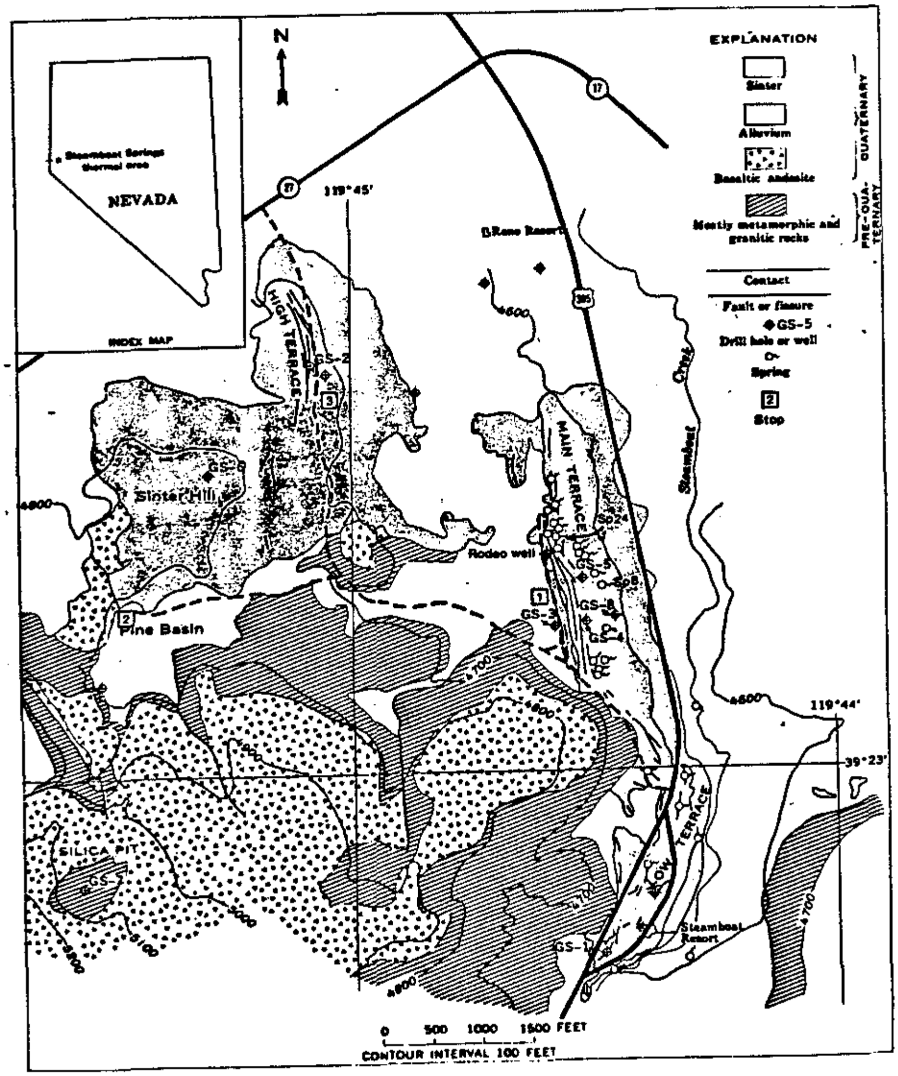


Figure 17. Generalized geologic map of Steamboat Springs thermal area, Nevada, after White, et al., 1964.

penetrated strongly altered basaltic andisite characterized by nearly complete replacement by adularia with a K-Ar age of 1.1 m.y. The alteration probably occurred during the hydrothermal episode which deposited the chalcedonic sinter deposits of Sinter Hill.

The Silica Pit area (Fig. 17) contains solfatarically altered granodiorite and basaltic andisite. The rocks are so strongly altered that their original textures have been destroyed. Opal, alunite, clays, and native sulfur are the solfataric mineral assemblages. Some acid leaching has occurred. The solfataric activity may be related to the subsurface boiling of the geothermal fluids. Minor quantities of cinnabar have been desposited in the opaline residues (White, 1981). Solfataric alteration and acid leaching occur over several other active geothermal systems including Cove Fort, Utah; Dixie Valley, Nevada; and Fish Lake, Nevada.

Broadlands, New Zealand - The Broadlands geothermal system in New Zealand represents one of the most thoroguly studied hydrothermal systems in the world. The Ohaki pool represented the major discharge vent for the system. The pool surface is about 800 m^2 and is lined with a gray-white silica sinter. The pool is located on the surface of a 10,000 m^2 silica mound (Browne, 1983). During 1957 a red-orange flocculent developed in the waters. The amorphous material is antimorny sulfide similar to the metastibnite reported at Steamboat Springs. Studies show the base metal contents and alteration increase with depth in the system. The gold content and pyrite content decrease with depth. The main pyrite zone occurs at a depth of 300 to 400 meters and is associated with adularia and calcite alteration minerals.

The main hydrothermal alteration products at depth are silicate-carbonate assemblages including: quartz-albite-K-mica-calcite-iron-chlorite-and K-spar. The minerals replace primary constituents and also from by precipitation from fluids in vugs and as veinlets. The metal concentrations in the geothermal fluids is very low and their great enrichment in the precipitates suggests that fluids with low initial metal contents can form ore deposits.

Borealis, Nevada - The Borealis gold deposit in Mineral County, Nevada has been described as a hot spring related deposit (Beane, 1982 and Bonham & Giles, 1983). These deposits are silicified breccias and stockworks of quartz-sulfide mineralization found at or very near the pre-mineral surface as evidenced by fossil hot spring sinter deposits.

The ore is typically composed of micron sized gold, electrum, pyrite, marcasite, and sulfosalts. The gangue includes microcrystalline quartz, chalcedony, calcite, and adularia. Host rocks are commonly andesitic volcanics (Giles and Nelson, 1982) which are typically hardened by pre-ore potassium-sodium metasomatism and near surface silica replacement (Fig. 18). Outward from the sulfide bearing core are successive envelopes of alunite, kaolinite and montmorillonite. The silicfication and alteration result in an impermeable seal which restricts upward migration. Hydrofracturing or seismic activity may break the seal. Boiling of the fluids is a common effect of such pressure releases. Such boiling often causes futher hydrofracturing and hydrothermal breccias. The channel ways thus formed allow high flow rates which then raise the boiling level and cause near surface precipitation of the precious metals and sulfides.

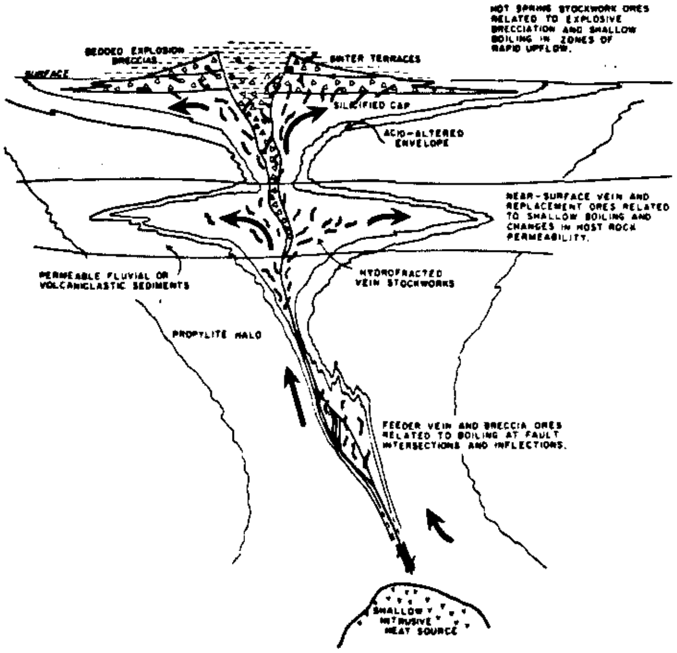


Figure 18. Schematic cross-section of Hot Spring - lude gold deposit, after Giles and Nelson, 1984.

SUMMARY

It seems reasonably clear that epithermal mineral deposits (hot spring lode-gold deposits, stockwork deposits, vein deposits and disseminated deposits) represent different levels or positions within a gecthermal system. Active hot springs systems such as Steamboat and Broadlands are depositing precious metals and sulfides from geothermal waters. The geothermal waters have chemical characteristics similar to those deduced from the limited fluid inclusion data from epithermal mineral deposits, i.e. low salinity and intermediate CO_2 contents. The temperature of formation of epithermal deposits is similar, near 250°C, to that found in the deeper geothermal reservoirs. Finally, the alteration found at depth in active hot spring systems, geothermal systems, is similar to that associated with epithemal deposits. An integrated plumbing system is a prerequisite for both epithermal deposits and geothermal systems.

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