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# Preliminary Study of Hydrothermal Alteration Associated With Hot Spring Activity, Gerlach Area

S. B. Romberger


## ABSTRACT

Alteration of surficial rocks by thermal waters is a phenomenon that may be used to study and understand subsurface geothermal systems. At Gerlach, present hot springs occur along fault scarps in recent valley alluvium. In general, alteration is that to be expected when hot, slightly acid, aqueous solutions come in contact with rocks of granodiorite composition. Silicification is widespread in alteration, indicating silica has been introduced. However, this silica need not have a deep-seated source, but could have been derived locally. No limits can be placed on temperatures of the altering solutions.


## INTRODUCTION

In any natural system involving the activity of hot waters, a characteristic hydrothermal alteration of the rocks will be produced. This alteration can be observed in most recognized geothermal areas, as well as in areas containing common metallic mineralization. The alteration results from the fact that the hot waters percolating through fractures and pore spaces of rocks have a chemical composition which is far out of equilibrium with these rocks. Therefore, the chemical reactions taking place during hydrothermal alteration will be those which bring the chemical composition of the rocks closer to being in equilibrium with the solutions. However, it must be recognized that the rocks have as large an effect on the chemical composition of the aqueous solutions, as the latter has on the mineralogical composition of the rocks, and much of the dissolved material in the waters is derived from the alteration of these rocks. Broadly speaking, the types of chemical reactions involved are: conversion of anhydrous silicates to hydrous silicates, and therefore decrease in bulk density (increase in volume) of the rocks; solution of minerals present in small amounts in the altering solutions; and precipitation of minerals whose solubility has been exceeded in the altering solutions.

The study of hydrothermal alteration in a geothermal system is far from simply academic. Such alteration has been used successfully as an exploration tool in the search for mineral deposits, and there is no reason to believe it would not be helpful in the search and study of geothermal areas. In addition, knowledge of the chemical reactions common to a hydrothermal system would be helpful in the engineering and design of recovery systems. These solutions are typically very reactive, and their mobilization during pumping could result in varying degrees of corrosion, scaling, or some other undesirable chemical change, perhaps resulting in the clogging of the aquifers or plumbing of the geothermal system. Such problems are well recognized in various geothermal fields.

With the above background material in mind, an investigation on the nature of the hydrothermal alteration associated with hot spring activity was carried out in the Black Rock Desert area, as part of a comprehensive study of the geothermal potential of this region. The objective was to determine the nature of the chemical reactions that might occur between the thermal aqueous solutions and the enclosing rocks.

## GERLACH HOT SPRING AREA

A reconnaissance investigation of the Black Rock Desert region suggests the present hot springs are associated with faults bounding the graben occupied by the Black Rock Desert. They occur in recent valley alluvium, and bedrock exposures in the immediate vicinity of the active hot springs are sparse. In these areas it was not possible to study hydrothermal alteration changes. Therefore, a search was made for a bedrock area that might represent an uplifted and eroded remnant of a hot spring area. The most favorable area was a block of altered granodiorite and lake sediments about 1 mile (1.6 km) northwest of the town of Gerlach, just to the west of the active Gerlach hot springs (fig. 1). This area was mapped in detail at a scale of 1 inch equals 200 feet (fig. 2).

In addition to the alteration, this area is characterized by well preserved tufa cones, coatings, and fracture fillings on and in the bedrock. The tufa deposits and intense alteration lie astride a well developed N. 20° E. trending fault zone separating the Black Rock Desert block on the east and the uplifted Granite Range block on the west. A similarly altered area lies along strike about 1 mile to the northeast. Tufa deposits can be traced another ⅜ of a mile along strike to the southeast. The area shown in figure 2 appears to fall on the intersection of the northeast-trending fault zone with a lineament running N. 35° W. which topographically separates Granite Point from the main Granite Range block. This is consistent with the observation that the intersection of fault zones represents a more favorable plumbing for rising hydrothermal solutions than a simple fault plane. Both trends are represented in the area shown in figure 2 by fracture sets consisting of brecciated altered granodiorite and distinct dikes of fragments of altered granodiorite in a fine-grained matrix (fig. 3). The fragments show increasing degree of rotation and transport from the walls, inward to the center of the dikes. In figure 2, the area of extensive tufa coatings and fracture fillings lies right on the best developed fracture zone, which, in this area, strikes nearly north-south (the change in strike of the fault zone in this area may be due to rotation on the northwest set).

The similarity of the structural setting of the tufa deposits and that of the active hot springs suggests that the area of figure 2 is an uplifted and exposed expression of processes taking place under the present hot springs. The tufa deposits and fracture fillings of the former consist of fine-grained calcium carbonate similar to surface deposits around present hot springs. We have an additional dimension in that it appears that the north end of the area in figure 3 has been eroded deeper, perhaps by a few tens of feet, than the southern end. Therefore, a study of the alteration in this area may give us an idea of the chemical processes taking place under the active hot springs.

# NATURE OF ALTERATION

The unaltered granodiorite is medium to coarse grained, equigranular consisting primarily of plagioclase and orthoclase,

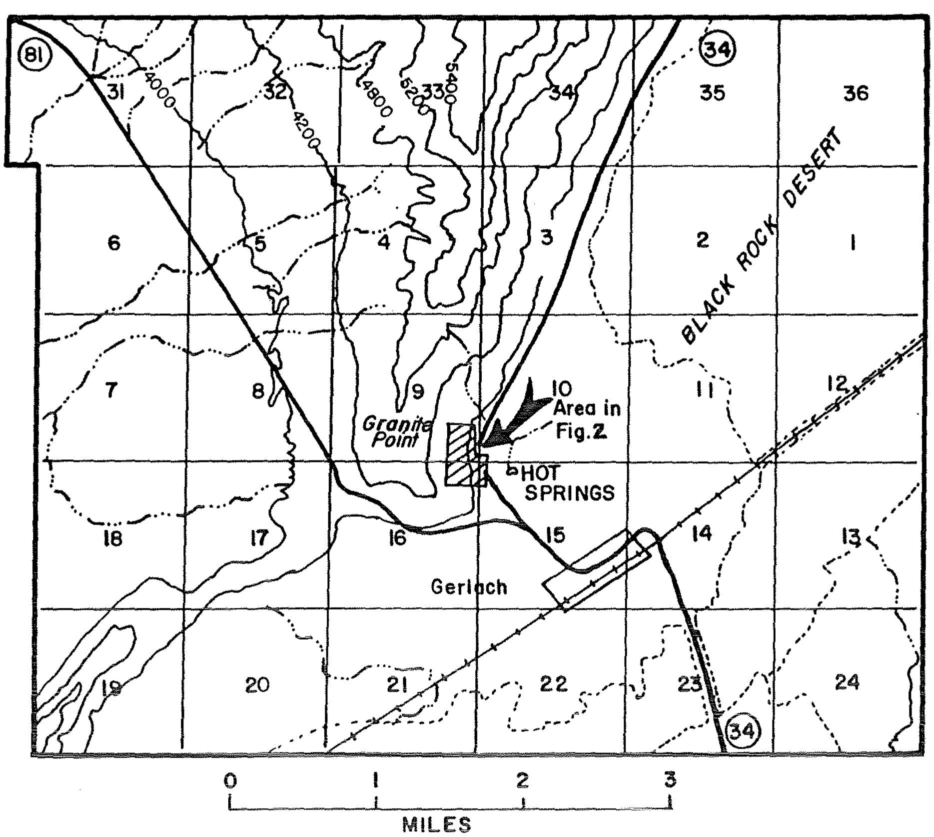


Figure 1.—Location of study area, Gerlach, Nevada.

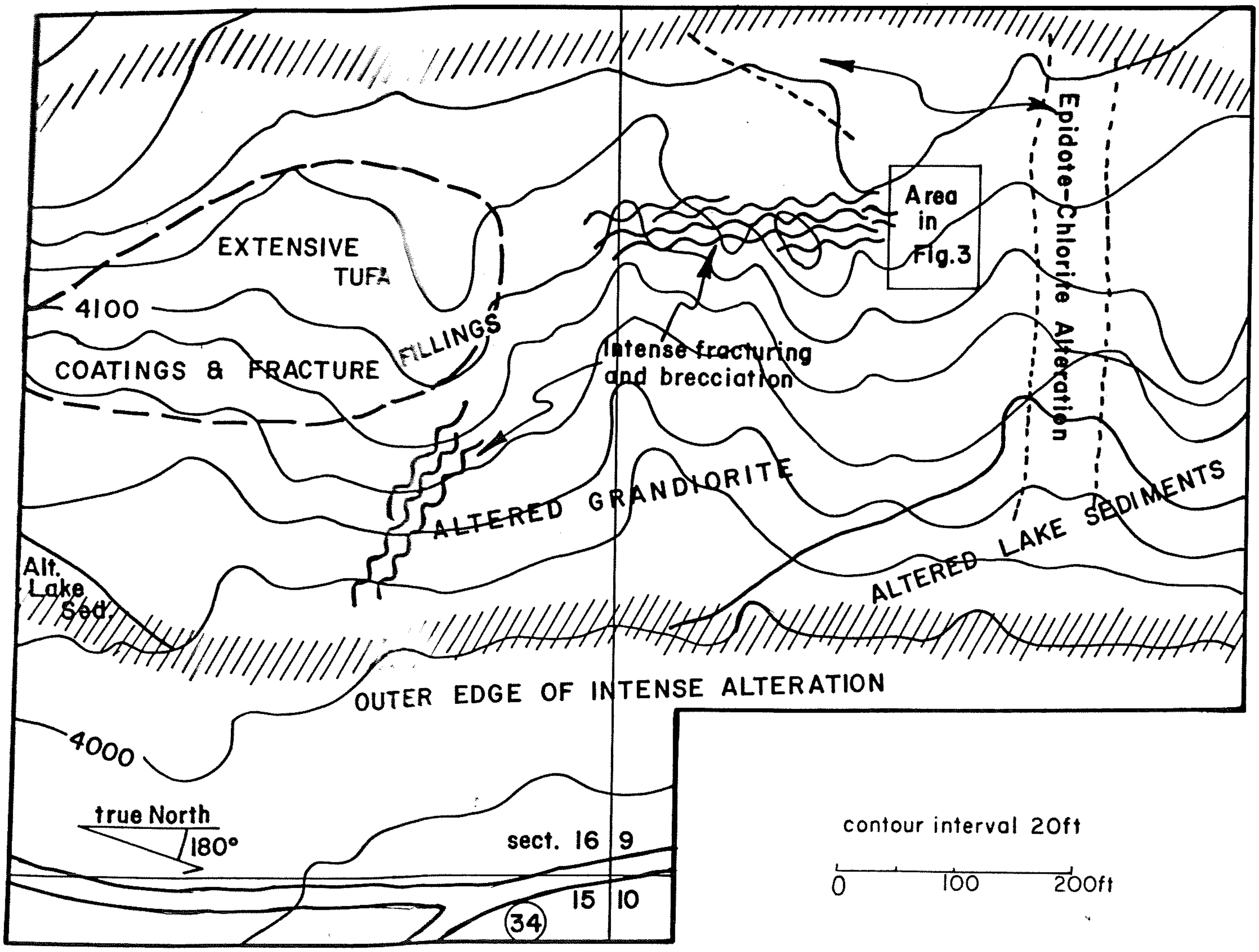


Figure 2.—Geologic map of study area, Gerlach, Nevada (see fig. 1 for location).

with lesser amounts of biotite and hornblende. Younger pods, lenses, and dikes of granitic aplite occur, with one prominent strike direction of N. 50° E. The rocks of Granite Point are relatively fresh; however, as the area of figure 2 is approached from the west, alteration becomes apparent. Biotite and hornblende gradually become converted to chlorite, and epidote replaces plagioclase. This is the common propylitic grade of alteration observed in hydrothermal mineral deposits.

There is no sharp contact between the low-intensity propylitic alteration to the west, and the intensely altered area of figure 2. Transition between the two zones appears to take place over a distance of about 100 feet (30 m). In general, the rocks in the area shown in figure 3 have been stained red, indicating the oxidation of iron. However, it is not clear if only the iron existing in the ferromagnesian minerals in the original granodiorite has been oxidized, or if additional iron has been introduced by the thermal waters. The only megascopically recognizable mineral from the original granodiorite is orthoclase. In the dikes of altered granodiorite breccia, the matrix is considerably more oxidized than the fragments. Although hand specimens of granodiorite do not indicate silicification, petrographic study of thin sections show this to be taking place.

The lake sediments appear to show the same type of alteration as the granodiorite, and in places altered sediments are indistinguishable from altered granodiorite in hand specimen. In other places, however, the sediments have been silicified to a dense, hard rock, particularly at the north end of figure 2. In this same area originally flat-lying beds have been tilted up by movement along faults.

There are two areas in figure 2 worthy of special note. At the north end is a zone of chlorite-epidote alteration running nearly east-west, and another less distinct zone about 400 feet south at the west edge. Here, the granodiorite has been altered to fine-grained clay, chlorite, and some epidote; the proportions of the various minerals varies from place to place. Where the east-west zone intersects the altered lake sediments, the latter are intensely silicified, and also include a fine-grained green mineral.

Also in this area several branching and cross-cutting dikes of

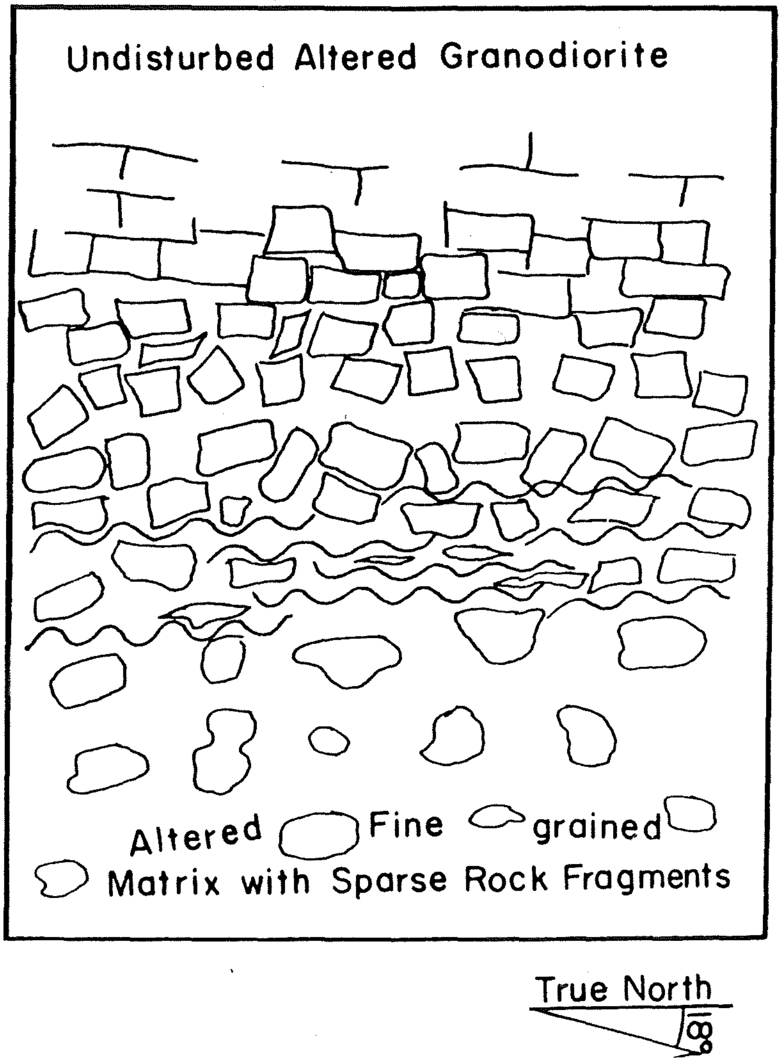


Figure 3.—Schematic showing the brecciation along north-south fault zone (see fig. 2 for location). Blocks not to scale.

tufa-like material occur, indicating this area was an active hot springs at one time. Small veins and dikes, from 1 to 4 inches (25.4 to 101.6 mm) wide, consisting of clay and chlorite, occur with fracture fillings of tufa in the area of extensive tufa coatings and fracture fillings. These are cross-cut by the tufa fracture fillings. Where the argillic alteration occurs, the red color of the altered granodiorite is bleached out, indicating either a reduction or mobilization of the iron.

Some general statements can be made on the nature of the alteration processes responsible for the mineralogical changes in the rocks described above. In general, the alteration is what would be expected when hot, slightly acid, aqueous solutions come in contact with rocks of granodiorite composition. At this time no limits can be placed on the temperatures of the altering solutions. The low grade propylitic alteration is characterized by the addition of water, hydrogen ions, and possibly carbon dioxide to the rocks, with the loss of very little material. The slightly higher grade argillic alteration is characterized by the same additions, with the loss of alkali and alkaline earth elements, and the mobilization of silica. No alteration higher than argillic is evident in the Gerlach area. No evidence of sulfides has been found. Silicification is widespread in both the granodiorite and lake sediments, indicating silica was introduced into the system. However, this silica need not have a deep-seated source, but could have been derived locally during the argillic alteration of the wall rocks.