EXTENSIVE ZEOLITIZATION ASSOCIATED WITH HOT SPRINGS IN CENTRAL COLORADO

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Abstract.—Extensive zeolitization that accompanied formation of laumontite-leonhardite in shattered quartz monzonite at the base of Mount Princeton in central Colorado is attributed to hot silica- and calcium-bearing alkaline waters reacting with the country rock at depth. The shattered and altered rocks and active thermal springs are related to faults that are part of the upper Arkansas Valley structure system. Apparent zoning of mineral assemblages around the thermal centers seems similar to that in other thermal areas, and is significant in terms of depth of formation, temperature, and pressure.

Two masses of shattered quartz monzonite are exposed as conspicuous white, chalky bluffs along Chalk and Cottonwood Creeks at the base of Mount Princeton in Chaffee County, Colo. These bluffs are outstanding mostly because of their color, which is largely a result of abundant leonhardite, a calcium zeolite. Hot springs issue from the base of the cliffs in both creek valleys; the Mount Princeton Hot Springs occur at Chalk Cliffs on Chalk Creek, and the smaller Cottonwood Hot Spring occurs along Cottonwood Creek.

The purpose of this paper is to briefly describe these occurrences of zeolitized rocks, and to give some suggestions as to their possible geologic significance.

Chalk Cliffs at Mount Princeton Hot Springs has been a landmark in central Colorado for many years. The white, rubbly, steep bluffs rise several hundred feet above the hot springs along Chalk Creek, and form the north wall at the entrance of Chalk Creek canyon, which is along the west side of the Arkansas Valley (fig. 1). Mount Princeton, with an altitude of 14,197 feet, towers over these cliffs, which have been well known from the time of legendary Indian visits before white settlement, through the mining and railroad operations in 1880's, the grand hotel-spas in 1920's, to the present era of modern swimming pools and commercial greenhouses. Indians allegedly used caves formed in the cliffs as steam baths and healing sites. This bit of folklore does not seem to be borne out by the nature of the caves, which are not spring sites; nevertheless, the place has been an attraction for many years. Hortense Hot Spring, one of the Mount Princeton Hot Springs group, is the hottest spring (83°C) in the State. Its output is used largely as a heat source in greenhouses and mountain homes.

Cottonwood Hot Spring, on Cottonwood Creek, a few miles to the northwest of Chalk Cliffs near the mouth of the narrow creek valley, marks a smaller thermal area than that of the Mount Princeton Hot Springs, but is similarly situated at the edge of a large zeolitized mass exposed for several miles along Cottonwood Creek. The cliff walls of the valley are considerably less spectacular than Chalk Cliffs, and are generally less zeolitized.

GEOLOGIC SETTING

The regional geology is generalized in figure 1. The structural framework of the upper Arkansas Valley is only partly understood. The elements shown were compiled from field studies and photographic interpretation by the author, from recent mapping by Van Alstine (1966) and Brock and Barker (1966), and from unpublished gravity work of J. E. Case, all of the U.S. Geological Survey.

The upper Arkansas Valley north of Salida is a narrow, north-trending, downdropped trough bounded by a complex of mostly normal, steeply dipping faults. This structural valley is accentuated by a rugged mountain system on the west and rugged but less conspicuous highlands on the east. The east side of the trough is marked generally by a single, narrow fault zone. The boundary faults on the west side appear to be more complex, and the total downward displacement is accumulated along several faults both paralleling and transecting the valley.

The sediments in the Arkansas Valley are river deposits of the Dry Union Formation of Miocene and

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Cottonwood Sp. Chapin (1971)

southern Rocky Mountains were beveled by an erosion surface of moderately low relief in the Late Eocene; thus the disappearance of great thicknesses of Oligocene volcanic rocks across the rift must be ascribed to Late Tertiary uplift and erosion rather than to nondeposition. Assuming an average elevation of 2,000 feet for the erosion surface in Late Eocene time, minimum uplift was approximately 5,000 to 12,000 feet during Late Tertiary time for ranges east of the rift and minimum subsidence was 4,000 to 24,000 feet within the rift. Numerous fault scarps cutting alluvial fans and Pleistocene surfaces indicate that differential movement is continuing.

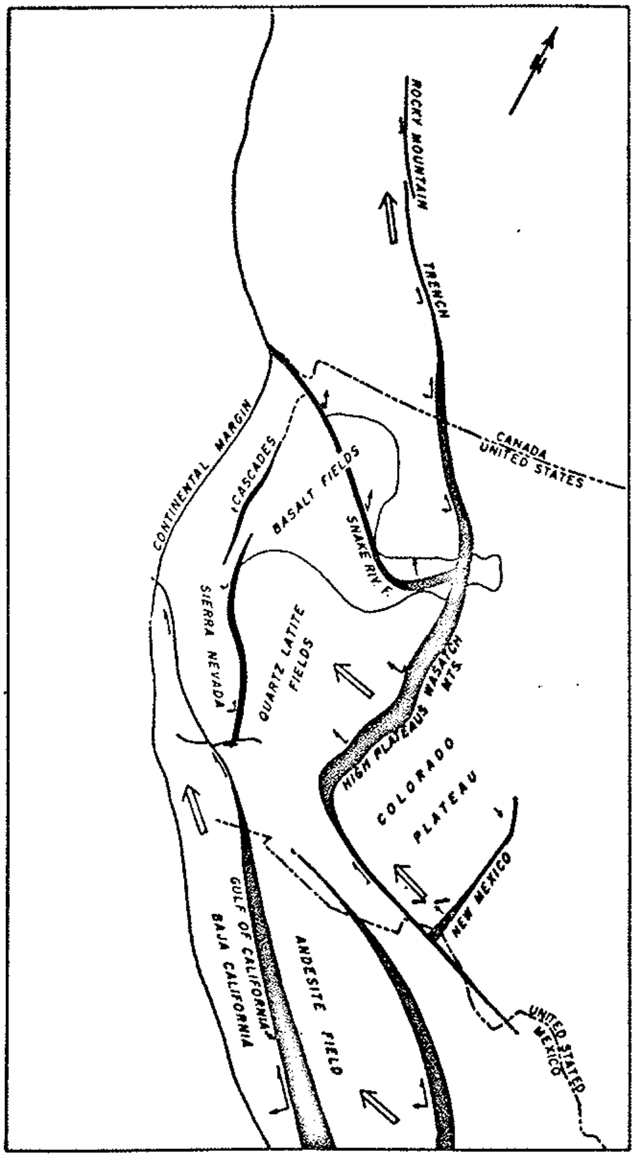

FIGURE 3.

Diagrammatic map exploring the concept of extension and drift affecting western North America. Black lines represent amount of expansion as if localized along a few separations. Small arrows represent apparent vectors of movement; large arrows the apparent resultant direction of the movement. From Eardley (1962, p. 510) with slight modifications along the Rio Grande rift.

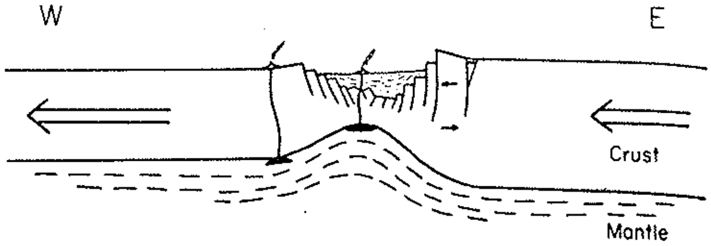

FIGURE 4.

Hypothetical cross-section of the Rio Grande rift. The large arrows indicate direction and relative rate of drift of continental plates. The small arrows indicate a force couple acting on the east shoulder of the rift. Freund (1965, p. 340) has experimentally produced a similar, but symmetric, model of the rifting and "necking" of sand above a convection current in a heavy fluid substratum.

Synthesis of the above observations suggests the following model (see figs. 3 and 4): (1) the continental plate west of the rift is drifting faster than the continental interior (mantle convection may be pulling it over the East Pacific Rise in a "conveyor belt" manner similar to that suggested by Cook, 1962); resultant crustal attenuation formed the Basin and Range province and is splitting the Colorado Plateau block away from the interior; (2) the east side of the rift developed greater structural relief due to riding up of thicker crust onto an upward bulge of mantle material beneath the rift; (3) the west side of the rift is relatively subdued due to crustal stretching accompanied by abundant normal faulting and a tendency to pull the crust away from the mantle bulge beneath the rift; (4) stretching and normal faulting along the west side relieves subcrustal pressure and provides avenues for ascent of magmas and hydrothermal solutions; (5) longitudinal faults along the east side are relatively tight and unconducive to magmatism; westward drift of the interior block against the mantle bulge tends to rotate the fault planes to a near vertical position and may change the sense of movement from normal to reverse; (6) northwestward drift of the Colorado Plateau as suggested by Eardley (1962) causes a slight clockwise rotation against the north end of the rift which tends to keep it tight and relatively free of volcanism; this may also explain the unusually high upthrusting of the Sangre de Cristo horst along the east side of the San Luis Valley; (7) continued widening of the Rio Grande rift in New Mexico appears to be accelerating volcanism and may cause the rift to evolve into a lava-filled trough similar to the Snake River rift.

THE UPPER ARKANSAS GRABEN AND PROBLEMS OF THE NORTH END

North of the San Luis Basin of Colorado, a narrow, north-tapering, sharply defined trough extends for at least 60 miles to the continental divide north of Leadville (fig. 2). That this basin is a graben with a tectonic style similar