GEOLOGY AND ALTERATION OF THE RAFT RIVER GEOTHERMAL SYSTEM, IDAHO

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ABSTRACT

Alteration zoning in the Raft River geothermal system is similar to other moderate-temperature liquid dominated systems. X-ray analyses of cuttings from deep exploration test wells indicate that montmorillonite occurs primarily in the outer portion of the system and that with increasing temperature, montmorillonite is replaced by chlorite and mixed-layer clay. Kaolinite and illite are present throughout the system. A parallel change is recorded in the distribution of zeolites. Clinoptilolite is the dominant zeolite in the low temperature portions of the field. Within the higher temperature portions of the field which are characterized by chlorite and mixed-layer clay, wairakite/analcime and laumontite are the important zeolites.

INTRODUCTION

Purpose and Scope

This report describes geological and mineralogical data from the Raft River geothermal system located in Cassia County, Idaho. The study was sponsored by the U.S. Department of Energy in support of DOE's Hydrothermal Injection Research and Development Program. The purpose of the study was to characterize the subsurface stratigraphy and geothermal mineral assemblages present in the Raft River system that could ultimately affect the results of injection research studies.

Previous Investigations

A geothermal exploration program was begun during 1973 by the U.S. Geological Survey in cooperation with the U.S. Department of Energy. Results of these early programs were summarized by Williams and others (1976). Covington (1980) later described the subsurface geology and factors contributing to the convective hot water system based upon drilling data from deep exploration and production wells. A report presenting and interpreting the geological, geophysical, geochemical, and hydrologic data was subsequently compiled by Dolence and others (1981).

GEOLOGY

Regional Setting

The Raft River Known Geothermal Resource Area (KGRA) is situated in Cassia, County, Idaho within the northeastern Basin and Range physiographic province near the southern border of the Snake River Plain and the western border of the Middle Rocky Mountain province.

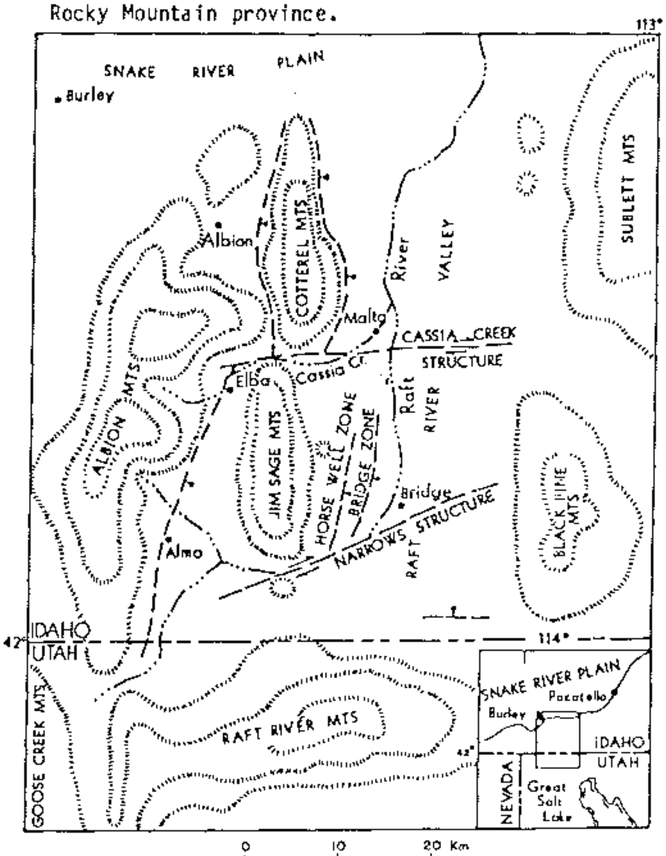

Figure 1. Regional Location Map

The Raft River Valley (Figure 1) is a north-trending Cenozoic structural basin (Covington, 1980) bounded on the west by the Jim Sage and Cotterel Mountains, which are composed of Tertiary rhyolitic volcanic rocks and volcaniclastic sediments. Allochthonous Paleozoic rocks are exposed to the east in the Black Pine and Sublett Mountains. The Raft River Range to the south and the Albion Mountains to the extreme west are composed of an autochthonous gneiss-dome complex of Precambrian adamellite mantled by metasedimentary rocks. Compton and others (1977) have described two major allochthonous sheets exposed within the Raft River Range resulting from regional metamorphic events that occurred during Oligocene (ending before 38.2my) and Miocene (still underway at 24.9my) times. Metamorphic relationships from these studies further indicate as much as 30km of eastward transport after metamorphism. Results from age dating indicate that some localities cooled below temperatures of 400°C as late as 10my ago.

Covington (1982) has proposed a tectonic denudation model for the Raft River basin to account for the absence of allochthonous Paleozoic rocks beneath the Raft River KGRA, and the chaotic nature of seismic reflectors within the thick Cenozoic basin fill.

Mapped geologic relationships and geophysical anomalies have indicated the existence of two steep, deep seated transcurrent structures called the Narrows and Cassia Creek structures (Covington, 1982). The Narrows structure, which may influence the geothermal system, passes through the lower Narrows of the Raft River at the southern end of the Jim Sage Mountains, and through the Raft River KGRA (Figure 1). Surface exposures of volcanic rock units on opposite sides of the lower Narrows indicate right-lateral offset along the Narrows structure. Eastward along the Narrows zone, there is no direct evidence for the existence of a discrete structure. The Bridge and Horse Wells fault zones terminate southward at their apparent juncture with the Narrows structure. Seismic data suggest numerous discontinuities within the Cenozoic basin fill within the zone, but deep drilling data indicate no apparent disturbance of the basement rocks. Cenozoic basin fill south of the structure appears less indurated than to the north.

Covington (1982) has proposed that the Narrows structure is a near vertical detachment surface within Cenozoic basin fill that has allowed lateral movement at the southern end of the Jim Sage Mountains.

Precambrian Rocks

Precambrian rocks penetrated by deep test wells in the Raft River KGRA are comprised of adamellite (quartz monzonite) basement overlain by a series of schists and quartzites. The adamellite has been described by Covington (1977) as gneissic, light to dark greenish-gray with a trace of pyrite and magnetite. Adamellite is overlain locally by the Older Schist, a discontinuous biotite-chlorite-muscovite-rich quartz-schist. The Elba Quartzite, a muscovite bearing quartzite, rests locally upon the Older Schist. Where the Older Schist is absent, the Elba rests directly upon adamellite. The Upper Narrows Schist, a biotite-muscovite-quartz schist, and the discontinuous Yost Quartzite overlie the Elba Quartzite.

Salt Lake Formation

Mid-Tertiary rocks of the Salt Lake Formation comprise a thick (up to 1600m) sequence of tuffaceous sedimentary rocks of largely fluviatile and possibly lacustrine origin. Fine grained tuffaceous lithologies predominate in the section with conglomerate as a minor rock type. Siltstone and sandstone of the Salt Lake Formation, as seen in core samples have been deformed by numerous high angle microfaults and bedding convolutions. Bedding is commonly inclined 10 to 30 degrees.

Raft Formation

Non-indurated Pleistocene deposits consisting of quartz sand, silt, and gravel which overlie the Salt Lake Formation and reach thicknesses of up to 300m have been assigned to the Raft Formation (Dolence and others, 1981). The Raft Formation - Salt Lake Formation contact is gradational and difficult to distinguish.

Hydrothermal Model

The Raft River geothermal system (Figures 2 and 3) is characterized by up to 1600m of Tertiary and Quaternary (Salt Lake Formation and Raft Formation respectively) basin fill unconformably overlying Precambrian metasediments, which in turn overlie Precambrian adamellite.

Geothermal fluids originate through deep circulation of meteoric water within an area of moderate thermal gradient. The primary reservoir rocks are fractured crystalline basement rocks which are probably recharged within the Raft River and Albion mountains where correlative rock units are exposed. The geothermal fluids penetrate upward through the overlying Tertiary volcaniclastic sediments through numerous faults and open fractures (Figure 3). Numerous open fractures have been determined from borehole televiewer logs (Keys and Sullivan, 1979), and core samples taken from drilling. Covington (1982) depicts the fault conduits as increasing in frequency with increasing depth and to be listric or concave in nature.

ALTERATION STUDIES

Mineralogic zonation patterns for zeolites and clay minerals were obtained from X-ray powder diffraction analysis of cuttings. The samples were composited over a 30 foot drilled interval beginning at each 100 foot level in the subsurface.

Figure 4 illustrates the zonation of clay minerals within the Raft River system. In general, clay mineral alteration is greater within the volcaniclastic sedimentary rocks of the Salt Lake Formation than within the crystalline basement. Montmorillonite is prevalent at high levels within the system, giving way to corrensite (or mixed layer clay) and chlorite at lower levels. Illite appears throughout most of the system and may be, in part, detrital in origin. Kaolinite is ubiquitous throughout the system, particularly at depths greater than 3500 feet.

Figure 5 illustrates the general occurrence of zeolites within the Raft River system. Clinoptilolite associated with minor natrolite is present to depths of about 2000 ft. Wairakite and/or analcime, and laumontite are the predominant natural zeolites at greater depths.

Clay mineral distributions within the Raft River system display temperature-depth relationships similar to those of other geothermal systems. Elders and others (1980), for example, defined the vertical distributions of hydrothermal minerals with respect to temperature at Cerro Prieto. They showed that montmorillonite and kaolinite occurred in moderate temperature zones (100 to 150°C) whereas chlorite and illite were characteristic of the higher temperature (175 to 225°C) regimes. Clay minerals within New Zealand geothermal systems have been observed to change, with increasing depth and temperature, from Ca-montmorillonite becoming increasingly stratified with illite, to illite and chlorite, which dominate the assemblage at temperatures greater than 220°C (Browne, 1978).

CONCLUSIONS

Studies of the alteration mineralogy of the Raft River KGRA have revealed mineral assemblages similar to the low and moderate temperature regimes of other geothermal systems. Using Elders' mineral zonation versus temperature data as a model, temperature predictions were made in the Raft River system. Figure 4 shows postulated paleo-temperature distribution based upon Elders' model. The mineral zones suggest that temperatures may have been higher in the past than those presently observed.

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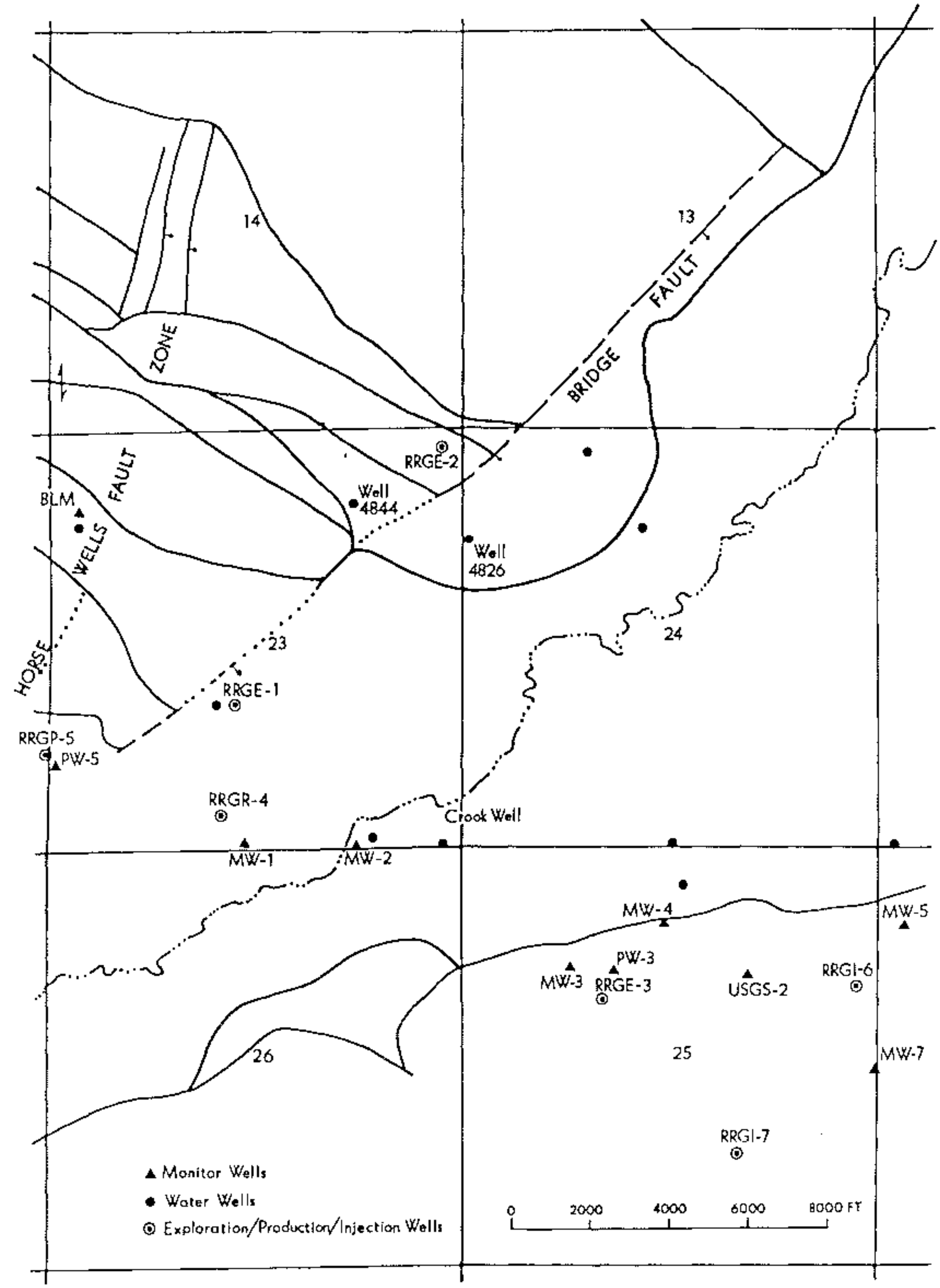

Figure 2: Raft River Well Field Diagram

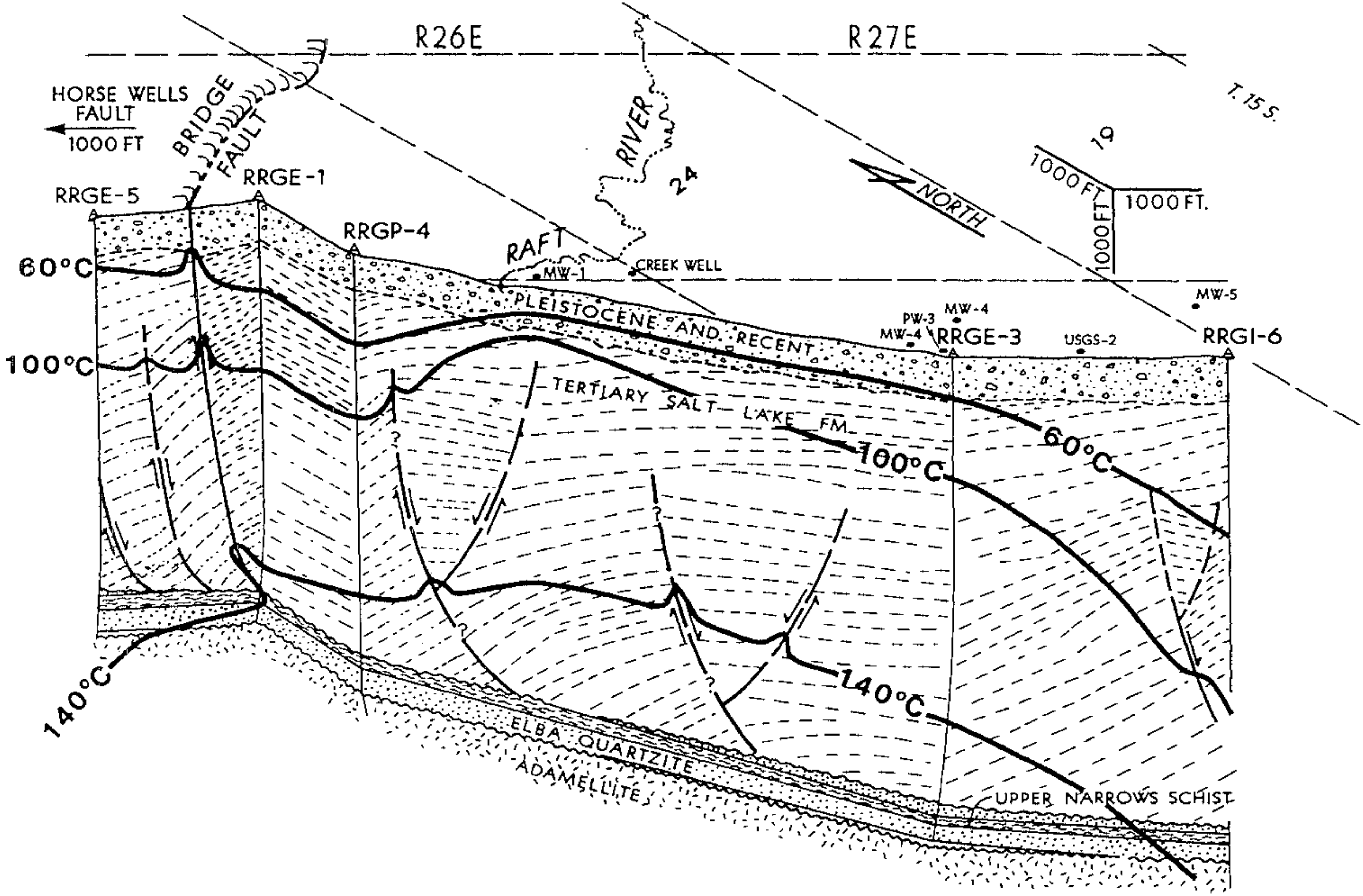

Figure 3: Isometric diagram showing subsurface geology and temperature distribution within the Raft River geothermal system.

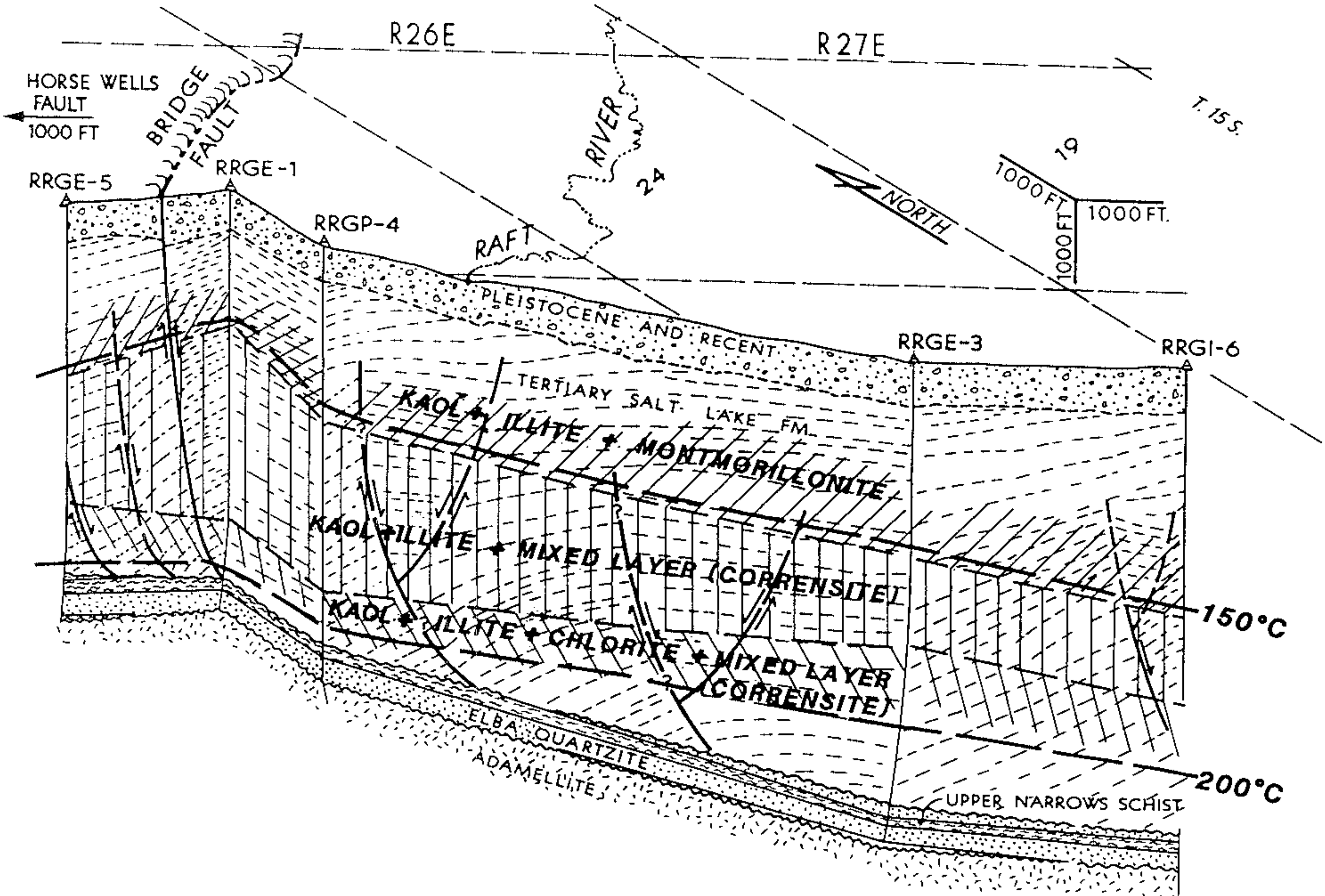

Figure 4: Generalized zonation of clay minerals within the Raft River geothermal system.

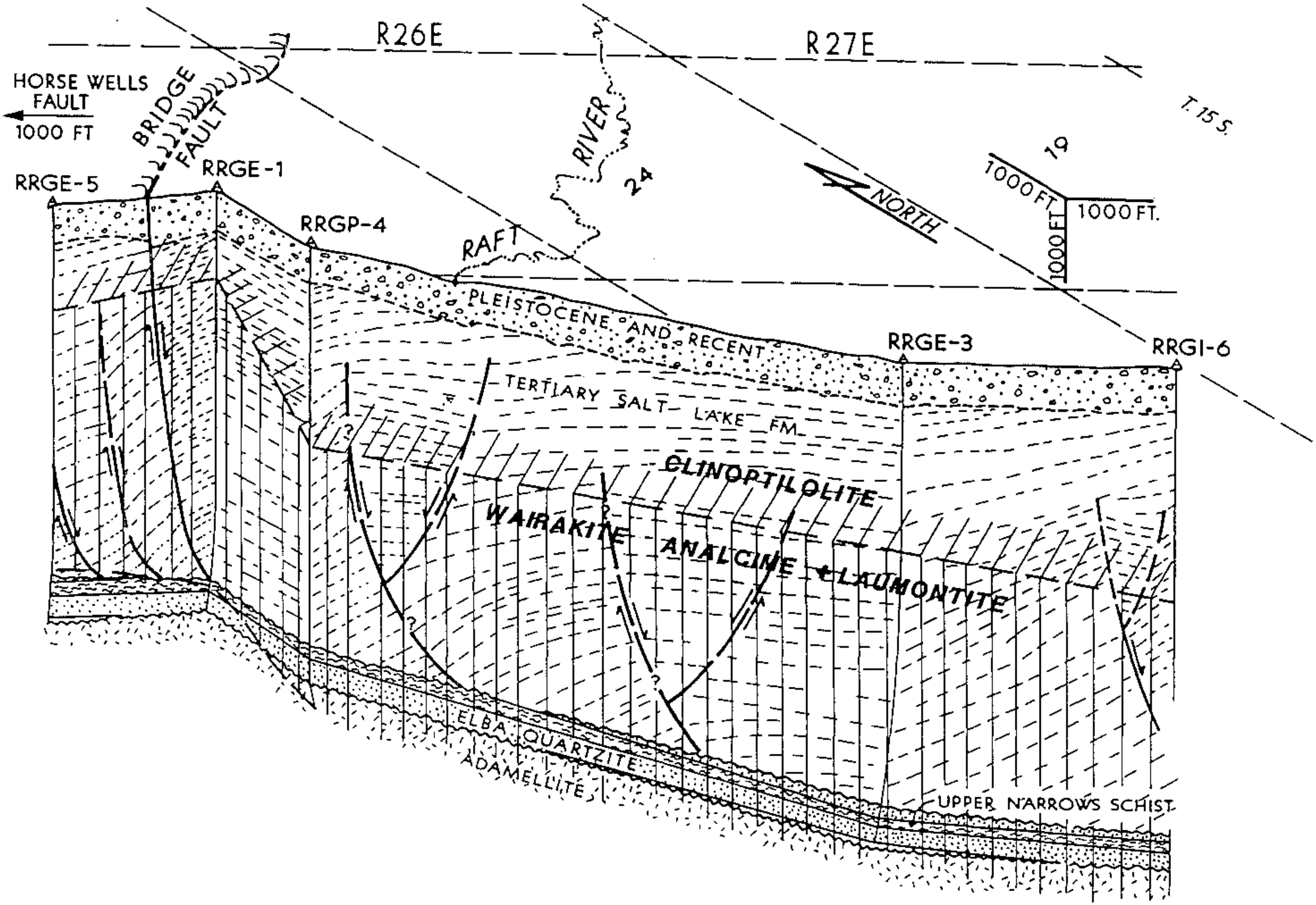

Figure 5: Generalized zonation of natural zeolites within the Raft River geothermal system.