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Delineation of Ground-Water Flow Systems in Nevada

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A far more commonly observed temperature range extends from the mid 50's to the mid 60's (°F). These temperatures average about 10°F above local average air temperature, and they prevail in many shallow or moderate depth wells constructed within most alluvial basins in the northern half of the state. These temperatures appear to be associated with ground water that has circulated to moderate depths in "local" ground-water systems.

A third temperature range frequently noted in ground water in Nevada is between the mid 60's to about 80°F. Temperatures within this range are often observed in relatively deep wells constructed in foothills or valley margin areas in the northern part of Nevada, in vicinities of thermal springs throughout most of the state and within alluvial basins in several areas of southern Nevada. These temperatures seem to be either associated with 1) lateral flow in moderate to low permeability rock environments where depth to saturation is commonly several hundred feet, 2) ground water which has circulated to moderate depths through indurated rocks which permit interbasin or regional flow systems and 3) ground water associated with localized concentrations of thermal ground water, usually near major structural features.

Locally, many areas within the state have even higher ground-water temperatures. In general, occurrence of hot wells and springs is more localized areally than lower temperature ground water. In areas of thermal ground water there is not necessarily a direct correlation between depth and encountered temperature of ground water (for example in the southwestern part of Truckee Meadows and in Pahrump Valley), yet there seems little doubt that the frequent occurrence of abnormally high temperatures observed in ground water is related to deep circulation.

Many geothermal gradients (change in temperature with respect to depth) could be illustrated in Nevada by picking the area. However, it seems likely that the gradients of 1° F to 2°F per 100 feet of depth are more common than 3°F per 100 feet or more. If so, an approximate idea of depth of circulation of waters commonly encountered can be made, *i.e.*, waters in the 55°F to 65°F range may not have circulated much deeper than 2,500 feet, and perhaps much less. Similarly, waters of 65°F to 80°F may have circulated to about 4,000 feet of less. On the other hand, waters with temperatures much over 80°F are likely to have circulated quite deep, perhaps greater than 4,000 feet. Deep drilling in eastern Nevada has indicated "vuggy" porosity in dolomite to depths greater than 10,000 feet (Lintz, 1957, p. 61) and caverns to greater than 4,000 feet (Lintz, 1957, p. 47). Also several reports of "fresh" water at depths greater than 4,000 feet (Nevada Oil and Gas Commission files) from drill stem tests would suggest deep circulation of considerable flux, and Nevada Test Site deep well samples and fluid potential measurements fully confirm similar deep circulation of ground water (Winograd, 1963).

In Nevada, it appears that average heat flow may be in the neighborhood of 2.1 to 2.36 $\mu cal/cm^2$ sec. (Lee and Uyeda, 1965), however, local areas are known to have much higher rates (White, 1957a). the "normal' geothermal gradient of Nevada may be higher than many other continental areas where heat flow measurements cluster around 1 $\mu cal/cm^2$ sec. However, a multitude of complicating conditions makes it difficult to recognize truly representative measurements. For example, in hydrothermal areas most authorities agree that abnormal heat flow and temperature gradients are a result of heat being transferred to near land surface by upward circulating high temperature water. Thus, on a local basis and perhaps even in some entire ground-water basins, upward movement of ground water may be a more efficient mechanism of heat transfer than normal conductivity, and in some situations may be sufficient to greatly modify the "normal" gradient of an area.

Significant to flow system analysis is the apparent meteoric source of the majority of high temperature ground water. Several studies (Craig, *et al.*, 1954, 1956; White, 1957a, 1957b, 1961, White *et al.*, 1963; DeGrys, 1965) have demonstrated that most, if not nearly all, thermal ground water that has been studied in detail is in some manner related to the normal hydrologic cycle. Water chemistry and stable isotope studies as well as other considerations indicate that in any given sample the majority of water is meteoric water (from precipitation) not greatly different from other ground water in the region with respect to certain isotope ratios. Thus, ground-water temperature may be used to study configuration of circulation. The heat displayed by ground water is somewhat a relic parameter, just as is water chemistry, and as such may indicate environments through which it has passed. It is suggested that temperature gives rough indication of depth of circulation in ground-water flow systems, but unfortunately its value is weakened by the usual absence of knowledge of the source of heat in any particular area.

The actual source of heat is problematical. Usually the immediate heat source cannot be clearly delineated in a tectonically active environment such as Nevada. Localized Quaternary volcanism is known throughout much of the Basin and Range Structural Province, as well as is the existence of deep-seated and relatively active faults. Where some sub-surface temperature data is available in Nevada, such as from wildcat test holes and AEC test holes in central and southern Nevada, temperatures at depth are relatively uniform over large areas. Unfortunately, most temperature data has been obtained in freshly constructed wells where temperature equilibrium has not been reestablished at the time of