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INTERBASIN MOVEMENT OF GROUND WATER AT THE NEVADA TEST SITE

By Isaac J. Winograd

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This report is preliminary and has not been edited for conformity with Geological Survey format.

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ILLUSTRATIONS

INTERBASIN MOVEMENT OF GROUND WATER AT THE NEVADA TEST SITE

By

Isaac J. Winograd

Hunt and Robinson (1960) have suggested that ground water may be moving through ridges of Paleozoic carbonate rocks that separate Death Valley from the flanking intermontane basins. Their argument is based upon chemical analyses of spring water.

The present paper presents hydraulic evidence for the interbasin circulation of ground water through carbonate rocks of Paleozoic age at the Nevada Test Site. An integral part of this evidence is the discovery that aquifers in alluvium and tuff, formerly thought to be the principal aquifers at the Test Site, are semiperched above a thick tuffaceous aquiclude that separates them from the carbonate rocks.

This paper is based on one of the studies being made by the Geological Survey for the Atomic Energy Commission. These studies seek to evaluate the risk that may arise if ground water should be contaminated as a result of underground nuclear detonations at the Test Site.

The Nevada Test Site is in the Basin and Range Province in south-central Nevada just north of the California State line, and northeast of Death Valley and the Amargosa Desert (fig. 1). The Test Site includes three large intermontane basins—Yucca Flat, Frenchman Flat, and Jackass Flats (fig. 2). Yucca and Frenchman Flats are closed topographically, whereas Jackass Flats is drained southwestward into the Amargosa Desert. The valley floors are at altitudes ranging from 3,000 to 4,000 feet. The intervening mesas, ridges, and low mountains rise to a maximum altitude of about 7,500 feet. The area drained into Yucca and Frenchman Flats and the southern half of the Jackass

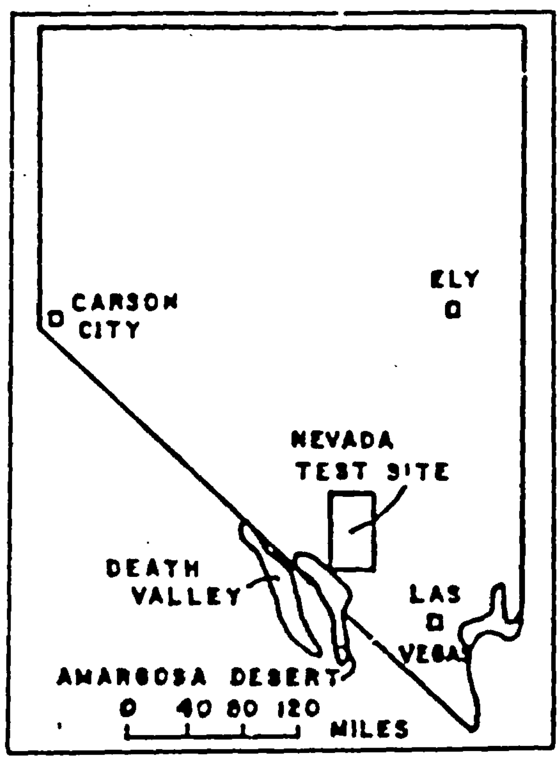

Figure 1.--Index map showing Nevada Test Site, Death Valley, and Amargosa Desert.

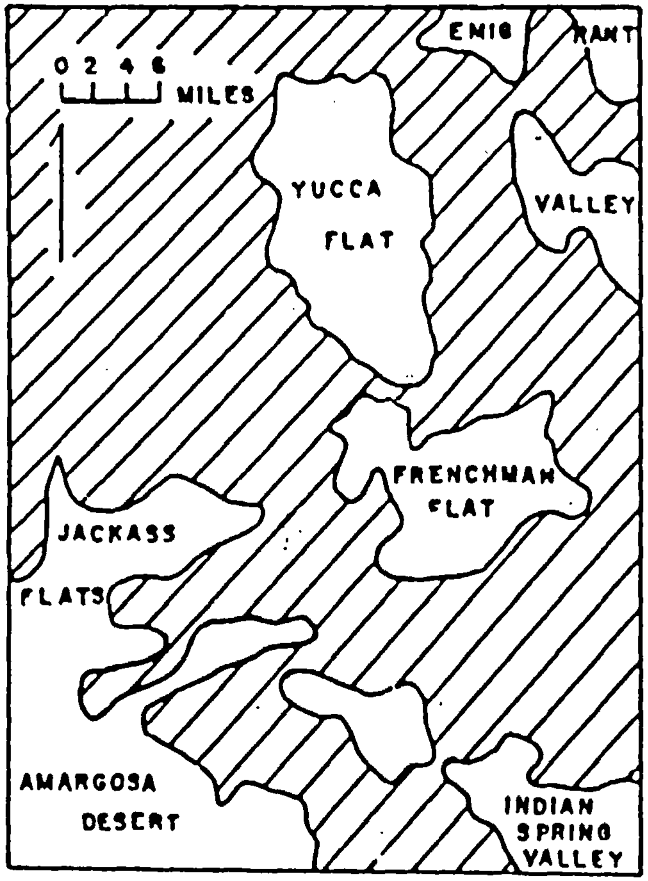

Figure 2.--Major intermontane basins at Nevada Test Site.

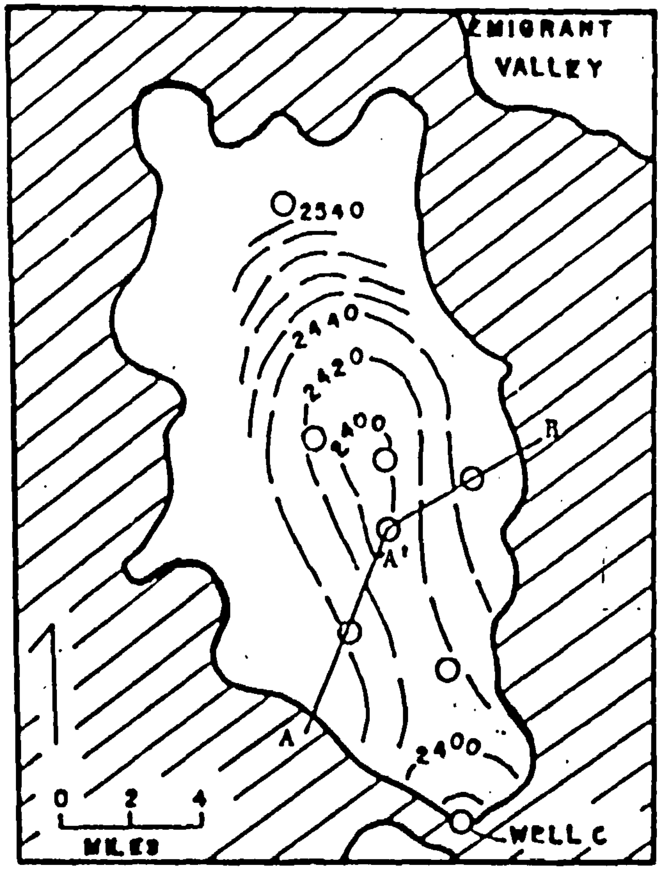

Figure 3.--Configuration of potentiometric surface, Yucca Flat, Nevada Test Site. A-A'-B, line of cross section, figure 4.

basin totals about 1,000 square miles.

The Test Site is in one of the most arid regions of Nevada, itself one of the most arid states in the Union. Precipitation on the mesas and ridges probably does not exceed 10 inches, whereas that on the basins ranges from 3 to 6 inches.

The oldest exposed strata are miogeosynclinal sediments of the Cordilleran geosyncline that range in age from Early Cambrian to Permian and aggregate more than 22,000 feet in thickness (Burchfiel, 1960, written communication; Johnson and Hibbard, 1957, p. 335-336, 369-380). Carbonate rocks make up about 17,000 feet of the Paleozoic section and clastic rocks make up the rest.

The Paleozoic strata have been intensely deformed by thrust and high-angle faults, believed to be chiefly Laramide in age. Three sets of normal faults break the rocks of the southwestern part of the Site, as does a major transcurrent fault having a reported movement of about 25 miles (Burchfiel, 1960, written communication).

The Paleozoic strata are overlain unconformably by Tertiary tuffs consisting of welded and semi-welded ashflows and bedded ashfalls, which over most of the Site are less than 5,000 feet thick. As much as 1,500 feet of the lower part of the tuffs has been intensely zeolitized or altered to clay.

Block faulting in the late Miocene to late Pliocene displaced the Paleozoic strata and the Tertiary tuffs by as much as 2,000 feet vertically, creating trough-like depressions. The detritus (valley fill) that washed into these fault troughs from the bordering highlands is at least 1,900 feet thick in the middle of Yucca Flat. The valley fill also is cut by high-angle faults.

When this study was started in 1960, only eight wells had been drilled to the regional water table beneath the three basins of major interest. Five of these eight wells tapped water in tuffaceous aquifers and three tapped water in the valley fill. The water table was at depths of 700 to 1,700 feet.

The altitudes of the static water levels in these wells differed by only 50 feet, ranging from about 2,390 to 2,440 feet above sea level. The similarity in altitudes suggested that the three basins probably are connected hydraulically. This hypothesis was supported to some degree by the rather wide range in altitudes of the piezometric surfaces beneath adjacent enclosed basins. The water-level altitudes in three intermontane basins (Gold Flat, Kawich Valley and Emigrant Valley) to the northwest, north, and northeast of Yucca Flat ranged from 1,100 to 2,500 feet higher than those within the Test Site. Even southeast of Frenchman Flat, in the southern half of Indian Spring Valley, the static water level is 800 to 900 feet higher than within the Site. Thus water levels in wells in basins flanking the Test Site differed markedly from one another, yet the water levels in the three basins on the Site were remarkably close to a common altitude.

Despite the implication of the similarity in altitude, and element of doubt persisted because the available control points failed to reveal hydraulic gradient between the basins. Moreover, the range in water-level altitudes within the individual basins was 15 to 40 feet, almost as much as the difference between the basins. The apparent absence of hydraulic gradient was attributed at first to possible inaccuracies in several water-level measurements, to errors in determination of altitudes at the wells, or to effects of pumping. These possibilities were checked, evaluated and dismissed. The absence of a gradient between the basins appeared to be real.

To some workers the apparent lack of gradient plus the great depth to water suggested that the basins are still filling up. This hypothesis, though at first intribuing, was tentatively dismissed because many closed basins both on and off the Site contained lakes during the Pleistocene pluvials. Should not these basins have been filled long since to their spill points? Several nearby basins are almost brimful of water, that is, full almost to playa level.

The solution of the problems outlined above is suggested by the data from the test drilling done in Yucca Flat in 1960-61. Six test holes penetrated aquifers in valley fill, tuff, and Paleozoic strata, and penetrated also a thick tuffaceous aquiclude. Hydraulic tests indicate that the Paleozoic carbonate rocks locally have the largest coefficient of transmissibility, the Paleozoic clastic rocks the lowest, and the tuff and valley fill intermediate values. The coefficients of transmissibility range from less than 1,000 gallons per day per foot for some tuffs and Paleozoic clastic rocks to more than 100,000 for the carbonate strata. The permeability values would be in roughly the same ratios because all the wells penetrated about equal thicknesses of saturated rock.

The aquiclude penetrated by the drill holes consists of intensely zeolitized or clayey tuffs that form the basal part of the Tertiary pyroclastic rocks and range from 200 to more than 1,500 feet in thickness. The interstitial permeability of these rocks ranges from 0.1 to 0.0001 gallon per day per square foot. The fracture permeability is likewise normally so small that wells penetrating these units can be bailed dry. The specific capacities of wells in these rocks are commonly less than 0.05 gallon per minute per foot of drawdown.

Periodic measurements of water levels were made in each test well as penetration of the saturated zone proceeded. In three wells in zeolitized tuff, a drop in head of 20 to 50 feet was noted in drilling through the tuff. In one of these, the head dropped just before or immediately after the well passed from the tuff into dolomite of the Paleozoic.

The relative permeabilities of the valley fill, the tuff, and the carbonate aquifers, and the decline in head with increasing depth within the aquiclude indicate that water is moving out of Yucca Flat, not laterally but vertically by drainage from the Cenozoic strata into the locally more permeable underlying Paleozoic carbonate rocks and then laterally out of the valley. The water in the Cenozoic rocks thus is semiperched with respect to water in the Paleozoic carbonate rocks.

The vertical drainage is illustrated by figure 3, based on water levels in 8 wells, 5 of them in tuff, 1 in valley fill, 1 in dolomite, and 1 in interbedded argillite and dolomite. The water-level measurements used in constructing the map were, with one exception, made before more than 50 feet of the aquifer had been penetrated. The depression near the center of the valley strongly suggests that the drainage of water from the Cenozoic rocks is into the underlying strata, although it must be recognized that only the horizontal component of the hydraulic gradient is portrayed. Other data collected during the study suggest that the vertical component may be as much as 10 times greater than the horizontal.

The vertical movement of water beneath Yucca Flat is portrayed by the diagramatic geologic section of figure 4. The heavy horizontal line of the diagram represents the piezometric surface. The vertical drainage suggested by the arrows of the figure is undoubtedly circuitous, and several flow paths can be visualized utilizing the available subsurface lithologic and structural data.

The semiperched conditions outlined for Yucca Flat probably exist also in Frenchman Flat, where the well having the lowest potentiometric surface was drilled 300 feet deeper into the saturated zone than the two nearby wells. Its water surface, therefore, is believed to be lower because it taps zones of lower potential than are tapped by the shallower wells.

The semiperched conditions observed at Yucca Flat and suggested for Frenchman Flat afford an explanation for the apparent absence of an hydraulic gradient between the three basins. The eight wells drilled in earlier investigations all tapped water in rocks, tuff, or valley fill of Cenozoic age. In any one of these wells the water-level altitude probably reflected the depth of penetration into the zone of saturation and the thickness and degree of fracturing of the aquiclude and the permeability of the underlying Paleozoic rocks, thus, it differed from the water-level altitudes in adjacent wells. When taken together these eight altitudes seemingly fitted no pattern and afforded no clue to the direction of ground-water flow.

The hydraulic connection postulated earlier on the basis of similarity of water-level altitudes in the three basins is believed to be effected by lateral movement of ground water along shattered blocks of underlying carbonate strata. That this may be so is suggested by the locally great permeability of the carbonate rocks.

The altitude of the piezometric surface in test well C which taps water in highly fractured limestone, indicates that such circulation of ground water is both possible and probable. This well, in southern Yucca Flat, has a static water level 10 to 170 feet lower than the static water levels in all the wells within a 25-mile radius that tap water in Cenozoic rocks or Paleozoic clastic strata. The head in this well, however, is 15 to 20 feet higher than the highest known water level at Ash Meadows in the eastern part of the Amargosa

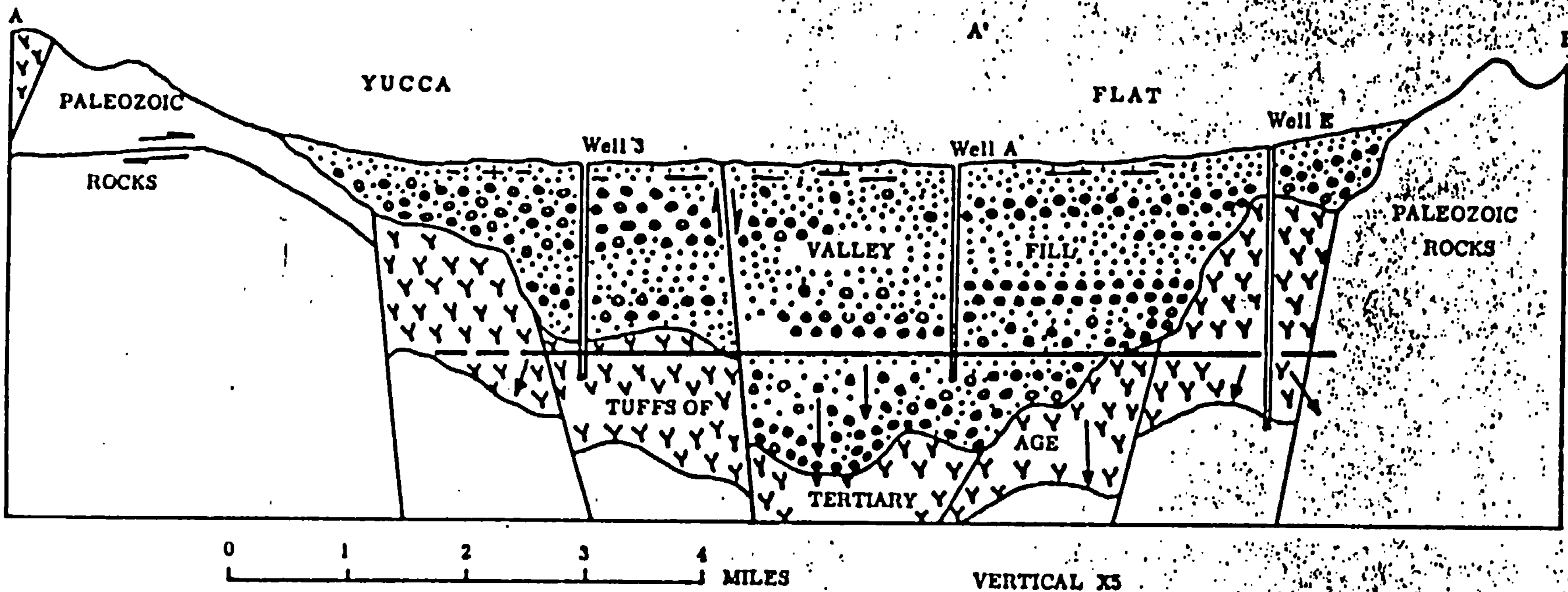

Figure 4. Diagrammatic geologic section across southern Yucca Flat. Line of section shown on figure 3.

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Desert (fig. 1), the nearest area of natural ground-water discharge. At Ash Meadows, which is about 35 miles southwest of Yucca Flat, some of the ground water issues from Paleozoic carbonate rocks, and the total is estimated to be more than 18,000 acre-feet annually (Loeltz, 1960).

Although the regional movement of water within the carbonate rocks thus may be southwestward toward Ash Meadows, the movement in detail probably is indirect. Movement locally is likely to be governed by the juxtaposition of clastic and carbonate facies brought about by faulting.

In summary, the movement of ground water in the valley fill and the tuffs beneath the bolsons of the Nevada Test Site is vertically downward into the Paleozoic carbonate rocks. The ground water moves laterally in the carbonate rocks beneath all three basins toward discharge areas, presumably to the southwest.

The present study, plus the work of Hunt and Robinson, and Loeltz, suggests that ground-water flow beneath some intermontane basins differs significantly from the usual picture of flow down the axis of an intermontane valley to a spill point at one end or flow to discharge areas within the basin, such as playas or springs.

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