PICEANCE BASIN HYDROLOGY: AQUITARDS AND AQUICLUDES

D. B. Tait
Anaconda Minerals
Denver, Colorado

Joe Birman in the preceeding paper presented a series of ideas which he felt should be looked at and evaluated before a final model of the hydrologic regime of the basin could be drawn. I am in agreement with all of the statements made. Based on the ideas and data presented and with a thorough understanding of the geology of the area, a workable hydrologic model of the basin can be developed. Most models of the basin are based on the principal that because the rocks are so highly fractured, there is relatively free movement of water both horizontally and vertically with vertical permeability generally being within about one order of magnitude of the horizontal permeability.

If we look at the stratigraphy of the basin, we find that from the top down we have the Uinta Formation outcropping over the major portion of the basin. This unit is composed of interbedded sands and silts with scattered interbeds of marlstone. The sands and silts typically display a well-developed fracture and joint system. The Uinta intertongues with the upper part of the Parachute Creek Formation. In the north end of the basin, the Uinta Formation rests almost directly on the Mahogany zone, while in the south side of the basin, there are about 300 to 400 feet (90 to 120 m) of Parachute Creek beds intervening between the Uinta and Mahogany zones.

In the high elevation areas along the south margin of the basin, there are numerous springs which issue from this Uinta Formation. Almost all of these springs originate at a sandstone--marlstone contact, or at a lean-rich marlstone contact, suggesting that the water has moved downward through the sand or fractured lean marlstone until it encounters the relatively impermeable marlstone. The Cattle Tank Bench marl in the south end of the basin is a notable example.

A similar relationship exists in the C-b Tract area toward the center of the basin. The waters issuing from the springs in both areas are surprisingly similar. In the C-b area, springs normally occur on the east side of the valley wall or at the termination of a ridge in a northerly direction into the Piceance Valley. These springs normally show increased flow rates in the springtime which more or less reflects the amount of snowfall which fell in the high country to the south, suggesting a rather direct connection between the two events. However, an analysis of the water shows that no tritium is present, suggesting that the issuing water was recharged prior to 1957 and, thus, quite old. The inference here is that there has been long distance migration from the high country down to the Piceance Creek through a permeable and fractured sandstone confined by marlstone layers. There has been no deep migration or percolation of this water. The waters are uniformly cold whether they issue from a spring producing 2 gallons per minute (.3 l/s) or 1,000 gallons per minute (63 l/s).

Below the Uinta, the Parachute Creek Member of the Green River Formation is made up almost entirely of marlstone of varying degrees of richness. These beds are well exposed in the deep canyons cutting into the south margin of the basin, and are also well exposed along the Cathedral Bluffs along the west edge of the basin. The member has been subdivided into a series of named units such as the Four Senators zone, the Mahogany zone, as well as various other rich and lean zones. The Parachute Creek member, as a whole, is well jointed and fractured throughout on the outcrop. In many instances, the rich zones often exhibit fewer fractures per unit area than do the leaner zones.

In studying the richer zones, it was found that at a richness of about 29 gallons per ton (121 l/tonne), the dolomite grains are no longer in contact with each other, but essentially float in a sea of kerogen. This kerogen is an organic solid, but under conditions of elevated temperature and pressure such as that found in the subsurface can act as a plastic or relatively incompetent rock. In some instances, these organically rich rocks remain unfractured, but under sufficient overburden pressure to keep the fracture closed to water movement. The plastic kerogen matrix is in itself impermeable.

An examination of the detailed stratigraphy of the Parachute Creek section in the C-b Tract area shows that there are 17 of these rich zones 1 m thick above the mine zone and an additional 22 rich zones within an 80 m interval below the mine floor. The mine zone was originally defined as a unit about 25 m thick within the Mahogany that averaged 35 gallons or more per ton (146 l/tonne) in richness. All of these rich zones, including the mine zone itself, are essentially impermeable. Thus, these rich zones act as significant retardants to vertical movement of water in the basin. In general, the leaner the rock the more fractures there are per unit area. The lean rocks thus act as an aquifer unit with the rich zones acting as significant aquitards or aquicludes.

In the C-b area, we have found that there is significant variation in water chemistry from the first encounter of the water table down to the Mahogany zone and below. This data suggests that there is little or no vertical communication among waters trapped between the many thin rich zones found in this section. If there were relatively free vertical movement of water, there would be a greater degree of uniformity of the water chemistry.

Many temperature logs have been run on wells scattered throughout the basin. Almost all of these logs show water movement either up or downward in the bore hole. Imbalance is found between zones below the Mahogany, between zones above the Mahogany zone, and between zones above and below the Mahogany zone. These data suggest that there are pressure imbalances within the Parachute Creek section and that these imbalances occur because the Parachute Creek section is separated into a multiplicity of thin aquifers which are behaving independently and are not in vertical communication with each other except where man has created a path of communication by drilling holes across them.

In much of the central part of the basin, especially in the area immediately adjacent to Black Sulfur Creek, the Parachute Creek section contains a number of zones that produce gas along with the water. Most of this gas is found below the Mahogany zone. There are several wells on and immediately adjacent to the C-b Tract that contain gassy zonesboth above and below the Mahogany zone. Perhaps this gas has been generated within the Parachute Creek rocks and is slowly being moved toward the basin center by the slow natural flow of the water in this direction. Perhaps it is still there because it has been confined or trapped between imprevious oil-shale layers or aquicludes. Had there been significant amounts of vertical water movement within the aquifer systems, this gas should have long since been dissipated.

Based on work done primarily in the late 1960's and early 1970's and prior to the concentrated drilling and hydrologic testing on Tracts C-a and C-b, the basin was considered to have had a two-aquifer system with the Mahogany zone being the separating unit between the two systems. Because of the very fractured nature of the rocks, it was believed that there was relatively free communication vertically: consequently deep basin water was free to circulate throughout the Uinta and Parachute Creek sections with the Mahogany zone acting only as a minor aquitard. With the advent of the concentrated drilling and hydrologic testing programs on Tracts C-a and C-b as well as on other tracts in the basin, we have come to realize that the aquifer system is much more complex than originally thought. The two aquifer concept with its attendant deep circulation of water into and out of the basin should be abandoned in favor of a model which recognizes that there are many thin impermeable zones scattered throughout the Uinta and Parachute Creek sections. These impermeable zones cause the flow in the system to be almost totally horizontal.

In summary, if we create a computer model which recognizes that the flow within the aquifer system is almost totally horizontal, we will have come a long way toward a more realistic characterization of the flow system within the basin.