The Blaine Formation is a major aquifer in the Hollis Basin of southwestern Oklahoma. Large quantities of irrigation water are produced at depths of 50 to 300 feet from cavernous gypsum and dolomite beds of the Permian-aged Blaine aquifer in Harmon County and nearby parts of Jackson and Greer Counties (figure 1). Recent interest in drilling for oil and gas in the Hollis Basin has caused concern about the possibility of contamination of the aquifer by drilling fluids, by the upward migration of underlying saline waters, or by the introduction of petroleum products that might accidentally escape into the shallow cavern system. Also of concern is the possibility of loss of fresh water locally by leakage downward from the aquifer through boreholes drilled into underlying strata. Therefore, the accompanying map and diagrams have been prepared to assist the Oklahoma Corporation Commission (OCC) and the petroleum industry in the planning of drilling activity so as to minimize the possibility of such accidental contamination.

With the cooperation of industry, landowners, and water-well operators, the OCC has developed Special Field Rules that are to be followed in drilling of any and all wells that will penetrate the base of the Blaine Formation in the Hollis Basin area. These Special Field Rules, which are available from the OCC, basically require the setting of surface casing to a depth just below the base of the Blaine aquifer, in order to keep the fresh water isolated from fluids that might be encountered in underlying formations.

Earlier reports on the hydrology of the Blaine aquifer in the Hollis Basin were done by Schoff (1948), Steele and Barclay (1965), Havens (1977), and Johnson (1983). Principal studies of the geology of the Blaine Formation and associated strata in the area include those of Johnson (1967), Johnson and Denison (1973), and Havens (1977).

In all earlier hydrologic reports the gypsum-dolomite aquifer was referred to as the "Blaine-Dog Creek aquifer," because the upper half of the Blaine had been considered to be part of the Dog Creek Formation. Recent work by Johnson (1967) showed that the base of the Dog Creek is above the massive gypsums that make up the aquifer in the Hollis Basin (figures 2 and 3). Inasmuch as virtually all the water being produced in the irrigation district is coming only from the Blaine Formation, it is herein proposed to refer to the aquifer as the "Blaine aquifer."

To aid the OCC and industry in determining the depth to the base of the Blaine aquifer, the accompanying map (plate 1) shows the elevation (in feet above sea level) of the base of the Blaine Formation. The map is based on field studies of the Oklahoma Geological Survey and examination of cores, of driller's logs for water wells, and of geophysical logs for petroleum tests and stratigraphic tests drilled into or through the Blaine Formation. Contour lines on the map are based on data from an average of one well per square mile for most of the study area, although in some areas, particularly north of Salt Fork of the Red River, it is 2 miles or more between control wells. Owing to undulations, gentle folds, and local changes in the dip of strata in the Blaine Formation, the elevations shown on the map in most areas are believed to be accurate within 10 to 20 feet; however, in some areas of sparse control, or in areas of abrupt changes in dip, the elevations may be slightly less accurate. It may be necessary, therefore, for a driller to evaluate the rock layers being drilled through while drilling in the Blaine Formation to pick more accurately the base of the Blaine at each drill site.

To use the map, one first determines the elevation of the base of the Blaine (shown by contour lines on the map) at a proposed drill site. This elevation is then subtracted from the land-surface elevation (shown on a topographic map), and the difference will be the approximate depth below land surface to the base of the Blaine Formation. For example, the surface elevation at the town of Duke is about 1,415 feet, and the elevation of the base of the Blaine is about 1,240 feet; thus the depth to the base of the Blaine at Duke is about 175 feet below land surface.

Also shown on the accompanying map are those areas where the Blaine aquifer has been proven to be a major source of irrigation water, with well yields generally ranging from 100 to 2,000 gallons per minute (gpm), and those areas where the Blaine aquifer yields less than 100 gpm in water wells or has not yet been adequately tested. Water from the Blaine aquifer, due to its high sulfate content, is not generally suitable for drinking, but the water is acceptable for irrigation purposes in most parts of the Hollis Basin. The dissolved-solids concentration of the water generally ranges from 1,500 to 6,000 milligrams per liter. Principal impurities are calcium and sulfate, dissolved from the host gypsum beds, as well as lesser amounts of magnesium, sodium, bicarbonate, and chloride.

Other information on the map shows the distribution of an important fresh-water aquifer that overlies, and is isolated from, the Blaine in the northern part of Harmon County, north and south of Salt Fork of the Red River. This shallow aquifer consists of unconsolidated sand and gravel in Quaternary terrace deposits of Salt Fork of the Red River, as well as unconsolidated sands of the Permian Whitehorse Group. The aquifer contains good-quality drinking water that is being provided to the towns of Hollis, Gould, and Duke. The relationship of this shallow aquifer to the Blaine aquifer is shown in the north-south cross section of figure 4.

To assist drillers in recognizing strata making up the Blaine aquifer in the Hollis Basin, several illustrations showing the stratigraphy of the Blaine Formation and overlying and underlying rock units are presented herein. The illustrations include a stratigraphic column showing lithologies and names for individual beds making up the Blaine and associated strata (figure 2). Also shown are four stratigraphic cross sections (figure 3) that transect the Hollis Basin and demonstrate the lateral continuity of the individual gypsum, dolomite, and shale units in a series of cores, water wells, stratigraphic tests, and petroleum tests. Of special interest in these cross sections are the geophysical logs (gamma-ray and resistivity logs) that show clearly the distinction between the gypsum-shale interbeds of the Blaine Formation and the thick shale sequence in the underlying Flowerpot Shale. Drillers will find gamma-ray logs especially useful to determine accurately the base of the Blaine Formation when drilling in any portion of the Hollis Basin. The remaining structural cross sections (figure 4) show schematically the surface and subsurface relationships of principal rock units in the Hollis Basin.

The Blaine Formation consists of a series of interbedded gypsum, dolomite, and shale beds (figure 2). Typically, each of the 9 white gypsum beds in the formation is underlain by a light-gray dolomite and is overlain by a shale that is reddish brown in the lower part and gray at the top. Individual gypsum beds typically are 10-25 feet thick, whereas the dolomite beds range from 0.1-5 feet thick and the shale beds range from 0.5-50 feet thick. Where the Blaine Formation is deeply buried it normally contains some beds of anhydrite instead of gypsum. Anhydrite in the Hollis Basin is a hard, dense, blue-gray rock from which gypsum is derived by hydration (combining with water), and in much of the area the deeper Blaine anhydrite beds have not been fully hydrated to gypsum.

The Blaine Formation and individual gypsum beds within the formation gradually thicken toward the west and southwest across the Hollis Basin (Johnson, 1967). The thickness of the entire formation ranges from about 180-200 feet in the north and east to about 200-210 feet in the southwest. The Van Vacter Member, the upper half of the Blaine, consists of 6 thick gypsum-dolomite units separated by shale beds only 0.5-4 feet thick; the Van Vacter ranges from about 80-90 feet thick in the north and east to about 90-100 feet thick in the southwest. Gypsum beds in the Van Vacter Member are informally referred to as gyp-1 through gyp-6 (figure 2). The Elm Fork Member, the lower half of the Blaine, consists of only 3 thick gypsum-dolomite units separated by shale beds 10-30 feet thick; the member typically ranges from about 90-110 feet thick in the north and east to about 110-120 feet thick in the southwest. Individual gypsum beds of the Blaine typically range from about 5-15 feet thick in the east to about 10-25 feet thick in the west; shale beds, on the other hand, typically thin westward across the basin. The thickest shale in the Blaine is the unit that underlies the Mangum Dolomite; this shale is about 50 feet thick in the east and 30 feet thick in the west.

Although individual beds of Blaine gypsum, dolomite, and shale are readily correlated across the Hollis Basin, there are many places where one or several of the gypsum beds are partially or totally dissolved, thus making it difficult to identify the remaining rock layers. Inasmuch as gypsum (and, to a lesser extent, dolomite) is a soluble rock, circulating ground waters have locally created a cavernous and karstic system that includes sinkholes, caves, springs, and streams that intermittently disappear into underground water courses. Caverns encountered in drilling generally have a height and width that ranges from several inches to about 15 feet. In some areas, the caverns have become so wide that their roofs have collapsed. And in many areas the clay, sand, and other sediment carried through cavern systems by stream waters are deposited locally, and they partly or totally fill some of the underground openings.

Overlying the Blaine Formation in the western part of the area is the Dog Creek Shale, which consists of 100 to 180 feet of red-brown shale with several gypsum and dolomite beds in the lower 50 feet of the formation. These gypsum and dolomite beds, mainly present in the southern half of Harmon County, locally yield small quantities of water, but generally they are separated from the Blaine aquifer and are not a source of irrigation water. The dolomite beds commonly are 0.5 to 2 feet thick and the gypsum beds are commonly 2 to 10 feet thick (figure 2).

The Flowerpot Shale underlies the Blaine Formation in all parts of the Hollis Basin and consists mainly of red-brown shale with several interbeds of gray shale and gypsum that are each 0.5 to 3 feet thick. Total thickness of the Flowerpot is 150-200 feet in Jackson County in the southeast and about 300 feet across the rest of the basin (Johnson, 1967). Interbedded with the red-brown shale in the northern part of Harmon County (T. 3 N. through T. 6 N.) are moderately thick layers of rock salt, referred to as the Flowerpot salt. The Flowerpot salt is generally 50 to 200 feet thick and its top is about 20 to 100 feet below the base of the Blaine Formation (figures 3 and 4). The Flowerpot salt originally extended farther to the east and south of its present limits, but it has been largely dissolved by circulating ground waters, leaving patches of undissolved salt and/or high-salinity brine in the upper part of the Flowerpot Shale at various places outside of these limits. Flowerpot salt at shallow depths (30 to 100 feet below the surface) adjacent to Elm Fork of the Red River in northern Harmon County is currently being dissolved by ground water, and the resultant brine is being discharged from natural springs in three canyons west of State Highway 30 (Johnson and Denison, 1973; Johnson, 1981).

In Jackson County the Flowerpot Shale is underlain by about 40 to 100 feet of interbedded sandstone and shale of the San Angelo Formation (figures 2, 3, and 4), formerly referred to as the Duncan Sandstone (Johnson, 1967). The San Angelo locally may yield small to moderate amounts of fair to poor quality water, but few data are available on this rock unit at present. The San Angelo sandstones grade westward into shales of the lower Flowerpot and are not recognizable in Harmon or Greer Counties.

Cooperation in providing hydrologic information on various parts of the Blaine aquifer for this report was provided by the following persons involved in ground-water production or use in the Hollis Basin: Paul Horton, Gary Bernard, Sonny Faulks, and Bobby Faulks of Hollis; John Moore and H. L. Myatt of Duke; Ivan Owens and Gary Hauck of Mangum; and Don Kizziar of Altus. Additional assistance and data were provided by the following persons involved in petroleum exploration in the Hollis Basin: Brad Curtis with Expando Oil Co.; Bill Harlow with the Harlow Corporation; Jim Witherspoon and Dave Hobbs with Anschutz Corporation; and Jim Hamilton with Phillips Petroleum Co.

Cooperation and assistance also were provided by staff members of the Oklahoma Corporation Commission and the Oklahoma Water Resources Board. The report was reviewed by them and staff members of the U.S. Geological Survey, Water Resources Division.

References Cited

Havens, J. S., 1977, Reconnaissance of the water resources of the Lawton Quadrangle, southwestern Oklahoma: Oklahoma Geological Survey Hydrologic Atlas 6, 4 sheets, scale 1:250,000.

Johnson, K. S., 1967, Stratigraphy of the Blaine Formation and associated strata in southwestern Oklahoma: University of Illinois, unpublished Ph.D. dissertation, 247 p.

Johnson, K. S., 1981, Dissolution of salt on the east flank of the Permian Basin in the southwestern U.S.A.: Journal of Hydrology, vol. 54, p. 75-93.

Johnson, K. S., 1983, Maps showing principal ground-water resources and recharge areas in Oklahoma: Oklahoma State Department of Health, scale 1:500,000.

Johnson, K. S., and Denison, R. E., 1973, Igneous geology of the Wichita Mountains and economic geology of Permian rocks in southwest Oklahoma: Oklahoma Geological Survey Special Pub. 73-2, Guidebook for Field Trip No. 6, Geological Society of America (Annual Meeting, 1973), 33 p.

Schoff, S. L., 1948, Ground-water irrigation in the Duke area, Jackson and Greer Counties, Oklahoma: Oklahoma Geological Survey Mineral Report 18, 10 p.

Steele C. E., and Barclay, J. E., 1965, Ground-water resources of Harmon County and adjacent parts of Greer and Jackson Counties, Oklahoma: Oklahoma Water Resources Board Bull. 29, 96 p.

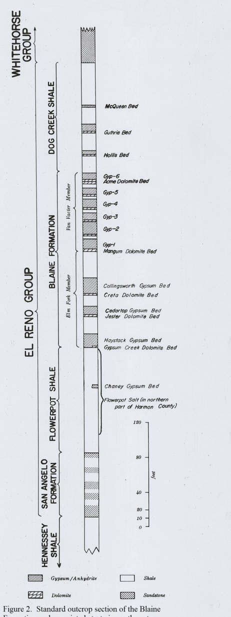


Figure 2. Standard outcrop section of the Blaine Formation and associated strata in southwestern Oklahoma.

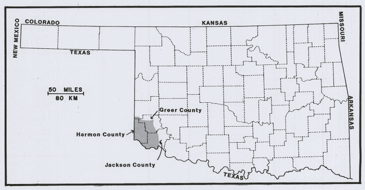


Figure 1. Location of study area (shaded area).

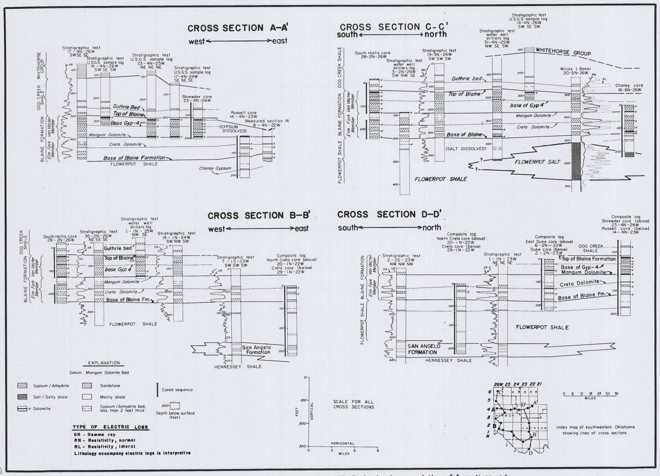


Figure 3. Stratigraphic cross sections through the Hollis Basin showing correlation of formations and individual beds of gypsum, dolomite, and shale (modified from Johnson, 1967).

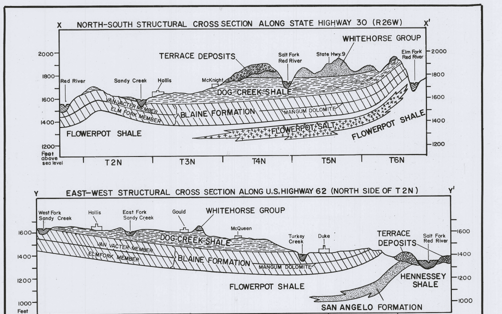
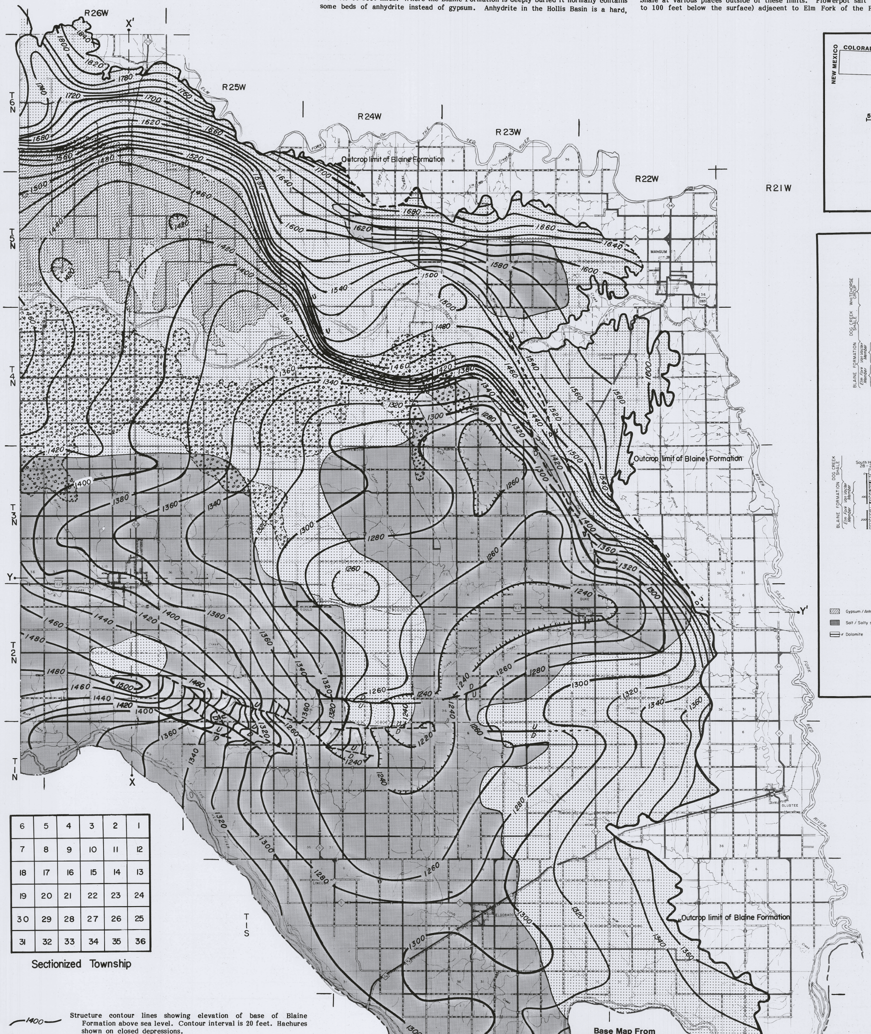


Figure 4. Schematic structural cross sections X-X' and Y-Y' showing thickness, distribution, and depth of principal rock units along State Highway 30 and U.S. Highway 62 in the Hollis Basin. Horizontal scale is 1 inch equals 4 miles, which is one-half the scale of the map in Plate 1.



Structure contour lines showing elevation of base of Blaine Formation above sea level. Contour interval is 20 feet. Hachures shown on closed depressions.

Fault or sharp flexure affecting base of Blaine Formation. Dashed where inferred. U = upthrown; D = downthrown.

Area where Blaine aquifer is expected to yield more than 100 gpm of water to water wells.

Area where Blaine aquifer is expected to yield less than 100 gpm to water wells, or where aquifer has not been adequately tested.

Area where Blaine aquifer is overlain by shallower sand or sand and gravel aquifers of Quaternary terrace deposits and the Permian Whitehorse Group. These shallower aquifers yield large quantities of good-quality drinking water.

Area where Blaine aquifer is overlain by shallower sand and sandstone of the Permian Whitehorse Group. In this area the Whitehorse Group has low yields or has not been adequately tested.

Plate 1. Map of the Hollis Basin showing structure contours on the base of the Blaine Formation and general data on ground-water yields of the Blaine aquifer.

Blaine aquifer in the Hollis Basin of southwest Oklahoma: structure-contour map and stratigraphic / hydrologic data

by
Kenneth S. Johnson
Retired Geologist
Oklahoma Geological Survey
ksjohnson@ou.edu

2019