CHARACTERIZATION OF A CRYSTALLINE-BEDROCK AQUIFER USING BOREHOLE GEOPHYSICS, MARIETTA, COBB COUNTY, GEORGIA

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Abstract. Borehole geophysical techniques were used to characterize a crystalline-bedrock aquifer at the U.S. Air Force Plant 6 in Marietta, Georgia. An integrated suite of geophysical logs was collected from 400- to 600-foot deep wells, which are steel cased to the top of bedrock with the remainder of the borehole open. The geophysical logs include caliper, fluid resistivity, temperature, natural gamma, electromagnetic induction, spontaneous potential, single-point resistance, digital optical and acoustic televiewer, and deviation heat-pulse flowmeter. Fluid resistivity, temperature, and flowmeter logs were used to delineate flow zones. Caliper and acoustic- and optical-televiewer logs were used to determine fracture and foliation character and orientation.

INTRODUCTION

U.S. Air Force (USAF) Plant 6 (AFP6) (Fig. 1) is in Marietta, Cobb County, Ga. The plant is located on 926 acres of a 3,336-acre military complex that includes Dobbins Air Reserve Base, Naval Air Station Atlanta, U.S. Army Reserve, and Georgia Air National Guard (Parsons Engineering Science, Inc., 1995). The plant was constructed during 1942 to support Aeronautical Systems Corporation. Bell Aircraft Corporation operated plant as "Bell Bomber Plant" from 1943 to 1946 (Tech-Law, Inc., 1997). Lockheed Martin Aeronautical Systems Corporation has operated AFP6 for the USAF as an aircraft production and modification facility since 1951 (B&V Waste Science and Technology Corporation, 1994).

During 1995, dissolved trichloroethylene was detected in ground water collected from a new, but unused, irrigation well on the Southern Polytechnic State University (SPSU) campus, indicating that volatile organic compounds may have migrated from known areas of contamination on AFP6. During 1995, the U.S. Geological Survey (USGS), in cooperation with the USAF Aeronautical Systems Center, began an investigation at SPSU to describe the vertical and areal distribution of volatile organic compounds, semivolatile organic compounds, and metals in ground water (Stewart, 2000).

Borehole geophysical logging is one method being used to characterize the ground-water flow system at the AFP6 study area (Fig. 1). The main goal in geophysical logging is to quickly and accurately describe the physical properties of the subsurface materials of a study area, particularly as it relates to flow and transport of contaminates.

GEOLOGY

The geology of the study area consists of late Precambrian to early Paleozoic igneous and metamorphic crystalline rocks (McConnell and Abrams, 1984), over-

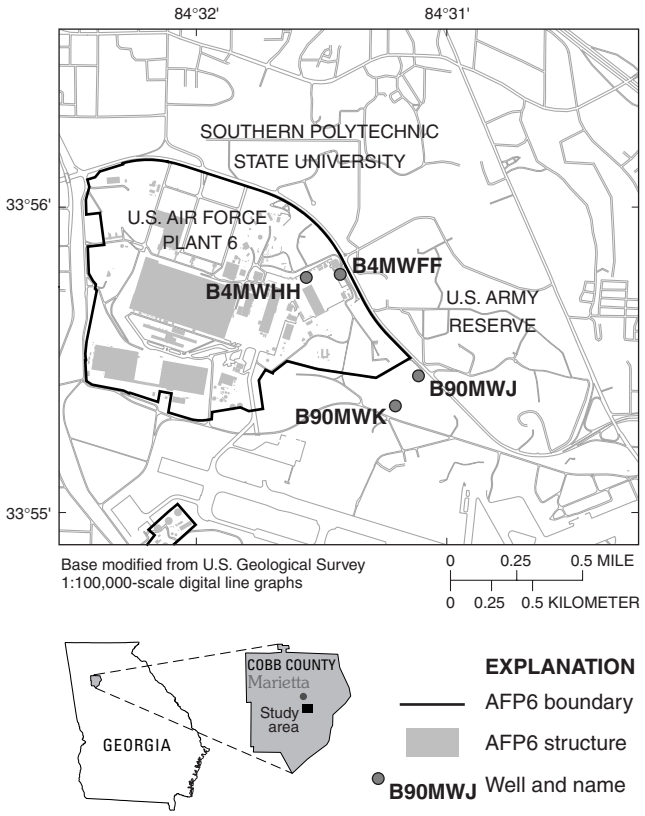

Figure 1. Study area at U.S. Air Force Plant 6 (AFP6) and adjacent areas, Marietta, Georgia.

lain by regolith. The crystalline rock was subjected to multiple deformation and metamorphic events that produced oriented structural features, such as foliation, joints, and faults (Cressler and others, 1983).

GEOPHYSICAL LOGGING METHODS

Geophysical logging methods used included caliper, gamma, temperature, fluid resistivity, electromagnetic induction, spontaneous potential, single-point resistance, optical televiewer (OTV), acoustic televiewer (ATV), borehole deviation, and heat-pulse flowmeter. The heat-pulse flowmeter logs were collected under ambient and low-rate pumping conditions. The rates during pumping ranged from 1 to 2 gallons per minute.

GEOPHYSICAL LOG ANALYSIS

The geophysical logs were analyzed as an integrated suite by use of a commercially available software package. The oriented features of the wells were picked manually and corrected for borehole deviation using the software package. Boreholes were deviated from vertical mostly near the bottom. Log analysis from four wells is presented herein. These wells were drilled during 2001 to fill data gaps in the bedrock observation well network. The wells were completed as 6-inch diameter open holes with near-surface steel casing. The well depths range from 395 to 600 feet. Depth of casings, completed to below the extent of the regolith, range from 33 to 79 feet. Wells B4MWFF and B4MWHH are in AFP6; wells B90MWJ and B90MWK are outside the AFP6 boundary (Fig. 1).

Borehole B4MWFF is cased to a depth of 33 feet and completed to a depth of 600 feet below land surface. The land surface elevation is 1,084 feet. The ambient water level in the borehole during the logging period was at a depth of 44.8 feet. The maximum borehole deviation from vertical of the well is 33°.

The character and orientation of foliation and fractures in borehole B4MWFF were determined from the analysis of the caliper and OTV logs. Foliation strikes from 40 to 65° and dips 30 to 56° to the southeast (SE). Fractures in B4MWFF include:

1. 14 fractures parallel to subparallel to foliation;
2. 3 steeply dipping fractures that strike at 5, 85, and 219°; and
3. 2 shallow to intermediate dipping fractures.

Integrated analysis of the fluid-resistivity, temperature, and heat-pulse flowmeter logs with the OTV log indicates that the borehole intersects flow zones at 80 and 545 feet. The zone at 80 feet consists of a steeply dipping fracture with several parallel to subparallel foliation fractures. The zone at 545 feet consists of one fracture parallel to subparallel to foliation.

Borehole B4MWHH is cased to a depth of 55 feet and completed to a depth of 598 feet below land surface. The land surface elevation is 1,098 feet. The ambient water level in the borehole during the logging period was at a depth of 71 feet. The maximum borehole deviation from vertical of the well is 17°.

The character and orientation of foliation and fractures in borehole B4MWHH were determined from the analysis of the caliper, OTV, and ATV logs. Foliation strikes range from 31 to 64° and dips 17 to 47° to the SE (Fig. 2). Fractures in B4MWHH include:

1. 2 fractures parallel to subparallel to foliation;
2. 5 steeply dipping fractures that strike at 130, 259, 263, 264 and 287°; and
3. 9 shallow to intermediate dipping fracture.

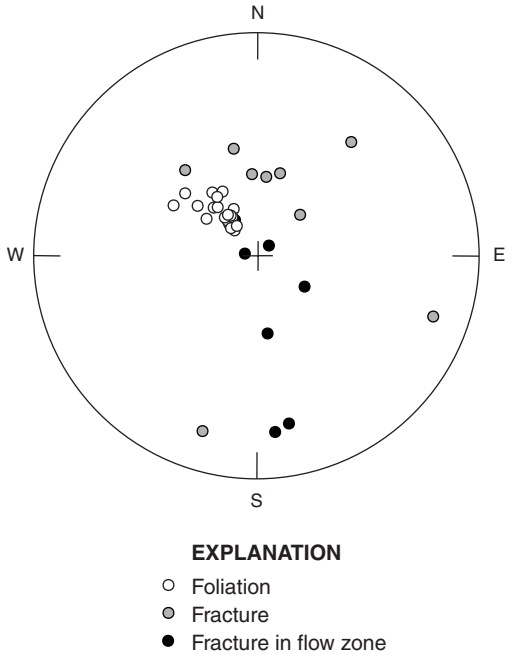

Figure 2. Lower hemisphere, equal-area projection (stereogram) of poles for foliation and fractures in borehole B4MWHH, Marietta, Georgia.

Integrated analysis of the fluid-resistivity, temperature, and heat-pulse flowmeter logs with the OTV and ATV logs indicates that the borehole intersects flow zones at 216 and 235 feet. The zone at 216 feet consists of three shallow to intermediate dipping fractures. The zone at 235 feet consists of two steeply dipping, one shallow to intermediate dipping, and one parallel to subparallel to foliation fracture (Fig. 3).

Borehole B90MWJ is cased to a depth of 46 feet and completed to a depth of 400 feet below land surface. The land surface elevation is 997 feet. The ambient water level in the borehole during the logging period was at a depth of 29.3 feet.

The character and orientation of foliation and fractures in borehole B90MWJ were determined from the analysis of the caliper and OTV logs. Foliation strikes from 32 to 66° and dips 15 to 41° to the southeast. Fractures in B90MWJ include:

1. 6 fractures parallel to subparallel to foliation,
2. 2 steeply dipping fractures that both strike at 104°, and
3. 8 shallow to intermediate dipping fractures.

Integrated analysis of the fluid-resistivity, temperature, and heat-pulse flowmeter logs with the OTV log indicates that the borehole intersects flow zones at 77 and 106 feet. The flow zone at 77 feet consists of a fracture parallel to foliation. The zone at 106 feet consists of two steeply dipping fractures that are less than 1 foot apart.

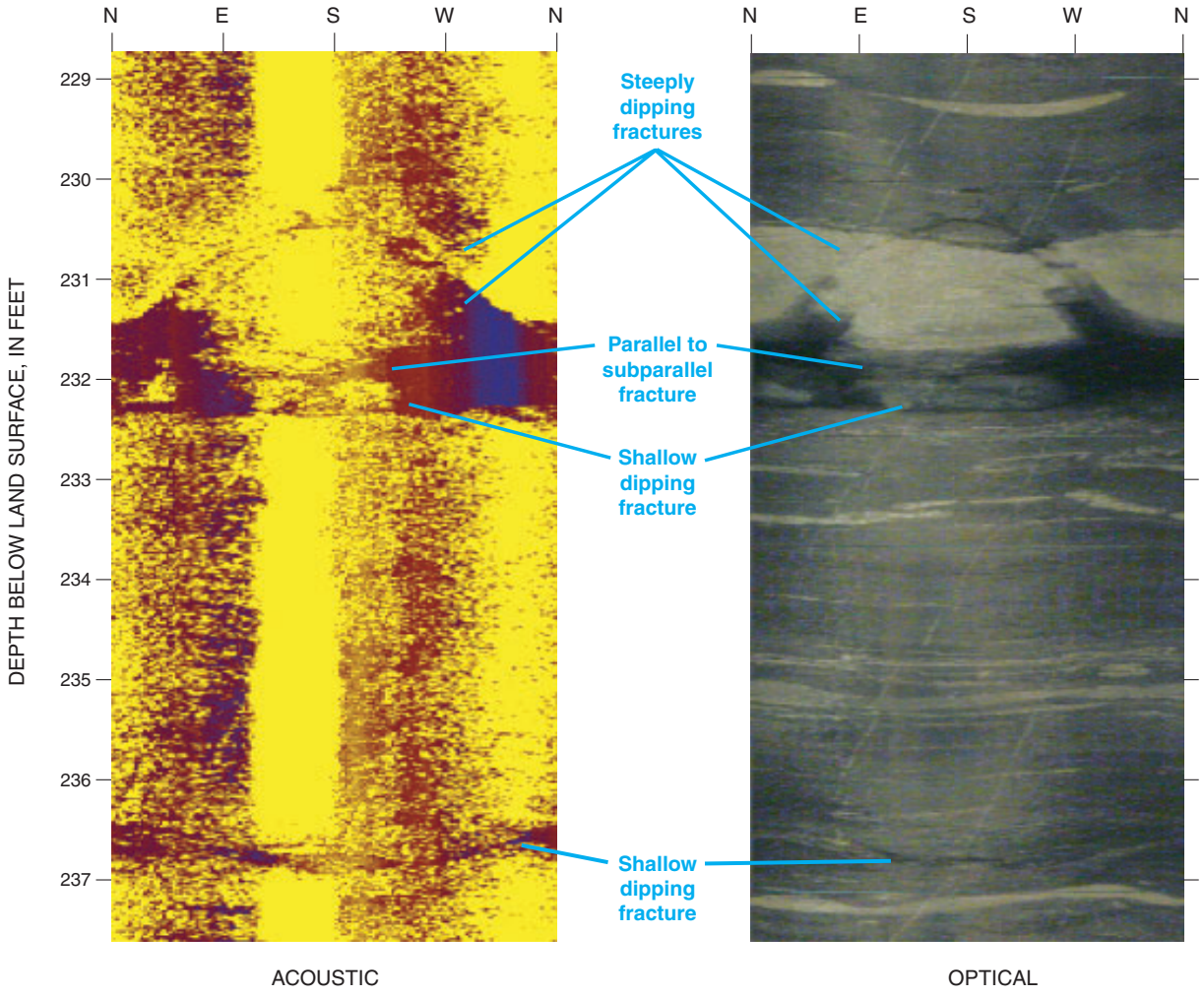

Figure 3. Acoustic- and optical-televiewer images of the flow zone near 230 feet in borehole B4MWHH, Marietta, Georgia (see Figure 1 for location).

Borehole B90MWK is cased to a depth of 79 feet and completed to a depth of 395 feet below land surface. The land surface elevation is 1,010 feet. The ambient water level in the borehole during the logging period was at a depth of 17.3 feet. The maximum borehole deviation from vertical of the well is 6°.

The character and orientation of foliation and fractures in borehole B90MWK were determined from the analysis of the caliper and OTV logs. Foliation strikes from 31 to 64° and dips 29 to 47°. Fractures in B90MWK include:

1. 7 fractures parallel to subparallel to foliation,
2. 2 steeply dipping fractures that strike at 30 and 126°, and
3. 2 shallow to intermediate dipping fractures that strike at 85 and 91°.

Integrated analysis of the fluid-resistivity, temperature, and heat-pulse flowmeter logs with the OTV log indicates that the borehole intersects a flow zone at 138 feet. The flow zone consists of a fracture parallel to foliation.

SUMMARY

The geophysical logging methods used in this paper provided means to characterize the hydrology of four boreholes completed in crystalline bedrock at the U.S. Air Force Plant 6 in Marietta, Georgia. The information provided by geophysical logging is being used to develop a conceptual model of site ground- water hydrology and to support the data collected by other borehole tools.

Boreholes B4MWFF, B4MWHH, B90MWJ, and B90MWK penetrate crystalline bedrock, with foliation generally striking from 40 to 50° and dipping 40 to 60° to the southeast. Fractures intersected by the boreholes include parallel to subparallel to foliation, shallow to intermediate dipping, and steeply dipping fractures.

Flow zones were detected at depths of 77 to 545 feet in the wells. The most productive flow zones during low-rate pumping and flowmeter logging were associated with fracture zones containing both shallow to intermediate and steeply dipping fractures. Flow zones that yielded lesser amounts of water were associated with fractures parallel to subparallel to foliation. The exception is well B90MWK, in which the parallel to subparallel foliation fractures yielded the only detectable amount of flow in the entire well.

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