STRUCTURAL AND LITHOLOGIC CONTROLS ON GROUND-WATER AVAILABILITY IN A GRANITE AND BIOTITE GNEISS IN THE CONYERS, GEORGIA, AREA

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Abstract. Historically, the lack of primary permeability in crystalline rocks of the Piedmont physiographic province of Georgia was believed to result in low ground-water yields. However, focused study of lithology, foliations, and fractures in crystalline rocks in the vicinity of the city of Conyers, Rockdale County, Georgia, shows that geologic controls can contribute to high well yields in these rocks. Although surface geologic mapping indicates that the Conyers area primarily is underlain by granite gneiss, borehole video images show that subsurface lithology is an interlayered granite gneiss and biotite gneiss. Preferential weathering of the biotite gneiss is a significant factor controlling well yield. Most of the yield in each of the two wells studied is from openings along lithologic contacts between the granite gneiss and biotite gneiss, or from openings along compositional layering within the biotite gneiss. The biotite gneiss is thin at land surface, but distinctive enough to be mapped. This geologic unit could be useful for identifying high-yielding areas within the granite gneiss.

INTRODUCTION

The availability of ground water in the Georgia Piedmont is not well understood. Cressler and others (1983) identified several geologic features that are associated with high well yields in the greater Atlanta region. These features primarily are associated with fracture systems, some of which may have resulted from local stress-relief in the bedrock (Cressler and others, 1983) or from regional tectonism (Prowell, 1988). However, ground-water development potential in the greater Atlanta region, which includes the city of Conyers, still is not well understood. The U.S. Geological Survey (USGS), in cooperation with Rockdale County, recently conducted a study of the lithology and geologic structure penetrated by two wells, and the surface geology of the area surrounding the wells, to gain a better understanding of features that control well yields in crystalline rocks in the Conyers area. Preliminary results of the geologic mapping, geophysical logging, and borehole video imaging used for this study are presented herein.

BACKGROUND INFORMATION

The study area is located in the vicinity of Conyers, Rockdale County, Georgia, about 20 miles east of Atlanta (Fig. 1). The area mapped for this study encompasses a region of about 10 square miles extending from south of Interstate 20 to the Yellow River north of Conyers. The study area is underlain by the Lithonia Gneiss, a light-colored granite gneiss composed of muscovite, biotite, feldspar, and quartz (Higgins and others, 1998; Crawford and others, 1999) with relatively thin (few inches to a few feet), alternating layers of biotite gneiss, and even thinner (few inches) interlayerings of muscovite schist. Although weakly developed, foliation in the granite gneiss generally strikes northwest and dips southwest. The strikes of fracture planes in this unit are varied, but dips primarily are near vertical.

Well yields in some areas of Conyers are unusually high, with reported yields ranging from 90 to 348 gallons per minute (gal/min) (McCollum, 1966). The city relied on ground-water resources for drinking water supplies from the early 1900s until the mid-1950s, when the Conyers' surface-water treatment plant was constructed (Scott Emmons, Rockdale County Water Resources, oral commun. with Lester J. Williams, 2002). The city continued to supplement its surface-water drinking supply with well water until 1985. At that time, the wells were furnishing about 500,000 gallons per day (according to Georgia Environmental Protection Division water-use reports). Borehole geophysical logs and video images were run in two (well 13DD69 and well 13DD56) of the five city wells to obtain subsurface lithology and fracture data (Fig. 2).

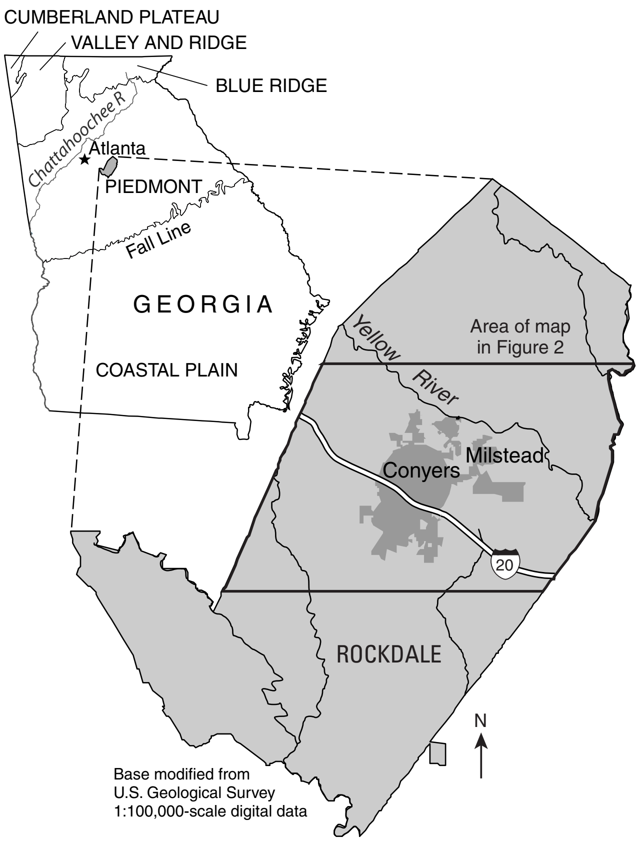

Figure 1. Study area, located approximately 20 miles east of Atlanta, Georgia.

Well 13DD69 has a reported yield of 172 gal/min (Cressler and others, 1983) and was used for public supply from 1974 to 1985. This well is about 405 feet deep, with a casing depth of 20 feet and static water-level depth of about 43 feet. The well penetrates alternating layers of granite gneiss and biotite gneiss; the thinnest identified compositional layers are between 2 inches and 5 feet thick, and the thickest layers are about 150 feet thick.

Well 13DD56 has a reported yield of 348 gal/min (Cressler and others, 1983; McCollum, 1966) and was one of the original wells used by the city prior to 1966 (Cressler and others, 1983). This well is about 403 feet deep, with a casing depth of 103.5 feet and static water-level depth of about 58 feet. Because of the high yield, it is likely that a large portion of the city's historical drinking-water supply was obtained from this well. From land surface, this well penetrates a 103-foot-thick layer of saprolite (rock weathered in place), which is underlain by 150-foot-thick layer of biotite gneiss and 150-foot-thick layer of granite gneiss.

METHODS

Traditional geologic mapping and borehole geophysical methods were used to collect data for this study. Using a geologic map of Rockdale County by McCollum (1966) for reference, a detailed geologic map of the study area was constructed using both competent rock and saprolite outcrops; road cuts, streambeds, and construction sites contain better rock exposure. Where possible, the strike and dip of rock foliation, layering, and joints were measured and recorded.

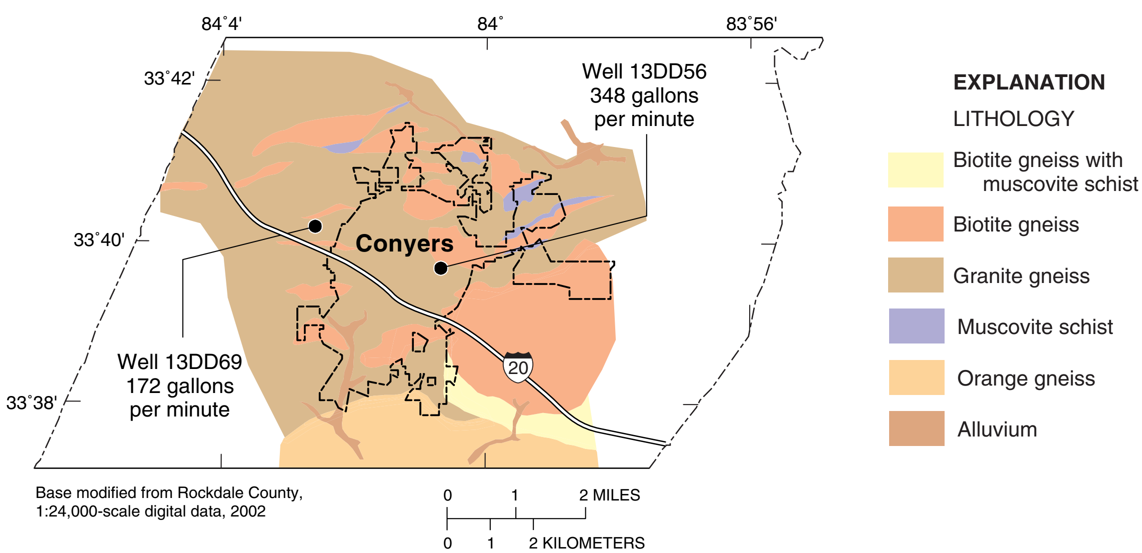

Figure 2. Lithology and well locations and yields for two wells in the study area.

Subsurface structure and lithology were described for the two wells using two borehole-imaging techniques. An acoustic televiewer (ATV) was used to identify the depth and orientation of fractures intersecting the wells. ATV images are magnetically oriented so that measurements of strike and dip of structural features intersecting the well bore can be calculated. A down-hole video camera, which is not oriented, provided down-view and side-view images of the rock type and structure in the well. In addition, geophysical logs, including caliper, natural gamma, resistivity, fluid temperature, and fluid resistivity were run to aid in characterizing subsurface stratigraphy and structure. Flow-meter surveys were conducted during static and pumping conditions to identify water-yielding fractures in the wells.

The two wells used in this study are no longer in use and had to be reopened and cleaned. Rock cuttings from the original well drilling were not available, but a few lithologic samples were collected when the wells were reamed and deepened.

STRUCTURAL AND LITHOLOGIC CONTROLS ON GROUND-WATER AVAILABILITY

Various hypotheses have been proposed to explain the origin of fractures that yield high volumes of ground water in the Piedmont. The most widely accepted ideas are that these fractures may be related to local stress relief in the rock units (Cressler and others, 1983) or to regional tectonism (Prowell, 1988). Widening of these fractures from chemical weathering also may contribute to high well yields. Analysis of borehole video images suggests that irregular fracture planes parallel or within compositional layering are more likely to be water bearing. Fracture planes with angular edges in uniform rock produce little or no ground water.

Flow-meter surveys show that water-bearing fractures in each well occur along lithologic contacts between the weakly foliated granite gneiss and the well-foliated biotite gneiss, or along compositional layering within the biotite gneiss. Fractures along or within thin layers of biotite gneiss in an otherwise uniform unit of granite gneiss appear to contribute to the high yield at well 13DD69, whereas fractures along or within one thick layer of biotite gneiss contribute to the yield at well 13DD56 (Fig. 3). The granite gneiss layer beneath the biotite gneiss in well 13DD56 was not water- bearing. This suggests a correlation between lithology, in this case biotite gneiss, and fractures that are conducive to high well yields.

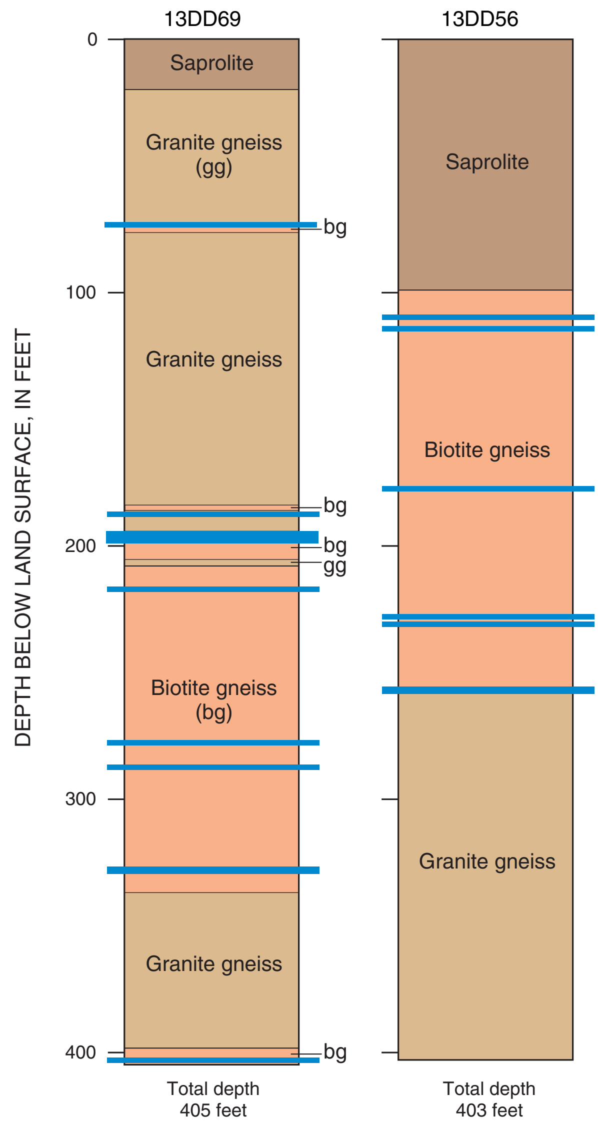

Figure 3. Lithologic logs for wells 13DD69 and 13DD56 showing interlayered biotite gneiss and granite gneiss. The horizontal blue lines represent water-bearing fractures.

The ATV images show these water-bearing fractures primarily are parallel to the rock foliation. Down-hole video images show that the fracture edges are no longer angular in most cases, likely a result of dissolution of feldspars and possibly other minerals along the fracture planes. Both ATV and video images show steeply dipping joints that may provide ground-water recharge to fractures from the overlying regolith. Steeply dipping joints and joint systems associated with ground-water recharge also have been documented in recent USGS studies in the Lawrenceville, Georgia, area (*see* Williams, 2003).

Development of productive wells in the Conyers area may be explained as follows. Fractures along and within the biotite gneiss layers, which originally may have formed from stress-relief or tectonic processes, are recharged with water from the overlying regolith by the vertical joint systems. This water, now enriched with acids from the overlying regolith, causes dissolution of feldspars and other minerals along the fracture planes, enlarging the openings. New fractures may form parallel to the existing fractures and compositional layering as the acidic ground water moves through the vertical joints and reacts with other incompetent layers in the biotite gneiss. Extensive chemical weathering of the rock may cause the support structure for the overlying burden to collapse, resulting in some existing fractures to close and new fractures to develop. A productive well intersects multiple open fractures in the biotite gneiss, which are connected and recharged by the vertical joint systems. A conceptual model of well 13DD69 that illustrates how the fractures are connected is shown in Figure 4.

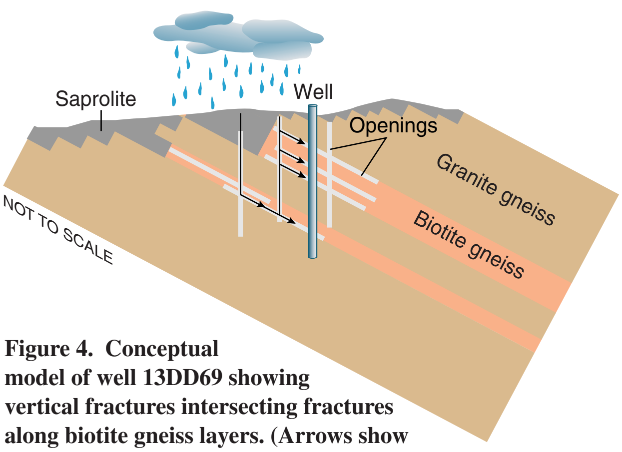

Figure 4. Conceptual model of well 13DD69 showing vertical fractures intersecting fractures along biotite gneiss layers. (Arrows show direction of ground-water flow.)

SUMMARY AND CONCLUSIONS

Geologic mapping, borehole images, and geophysical logs were used to study surface and subsurface lithology, foliations, and fractures near two former production wells in the Conyers, Georgia, area. The goal of this study was to gain a better understanding of factors that control ground-water yields in crystalline rocks. Although previous geologic maps indicate the entire area primarily is underlain by granite gneiss, borehole images show subsurface lithologies are actually an interlayered granite gneiss and biotite gneiss. Detailed surface geologic mapping confirmed the presence of thin layers of biotite gneiss within the more massive granite gneiss.

The fractures in the biotite gneiss appear to contribute to the high well yields of the two wells in the study area. Well 13DD69 penetrates a southward-dipping sequence of granite gneiss and biotite gneiss, in which most of the ground water is from fractures formed parallel to, or between compositional layers of the biotite gneiss. Steeply dipping open joints in this well suggest likely recharge from the overlying regolith. Well 13DD56 penetrates a thick sequence of biotite gneiss, in which most of the ground water also is from fractures along foliations and compositional layers.

Results obtained from geophysical logging of the two high-yield wells in the Conyers area, combined with geologic mapping, indicate the importance of understanding geologic controls on ground-water availability in crystalline rocks. The preferential weathering of biotite gneiss appears to be the significant controlling factor of well yield in this area. Wells that penetrate layers of biotite gneiss are highly productive. These biotite gneiss layers also are distinctive enough to be mapped at land surface; therefore, these layers could be useful in identifying productive areas within the granite gneiss in this area.

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