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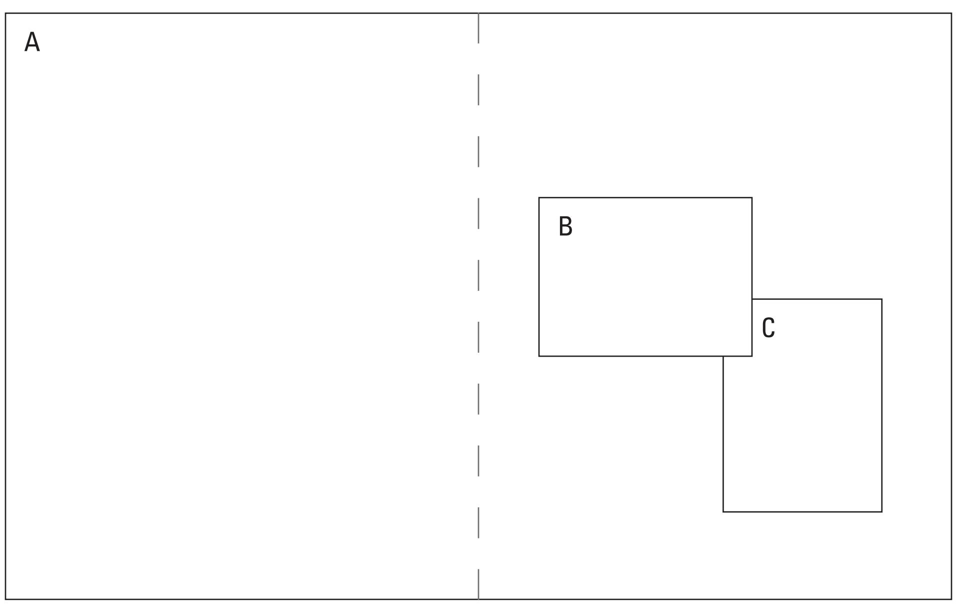
Geologic Framework and Hydrostratigraphy of the Edwards and Trinity Aquifers Within Hays County, Texas

Pamphlet to accompany
Scientific Investigations Map 3418

U.S. Department of the Interior
U.S. Geological Survey



Cover. *A*, Photograph showing the Blanco River Valley, looking north from Little Arkansas Road, Hays County, Texas (photograph by Allan K. Clark, U.S. Geological Survey, February 27, 2018). *B*, Photograph showing a low water crossing on the Blanco River, looking south from Little Arkansas Road, Hays County, Texas (photograph by Allan K. Clark, U.S. Geological Survey, February 27, 2018). *C*, Photograph showing swimming hole on Cypress Creek in Blue Hole Regional Park, Wimberley, Hays County, Texas (photograph by Allan K. Clark, U.S. Geological Survey, February 27, 2018).

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Conversion Factors

International System of Units to U.S. customary units

Multiply	By	To obtain
	Length	
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
	Area	
square kilometer (km^2)	0.3861	square mile (mi^2)

U.S. customary units to International System of Units

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

Datum

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Altitude, as used in this report, refers to distance above the vertical datum.

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Abstract

The Edwards and Trinity aquifers are classified as major aquifers by the Texas Water Development Board and are major sources of water in south-central Texas, where Hays County is located. Detailed maps and descriptions of the geologic framework and hydrostratigraphic units (HSUs) of these karstic aquifers in Hays County are needed for water managers to effectively manage groundwater resources in the area. During 2016–18, the U.S. Geological Survey, in cooperation with the Edwards Aquifer Authority, documented the geologic framework and hydrostratigraphy of the Edwards and Trinity aquifers for a large part of Hays County, characterizing approximately 560 square miles of the county. The report includes a 1:24,000-scale hydrostratigraphic map and descriptions of the geology and HSUs in the study area. In addition, parts of the adjacent upper confining unit to the Edwards aquifer are described.

The rocks exposed within the study area are within outcrops of the Trinity and Edwards Groups and the overlying Washita, Eagle Ford, Austin, and Taylor Groups. The rocks are sedimentary and formed during the Cretaceous age. The principal structural feature in Hays County is the Balcones fault zone, which is the result of late Oligocene and early Miocene age high-angle normal faulting and fracturing. Hydrostratigraphically, the exposed rocks represent a section of the upper confining unit to the Edwards aquifer, the Edwards aquifer, the upper zone of the Trinity aquifer, the middle zone of the Trinity aquifer, and the upper part of the lower zone of the Trinity aquifer. Complexity in the aquifer system results from a combination of the original depositional history, bioturbation, primary and secondary porosity, diagenesis, fracturing, and faulting.

Introduction

The Texas Water Development Board classifies the karstic Edwards and Trinity aquifers (fig. 1) as major sources of water in south-central Texas, where Hays County is located (George and others, 2011). Hays County was the third-fastest-growing county in the Nation in 2016, as well as the fastest growing county in the Nation with a population of at least 100,000 people (U.S. Census Bureau, 2016). To effectively manage available water resources, water managers need detailed maps and descriptions of the geologic framework and hydrostratigraphic units (HSUs) of the aquifers in Hays County. The geologic framework and hydrostratigraphy of the Edwards and Trinity aquifers largely control groundwater flow paths and storage in the aquifers (Kuniansky and Ardis, 2004). During 2016–18, the U.S. Geological Survey (USGS), in cooperation with the Edwards Aquifer Authority, documented the geologic framework and hydrostratigraphy of the Edwards and Trinity aquifers within Hays County at a 1:24,000 scale. In 2016, the USGS published similar hydrogeologic assessments of the Edwards and Trinity aquifers for different study areas in south-central Texas (Clark and others, 2016a, b). Descriptions of the geologic framework and HSUs in this report were modified from those in Clark and others (2016a, b).

Purpose and Scope

The purpose of this report is to present the geologic framework and hydrostratigraphy of the Edwards and Trinity aquifers within Hays County (fig. 1). The HSUs that compose the Edwards and Trinity aquifers were mapped to aid in the understanding of groundwater recharge, discharge, and flow paths. The scope of the report is focused on the geologic framework and hydrostratigraphy of the outcrops and hydrostratigraphy of the Edwards and Trinity aquifers within Hays County (fig. 1). Descriptions of the geologic framework and hydrostratigraphy of the Edwards and Trinity aquifers within Hays County are provided, as well as a detailed map of the hydrostratigraphy at a 1:24,000 scale. Compared to the level of detail available in existing geologic maps, the geologic map in this report was prepared at a finer scale to aid water managers as they work to anticipate and mitigate issues related to changing land use and increasing groundwater demands.

Description of Study Area

The study area consists of about 560 square miles (mi^2) of Hays County, which is northeast of San Antonio, Tex., and southwest of Austin, Tex. (fig. 1). The rocks exposed within the study area are within outcrops of the Trinity and Edwards

Groups and the overlying Washita, Eagle Ford, Austin, and Taylor Groups (Barker and Ardis, 1996) (fig. 2). The rocks in the study area are primarily sedimentary carbonates that formed during the Cretaceous age (Barker and Ardis, 1996). Karst features in the study area include sinkholes, caves, and underground streams that allow rapid infiltration of surface waters to the subsurface (Veni, 1988). Faulting in the study area is late Oligocene to early Miocene age (Weeks, 1945b) and is an extensional fault system known as the Balcones fault zone (Hill, 1900). The Balcones fault zone trends, generally, southwest to northeast in south-central Texas (Maclay and Small, 1986). The faults are vertical to near vertical with normal throw, are en echelon, and are mostly downthrown to the southeast (Hill, 1900; Maclay and Small, 1986).

Methods of Investigation

Geological data and information from previous reports (Hanson and Small, 1995; Stein and Ozuna, 1995; Clark, 2003, 2004; Clark and others, 2009; Blome and Clark, 2014; Clark and others, 2016a, b) were reviewed to assist in field mapping. During 2016–18, geologic framework and hydrostratigraphic mapping was completed on public and private land in Hays County. Field-mapping techniques were consistent with those used in previous similar studies (Clark, 2003; Clark and Morris, 2015; Clark and others, 2016a, b) and guided by the use of Global Positioning System (GPS) units and digital maps and geologic mapping applications installed on a tablet computer; field-mapping observations were recorded onsite by using a tablet computer loaded with geospatially registered 7.5-minute USGS topographic maps. Locations of visible and interpreted geologic contacts, faults and fractures, marker units, and other areas of interest were recorded by using an integrated third generation (3G) network assisted GPS receiver on the tablet computer. In areas without cellular service, positions were determined by using a hand-held compass and triangulation techniques. Faults identified in the field were based on observed and inferred stratigraphic offsets. Strikes and dips of faults and fractures were noted where possible. Bedding attitudes of fractures and faults were obtained by using a hand-held compass or the tablet computer compass application. The locations of springs and sinkholes were obtained from field mapping, topographic maps, and the previous geologic mapping report produced by Hanson and Small (1995). The data obtained by using the tablet computer compass application were independently cross verified on a regular basis with data obtained by using a hand-held compass. The field data were transferred by using ArcGIS Desktop version 10.3.1 (Esri, 2016), quality checked by comparison with original draft maps, and then used to examine the geologic framework and develop the hydrostratigraphic map of the study area. Digital data of the geographical extent of the surficial hydrostratigraphic units and faulting within the study area and associated metadata are available for download in a companion data release (Pedraza and others, 2018).

Lithologic descriptions, HSU names, and porosity type are consistent with those used previous publications such as Clark and others (2016a, b). The descriptions of the geologic framework and hydrostratigraphy in this report were adapted for the study area from Clark and others (2016a, b). Formal geologic names are consistent with those in the National Geologic Map Database (U.S. Geological Survey, 2018). Informal geologic and HSU names are consistent with those used in previous publications (Maclay and Small, 1976; Clark and others, 2009, 2016a, b; Blome and Clark, 2014) (fig. 2). The thicknesses of the mapped lithostratigraphic members and HSUs were determined from field observations. Thickness variations are caused by variations in local depositional and erosional conditions. Porosity varies in each lithostratigraphic unit and is dependent on the unit's original depositional environment, lithology, structural history, and diagenesis. HSUs were identified as either fabric selective or not fabric selective on the basis of variations in the amount and type of porosity visually evident in the outcrop.

Lithologic descriptions follow the classification system of Dunham (1962). Porosity descriptions are based on the sedimentary carbonate classification system of Choquette and Pray (1970). Descriptions of clastic rocks were done under the classification scale of Wentworth (1922).

HSUs were identified on the basis of the type of porosity visually evident in the outcrop. Porosity varies in each lithostratigraphic member, depending on the unit's original depositional environment, lithology, structural history, and diagenesis. Porosity types were described as either fabric selective or not fabric selective in accordance with the sedimentary carbonate classification system of Choquette and Pray (1970).

Geologic Framework

The rocks within the study area are Cretaceous age, sedimentary, and primarily composed of sands, silts, clays, and limestones (fig. 2). Stratigraphically (ascending order), the geologic units are the Trinity Group (Sycamore Sand, Hammett Shale, Cow Creek Limestone, Hensell Sand, and the lower and upper members of the Glen Rose Limestone), Edwards Group (Kainer and Person Formations), Washita Group (Georgetown Formation, Del Rio Clay, and Buda Limestone), Eagle Ford Group, Austin Group, and Taylor Group (Pecan Gap Chalk).

Trinity Group

The Early Cretaceous to late Early Cretaceous Trinity Group (Imlay, 1940) contains shale, mudstone to grainstone, boundstone, evaporites, sandstone, siltstone, conglomerates, and argillaceous limestone (fig. 2). The sediments were deposited on a large, shallow marine carbonate platform (Comanche shelf) as clastic-carbonate "couplets" during three marine transgressional events (Lozo and Stricklin, 1956; Stricklin and others, 1971). These three distinct "couplets" contain sediments that formed (1) the Hosston (Sycamore Sand [Hill, 1901], fig. 3) and Sligo Formations (Imlay, 1940); (2) the Hammett Shale (Hill, 1901; Lozo and Stricklin, 1956) and the Cow Creek Limestone (Hill, 1901) (fig. 4); and (3) the Hensell Sand (Hill, 1901) and the Glen Rose Limestone (Hill, 1891) (fig. 5). According to Wierman and others (2010) both the Hosston Formation and the stratigraphically higher, but thinner, Sligo Formation thin and pinch out to the northwest. The Sycamore Sand, which is the outcrop equivalent to the Hosston Formation, appears at the surface in the bed of the Pedernales River in the northern part of the study area. The Sligo Formation pinches out in the subsurface farther to the southeast and is not found except at depth (for example, in well logs) in the study area; therefore, the Sligo Formation is not shown in figure 2, and it is not discussed further in this report.

In the study area, the thickness of the Trinity Group thins from the south to the north (Barker and Ardis, 1996). Although all formations in the outcrop thin toward the north, the most pronounced thinning is found in the lower member of the Glen Rose Limestone, which is 195 feet (ft) thick in the south and thins to 130 ft thick near the Pedernales River in the north (fig. 1). Descriptions of each of the geologic units and their associated lithology are shown in figure 2. Additional geologic and ichnofossil descriptions are provided in Clark and others (2016a, b) and Clark and Morris (2017).

Edwards Group

The late Early Cretaceous Edwards Group (fig. 2) is composed of mudstone to grainstone, shales, and chert deposited in an open marine to supratidal flats environment (Rose, 1972; Maclay and Small, 1986) during separate marine transgressions. A marine transgression during the Early Cretaceous resulted in the deposition of the Kainer Formation (Rose, 1972). The Person Formation was deposited during a subsequent marine transgression (Rose, 1972). The Edwards Group formed on the landward margin of the Comanche shelf, which was sheltered from storm waves and deep ocean currents by the Stuart City reef trend in the ancestral Gulf of Mexico (Barker and Ardis, 1996; Clark and others, 2006) (fig. 1). Descriptions of each of the geologic units and their associated lithology are shown (fig. 2) and discussed in further detail in Clark and others (2016a, b) and Clark and Morris (2017).

Washita, Eagle Ford, Austin, and Taylor Groups

Following the deposition of the Edwards Group was tectonic uplift, subaerial exposure, and erosion in the area that is now south-central Texas. This area was then once again submerged during the late Early Cretaceous when another marine transgression resulted in the deposition of shales, mudstones, and wackestones that formed the Georgetown Formation (Richardson, 1904) of the Washita Group (fig. 2). Much of the Georgetown Formation was subsequently removed during a period of marine regression (Rose, 1972).

The Del Rio Clay of the Washita Group (fig. 2), which contains clay and packstone, was deposited during a marine transgression during the early Late Cretaceous when the Stuart City reef (to the south) was breached. Continued deposition of sediments in shallow subtidal to intertidal zones resulted in the mudstone and wackestone that formed the Buda Limestone (Grunig and others, 1977) of the Washita Group (fig. 2). The Late Cretaceous Eagle Ford Group (fig. 2) was deposited as sandy shale and argillaceous limestone in a lagoonal to marine, open shelf environment (Grunig and others, 1977). As the marine transgression continued in the Late Cretaceous, an open, shallow shelf developed, and sediments were deposited far from shore, resulting in the mudstones and wackestones that form the Austin Group (fig. 2) (Grunig and others, 1977). The uppermost stratigraphic unit exposed in the study area is the Late Cretaceous Pecan Gap Chalk of the Taylor Group (fig. 2). The Pecan Gap Chalk is composed of marl and calcareous clay and was deposited in an open marine environment following a marine transgression (Ellisor and Teagle, 1934). A description of the stratigraphy, lithology, index fossils, and stratigraphic thickness is provided (fig. 2), with additional detailed discussion available in Clark and others (2016b).

Structure

The principal structural feature in Hays County is the Balcones fault zone (fig. 1), which is the result of late Oligocene and early Miocene age (Weeks, 1945b) extensional faulting (Weeks, 1945a, b; Galloway and others, 2000, 2011; Rose, 2016, 2017) and fracturing. The Balcones faulting resulted from the eastern Edwards Plateau uplift (Rose, 2017). In the Balcones fault zone, most of the faults in the study area are high-angle to vertical, en echelon, normal faults that are downthrown to the southeast (George, 1952). As is typical with extensional fault zones, the Balcones fault zone includes horst and graben structures (Pantea and others, 2014). The Balcones fault zone is considered dormant (Ewing, 2005).

Relay ramp structures are also common within an extensional fault system (Ferrill and Morris, 2007). Ramp structures can be relatively small features that extend less than a few miles or relatively large features that extend tens of miles. Relay ramps form in extensional fault systems to accommodate rock fabric stress relief and an increase in deformation (Clark and Journey, 2006). Ramp structures link the footwall of a fault segment with the hanging wall of an overlapping fault segment (Collins, 1995; Clark and Journey, 2006; Hunt and others, 2015). As extension occurs, the increased strain on the rock fabric causes faulting that results in the formation of relay ramps with rotation and internal fracturing occurring along the relay ramps (Trudgill, 2002; Ferrill and Morris, 2007). Continued extension results in the formation of cross faults within the relay ramp structure

(Trudgill, 2002). Some examples of reports documenting relay ramp structures within the Balcones fault zone include Collins (1995), Clark and Journey (2006), Clark and others (2013), and Hunt and others (2015).

Hydrostratigraphy

Hydrostratigraphically, the rocks exposed in the study area represent a section of the upper confining unit to the Edwards aquifer, the Edwards aquifer, the upper zone of the Trinity aquifer, the middle zone of the Trinity aquifer, and the upper part of the lower zone of the Trinity aquifer (fig. 2). Descriptions of the HSUs, thicknesses, hydrologic function, porosity type, and field identification are provided (fig. 2) and are described further in Clark and others (2016b) and Clark and Morris (2017).

Upper Confining Unit of the Edwards Aquifer

The rocks that form the upper confining unit to the Edwards aquifer are (top to bottom) the Pecan Gap Chalk, Austin Group, Eagle Ford Group, Buda Limestone, and Del Rio Clay (Maclay and Small, 1976; Hanson and Small, 1995) (fig. 2). Because the formations and groups are generally categorized as a confining unit to the Edwards aquifer and not as separate water-bearing aquifers, the lithologic terms (group, formation, limestone, and clay) will be used to describe both the geologic framework and the hydrologic characteristics of the HSU being discussed. The rocks that form the upper confining unit to the Edwards aquifer do not supply appreciable amounts of water to wells in the study area except for the Austin Group (Petitt and George, 1956) and parts of the Georgetown Formation (Stein and Ozuna, 1995); for this reason, of the units that compose the upper confining unit to the Edwards aquifer, only the Austin Group and Georgetown Formation will be described.

The Austin Group supplies water to several springs in Uvalde, Medina, and Bexar Counties, as well as to some domestic and irrigation wells (Garza, 1962; Arnow, 1963; Banta and Clark, 2012). The most notable springs supplied by the Austin Group are San Pedro Spring and San Antonio Springs in Bexar County (fig. 1). The most prolific wells and springs within the Austin Group likely tap water that moves up faults and fractures under artesian conditions from the underlying Edwards aquifer (Livingston and others, 1936; Veni, 1988; Banta and Clark, 2012). San Marcos Springs in Hays County, which is the second-largest spring system in Texas, issues from faults that juxtapose the Edwards aquifer against the Austin Group (Hanson and Small, 1995).

Although commonly considered part of the Edwards aquifer, the Georgetown Formation is part of the upper confining unit to the Edwards aquifer (George, 1952; Maclay and Small, 1976; Stein and Ozuna, 1995). Maclay and Small (1976) listed the Georgetown Formation as HSU I of the Edwards aquifer because the formation was the unit where drillers would set casing before drilling through to the water-bearing units in the underlying Edwards aquifer.

Edwards and Trinity Aquifers

In the study area, the Edwards aquifer is within the Edwards Group, and the Trinity aquifer is within the Trinity Group. The Edwards and Trinity aquifers contain enhanced secondary porosity that is developed along bedding planes, fractures, and caves (Maclay and Small, 1983; Veni, 1987, 1988, 1994a; Johnson and others, 2002; Ferrill and others, 2003; Gary and others, 2011). The Edwards and Trinity aquifers have been considered separate aquifers on the basis of differences in permeability (Hammond, 1984; Kuniansky and Ardis, 2004); other assessments have shown that the Edwards aquifer and the upper part of the upper zone of the Trinity aquifer might function as a single aquifer (Johnson and others, 2002; Clark, 2003; Clark and others, 2009; Hunt and others, 2016). Barker and Ardis (1996) also stated that recharge to the Edwards aquifer from the underlying Trinity aquifer occurs from diffuse upward leakage. A detailed description of the HSUs, thicknesses, hydrologic function, porosity type, and field identification is provided (fig. 2).

Edwards Aquifer

Maclay and Small (1976) subdivided the Edwards aquifer into HSUs I to VIII (fig. 2). In the informal naming convention used by Maclay and Small (1976), the Georgetown Formation of the Washita Group was designated as HSU I. Different layers that Maclay and Small (1976) discerned in the Person Formation of the Edwards Group were designated as HSUs II, III, and IV, and different layers of the Kainer Formation of the Edwards Group were designated as HSUs V, VI, VII, and VIII.

Trinity Aquifer

Ashworth (1983) subdivided the Trinity aquifer into upper, middle, and lower zones (fig. 2). The upper zone of the Trinity aquifer yields water from the upper member of the Glen Rose Limestone. The middle zone of the Trinity aquifer yields water from the lower member of the Glen Rose Limestone, the Hensell Sand, and the Cow Creek Limestone. The regionally extensive Hammett HSU forms a confining unit between the middle and lower zones of the Trinity aquifer (Ashworth, 1983; Wierman and others, 2010; Clark and others, 2016b). The lower zone of the Trinity aquifer yields water from the Sycamore Sand of the Hosston Formation. The only outcrop of the Sycamore Sand in Hays County is along the Pedernales River in the far northern corner of the county (Ashworth, 1983).

From field observations the authors believe that there may be a difference in permeability between the beds in the upper and middle zones of the Trinity aquifer depending on the presence or absence of argillaceous limestone. Argillaceous limestone beds (marl beds) appear to store water for extended periods of time and slowly release it into fractures or into the contact between beds. From these observations the authors believe that significant quantities of water may be stored in argillaceous limestone beds in the vadose and phreatic zones of the aquifer.

Upper Zone of the Trinity Aquifer

The upper zone of the Trinity aquifer was informally subdivided into five HSUs in Bexar County by Clark (2003). In the study area, however, there are only four HSUs present (listed from top to bottom): Camp Bullis, upper evaporite, fossiliferous, and lower evaporite. Although not mapped in Hays County, the Cavernous HSU (upper part of the upper zone of the Trinity aquifer) found in Bexar County and parts of Comal County (Clark and others, 2016b) may exist in Hays County in areas that are covered by outcrops of the Edwards Group. The possible existence of the Cavernous HSU in Hays County is based on a few outcrop observations in deeper canyons that dissect through the Edwards aquifer and into the underlying upper zone of the Trinity aquifer. Additional evidence for the existence of at least a portion of the Cavernous HSU in Hays County comes from aquifer tests carried out by Hunt and others (2016).

Middle Zone of the Trinity Aquifer

The middle zone of the Trinity aquifer is composed of the Bulverde, Little Blanco, Twin Sisters, Doeppenschmidt, Rust, Honey Creek, Hensell, and Cow Creek HSUs (Clark and Morris, 2015) (fig. 2). Across the study area south to north the various HSUs thin, and the Bulverde, Little Blanco, Twin Sisters, and Doeppenschmidt grade into the Rust HSU because of changes in the depositional environment. Underlying the Cow Creek HSU is the regional confining unit, the Hammett HSU, which separates the middle and lower zones of the Trinity aquifer.

Several large springs likely issue out of the Honey Creek HSU in Hays County, most notably Jacobs Well Spring (figs. 1 and 6) (Brune, 1975). Also, Pleasant Valley spring (fig. 1) was recently documented as the Trinity aquifer spring in south-central Texas with the largest discharge (Watson and others, 2014); its discharge was measured as ranging from 9 to 18 cubic feet per second (Barton Springs Edwards Aquifer Conservation District, 2013). It is likely that the water that flows out of Pleasant Valley spring and Jacobs Well Spring originates from the underlying Cow Creek HSU and that the water flows upward under artesian conditions through fractures, faults, and conduits into the Honey Creek HSU and ultimately to land surface (Barton Springs Edwards Aquifer Conservation District, 2013).

Hammett HSU Confining Unit

Overlying the lower zone of the Trinity aquifer is the confining Hammett HSU, which likely restricts the downward flow of groundwater and results in contact springs near the base of the Cow Creek HSU in some locations (Clark and Morris, 2017). In addition to likely restricting downward flow in some locations, the Hammett HSU also likely restricts the upward flow where the groundwater has a relatively high hydraulic head and would otherwise flow towards land surface (Clark and others, 2016a, b).

Lower Zone of the Trinity Aquifer

The only exposed part of the lower zone of the Trinity aquifer is the Sycamore HSU in the far northern corner of Hays County. The Sycamore HSU where exposed along the Pedernales River is probably a point of recharge for the lower zone of the Trinity aquifer (Wierman and others, 2010). Ashworth (1983) and Ashworth and others (2001) stated that the primary source of recharge to the lower zone of the Trinity aquifer is leakage across the Hammett HSU through faults and fractures.

Implications of Hydrostratigraphic Characteristics and Geologic Structure on Groundwater Recharge and Flow Paths

Groundwater recharge and flow paths in the study area are influenced not only by the hydrostratigraphic characteristics of the individual HSUs but also by faults and fractures and geologic structure. Faulting and the resulting structures (grabens and horsts) common in fault zones like the Balcones fault zone may increase the potential of controlling or altering local groundwater flow (Pantea and others, 2014) by juxtaposing permeable and less permeable lithologies against one another. Dye-tracing studies by Johnson and others (2010) indicate that the permeable zones in juxtaposed members might be narrow; however, if cavernous permeability is present then all available water might be transmitted at or through the fault. When juxtaposed against zones with relatively more permeability, zones with relatively less permeability might act as a barrier to groundwater flow (Stein and Ozuna, 1995).

Current (2018) and past studies, as well as field observations, have shown that the groundwater flow paths between the Edwards and Trinity aquifers and the various HSUs are complex. The source of complexity in the aquifer system results from a combination of the original depositional history, bioturbation, primary and secondary porosity, diagenesis, fracturing, and faulting (Clark and others, 2016b). The combination of these factors has resulted in the development of modified porosity, permeability, and transmissivity within and between the aquifers (Clark and others, 2016b). Faulting has produced highly fractured areas that have allowed for the rapid infiltration of water and subsequently formed solutionally enhanced fractures, bedding planes, channels, and caves that are highly permeable and transmissive (Clark and others, 2016b). The juxtaposition of the aquifers and the HSUs caused by faulting has resulted in areas of interconnectedness between the Edwards and Trinity aquifers and the various HSUs that form the aquifers (Clark, 2003, 2004; Clark and others, 2009; Pantea and others, 2014; Hunt and others, 2015).

According to Ferrill and Morris (2003), faults within the Edwards Group are more dilatant (open) than those in the Glen Rose Limestone because the Edwards Group lithologies are more competent. Ferrill and Morris (2003) also stated that fault deformation increases permeability at or near faults. Fault permeability in the Glen Rose Limestone is heterogeneous and affects groundwater flow both parallel and perpendicular to faults (Ferrill and others, 2003). Clay smear and calcite deposition can affect cross-fault flow and may inhibit the flow if the deposit is appreciable (Ferrill and others, 2003). Solution-enlarged fractures and conduits might also form parallel to the dip of relay ramps in the Edwards Group (Clark and Journey, 2006) because of the northeast to southwest extension. The effects of relay ramps on groundwater flow paths within the Edwards and Trinity aquifers are documented in Maclay and Small (1983), Groschen (1996), Clark and Journey (2006), Clark and others (2013), Pantea and others (2014), and Hunt and others (2015).

According to Veni (1988), cave formation is strongly guided by secondary fractures that form as a result of faulting, rather than by the actual fault plane. Clark and Journey (2006) stated that the fractures generally are parallel or perpendicular to the main fault trend of the Balcones fault zone. Faulting affects cave development through fractures that form because of extension perpendicular to the Balcones fault zone (Clark and Journey, 2006). As extension of the series of en echelon, mainly down-to-the-coast faults occurred, the material had to occupy a larger area, resulting in extension perpendicular to the fault zone (Clark and Journey, 2006).

Summary

During 2016–18, the U.S. Geological Survey, in cooperation with the Edwards Aquifer Authority, mapped the geologic framework and hydrostratigraphy of the Edwards and Trinity aquifers within Hays County, Texas. The Texas Water Development Board classifies the karstic Edwards and Trinity aquifers as major sources of water in south-central Texas. The geologic framework and hydrostratigraphy of the Edwards and Trinity aquifers largely control groundwater flow paths and storage in the aquifers, and therefore, refined mapping will aid in anticipating and mitigating issues related to changing land use and increasing groundwater demands.

The purpose of this report is to present the geologic framework and hydrostratigraphy of the Edwards and Trinity aquifers within Hays County, Tex. The HSUs were mapped to improve the understanding of groundwater recharge, groundwater flow paths, and discharge. In addition, this report contains a detailed map at a scale of 1:24,000 of the hydrostratigraphy of the Edwards and Trinity aquifers in Hays County.

The rocks exposed within the approximately 560 square miles of the study area are within the outcrops of the Trinity and Edwards Groups and the overlying Washita, Eagle Ford, Austin, and Taylor Groups in Hays County. The rocks are sedimentary and formed during the Cretaceous age. Karst areas in the study area are characterized by sinkholes, caves, and underground streams that allow rapid infiltration of surface waters to the subsurface. Faulting in the study area is primarily from an Oligocene and early Miocene age extensional fault system known as the Balcones fault zone. The Balcones fault zone generally trends southwest to northeast in south-central Texas. The faults are vertical to near vertical with normal throw, are en echelon, and are mostly downthrown to the southeast.

Hydrostratigraphically, the rocks exposed in the study area represent a section of the upper confining unit to the Edwards aquifer, the Edwards aquifer, the upper zone of the Trinity aquifer, the middle zone of the Trinity aquifer, and the upper part of the lower zone of the Trinity aquifer.

The rocks that form the upper confining unit to the Edwards aquifer are (top to bottom) the Pecan Gap Chalk, Austin Group, Eagle Ford Group, Buda Limestone, Del Rio Clay, and Georgetown Formation. Although commonly referred to as part of the Edwards aquifer, the Georgetown Formation is part of the upper confining unit to the Edwards aquifer. Previous investigators informally designated the Georgetown Formation as hydrostratigraphic unit (HSU) I; different layers of the Person Formation of the Edwards Group as HSUs II, III, and IV; and different layers of the Kainer Formation of the Edwards Group as HSUs V, VI, VII, and VIII.

The upper zone of the Trinity aquifer was informally subdivided by previous investigators into five HSUs in Bexar County. In the study area, however, there are only four HSUs present (listed top to bottom): Camp Bullis, upper evaporite, fossiliferous, and lower evaporite. Although not mapped in Hays County, the Cavernous HSU (upper part of the upper zone of the Trinity aquifer) found in Bexar County and parts of Comal County may exist in Hays County in areas that are covered by outcrops of the Edwards Group. The middle zone of the Trinity aquifer is composed of the Bulverde, Little Blanco, Twin Sisters, Doeppenschmidt, Rust, Honey Creek, Hensell, and Cow Creek HSUs. Underlying the Cow Creek HSU is the regional confining unit, the Hammett HSU, which separates the middle and lower zones of the Trinity aquifer. The only exposed portion of the lower zone of the Trinity aquifer in the study area is the Sycamore HSU in the far northern corner of Hays County.

Groundwater recharge and flow paths in the study area are influenced not only by the hydrostratigraphic characteristics of the individual HSUs but also by faults and fractures and geologic structure. Faulting and the resulting structures (grabens and horsts) common in fault zones like the Balcones fault zone may increase the potential of controlling or altering local groundwater flow by juxtaposing permeable and less permeable lithologies against one another.

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