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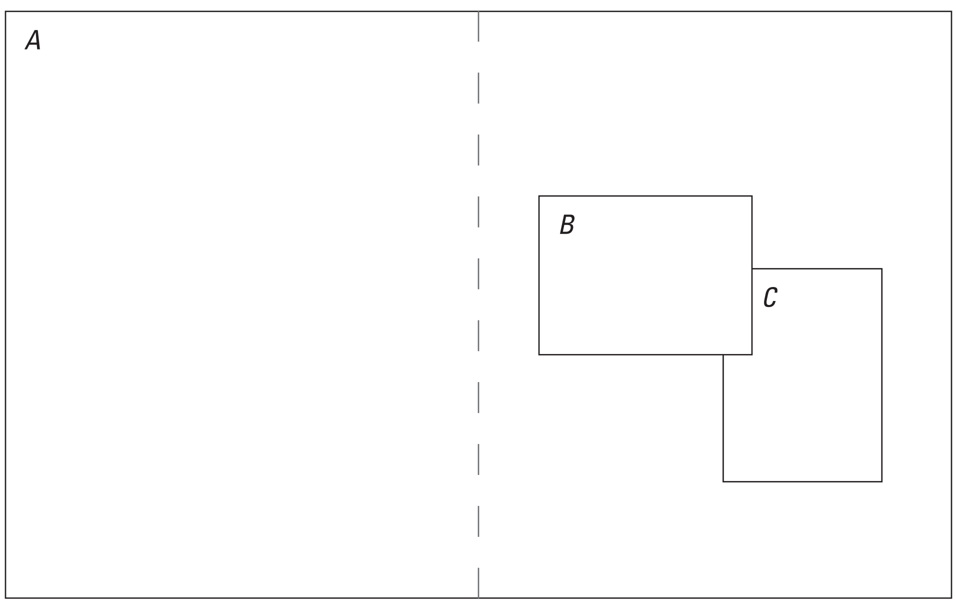
Geologic Framework and Hydrostratigraphy of the Edwards and Trinity Aquifers Within Hays County, Texas

Pamphlet to accompany

Scientific Investigations Map 3540

Supersedes USGS 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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Figures

[On sheet]

Conversion Factors

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)

Datums

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).

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

By Allan K. Clark, Robert R. Morris, and Alexis P. Lamberts

Abstract

During 2023–24, the U.S. Geological Survey, in cooperation with the Edwards Aquifer Authority, revised a previous publication of the geologic framework and hydrostratigraphy of the Edwards and Trinity aquifers that was completed during 2018 within Hays County, Texas. The purpose of this report is to present the updated geologic framework and hydrostratigraphy of the rocks containing the Edwards and Trinity aquifers in Hays County from field observations of the surficial expressions of the rocks. The report includes a detailed 1:24,000-scale hydrostratigraphic map with names and descriptions of the geologic framework and hydrostratigraphic units (HSUs) in the study area. The study includes updates to the interpretation of the Kainer Formation of the Edwards Group with the addition of a burrowed unit between the basal nodular and dolomitic members. Hydrostratigraphy was also updated with the addition of the Seco Pass HSU for the burrowed member of the Kainer Formation. The study also includes updates to the interpretation of the hydrostratigraphy of the Trinity aquifer with the addition of the cavernous HSU at the top of the upper zone of the Trinity aquifer and the Herff Falls HSU between the Bulverde and Rust HSUs of the middle zone of the Trinity aquifer.

This updated report provides additional information about a complex aquifer system. The complexity in the aquifer system results from a combination of the original depositional history, bioturbation, development of primary and secondary porosity, postdepositional 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 the study area, which includes most of Hays County, is located (George and others, 2011). The population of Hays County increased by about 78 percent during 2010–23, making it the fastest growing county with a population of more than 100,000 in the United States according to the U.S. Census Bureau (2024). To effectively manage available water resources, water managers may rely on 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, 1997). Hence, a characterization of the geologic framework and hydrostratigraphy of the Edwards and Trinity aquifers within Hays County was completed during 2016–18 (Clark and others, 2018; Pedraza and others, 2018). The initial mapping was subsequently updated with additional field data during 2023–24 by the U.S. Geological Survey (USGS), in cooperation with the Edwards Aquifer Authority, to improve documentation of the geologic framework and hydrostratigraphy of the Edwards and Trinity aquifers within Hays County at a 1:24,000 scale. Descriptions of the geologic framework and HSUs in this report were modified from those in Clark and others (2016a, b, 2018, 2020, 2023, 2024).

Purpose and Scope

The purpose of this report is to present an updated geologic framework and hydrostratigraphy of the Edwards and Trinity aquifers within Hays County, Tex., including a detailed map of the hydrostratigraphy at a 1:24,000 scale (figs. 1–3). By using additional data obtained from field mapping, including from areas previously inaccessible, refinements were made to the map of the HSUs that contain the Edwards and Trinity aquifers previously documented in Clark and others (2018). The information published in this report can help water managers gain an improved understanding of hydrogeologic controls on groundwater recharge, discharge, and flow paths. The text and figures in this report were modified from the superseded version of this report (Clark and others, 2018).

Description of Study Area

The study area consists of about 560 square miles in Hays County, which is northeast of San Antonio, Tex., and southwest of Austin, Tex. (fig. 1). The rocks exposed within the study area include outcrops of the Trinity and Edwards Groups and the overlying Washita, Eagle Ford, Austin, and

Taylor Groups (Barker and Ardis, 1996) (fig. 3). The rocks in the study area are primarily sedimentary in origin; thick layers of carbonate muds were deposited during the Cretaceous age when the ancestral Gulf of America repeatedly inundated the area during a series of marine transgressions (Barker and Ardis, 1996). Interbedded layers of sand, silt, and clay were deposited during intervals when the ancestral sea retreated (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). Recent work by Hippolyte and others (2024) incorporated uranium-lead age dating of calcite mineralization along the Balcones fault zone (Hill, 1900). The age-dating work of Hippolyte and others (2024) indicated that faulting of the Balcones fault zone occurred during the Paleocene to middle Eocene. 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

The methods used in this study were consistent with those used in Hanson and Small (1995), Stein and Ozuna (1995), Clark (2003, 2004), Clark and others (2009), and Clark and others (2016a, b, 2020, 2024). 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, 2018, 2020, 2024) were reviewed to assist in field mapping. During 2023–24, geologic framework and hydrostratigraphic mapping was completed on public and private land in Hays County, augmenting field mapping done in and near the same area during 2016–18 and published in Clark and others (2018). Field-mapping techniques were consistent with those used in previous similar studies (Clark, 2003; Clark and Morris, 2015; Clark and others, 2016a, b, 2018, 2020, 2023) and relied on Global Positioning System (GPS) units and tablet-based digital maps and geologic mapping applications. Differences in the thicknesses of the mapped lithostratigraphic units and HSUs were caused by variations in local depositional and erosional conditions; reported thicknesses were derived from field observations obtained for this report and from data obtained from previous field mapping in the study area (Wierman and others, 2010; Clark and others, 2016a, 2018; Pedraza and others, 2018). Observations were recorded onsite by using a tablet computer loaded with geospatially registered 7.5-minute USGS topographic maps. Precise locations of interpreted contacts, faults and fractures, marker units, and other areas of interest were recorded by using the integrated third and fourth generation (3G and 4G) 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 were identified in the field on the basis of observed and inferred stratigraphic offsets. Strikes and dips of faults and fractures were also noted. 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 the 2016–18 field mapping in the area (Clark and others, 2018; Pedraza and others, 2018), from topographic maps, and from an earlier geologic mapping report (Hanson and Small, 1995). The data obtained by using the tablet-computer compass application were independently cross-verified daily with data obtained by using the hand-held compass. The field data were transferred by using ArcGIS ArcMap version 10.8.1 (Esri, 2020), 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. The data that were collected and compiled for this study, including the ArcGIS coverages derived from the data, are available in a companion data release (Lamberts and others, 2025).

Geologic names, HSU names, lithologic descriptions, and porosity types were based on information obtained from previous publications and field mapping associated with this study. The descriptions of the geologic framework and hydrostratigraphy in this report were adapted for the study area from Clark and others (2016a, b, 2018). Formal geologic names are consistent with those in the U.S. Geologic Map Database (USGS, 2024). Informal geologic and HSU names are consistent with those used in previous publications (Rose, 1972; Maclay and Small, 1976; Clark and others, 2009; Blome and Clark, 2014; Clark and others, 2014, 2016a, b, 2018, 2020, 2023) (fig. 3).

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 using the classification scale of Wentworth (1922).

HSUs were identified on the basis of the type of porosity visually evident in outcrops of the rocks that contain the Edwards or Trinity aquifer. 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 non-fabric selective in accordance with the sedimentary carbonate classification system of Choquette and Pray (1970). Fabric-selective porosity results from original deposition processes or diagenetic changes in the sediments, whereas non-fabric-selective porosity results from subsequent deformation or dissolution of the sediments (Choquette and Pray, 1970).

Geologic Framework

The rocks of the study area are Cretaceous age, sedimentary, primarily composed of limestones, and interbedded with rocks derived from deposits of sands, silts, and clays (fig. 3). Stratigraphically (listed in ascending order here and throughout the remainder of the report), the geologic units are the Trinity Group (Hosston [and its updip stratigraphic equivalent, “Sycamore Sand,” fig. 7 in Barker and others, 1994, and fig. 9 and pl. 1 in Barker and Ardis, 1996], Pearsall, and Glen Rose Limestone Formations), 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 Lower Cretaceous Trinity Group (Imlay, 1940) contains shale, mudstone to grainstone, boundstone, evaporites, sandstone, siltstone, conglomerates, and argillaceous limestone (fig. 3). 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 Formation (and its updip stratigraphic equivalent, the Sycamore Sand [Hill, 1901]) (fig. 4) and Sligo Formation (not present in the study area) (Imlay, 1940); (2) the Hammett Shale (Hill, 1901; Lozo and Stricklin, 1956) and the Cow Creek Limestone (Hill, 1901) (fig. 5); and (3) the Hensell Sand (Hill, 1901) and the Glen Rose Limestone (Hill, 1891) (fig. 6). The Sycamore Sand, the updip stratigraphic equivalent of the Hosston Formation (Barker and others, 1994; Barker and Ardis, 1996), appears at the surface in the bed of the Pedernales River in the northern part of the study area (Barker and Ardis, 1996; Hunt and others, 2015).

In the study area, 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 thick in the south and 130 feet thick near the Pedernales River in the north (figs. 1 and 2). Descriptions of each of the geologic units and their associated lithologies are shown in figure 3. Additional geologic and ichnofossil descriptions are provided in Clark and others (2016a, b) and Clark and Morris (2017).

Edwards Group

The Lower Cretaceous Edwards Group contains mudstone to grainstone, shales, and chert (fig. 3) 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 America (Barker and Ardis, 1996; Clark and others, 2006) (fig. 1). Descriptions of each of the geologic units and their associated lithologies are shown (fig. 3) and discussed in further detail in Clark and others (2016a, b, 2023) and Clark and Morris (2017).

Washita, Eagle Ford, Austin, and Taylor Groups

Following the deposition of the Edwards Group were tectonic uplift, subaerial exposure, and erosion in the area that is now south-central Texas. This area was then resubmerged 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. 3). 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. 3), which contains clay and packstone, was deposited during an early Late Cretaceous marine transgression when the Stuart City reef (to the south) was breached. Continued deposition of carbonate sediments in the 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. 3). The Upper Cretaceous Eagle Ford Group was deposited as sandy shale and argillaceous limestone (fig. 3) in a lagoonal to marine, open shelf environment (Grunig and others, 1977). As the marine transgression continued in the Late Cretaceous, an open, shallow carbonate shelf developed, and sediments were deposited far from shore, resulting in the mudstones and wackestones that form the Austin Group (fig. 3) (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. 3). The Pecan Gap Chalk contains argillaceous limestone and calcareous clay and was deposited in an open marine environment following a marine transgression (Ellisor and Teagle, 1934). Descriptions of the stratigraphy, lithology, and index fossils, as well as stratigraphic thicknesses, are provided (fig. 3), with additional detailed discussion available in Clark and others (2016b, 2023).

Structure

The principal structural feature in Hays County is the Balcones fault zone (fig. 1), which is the result of Paleocene to middle Eocene (Hippolyte and others, 2024) 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, 2010).

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, the confining unit between the middle and lower zones of the Trinity aquifer, and the lower zone of the Trinity aquifer (fig. 3). Descriptions of the HSUs, thicknesses, hydrogeologic functions, porosity types, and field identifications are provided (fig. 3) and are described further in Clark and others (2023, 2024).

Upper Confining Unit to 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, Del Rio Clay (Maclay and Small, 1976; Hanson and Small, 1995), and parts of the Georgetown Formation (Stein and Ozuna, 1995) (fig. 3). Because the formations and groups are generally categorized collectively as a confining unit to the Edwards aquifer and not as separate aquifers, the lithologic terms (group, formation, limestone, and clay) will be used to describe both the geologic framework and the hydrogeologic 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 (fig. 1) is the second-largest spring system in Texas and issues from faults that juxtapose the Edwards aquifer against the Austin Group (Hanson and Small, 1995).

In this report, the Georgetown Formation of the Washita Group is considered part of the upper confining unit to the Edwards aquifer (figs. 1–3). The Georgetown Formation being part of the upper confining unit to the Edwards aquifer is supported by George (1952), Land and Dorsey (1988), Stein and Ozuna (1995), Blome and others (2005), and Clark and others (2006). The Georgetown Formation contains porosities of less than 5 percent as reported by Maclay and Small (1976). The authors have noted, from field observations, that unlined stock tanks are commonly built directly on the outcrop of the Georgetown Formation; the unlined stock tanks are only feasible because the formation transmits water slowly, which is a result of the low porosities. The ability to support unlined stock tanks is consistent with the premise that the formation functions as a confining unit.

Edwards and Trinity Aquifers

In the study area, the Edwards aquifer is within rocks of the Edwards Group, and the Trinity aquifer is within rocks of the Trinity Group. The Edwards and Trinity aquifers contain enhanced secondary porosity that is in the form of bedding planes, fractures, and caves (Maclay and Small, 1983; Veni, 1988, 1994; Johnson and others, 2002; Ferrill and others, 2003; Gary and others, 2011). The Edwards and Trinity aquifers have been considered separate aquifers because of differences in permeability (Hammond, 1984; Kuniansky and Ardis, 1997); 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, 2015). Barker and Ardis (1996) also stated that recharge to the Edwards aquifer from the underlying Trinity aquifer occurs from diffuse upward leakage, which was corroborated by

Kuniansky and Ardis (1997). A detailed description of the HSUs, thicknesses, hydrogeologic functions, porosity types, and field identifications is provided (fig. 3).

Edwards Aquifer

The Edwards aquifer is contained within the Edwards Group. Maclay and Small (1976) subdivided the Edwards aquifer into eight informal HSUs (top to bottom) I to VIII (fig. 3). On the basis of field observations, a ninth informal HSU (Seco Pass HSU) located between HSUs VII and VIII was added (Clark and others, 2024). The Georgetown Formation of the Washita Group contains HSU I (Kg). As noted in the "Upper Confining Unit to the Edwards Aquifer" section of this report, the authors consider the Georgetown Formation to be part of the upper confining unit to the Edwards aquifer. The Person Formation of the Edwards Group contains HSUs II (cyclic and marine members, undivided [Kpcm]), III (leached and collapsed members, undivided [Kplc]), and IV (regional dense member [Kprd]), and the Kainer Formation of the Edwards Group contains HSUs V (grainstone member [Kkg]), VI (Kirschberg Evaporite Member [Kkke]; Hanson and Small, 1995), VII (dolomitic member [Kkd]), Seco Pass (burrowed member [Kkb], where present; Clark and others, 2024), and VIII (basal nodular member [Kkbn]).

Trinity Aquifer

Ashworth (1983) subdivided the Trinity aquifer into upper, middle, and lower units (hereinafter referred to as "zones") (fig. 3). The upper zone of the Trinity aquifer is contained in 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 Shale forms a confining unit between the middle and lower zones of the Trinity aquifer (Ashworth, 1983; Wierman and others, 2010; Clark and others, 2016b, 2023). In the study area the lower zone of the Trinity aquifer yields water from the Sycamore Sand of the Trinity Group. 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 is contained in the upper member of the Glen Rose Limestone (fig. 3). The upper zone of the Trinity aquifer was subdivided informally into five HSUs in Bexar and Comal Counties by Clark (2003). The five informal HSUs present in Hays County are (top to bottom) cavernous (Kgrc), Camp Bullis (Kgrcb), upper evaporite (Kgrue), fossiliferous (Kgrf), and lower evaporite (Kgrle) (fig. 3).

Middle Zone of the Trinity Aquifer

The middle zone of the Trinity aquifer is contained in the lower member of the Glen Rose Limestone, Hensell Sand, and Cow Creek Limestone (fig. 3). The lower member of the Glen Rose Limestone is subdivided into seven informal HSUs (Clark and others, 2023) (top to bottom): Bulverde (Kgrb), Herff Falls (Kgrhf; where present), Little Blanco (Kgrlb), Twin Sisters (Kgrts), Doeppenschmidt (Kgrd), Rust (Kgrr), and Honey Creek (Kgrhc). The Hensell Sand is informally identified as the Hensell HSU and the Cow Creek Limestone as the Cow Creek HSU (Clark and Morris, 2015) (fig. 3). Across the study area from south to north the various HSUs thin, and the Bulverde, Herff Falls, Little Blanco, Twin Sisters, and Doeppenschmidt HSUs grade into the Rust HSU likely because of changes in the depositional environment. Underlying the Cow Creek HSU is the regional Hammett confining unit, which consists of the Hammett HSU and 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 7) (Brune, 1975). Also, a spring known locally as "Pleasant Valley spring" (Barton Springs-Edwards Aquifer Conservation District, 2013) (fig. 1, site 1) was recently documented as the Trinity aquifer spring in south-central Texas with the largest discharge (Watson and others, 2014); its measured discharge ranged 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 flows upward under artesian conditions through fractures, faults, and conduits into the Honey Creek HSU and ultimately is discharged at land surface (Barton Springs-Edwards Aquifer Conservation District, 2013).

Hammett Confining Unit

Overlying the lower zone of the Trinity aquifer is the Hammett confining unit, which consists of the Hammett HSU, is contained in the Hammett Shale, and likely restricts the downward flow of groundwater and results in contact springs near the base of the Cow Creek HSU in some locations (fig. 3; Clark and Morris, 2017). The Hammett HSU also likely restricts upward flow of groundwater from the Sycamore HSU where the groundwater has a relatively high hydraulic head because the areas of surface water recharge to the Sycamore HSU are upgradient from the confined part of the Sycamore HSU and would otherwise flow towards land surface (Clark and others, 2016a, b, 2018, 2023).

Lower Zone of the Trinity aquifer

In the study area, the lower zone of the Trinity aquifer consists exclusively of the Sycamore HSU, which is contained in the Sycamore Sand and is only exposed at land surface 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 (and Sycamore 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, 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 for controlling or altering local groundwater flow (Pantea and others, 2014; Saribudak and Hauwert, 2017; Saribudak and Hawkins, 2019) by juxtaposing permeable and less permeable lithologies against one another. Dye-tracing studies by Johnson and others (2010) indicated that the permeable zones in juxtaposed HSUs (regardless of the formation in which they reside) exchange groundwater—even when there is substantial displacement between HSUs that is caused by faults. When juxtaposed against HSU zones with relatively more permeability, the zones with relatively less permeability might function as a barrier to groundwater flow (Stein and Ozuna, 1995).

Current (2024) 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 complexity in the aquifer system results from a combination of the original depositional history, bioturbation, development of primary and secondary porosity, postdepositional diagenesis, fracturing, and faulting (Clark and others, 2016b, 2018, 2023). 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, 2018, 2023). 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, 2018, 2023). 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; Hunt and others, 2015; Pantea and others, 2014).

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). Solutionally enhanced fractures and conduits may also form parallel to the dip of relay ramps in the Edwards Group (Clark and Journey, 2006; Saribudak and Hauwert, 2017; Saribudak and Hawkins, 2019) 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 result from 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 downthrown to the southeast faults occurred, the material was forced to occupy a larger area, resulting in extension perpendicular to the fault zone (Clark and Journey, 2006).

Summary

During 2023–24, the U.S. Geological Survey, in cooperation with the Edwards Aquifer Authority, revised a previous publication of the geologic framework and hydrostratigraphy of the Edwards and Trinity aquifers that was completed during 2018 within Hays County, Texas. The purpose of this report is to present the updated geologic framework and hydrostratigraphy of the rocks containing the Edwards and Trinity aquifers in Hays County from field observations of the surficial expressions of the rocks. The report includes a detailed 1:24,000-scale hydrostratigraphic map with names and descriptions of the geologic framework and hydrostratigraphic units (HSUs) in the study area. The study includes updates to the interpretation of the Kainer Formation with the addition of a burrowed unit between the basal nodular and dolomitic members. Hydrostratigraphy was also updated with the addition of the Seco Pass HSU for the burrowed member of the Kainer Formation. The study also includes updates to the interpretation of the hydrostratigraphy of the Trinity aquifer with the addition of the cavernous HSU at the top of the upper zone of the Trinity aquifer and the Herff Falls HSU between the Bulverde and Rust HSUs of the middle zone of the Trinity aquifer.

This updated report provides additional information about a complex aquifer system. The complexity in the aquifer system results from a combination of the original depositional history, bioturbation, development of primary and secondary porosity, postdepositional diagenesis, fracturing, and faulting.

The Texas Water Development Board classifies the karstic Edwards and Trinity aquifers as major sources of water in south-central Texas, where the study area, which includes most of Hays County, is located. The geologic framework and hydrostratigraphy of the Edwards and Trinity aquifers largely control groundwater flow paths and storage in the aquifers. The results of the initial mapping were updated with additional field data collected during 2023–24 to improve documentation of the geologic framework and hydrostratigraphy of the Edwards and Trinity aquifers within Hays County. The hydrostratigraphic units (HSUs) that contain the Edwards and Trinity aquifers were mapped to aid in the understanding of groundwater recharge, discharge, and flow paths.

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 in the study area are primarily sedimentary in origin; thick layers of carbonate muds were deposited during the Cretaceous when the ancestral Gulf of America repeatedly inundated the area during a series of marine transgressions. Interbedded layers of sand, silt, and clay were deposited during intervals when the ancestral sea retreated. Karst features in the study area include sinkholes, caves, and underground streams that allow rapid infiltration of surface waters to the subsurface. The principal structural feature in Hays County is the Balcones fault zone, which is the result of Paleocene to middle Eocene extensional faulting and fracturing. 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, the confining unit between the middle and lower zones of the Trinity aquifer, and 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 parts of the Georgetown Formation. Although commonly referred to as part of the Edwards aquifer, the Georgetown Formation is considered part of the upper confining unit to the Edwards aquifer in this report.

The Edwards aquifer is contained within the Edwards Group. The Edwards aquifer was subdivided into eight informal HSUs (top to bottom) I to VIII by previous authors. A ninth informal HSU (Seco Pass HSU) located between HSUs VII and VIII was added on the basis of additional field observations. The Georgetown Formation of the Washita Group contains HSU I. The Person Formation of the Edwards Group contains HSUs II (cyclic and marine members, undivided), III (leached and collapsed members, undivided), and IV (regional dense member), and the Kainer Formation of the Edwards Group contains HSUs V (grainstone member), VI (Kirschberg Evaporite Member), VII (dolomitic member), Seco Pass (burrowed member, where present), and VIII (basal nodular member).

The upper zone of the Trinity aquifer is contained in the upper member of the Glen Rose Limestone. The upper zone of the Trinity aquifer was subdivided informally into five HSUs in Bexar and Comal Counties. The five informal HSUs present in Hays County are (top to bottom) cavernous, Camp Bullis, upper evaporite, fossiliferous, and lower evaporite. The middle zone of the Trinity aquifer is contained in the lower member of the Glen Rose Limestone, Hensell Sand, and Cow Creek Limestone. The lower member of the Glen Rose Limestone is subdivided into seven informal HSUs (top to bottom): Bulverde, Herff Falls, Little Blanco, Twin Sisters, Doeppenschmidt, Rust, and Honey Creek. The Hensell Sand and Cow Creek Limestone are informally identified as the Hensell HSU and Cow Creek HSU, respectively. Underlying the Cow Creek HSU is the regional Hammett confining unit, which consists of the Hammett HSU and separates the middle and lower zones of the Trinity aquifer. In the study area, the lower zone of the Trinity aquifer consists exclusively of the Sycamore HSU, which is contained in the Sycamore Sand and is only exposed at land surface 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, 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 for controlling or altering local groundwater flow by juxtaposing permeable and less permeable lithologies against one another. The complexity in the aquifer system results from a combination of the original depositional history, bioturbation, development of primary and secondary porosity, postdepositional diagenesis, fracturing, and faulting.

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