Map Showing Geology and Hydrostratigraphy of the Edwards Aquifer Catchment Area, Northern Bexar County, South-Central Texas

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Introduction

The San Antonio metropolitan area in Bexar County, south-central Texas, is home to almost 2 million people whose primary source of water is supplied by the Edwards and Trinity aquifers (fig. 1). The carbonate rock units forming these aquifers include the Edwards and Trinity Groups, respectively. The regional geology is structurally complex due to deformation related to the Balcones fault zone, an intricate network of Miocene-age normal faults that trend northeast and are downthrown to the southeast.

Figure 1. Distribution of the Trinity and Edwards aquifers.

The Edwards aquifer is the most prolific ground-water source in Bexar County and supplies water for agricultural, residential, commercial, and industrial purposes. It also supplies major springs that support recreational activities and businesses, and offers habitat for several endangered species. Although the Edwards aquifer regional ground-water flow is east-northeast and parallels the major fault trend of the Balcones fault zone, local variations in ground-water flow patterns are most likely related to secondary fracture permeability produced by extensional deformation (Faith, 2004).

The Trinity aquifer supplies water for residential, commercial, and industrial uses north of the San Antonio metropolitan area. The Glen Rose Limestone contains the upper Trinity aquifer and parts of the middle Trinity aquifer and it also forms the catchment area of the Edwards aquifer recharge zone to the south (fig. 1). The Glen Rose Limestone is relatively impermeable and is the primary lower confining unit of the Edwards aquifer. The Trinity aquifer also provides recharge to the Edwards aquifer by supplying base flow to several streams in the catchment area that flow south and down-gradient over the Edwards aquifer recharge zone (fig. 2). Recharge may also occur through lateral, subsurface migration of ground water into stratigraphically younger Edwards Group rocks that are faulted against rocks of the Trinity Group (Stein and Klemt, 1995). An improved understanding of the relationship between the Edwards and Trinity aquifers is crucial for effective characterization and management of the aquifers, both locally and throughout the region.

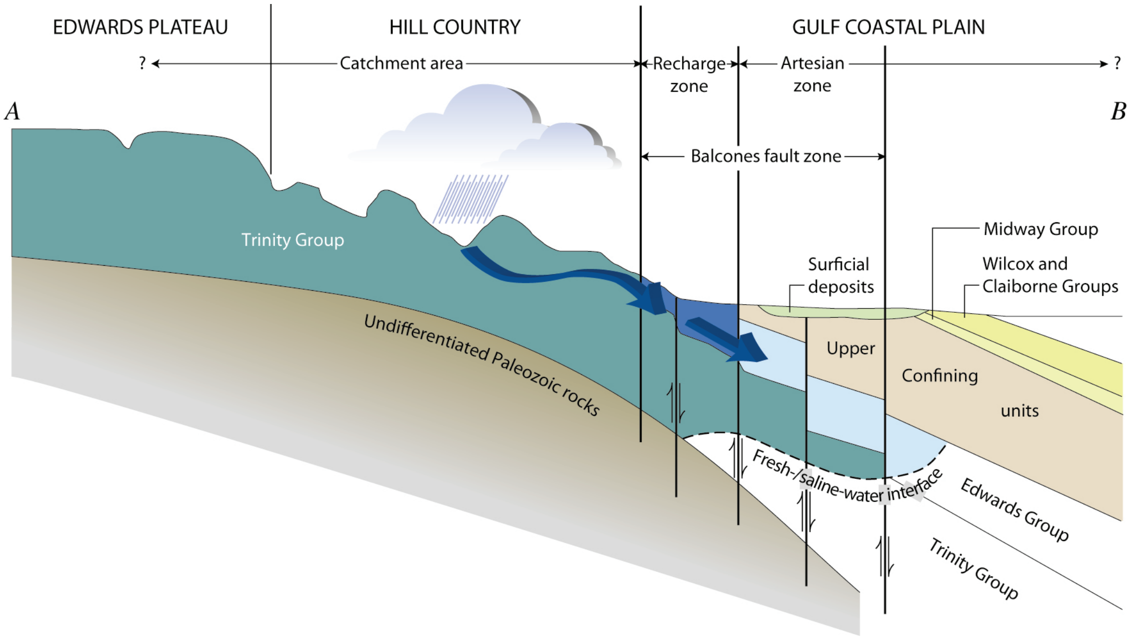

Figure 2. Conceptual cross section through the Trinity and Edwards aquifers (profile A-B shown in fig. 1).

The Trinity aquifer is subdivided into upper, middle, and lower segments (Ashworth, 1983). Although the upper member of the Glen Rose Limestone contains enough clay and marl beds to form a relatively impermeable unit that restricts infiltration of surface water and ground-water flow, the upper 150 m of the Glen Rose Limestone has substantial karst development (Stein and Klemt, 1995). This may imply that the Glen Rose Limestone is not as an effective aquiclude as was previously thought and therefore the Trinity aquifer may have some lateral hydrologic connectivity with the Edwards aquifer. The lower member of the Glen Rose Limestone and the underlying Hensel Sand and Cow Creek Limestone contain the middle part of the Trinity aquifer, the most productive of the three aquifer segments. This middle part of the aquifer is largely unconfined but the Trinity water-bearing, down-faulted confined portions of the Balcones fault zone are suspected to lose water to the Edwards aquifer (Hammond, 1984).

Clark (2003) subdivided the upper member of the Glen Rose Limestone into five informal hydrostratigraphic zones (A-E) to better describe the unit's hydrologic properties. The same five hydrostratigraphic subdivisions of the Glen Rose Limestone were used by Clark (2005) when mapping the geology of Camp Stanley. Maclay and Small (1976) originally proposed a similar hydrostratigraphic subdivision for the Edwards Group (Person and Kainer Formations), which included the Georgetown Formation as its youngest member. The other Edwards informal hydrostratigraphic members of Maclay and Small (1976) include, in descending order, the Cyclic and marine, Leached and collapsed, Regional dense, Grainstone, Kirschberg evaporite, Dolomitic, and Basal nodular hydrostratigraphic members.

This study includes 1:50,000-scale hydrostratigraphic mapping of the northern Bexar County area, which encompasses all or parts of seven 7.5-minute quadrangles: Bulverde, Camp Bullis, Castle Hills, Helotes, Jack Mountain, San Geronimo, and Van Raub. The resulting geologic map shows the distribution of informal hydrostratigraphic members of both the Edwards Group and the underlying upper member of the Glen Rose Limestone. Exposures of Glen Rose Limestone alone cover approximately 467 km^2 in northern Bexar County. The other purpose of this study is to describe and name the informal hydrostratigraphic members of the upper part of the Glen Rose Limestone.

Physical Setting

Stratigraphy

The Glen Rose Limestone of the upper part of the Trinity Group of south-central Texas is partly clayey and sandy and is of neritic (sublittoral) facies (Sellards and others, 1933). The Glen Rose Limestone, which has a thickness of approximately 220–235 m in the San Antonio area (Ashworth, 1983), is separated into upper and lower lithostratigraphic members. The lower member of the Trinity Group is not exposed in the study area.

Sedimentary rocks in the study area have a regional dip of 3–5 m/km (less than 1°) to the southeast. According to Bay (1977), the Glen Rose Limestone is the thickest and is the most extensively exposed of all the Trinity Group lithostratigraphic units. Facies analyses indicate that the Trinity Group represents shallow-water deposits that were subaerially exposed during regressions and low sea stands (Stricklin and others, 1971). Rudist and coral reefs, intertidal beds and associated evaporites, and beach deposits are the most obvious evidence for shallow-water deposition. Inferred degrees of water depth, energy, and salinity are used to interpret depositional environments for these deposits. Sudden fluctuations in water circulation over a broad, low-relief shelf resulted in abrupt changes in rock types (Bay, 1977). Paleoenvironmentally diverse strata in the Trinity Group include blanket-like beach deposits, rudist reefs, wide-spread tidal-flat deposits, and shallow-water and shore deposits of caliche and alluvium.

Many of the lower beds of the Glen Rose Limestone are very fossiliferous, with the most plentiful fossils represented by internal casts of pelecypods and gastropods. A particularly varied fauna occurs in nodular limestone and clay near the top of the lower member of the Glen Rose Limestone that has been assigned by Whitney (1952) to the *Salenia texana* Zone based on the occurrence of this distinctive regular echinoid. A bivalve-rich, “*Corbula* bed” (Stricklin and others, 1971) occurs at the top of the lower member of the Glen Rose Limestone and is generally accepted as the boundary between the upper and lower members of the Glen Rose Limestone. The lower member of the Glen Rose Limestone attains a maximum thickness of approximately 120 m in the subsurface along the eastern and southern margins of the Edwards Plateau (Hammond, 1984). In contrast, the upper member of the Glen Rose, which is 125–180 m thick in northern Bexar County, is primarily a sequence of alternating resistant and nonresistant beds whose “stair-step topography” is pervasive throughout much of central Texas. The contact of the Glen Rose Limestone with the overlying Edwards Group is conformable and gradational.

The lithostratigraphy of the Edwards Group and equivalent rocks varies from northeast to southwest due to the three fluctuating depositional facies: the San Marcos platform, the Devils River trend, and the Maverick basin (fig. 3). The Kainer and Person Formations of the Edwards Group, including the overlying Georgetown Formation, are approximately 55 m and 85 m thick, respectively.

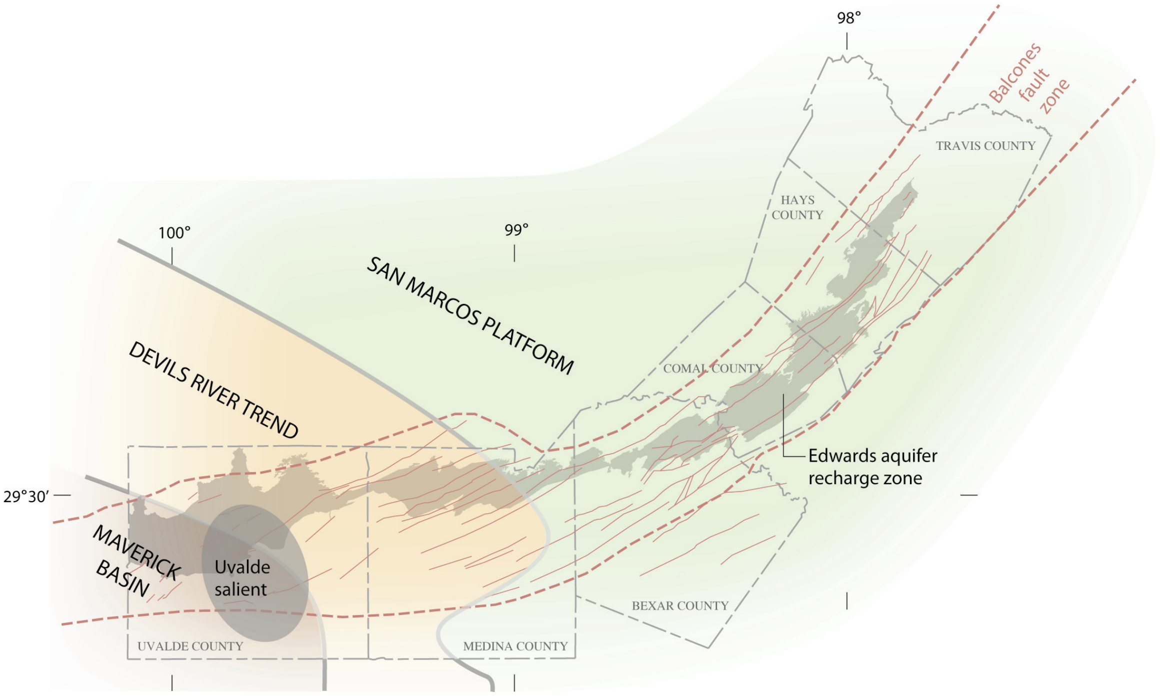

Figure 3. Distribution of depositional facies during the Late Cretaceous and the location of the Edwards aquifer recharge zone and Balcones fault zone.

The Edwards Group of the San Marcos Platform facies formed in shallow marine waters and is divided into seven informal hydrostratigraphic members (Maclay and Small, 1984; Blome and others, 2005). Maclay and Small (1984) included the overlying Georgetown Formation as the eighth informal hydrostratigraphic member forming the Edwards aquifer. Mapped Edwards Group hydrostratigraphic subdivisions in the study area include, in descending order, the Cyclic and marine, Leached and collapsed, Regional dense, Grainstone, Kirschberg evaporite, Dolomitic, and Basal nodular hydrostratigraphic members of the Kainer and Person Formations, all of which are described in detail below in the “Description of Map Units.”

The Lower Cretaceous depositional environment of the Edwards Group rocks is defined as a complex, highly variable carbonate platform environment disrupted by erratic sea level fluctuations that were contemporaneous with deposition. The depositional sequence stratigraphy model for the Edwards Group is generally characterized to represent a detached, rimmed carbonate platform with layer-cake lithologies and periodic karst development (Ashworth, 1983; Maclay, 1995). Two separate episodes of subaerial exposure and incipient karst development occurred, the first in the middle part of the Kainer Formation and the second in the middle to upper parts of the Person Formation.

Structural Framework

Faults in northern Bexar County are part of the Balcones fault zone; most faults in the area trend southwest to northeast. The faults are *en echelon* (in step-like fashion) and normal in dip angle; the fault blocks are typically downthrown to the southeast. Numerous smaller cross-faults trend to the northwest and connect with the primary faults (Stein and Ozuna, 1995). The complex network of faults, with stratigraphic offsets as much as 50 percent or more of the Edwards Group thickness, becomes increasingly more complex to the northeast (Maclay and Small, 1984; Clark, 2000).

Relay ramps often form between overlapping faults with varying lateral displacement gradients to accommodate the deformation occurring in their bounding hanging-wall and footwall blocks. The displacement of fault blocks and the subsequent development and deformation of relay ramps in carbonate rocks, such as those confining the Edwards and Trinity aquifers, can produce increased fracture porosity and directional permeability within the aquifer-bearing strata. This style of faulting, in turn, can create potential flow barriers or allow communication between contiguous aquifers (Ferrill and others, 2004; Faith, 2004). Those faults with sufficiently large displacements may juxtapose the Edwards and Trinity aquifer-bearing units and provide ground-water flow from the upper or lower Trinity to the Edwards aquifer or vice versa depending on hydraulic gradients between the two aquifers (Stein and Ozuna, 1995).

Some of the informal hydrostratigraphic members that encompass the upper member of the Glen Rose Limestone and the Kainer and Person Formations have greater effective porosity than others, and may provide efficient avenues for contaminants to enter the aquifer. The flow of ground water from the water-bearing rocks of the Glen Rose Limestone (Trinity aquifer), across the catchment area and Balcones fault zone to the aquifer-bearing Edwards units, depends on a multiple factors including: (1) the ability of the Trinity aquifer to transmit water across faults where the two aquifers are displaced and in lateral communication, (2) whether the aquifers have a common hydraulic gradient, and (3) the amount of fault displacement that juxtaposes the aquifers. An improved understanding of the geologic and hydrostratigraphic processes controlling the infiltration of surface water and subsurface flow of ground water from the catchment area (outcropping Trinity aquifer rocks) to the Edwards water-bearing exposures will allow for a better regional understanding of the hydrogeologic connection between the two.

Description of Map Units

The Trinity Group rocks that crop out in northern Bexar County and that form the Edwards aquifer catchment area were originally mapped and described using the stratigraphic nomenclature from the hydrogeologic framework study of the Edwards-Trinity aquifer system, west-central, Texas (Barker and Ardis, 1996) and the stratigraphic nomenclature of the Lower Cretaceous Trinity deposits of central Texas (Stricklin and others, 1971). Clark (2003, 2005) later subdivided the upper Trinity Group (upper member of the Glen Rose Limestone) into five informal hydrostratigraphic units that included, in descending order, zones A-E. These previous studies compliment the work of Maclay and Small (1976), who subdivided the Edwards Group into seven informal hydrostratigraphic members. This report continues to follow the nomenclature proposed by Maclay and Small (1976) in capitalizing the first word of all hydrostratigraphic members of the Edwards Group. These hydrostratigraphic members include, in descending stratigraphic order, the Cyclic and marine, Leached and collapsed, Regional dense, Grainstone, Kirschberg evaporite, Dolomitic, and Basal nodular hydrostratigraphic members.

This geologic mapping effort cartographically depicts the surface exposures of the informal hydrostratigraphic members that comprise the Trinity and Edwards aquifers in the northern Bexar County area. Faults were identified on the basis of abrupt lithologic or stratigraphic dissimilarities, fault scarps, fault breccia, linear travertine, or sparry calcite deposits. Locally caves, faults, and fractures represent the primary means of hydrologic communication between the catchment area (Trinity aquifer) and the Edwards aquifer. This report contains descriptions of the lithologic and hydrologic characteristics of the hydrostratigraphic subdivisions of the Glen Rose Limestone in the Edwards aquifer catchment area of northern Bexar County. Five informal hydrostratigraphic members are herein named for the upper member of the Glen Rose Limestone; these include , in descending order, the Cavernous, Camp Bullis, Upper evaporite, Fossiliferous, and Lower evaporite hydrostratigraphic members.

Edwards Group (Lower Cretaceous)

Person Formation—Variably burrowed mudstone, grainstone, and crystalline limestone. Also contains collapsed breccia, dolomitized biomicrite, burrowed mudstone, and stromatolitic limestone. Chert is locally abundant; common fossils include pelecypods, gastropods, and rudistids (Collins, 2000). Limestone, dolomitic limestone, and dolomite reflect shallow subtidal to tidal-flat cyclic depositional environments (Rose, 1972; Abbott, 1973). Thickness varies from 52 to 55 m

Informal hydrostratigraphic units

Kpcm **Cyclic and marine hydrostratigraphic member—N**ot mapped in study area. Chert-bearing mudstone to packestone and *miliolid* grainstone. Fabric and nonfabric-selective porosity (Small and Hanson, 1994; Stein and Ozuna, 1995). Thickness 3–32 m

Kplc **Leached and collapsed hydrostratigraphic member**—Crystalline limestone; mudstone to grainstone, with chert, extensivey collapsed breccia, and isolated stromatolitic limestone. Identified in field by bioturbated, iron-stained beds separated by massive limestone beds, and presence of fossil coral *Montastrea* sp. Contains abundant caves in study area. Nonfabric-selective porosity and very high permeability rates (Small and Hanson, 1994). Thickness 21–30 m

Kprd **Regional dense hydrostratigraphic member**—Dense, very thin bedded, argillaceous mudstone. Unit most susceptible to erosion within the Edwards Group; also considered a vertical barrier to flow throughout the Edwards aquifer. Small and Clark (2000, p. 4) noted the occurrence of wispy iron-oxide stains and a weathered nodular appearance for field identification purposes. Very few caverns have been found, but vertical fracture enlargement does occur locally in this nonfabric-selective, low permeability unit (Small and Hanson, 1994). Thickness 4–7 m

Kainer Formation—Ranges from mudstones to miliolid grainstones to crystalline limestones. Much of formation is fossiliferous; typified by rudistid-rich mudstones and wackestones that grade into intertidal and supratidal dolomitic mudstones with evaporites and miliolid-rich grainstones. Other fossil groups include oysters and gastropods (Rose, 1972; Abbott, 1973). With the exception of the Basal nodular member, chert occurs throughout unit in varying amounts and is locally abundant (Collins, 2000). Limestones and dolomitic limestones represent cyclic subtidal to tidal-flat depositional environments (Rose, 1972; Abbott, 1973). Thickness 76 m to more than 90 m

Informal hydrostratigraphic units

Kkg **Grainstone hydrostratigraphic member**—White, chert-bearing, *miliolid*-rich grainstone and mudstone to wackestone. Cross-bedding and ripple marks occur in grainstone; cavern development is rare to nonexistent. Nonfabric-selective porosity and low permeability due

	to recrystallization (Stein and Ozuna, 1995; Small and Clark, 2000). Thickness 15–18 m
Kkke	**Kirschberg evaporite hydrostratigraphic member—**Highly altered, crystalline limestone, chalky mudstone, and chert; fossils uncommon. Identified by boxwork voids with neospar and travertine framing. Extensive cavern development throughout unit makes the Kirschberg one of the most porous (majority fabric-selective) and permeable hydrostratigraphic members in the Edwards Group (Stein and Ozuna, 1995). Average thickness 15–18 m
Kkd	**Dolomitic hydrostratigraphic member—**Mudstone to grainstone; crystalline limestone with chert. Contains the most caves in Bexar County area; development directly related to faults and fractures. Member hydrologically considered to possess mostly nonfabric-selective porosity except where solution along bedding planes yields water. The massively bedded unit weathers to light gray in outcrop and contains abundant forms of the rudist *Toucasia* (Stein and Ozuna, 1995; Small and Clark, 2000). Thickness 32–42 m
Kkbn	**Basal nodular hydrostratigraphic member—**Shaley, nodular limestone; burrowed mudstone to wackestone with minor lateral cavern development at the surface and nonfabric-selective porosity. Identified in the field by nodular gray mudstone containing black rotund bodies (commonly called “brb’s”) and the occurrence of

miliolids, gastropods, and the fossil oyster *Protocardia texana* (Conrad) (Stein and Ozuna, 1995; Clark, 2003). Considered regionally to be a lower confining unit; locally water bearing through dissolution along bedding planes. Thickness 6–21 m

Trinity Group (Lower Cretaceous)

Glen Rose Limestone, upper member—Conformably underlies the Kainer Formation of the San Marcos platform (Miller, 1984) and forms the lower confining unit of the Edwards aquifer. Contains alternating beds of yellowish-tan, medium-bedded limestone and argillaceous limestone with minor evaporite layers. Surface cavern development associated with faults and fractures and some water production at the evaporite beds have been noted, but are considered a rare occurrence. Field identification of the upper member is commonly associated with stair-step topography that forms through differential erosion of the alternating limestone and marl beds and the presence of fossilized ripple marks and sparse casts of *Tylostoma* sp., *Turitella* sp., *Protocardia texana* (Conrad), and the foraminifera, *Orbitolina minuta* (Romer). Mostly nonfabric-selective porosity and generally low permeability (Small and Clark, 2000; Clark, 2003). Ranges in thickness from 102 to 235 m in northern Bexar County area.

Conformably overlies the bivalve-rich *Corbula* bed at the top of the lower member of the Glen Rose Limestone. Eight lithologic intervals were recognized by Stricklin and others (1971) in the upper lithostratigraphic member of the Glen Rose Limestone. In descending stratigraphic order, these intervals are as follows:

Unit 8: uppermost sequence of interbedded clay and finely crystalline dolomite;
Unit 7: alternating beds of fossiliferous limestone, dolomite, and clay;
Unit 6: a clay section with thin, resistant beds of calcarenite and a few dolomite stringers;
Unit 5: a second collapse breccia zone resulting from leached evaporites;
Unit 4: a sequence mostly of calcarenite;
Unit 3: nodular, very fossiliferous limestone and clay containing *Orbitulina texana* and abundant steinkerns of various species of gastropods and pelecypods;
Unit 2: thinly bedded, slightly fossiliferous clay, claystone, and limestone; and
Unit 1: a collapsed brown-to-red stained breccia zone from which gypsum has been removed.

The upper lithostratigraphic member of the Glen Rose Limestone is herein divided into five informal hydrostratigraphic members [originally termed the "A-E Zones" by Clark (2003, 2005)] for the geology in the Camp Bullis and Camp Stanley areas in northern Bexar County. Characteristics of these mapped intervals are summarized below in descending stratigraphic order

Informal hydrostratigraphic units

Kgrc **Cavernous hydrostratigraphic member—**Alternating and interfingering mudstone, clay, and wackestone to grainstone. An abundance of caves is indicative of its generally well developed fracture, channel, and cavern porosity. According to Clark (2005), one of the distinguishing features between the Cavernous and underlying Camp Bullis members is the large number of caves in the Cavernous member as both members are indistinguishable on the basis of lithology, and both members are relatively devoid of fossils.

Greater than 35 m thick. Contact between the Cavernous member and the overlying Kainer Formation is conformable (Clark, 2005).

Porosity of the Cavernous member is primarily associated with fractures and caves and thus is interconnected and more permeable relative to that of the underlying Camp Bullis member. Therefore, the Cavernous member contains more avenues of recharge (Clark, 2005)

Kgrcb **Camp Bullis hydrostratigraphic member—**Similar to the Cavernous member but with less karst development and permeability. Named after the Camp Bullis Military Training Reservation, located in northwest San Antonio, Texas. This member is also relatively devoid of fossils; primary fossils found are *Protocardia texana* (Conrad) and *Tylostoma sp.* Thickness from 35 to 44 m. According to Clark (2005), member is 37–46 m thick in the adjoining Camp Stanley area.

Camp Bullis member exhibits little porosity and permeability. Most of its fractures have little solution enlargement and it acts as a confining layer except where caves are present (Clark, 2005)

Kgrue **Upper evaporite hydrostratigraphic member—**Partly to mostly dissolved zone of soluble carbonate rock; characterized by breccia porosity, with collapse structures and boxwork permeability that typically intercepts the downward percolation of ground water and diverts water laterally. Member also tends to channel water laterally to discharge at springs and seeps. Some boxwork structure appears in cavities where evaporites have been dissolved. Thickness 5–7.5 m (Clark, 2005)

Kgrf **Fossiliferous hydrostratigraphic member—**Contains several marker beds. First marker bed is 4.5–6 m above the *Corbula* bed and is a thin-bedded, silty mudstone that can be easily recognized by its "platy" character in outcrop. Overlying this thin-bedded silty mudstone are approximately 26 m of alternating wackestone, packstone, clay, and mudstone. Above these 26 m of alternating beds is a boundstone formed by a locally massive rudist biostrome. Fossils commonly found include abundant *Orbitulina texana* Roemer, *Porocystis golobularis* (Giebel)*, Tapes decepta* (Hill), *Protocardia texana* (Conrad), *Loriolia* sp., *Turritella sp., Hemiaster* sp., *Neithea* sp., and various species of mollusks. Thickness is 40–53 m.

Generally little porosity and permeability but some local exceptions, most notably the biostromal limestone near the top of the interval, exhibit greater porosity and permeability. Porosity also appears to be interconnected making this interval one of the more permeable zones in the Glen Rose Limestone. Also, permeability can be high in some areas where fractures or caves have been enlarged through dissolution (Clark, 2005)

Kgrle **Lower evaporite hydrostratigraphic member**—Partially to mostly dissolved sequence of evaporites similar to that in the Upper evaporite hydrostratigraphic member. This interval commonly diverts ground water laterally. Member consists of highly altered crystalline limestone and chalky mudstone.

Lower evaporite member (interval E of Clark, 2003, 2005) contains a *Corbula* bed, which is a thin-bedded grainstone that lies at the base of the member and marks the top of the lower member of the Glen Rose Limestone. According to Clark (2005), this bed is usually exposed as float because of its more resistant nature relative to the surrounding calcareous mudstone. In outcrop view, the member appears as a yellow to white calcareous mud, and, in some places, contains gray sparite with boxwork structures. The member also forms broad, gentle valleys as a result of differences in rates of erosion between it and the overlying fossiliferous member and underlying lower lithostratigraphic member of the Glen Rose Limestone. This interval also contains numerous species of fossils, including the very large gastropod *Nerinea romeri* (Whitney), *Orbitolina texana* Roemer, *Porocystis globularis* (Giebel), and *Turritella* sp. in addition to numerous species of pelecypods and gastropods, as well as shell fragments and worm tubes. Thickness 1.8–4.7 m.

This member exhibits collapse braccia associated with the dissolution of evaporites and can act as a lateral conduit (diverting ground water laterally) as reflected by the numerous seeps and springs (Clark, 2005)

Kgrl **Glen Rose Limestone, lower member**—Composed of thick-bedded grainstones within northern Bexar County. Light-colored, cross-bedded grainstone contains abundant large *Trigonia sp.*, other clams, gastropods, oysters, and corals in a matrix of fine- to medium-grained, well-rounded mollusk fragments, echinoid fragments, coated grains, and pellets. Terrigenous sand and glauconite are present in some cores, and grainstones vary regionally in composition (Amsbury, 1996). Reef deposits in the Glen Rose Limestone show a high degree of porosity because of the dissolution of the original shell material leaving molds; unless the member has become fractured, the permeability remains low (Ashworth, 1983). The lower member of the Glen Rose Limestone attains a maximum thickness of approximately 120 m in the subsurface along the eastern and southern margins of the Edwards Plateau (Hammond, 1984).

Numerous local reef deposits occur within the lower member. The majority of these small mounds occur in the upper part, but several more extensive tabular reefs are present in the same stratigraphic interval. An older reef complex occurs within the lower 30 m of the lower member of the Glen Rose Limestone. Perkins (1974) examined the rudist reef complex in the upper 30–55 m of the lower member and described four principal, laterally equivalent facies that crop out over an area of about 7,770 km^2 in the Texas Hill Country that include:

- an oyster biostrome facies
- a monopleurid rudist biostromes facies
- a caprinid rudist reef, and
- plant fragments beds

All parts of the reef complex were deposited within 80 km of the paleoshoreline and it is estimated to have been located more than 161 km from the Cretaceous shelf edge. Sea level was low enough during deposition of the reef interval to expose the reef and occasionally other parts of the complex to promote vadose diagenesis and subaerial erosion. These small mounds appear to be analogous to patch reefs developed in lagoons of present-day reef tracts. The mounds are circular to slightly elongate in planar view, and are usually less than 23 m across and no more than 9 m thick. They also have flat or slightly convex-downward bases and are composed primarily of steinkerns and shells of caprinid-type rudists in a lime-mudstone matrix.

Hammond (1984) divided the lower member of the Glen Rose Limestone into two informal stratigraphic units on the basis of contrasting lithologies. The upper unit of the lower Glen Rose member consists of sandy, clayey, nodular biomicrite, and fine-grained dolomite and marl. Marls in this upper unit are fossiliferous with a rich and varied fauna. Upper unit contains a sequence of thin-bedded biomicrite and marly biomicrite overlain by a thick marl bed containing the foraminifer *Orbitulina texana* Roemer. This unit is of comparatively uniform thickness of 15 m. The basal unit of the lower member of the Glen Rose Limestone consists mostly of massive, ledge-forming biomicrite and biosparite limestone beds comprised of shell fragments in a lime mudstone or sparry calcite matrix. These limestone beds are interbedded with a few thin layers of marl and marly biomicrite. The lower member is massive and is more susceptible than the upper member to the development of secondary porosity resulting from jointing, faulting, and the dissolving action of ground water. The lower member thickens to the west

Summary

In northern Bexar County, the upper member of the Glen Rose Limestone is from 125 to 180 m thick. It also conformably underlies the Kainer Formation of the San Marcos platform and forms the lower confining unit of the water-bearing rocks that form the Edwards aquifer. Edwards Group rocks mapped in the study area are described in detail in Blome and others (2005) and other USGS reports that can be found at the URL: http://esp.cr.usgs.gov/info/edwards.

In this report, the Lower Cretaceous upper member of the Glen Rose Limestone is divided into five informal hydrostratigraphic members (A-E Zones of Clark, 2003) that include, stratigraphically from top to bottom, the Cavernous, Camp Bullis, Upper evaporite, Fossiliferous, and Lower evaporite members. All of these informal members are defined on the basis of their lithologic and hydrologic characteristics and their hydrologically important structures and properties. The uppermost Cavernous member is noted for its well-developed fracture, channel, and cavern porosity, whereas the underlying Camp Bullis member has less karst development and permeability. In outcrop the most porosity and permeability is found within the Upper and Lower evaporite members. Both of these members are characterized by breccia porosity with collapse structures and boxwork permeability. The Fossiliferous member divides the Upper and Lower evaporite members and generally displays little porosity and permeability with the exception of a biostrome near the top of the member.

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