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GEOLOGIC MAP OF THE EDWARDS AQUIFER RECHARGE ZONE, SOUTH-CENTRAL TEXAS

Compiled by
Charles D. Blome, Jason R. Faith, Diana E. Pedraza, George B. Ozuna, James C. Cole, Allan K. Clark, Ted A. Small, and Robert R. Morris
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SCALE 1:200,000

Base modified from U.S. Geological Survey digital data (1:24,000-scale county boundaries and hydrography).
Universal Transverse Mercator projection, zone 14,
North American Datum 1983

Geology compiled and modified from Clark (2003), Clark and Small (1997), Hanson and Small (1995), Small and Clark (2000), Small and Hanson (1994), Small and others (1996), and Stein and Ozuna (1995).
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ABSTRACT

Efforts by a National Cooperative Geologic Mapping Program project to compile the geology of the Edwards aquifer recharge area in south-central Texas have helped to refine the hydrostratigraphy of one of the most permeable and productive carbonate aquifers in the United States. The complex geology of the recharge area includes lithologic units assignable to the Lower Cretaceous Edwards Group and related units and the Georgetown Formation, which is underlain by the Lower Cretaceous Glen Rose Limestone (lower confining unit) and overlain by the Upper Cretaceous Del Rio Clay, Buda Limestone, and Eagle Ford, Austin, Taylor, and Navarro Groups (upper confining units). The rock units constituting the Edwards aquifer in the northeastern part of the recharge area (San Marcos platform facies) include the Kainer, Person, and Georgetown Formations. The Kainer and Person Formations are subdivided into seven informal hydrostratigraphic members. The central part of the recharge area (Devils River trend facies) contains reefal facies lithologies of the Lower Cretaceous Devils River Formation and the overlying Georgetown Formation. The western part of the

recharge area contains Edwards Group lithologies of deeper water origin (Maverick basin facies) composed of the West Nueces, McKnight, Salmon Peak, and Georgetown Formations.
Geologic maps of previous workers typically show a vague, dashed boundary separating San Marcos platform and Devils River trend exposures because the Devils River Formation was historically interpreted as discontinuous and lithologically variable. However, current field studies of the San Marcos platform—Devils River trend transition area reveal that the facies boundary is distinct and follows topographic expression in some areas. We believe that future work will show that some of the hydrostratigraphic units belonging to the Kainer Formation, particularly the informal basal nodular and dolomitic members, occur in the Devils River trend and deeper water Maverick basin units. Hydrostratigraphic subdivision of the lower part of the Devils River Formation in Medina and Uvalde Counties and mapping of Maverick basin lithologies in Kinney County are ongoing.

INTRODUCTION

The Edwards aquifer serves the domestic, industrial, and agricultural needs of about 2 million people and is the primary source of water for San Antonio, Texas, the Nation's eighth largest city. Northeast of San Antonio, along the Balcones fault zone, the Edwards aquifer discharges from major artesian springs and provides unique habitats for at least eight endangered species. Ground-water development, especially near San Antonio, has significantly diminished spring flow during recent periods of below-normal rainfall.
The complex geology of the recharge area includes lithologic units assignable to the Lower Cretaceous Edwards Group and related units and the Georgetown Formation, which is underlain by the Lower Cretaceous Glen Rose Limestone (lower confining unit) and overlain by the Upper Cretaceous Del Rio Clay, Buda Limestone, and Eagle Ford, Austin, Taylor, and Navarro Groups (upper confining units). The rock units constituting the Edwards aquifer in the northeastern part of the recharge area (San Marcos platform facies) include the Kainer, Person, and Georgetown Formations. The Kainer and Person Formations of the Edwards Group were divided into seven informal lithostratigraphic units by Rose (1972). These units were later categorized into seven informal hydrostratigraphic members with the overlying Georgetown Formation considered the eighth member of the Edwards aquifer (Maclay and Small, 1976). The central part of the recharge area (Devils River trend facies) contains reefal facies lithologies of the Lower Cretaceous Devils River Formation and the overlying Georgetown Formation. The western part of the recharge area contains Edwards Group lithologies of

deeper water origin (Maverick basin facies) composed of the West Nueces, McKnight, Salmon Peak, and Georgetown Formations (Clark, 2003).

The Edwards aquifer is structurally complex due to the numerous high-angle normal faults of the Balcones fault zone, which trend, on average, to the northeast, are downthrown to the southeast, and are linked by scattered cross-faults. This network of overlapping faults has a significant impact on the geohydrology of the Edwards aquifer. The relationship between recharge, ground-water flow paths, fault characteristics, and productivity/sustainability of the aquifer must be better understood if regional planners are to meet future water needs of south-central Texas.

Geologic mapping of the Edwards recharge area by the U.S. Geological Survey has been conducted at 1:24,000 scale and compiled for each county. This map compilation was constructed from the original mapping by Clark and Small (1997), Clark (2003), Hanson and Small (1995), Small and Hanson (1994), Small and others (1996), Small and Clark (2000), and Stein and Ozuna (1995).

Geologic maps of previous workers typically showed a straight, dashed, northwest-trending boundary line separating San Marcos platform and Devil River trend exposures. This dashed boundary line implied uncertainty, which was due, in part, to inaccessibility and poor exposure; but we believe that this vague boundary was also the result of geologists' conception that the Devils River Formation is discontinuous and lithologically variable. Our current mapping of the San Marcos platform–Devils River trend transition area in this 1:200,000-scale compilation reveals that the Devils River exposures along the boundary can be differentiated from the San Marcos platform hydrostratigraphic units.

EDWARDS AQUIFER RECHARGE AREA

The State of Texas officially defined the recharge area and contributing zones of the Edwards aquifer in Title 30, Part 1 of the Texas Administrative Code, Chapter 213, Subchapters A and B. The Texas Commission on Environmental Quality (TCEQ) regulates and enforces the Edwards aquifer protection plan as stated in Title 30. The recharge zone is generally defined as the area where the stratigraphic units of the Edwards aquifer are exposed "including the outcrops of other geologic formations in proximity to the Edwards aquifer, where caves, sinkholes, faults, fractures, or other permeable features would create a potential for recharge of surface waters into the Edwards aquifer. The recharge zone is identified as that area designated as such on official maps located in the appropriate regional

office and groundwater conservation districts" (Texas Commission on Environmental Quality, 2003). North of the Edwards aquifer recharge zone, upgradient of the regional drainage, the State of Texas has defined the contributing zone as "the area or watershed where runoff from precipitation flows downgradient to the recharge zone of the Edwards aquifer" (Texas Commission on Environmental Quality, 2003). The jurisdictional extent of the Edwards aquifer recharge zone as identified and provided online by the TCEQ was slightly modified for illustrative purposes in the current compilation map.

DESCRIPTION OF MAP UNITS

QUATERNARY DEPOSITS

Alluvium (Quaternary)—Unconsolidated gravel, sand, silt, and clay normally found around rivers and streams; inundated regularly. Gravel mostly contains limestone and minor chert. Undivided terrace deposits included within unit
Leona Formation (Quaternary)—Lenticular beds of sand, gravel, silt, and clay. Pebbles and cobbles in the Leona are predominantly limestone with some chert. Coarser gravels are present near base of formation; silt increases up-section. The Leona is locally a prolific ground-water source and has rare cavern development and variable (low to high) porosity due to the poorly sorted gravels. Locally, silty and clayey cement significantly reduces the permeability. In general, formation is thickest near stream channels or older abandoned meander channels. Thickness a few feet to 80 ft

UPPER CRETACEOUS STRATA

Igneous intrusive rocks, undifferentiated (Upper Cretaceous)—Fine- to coarse-grained ultramafic and hypabyssal rocks that occur as surface exposures or in subsurface as dikes, plugs, and shallow intrusions. Ultramafic field is centered in Uvalde County and extends to the west of map area into Kinney County. Igneous rocks are represented by five rock types—alkali basalt, melilite-olivine nephelinite, olivine nephelinite, nepheline basinite, and phonolite (Miggins and others, 2004).
A high-resolution aeromagnetic survey flown in 2001 (Smith and others, 2002) revealed more than 200 shallow igneous intrusive bodies, whereas fewer than 70 have been mapped. An 40Ar/39Ar geochronologic study (Miggins and others, 2004) showed at least two distinct phases of magmatic activity in Uvalde County. First phase of intrusive activity occurred approximately 82—80 m.y. ago, whereas younger intrusive rocks (phonolites) were emplaced 74—72 m.y. ago

Upper confining units, undivided (Upper Cretaceous)—Original mapping of much of the recharge zone concentrated on the Edwards Group, the main aquifer-bearing unit of the Edwards aquifer system, and, in some areas, the upper confining units were consolidated. Areas mapped as upper confining unit include any or all of the following map units: Ka (Austin Group), Kef (Eagle Ford Group), Kb (Buda Limestone), and Kdr (Del Rio Clay)
Navarro and Taylor Groups, undivided (Upper Cretaceous)—Lithologic similarity makes the Navarro and Taylor difficult to differentiate in many areas. Mapped only in the San Marcos platform, where unit contains gray to brown clay and marly limestone. Very low porosity and permeability, with no cavern development. The groups are sometimes considered confining units in the Edwards aquifer region (Hanson and Small, 1995). Thickness averages 600 ft
Austin Group (Upper Cretaceous)—Commonly called the Austin Chalk. Massive, gray to white, chalky to marly, fossiliferous mudstone. Identified in the field as white, chalky limestone, commonly containing the fossil oyster Gryphaea aucella. The group is generally referred to as a confining unit; however, ground water is locally associated with fractures. Scarce cavern development and low porosity and permeability. Thickness 130—350 ft
Eagle Ford Group (Upper Cretaceous)—Brown, flaggy, sandy shale and argillaceous limestone identified in the field as thin flagstone with a petroliferous odor. Strata weather easily and form flat to gently rolling topography. Primary porosity has been lost, rendering very low permeability rates in the Eagle Ford Group. Known as lignite by local drillers. No cavern development or fossils are evident in this group. Thickness 30—150 ft throughout the Edwards aquifer region
Buda Limestone (Upper Cretaceous)—Variably nodular, buff, light-gray, dense mudstone. Identified in the field as nodular, porcelaneous limestone with calcite-filled veins and no common fossils. Limestone beds in the upper part of the Buda are generally hard and dense and may exhibit conchoidal fracturing and a porcelaneous texture when broken. Limestone beds in the lower part of the Buda tend to be chalky (Collins, 2000). Regionally considered a confining unit. Unit has minor surface karst with low porosity and permeability (Small and Hanson, 1994). Thickness 40—90 ft
Del Rio Clay (Upper Cretaceous)—Primary upper confining unit of the Edwards aquifer. Small and Hanson (1994, p. 6) described it as a blue-green to yellow-brown, variably gypsiferous clay containing iron nodules, abundant pectin-type fossil clams, and the fossil oyster Ilymatogyra arietina (formerly Exogyra arietina) (Young, 1967). Minor, thin lenticular beds of highly calcareous siltstone may also occur. Unweathered Del Rio Clay

is composed of kaolinite, illite, and lesser amounts of montmorillonite (Collins, 2000). Secondary gypsum occurs as fracture fillings in clay-rich exposures near igneous bodies (Clark, 2003). The Del Rio has no recognized cavern development and no significant porosity or permeability. Directly overlies the Lower Cretaceous formations in many areas. Thickness about 40—110 ft

LOWER CRETACEOUS STRATA AND EDWARDS GROUP HYDROSTRATIGRAPHY

The lithostratigraphy of the Edwards aquifer varies from northeast to southwest due to the three fluctuating depositional environments: the San Marcos platform, the Devils River trend, and the Maverick basin. The Edwards Group of the San Marcos platform was deposited in shallow to very shallow marine waters and is divided into seven hydrostratigraphic units, the eighth hydrostratigraphic unit being the overlying Georgetown Formation. The San Marcos platform facies grades abruptly into the Devils River trend facies in northern Medina County. The Devils River trend is represented by two lithostratigraphic units: the Devils River Formation, historically considered indivisible, and the overlying Georgetown Formation. The lateral transition from the Devils River Formation to the deeper water West Nueces, McKnight, and Salmon Peak Formations of the Maverick basin facies is highly gradational and variable along their assumed boundaries (Clark, 2003)

Georgetown Formation (Lower Cretaceous)—Uppermost unit of the Edwards aquifer. Reddish-brown and gray to light-tan, marly limestone with biomicritic texture; commonly contains the brachiopod Waconella wacoensis, pectins, the mollusks Kingena wacoensis and Gryphaea washitaensis (Young, 1967), as well as other pelecypods. Strata covered by vegetation and soil in some areas. The Georgetown is considered an upper confining unit, has very low porosity and permeability, and has little or no karstification or cavern development (Stein and Ozuna, 1995). Thickness 2—20 ft; generally thins from northeast to southwest

Edwards Group

San Marcos platform

In the San Marcos platform, the Person and Kainer Formations of the Edwards Group were divided into seven informal lithostratigraphic units by Rose (1972). These units, in addition to the Georgetown Formation, were further modified by Maclay and Small (1976) into eight informal hydrostratigraphic members that formed the Edwards aquifer strata

Person Formation (Lower Cretaceous)—Variably burrowed mudstone, grainstone, and crystalline limestone. Also contains collapsed breccia, dolomitized biomicrite, burrowed mudstone, and stromatolitic limestone. Chert is locally abundant and common fossils include pelecypods, gastropods, and rudistids (Collins, 2000). The Person's limestone, dolomitic limestone, and dolomite reflect shallow subtidal to tidal-flat cyclic depositional environments (Rose, 1972; Abbott, 1973). Thickness 170—180 ft

Cyclic and marine member—Chert-bearing mudstone to packstone and miliolid grainstone. Weathers to massive, light-tan outcrops with scattered Toucasia present. Member is one of the most productive hydrologically because of the large number of subsurface caverns associated with incipient karstification. Very permeable with laterally extensive, fabric and nonfabric-selective porosity (Small and Hanson, 1994; Stein and Ozuna, 1995). Thickness 10—100 ft

Leached and collapsed member—Crystalline limestone; mudstone to grainstone, with chert, extensive collapsed breccia, and isolated stromatolitic limestone. Identified in the field by bioturbated iron-stained beds separated by massive limestone beds, and presence of the fossil coral Montastrea sp. Considered the most cavernous unit in the San Marcos platform facies. Classified as having nonfabric-selective porosity and very high permeability rates (Small and Hanson, 1994). Thickness 70—100 ft

Regional dense member—Dense, 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 for field identification purposes. Very few caverns have been found, but vertical fracture enlargement does occur locally in the nonfabric-selective, low-permeability unit (Small and Hanson, 1994). Thickness 16—24 ft

Kainer Formation (Lower Cretaceous)—Contains lithologies that range from mudstone to miliolid grainstone to crystalline limestone. Much of formation is fossiliferous; typified by rudistid-rich mudstones and wackestones that grade into intertidal and supratidal dolomitic mudstones with evaporites and miliolid grainstones. Other fossil groups include oysters and gastropods (Rose, 1972; Abbott, 1973). Chert occurs throughout unit in varying amounts and is locally abundant (Collins, 2000). The Kainer's limestone and dolomitic limestone represent cyclic subtidal to tidal-flat depositional environments (Rose, 1972; Abbott, 1973). Thickness 250 to more than 300 ft

Grainstone member—White, chert-bearing, miliolid grainstone and mudstone to wackestone. Crossbedding and ripple marks occur in

grainstone; cavern development is rare to nonexistent throughout. Unit is classified as having nonfabric-selective porosity and low permeability due to recrystallization (Stein and Ozuna, 1995; Small and Clark, 2000). Thickness 50–60 ft
Kirschberg evaporite 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 members of the Edwards aquifer (Stein and Ozuna, 1995). Average thickness 50–60 ft
Dolomitic member–Mudstone to grainstone and chert-bearing, crystalline limestone. Massive-bedded dolomitic member weathers light gray in outcrop and has abundant Toucasia. Cavern development is directly related to faults, fractures, and bedding planes; thus, considered nonfabric-selective porosity except where solution along bedding planes yields water (Stein and Ozuna, 1995; Small and Clark, 2000). Thickness 110–140 ft
Basal nodular member–Shaly, nodular limestone and burrowed mudstone to wackestone; minor lateral cavern development at surface and nonfabric-selective porosity. Identified in the field as gray nodular mudstone, containing black rotund bodies and miliolids, gastropods, and Exogyra texana. Considered regionally as a lower confining unit, and is locally water bearing through dissolution along bedding planes (Stein and Ozuna, 1995; Clark, 2003). Thickness 20–70 ft

Devils River trend facies

Devils River Formation (Lower Cretaceous)–Upper 250 ft consists of miliolid, shell-fragment wackestones and grainstones containing rudists and chert. Middle of formation consists of recrystallized and brecciated mudstones that grade downward into alternating beds of vuggy spar and chert-bearing wackestone and grainstone. Lower 120–250 ft contains sparry limestone and nodular, burrowed mudstone to wackestone, with gastropods, miliolids, and Exogyra texana. Upper part of formation has extensive cavern development and abundant caprinids, monopleurids, and requieniids. Highly dissolutioned and brecciated, the middle part has vuggy porosity and abundant chert, with numerous sinkholes and some cavern development. Solution-enlarged fractures are present in the relatively massive, nodular, burrowed mudstone near base of formation. Upper part of formation is classified as having fabric-selective porosity, which grades downward into more nonfabric-selective porosity near base. Small porosity and permeability are related to solution-enlarged fractures in lowermost part of formation.

Formal subdivision of the Devils River Formation has been lacking to date. Geologic maps of the Texas Bureau of Economic Geology show the Devils River Formation subdivided into upper and lower units, whereas all USGS mapping to date (including this map) shows the Devils River Formation as a single undifferentiated unit. According to Clark (2003), most workers since Lozo and Smith (1964) have recognized that the Devils River Formation lacks sufficient marker beds to permit detailed or widespread subdivision.
A helicopter electromagnetic survey flown in the Seco Creek area in Medina and Uvalde Counties (Smith and others, 2003) clearly shows the Devils River as two separate units on the basis of contrasts in resistivity. Clark (2003), in mapping Uvalde County, also demonstrated that the informal basal nodular member of the Kainer Formation could be traced from the San Marcos platform into the Maverick basin. Recent fieldwork by a number of authors (Clark, Blome, and Faith) now shows that at least the informal basal nodular and dolomitic members of the Kainer Formation may be laterally traceable from the San Marcos platform into the Devils River trend and even into the deeper water Maverick basin. This lateral continuity of the lowermost units was first observed by Rose (1972) and revisited by Miller (1983). Nevertheless, local aquifer researchers have not to date accepted the informal subdivisions throughout the Edwards Group. Hydrostratigraphic subdivision of the lower part of the Devils River Formation in Medina and Uvalde Counties and mapping of Maverick basin lithologies in Kinney County are ongoing.
Thickness 540—670 ft in Medina and Uvalde Counties, of which Clark (2003, p. 4, 10) believed the lower 20—70 ft to be equivalent to the basal nodular hydrostratigraphic member of the Kainer Formation, San Marcos Platform facies

Maverick basin facies

Salmon Peak Formation (Lower Cretaceous)—Upper part of the Salmon Peak is typified by grainstone grading downward to light-gray, fossiliferous mudstone; about 75 ft thick. Minor karst and limited fracture enlargement classifies this unit as having both fabric- and nonfabric-selective porosity, except for areas of high dissolution. Lower part of the Salmon Peak is a thick, chert-bearing, massive lime mudstone to grainstone; average thickness 310 ft. Lower part has mostly nonfabric-selective porosity associated with minor karst development and solution along fractures. Total thickness averages 385 ft
McKnight Formation (Lower Cretaceous)
Upper unit—Brown to tan, thin-bedded mudstone, wackestone, packstone, and grainstone. Most porous and permeable unit within the McKnight Formation, with collapse breccia, no cavern

development, and very high, mostly fabric-selective porosity where dissolution of evaporite layers occurs. Contact between the upper and middle units of the McKnight is gradational, just as the upper unit is conformable with the overlying Salmon Peak Formation. A horizon of bored rip-up clasts described as a conformable "conglomeratic zone" by Lozo and Smith (1964) underlies the Salmon Peak Formation and is considered part of the upper McKnight (Clark, 2003). Thickness 100—160 ft

Middle unit—Dark, laminated, fissile mudstone identified by its petroliferous odor and vegetative band on aerial photographs. Very low permeability, no notable cavern development, and classified as having mostly nonfabric-selective porosity. Considered a confining unit by Clark (2003, p. 5). Thickness about 40 ft

Lower unit—Thin-bedded, miliolid- and gryphaeid-rich, fragmented mudstone to grainstone. Also contains laminated pellet mudstone and packstone (Miller, 1983). Thin solution zones and chert beds, but no significant cavern development. Thickness about 60—80 ft

West Nueces Formation (Lower Cretaceous)—Upper unit, considered a confining unit, is gray, thick-bedded, burrowed, shell-fragment wackestone, packstone, and grainstone; thickness 120—260 ft. Identified in the field as a miliolid-, gastropod-, and Texigryphaea-bearing, gray wackestone. Classified as having mostly nonfabric-selective porosity and low permeability, due to only minor cavern formation directly associated with fracture dissolution. Lower unit is composed of thin-bedded, miliolid

solution zones and chert beds (Clark, 2003); thickness 20—60 ft (Miller, 1984). Clark (2003, p. 5) stated that the lower unit is equivalent to the basal nodular member of the Kainer Formation, San Marcos platform facies. Lower unit is a lower confining unit of the Edwards aquifer, except for areas that are higher in porosity and permeability due to solution enhancement of bedding planes. Formation thickness 140—320 ft

Trinity Group (upper part)

Glen Rose Limestone, upper member (Lower Cretaceous)—Conformably underlies the West Nueces Formation in the Maverick basin and the Kainer Formation in the San Marcos platform, but unconformably underlies the Devils River Formation in the Devils River trend (Miller, 1984). Lower confining unit of the Edwards aquifer in south-central Texas.

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 evaporite beds have been noted, but are

considered a rare occurrence. Field identification is commonly associated with (1) stair-step topography that forms through differential erosion of the alternating limestone and marl beds, and (2) the presence of fossilized ripple marks and sparse casts of Tylostoma sp., Turitella sp., Protocardia texana, and the foraminiferan Orbitolina minuta. Classified hydrologically as having mostly nonfabric-selective porosity and generally low permeability (Small and Clark, 2000; Clark, 2003). Thickness 350—800 ft

Contact
Fault—Dashed where inferred. U, upthrown side; D, downthrown side. Displacement amount in feet
Geographic Information System polygon extent of county maps
Cave or sink
Spring

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